


# Erlang Run-Time System Application (ERTS)

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Erlang Run-Time System Application (ERTS) 7.3.1.4
December 1, 2017

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**December 1, 2017**

# 1 ERTS User's Guide

The Erlang Runtime System Application *ERTS*.

## 1.1 Communication in Erlang

Communication in Erlang is conceptually performed using asynchronous signaling. All different executing entities such as processes, and ports communicate via asynchronous signals. The most commonly used signal is a message. Other common signals are exit, link, unlink, monitor, demonitor signals.

### 1.1.1 Passing of Signals

The amount of time that passes between a signal being sent and the arrival of the signal at the destination is unspecified but positive. If the receiver has terminated, the signal will not arrive, but it is possible that it triggers another signal. For example, a link signal sent to a non-existing process will trigger an exit signal which will be sent back to where the link signal originated from. When communicating over the distribution, signals may be lost if the distribution channel goes down.

The only signal ordering guarantee given is the following. If an entity sends multiple signals to the same destination entity, the order will be preserved. That is, if `A` sends a signal `S1` to `B`, and later sends the signal `S2` to `B`, `S1` is guaranteed not to arrive after `S2`.

### 1.1.2 Synchronous Communication

Some communication is synchronous. If broken down into pieces, a synchronous communication operation, consists of two asynchronous signals. One request signal and one reply signal. An example of such a synchronous communication is a call to `process_info/2` when the first argument is not `self()`. The caller will send an asynchronous signal requesting information, and will then wait for the reply signal containing the requested information. When the request signal reaches its destination the destination process replies with the requested information.

### 1.1.3 Implementation

The implementation of different asynchronous signals in the VM may vary over time, but the behaviour will always respect this concept of asynchronous signals being passed between entities as described above.

By inspecting the implementation you might notice that some specific signal actually gives a stricter guarantee than described above. It is of vital importance that such knowledge about the implementation is *not* used by Erlang code, since the implementation might change at any time without prior notice.

Some example of major implementation changes:

- As of ERTS version 5.5.2 exit signals to processes are truly asynchronously delivered.
- As of ERTS version 5.10 all signals from processes to ports are truly asynchronously delivered.

# 1.2 Time and Time Correction in Erlang

## 1.2.1 New Extended Time Functionality

> **Note:**
>
> As of OTP 18 (ERTS version 7.0) the time functionality of Erlang has been extended. This includes a *new API* for time and *time warp modes* that alter the system behavior when system time changes.
>
> The *default time warp mode* has the same behavior as before, and the old API still works. Thus, you are not required to change anything unless you want to. However, *you are strongly encouraged to use the new API* instead of the old API based on *`erlang:now/0`*. `erlang:now/0` is deprecated, as it is and will be a scalability bottleneck.
>
> By using the new API, you automatically get scalability and performance improvements. This also enables you to use the *multi-time warp mode* that improves accuracy and precision of time measurements.

## 1.2.2 Terminology

To make it easier to understand this section, some terms are defined. This is a mix of our own terminology (Erlang/OS system time, Erlang/OS monotonic time, time warp) and globally accepted terminology.

### Monotonically Increasing

In a monotonically increasing sequence of values, all values that have a predecessor are either larger than or equal to its predecessor.

### Strictly Monotonically Increasing

In a strictly monotonically increasing sequence of values, all values that have a predecessor are larger than its predecessor.

### UT1

Universal Time. UT1 is based on the rotation of the earth and conceptually means solar time at 0° longitude.

### UTC

Coordinated Universal Time. UTC almost aligns with *UT1*. However, UTC uses the SI definition of a second, which has not exactly the same length as the second used by UT1. This means that UTC slowly drifts from UT1. To keep UTC relatively in sync with UT1, leap seconds are inserted, and potentially also deleted. That is, an UTC day can be 86400, 86401, or 86399 seconds long.

### POSIX Time

Time since **Epoch**. Epoch is defined to be 00:00:00 *UTC*, 1970-01-01. **A day in POSIX time** is defined to be exactly 86400 seconds long. Strangely enough Epoch is defined to be a time in UTC, and UTC has another definition of how long a day is. Quoting the Open Group **"POSIX time is therefore not necessarily UTC, despite its appearance"**. The effect of this is that when an UTC leap second is inserted, POSIX time either stops for a second, or repeats the last second. If an UTC leap second would be deleted (which has not happened yet), POSIX time would make a one second leap forward.

### Time Resolution

The shortest time interval that can be distinguished when reading time values.

### Time Precision

The shortest time interval that can be distinguished repeatedly and reliably when reading time values. Precision is limited by the *resolution*, but resolution and precision can differ significantly.

### Time Accuracy

The correctness of time values.

### Time Warp

A time warp is a leap forwards or backwards in time. That is, the difference of time values taken before and after the time warp does not correspond to the actual elapsed time.

### OS System Time

The operating systems view of *POSIX time*. To retrieve it, call `os:system_time()`. This may or may not be an accurate view of POSIX time. This time may typically be adjusted both backwards and forwards without limitation. That is, *time warps* may be observed.

To get information about the Erlang runtime system's source of OS system time, call `erlang:system_info(os_system_time_source)`.

### OS Monotonic Time

A monotonically increasing time provided by the operating system. This time does not leap and has a relatively steady frequency although not completely correct. However, it is not uncommon that OS monotonic time stops if the system is suspended. This time typically increases since some unspecified point in time that is not connected to *OS system time*. This type of time is not necessarily provided by all operating systems.

To get information about the Erlang runtime system's source of OS monotonic time, call `erlang:system_info(os_monotonic_time_source)`.

### Erlang System Time

The Erlang runtime systems view of *POSIX time*. To retrieve it, call `erlang:system_time()`.

This time may or may not be an accurate view of POSIX time, and may or may not align with *OS system time*. The runtime system works towards aligning the two system times. Depending on the *time warp mode* used, this can be achieved by letting Erlang system time perform a *time warp*.

### Erlang Monotonic Time

A monotonically increasing time provided by the Erlang runtime system. Erlang monotonic time increases since some unspecified point in time. To retrieve it, call `erlang:monotonic_time()`.

The *accuracy* and *precision* of Erlang monotonic time heavily depends on the following:

- Accuracy and precision of *OS monotonic time*
- Accuracy and precision of *OS system time*
- *time warp mode* used

On a system without OS monotonic time, Erlang monotonic time guarantees monotonicity, but cannot give other guarantees. The frequency adjustments made to Erlang monotonic time depend on the time warp mode used.

Internally in the runtime system, Erlang monotonic time is the "time engine" that is used for more or less everything that has anything to do with time. All timers, regardless of it is a `receive ... after` timer, BIF timer, or a timer in the `timer` module, are triggered relative Erlang monotonic time. Even *Erlang system time* is based on Erlang monotonic time. By adding current Erlang monotonic time with current time offset, you get current Erlang system time.

To retrieve current time offset, call `erlang:time_offset/0`.

### 1.2.3 Introduction

Time is vital to an Erlang program and, more importantly, *correct* time is vital to an Erlang program. As Erlang is a language with soft real-time properties and we can express time in our programs, the Virtual Machine and the language must be careful about what is considered a correct time and in how time functions behave.

When Erlang was designed, it was assumed that the wall clock time in the system showed a monotonic time moving forward at exactly the same pace as the definition of time. This more or less meant that an atomic clock (or better time source) was expected to be attached to your hardware and that the hardware was then expected to be locked away from any human tinkering forever. While this can be a compelling thought, it is simply never the case.

A "normal" modern computer cannot keep time, not on itself and not unless you have a chip-level atomic clock wired to it. Time, as perceived by your computer, must normally be corrected. Hence the Network Time Protocol (NTP) protocol, together with the `ntpd` process, does its best to keep your computer time in sync with the correct time. Between NTP corrections, usually a less potent time-keeper than an atomic clock is used.

However, NTP is not fail-safe. The NTP server can be unavailable, `ntp.conf` can be wrongly configured, or your computer may sometimes be disconnected from Internet. Furthermore, you can have a user (or even system administrator) who thinks the correct way to handle Daylight Saving Time is to adjust the clock one hour two times a year (which is the incorrect way to do it). To complicate things further, this user fetched your software from Internet and has not considered what the correct time is as perceived by a computer. The user does not care about keeping the wall clock in sync with the correct time. The user expects your program to have unlimited knowledge about the time.

Most programmers also expect time to be reliable, at least until they realize that the wall clock time on their workstation is off by a minute. Then they set it to the correct time, but most probably not in a smooth way.

The number of problems that arise when you always expect the wall clock time on the system to be correct can be immense. Erlang therefore introduced the "corrected estimate of time", or the "time correction", many years ago. The time correction relies on the fact that most operating systems have some kind of monotonic clock, either a real-time extension or some built-in "tick counter" that is independent of the wall clock settings. This counter can have microsecond resolution or much less, but it has a drift that cannot be ignored.

### 1.2.4 Time Correction

If time correction is enabled, the Erlang runtime system makes use of both *OS system time* and *OS monotonic time*, to adjust the frequency of the Erlang monotonic clock. Time correction ensures that *Erlang monotonic time* does not warp and that the frequency is relatively accurate. The type of frequency adjustments depends on the time warp mode used. Section *Time Warp Modes* provides more details.

By default time correction is enabled if support for it exists on the specific platform. Support for it includes both OS monotonic time, provided by the OS, and an implementation in the Erlang runtime system using OS monotonic time. To check if your system has support for OS monotonic time, call `erlang:system_info(os_monotonic_time_source)`. To check if time correction is enabled on your system, call `erlang:system_info(time_correction)`.

To enable or disable time correction, pass command-line argument `+c [true|false]` to `erl`.

If time correction is disabled, Erlang monotonic time may warp forwards or stop, or even freeze for extended periods of time. There are then no guarantees that the frequency of the Erlang monotonic clock is accurate or stable.

*You typically never want to disable time correction*. Previously a performance penalty was associated with time correction, but nowadays it is usually the other way around. If time correction is disabled, you probably get bad scalability, bad performance, and bad time measurements.

### 1.2.5 Time Warp Safe Code

Time warp safe code can handle a *time warp* of *Erlang system time*.

*erlang:now/0* behaves bad when Erlang system time warps. When Erlang system time does a time warp backwards, the values returned from `erlang:now/0` freeze (if you disregard the microsecond increments made because of the actual call) until OS system time reaches the point of the last value returned by `erlang:now/0`. This freeze can continue for a long time. It can take years, decades, and even longer until the freeze stops.

All uses of `erlang:now/0` are not necessarily time warp unsafe. If you do not use it to get time, it is time warp safe. However, *all uses of `erlang:now/0` are suboptimal* from a performance and scalability perspective. So you really want to replace the use of it with other functionality. For examples of how to replace the use of `erlang:now/0`, see Section *How to Work with the New API*.

### 1.2.6 Time Warp Modes

Current *Erlang system time* is determined by adding current *Erlang monotonic time* with current *time offset*. The time offset is managed differently depending on which time warp mode you use.

To set the time warp mode, pass command-line argument `+C [no_time_warp|single_time_warp|multi_time_warp]` to `erl`.

#### No Time Warp Mode

The time offset is determined at runtime system start and does not change later. This is the default behavior, but not because it is the best mode (which it is not). It is default *only* because this is how the runtime system behaved until ERTS 7.0. Ensure that your Erlang code that may execute during a time warp is *time warp safe* before enabling other modes.

As the time offset is not allowed to change, time correction must adjust the frequency of the Erlang monotonic clock to align Erlang system time with OS system time smoothly. A significant downside of this approach is that we on purpose will use a faulty frequency on the Erlang monotonic clock if adjustments are needed. This error can be as large as 1%. This error will show up in all time measurements in the runtime system.

If time correction is not enabled, Erlang monotonic time freezes when OS system time leaps backwards. The freeze of monotonic time continues until OS system time catches up. The freeze can continue for a long time. When OS system time leaps forwards, Erlang monotonic time also leaps forward.

#### Single Time Warp Mode

This mode is more or less a backwards compatibility mode as of its introduction.

On an embedded system it is not uncommon that the system has no power supply, not even a battery, when it is shut off. The system clock on such a system is typically way off when the system boots. If *no time warp mode* is used, and the Erlang runtime system is started before OS system time has been corrected, Erlang system time can be wrong for a long time, centuries or even longer.

If you need to use Erlang code that is not *time warp safe*, and you need to start the Erlang runtime system before OS system time has been corrected, you may want to use the single time warp mode.

> **Note:**
>
> There are limitations to when you can execute time warp unsafe code using this mode. If it is possible to use time warp safe code only, it is *much* better to use the *multi-time warp mode* instead.

Using the single time warp mode, the time offset is handled in two phases:

Preliminary Phase

This phase starts when the runtime system starts. A preliminary time offset based on current OS system time is determined. This offset is from now on to be fixed during the whole preliminary phase.

If time correction is enabled, adjustments to the Erlang monotonic clock are made to keep its frequency as correct as possible. However, *no* adjustments are made trying to align Erlang system time and OS system time. That is, during the preliminary phase Erlang system time and OS system time can diverge from each other, and no attempt is made to prevent this.

If time correction is disabled, changes in OS system time affects the monotonic clock the same way as when the *no time warp mode* is used.

Final Phase

This phase begins when the user finalizes the time offset by calling `erlang:system_flag(time_offset, finalize)`. The finalization can only be performed once.

During finalization, the time offset is adjusted and fixated so that current Erlang system time aligns with current OS system time. As the time offset can change during the finalization, Erlang system time can do a time warp at this point. The time offset is from now on fixed until the runtime system terminates. If time correction has been enabled, the time correction from now on also makes adjustments to align Erlang system time with OS system time. When the system is in the final phase, it behaves exactly as in the *no time warp mode*.

In order for this to work properly, the user must ensure that the following two requirements are satisfied:

Forward Time Warp

The time warp made when finalizing the time offset can only be done forwards without encountering problems. This implies that the user must ensure that OS system time is set to a time earlier or equal to actual POSIX time before starting the Erlang runtime system.

If you are not sure that OS system time is correct, set it to a time that is guaranteed to be earlier than actual POSIX time before starting the Erlang runtime system, just to be safe.

Finalize Correct OS System Time

OS system time must be correct when the user finalizes the time offset.

If these requirements are not fulfilled, the system may behave very bad.

Assuming that these requirements are fulfilled, time correction is enabled, and that OS system time is adjusted using a time adjustment protocol such as NTP, only small adjustments of Erlang monotonic time are needed to keep system times aligned after finalization. As long as the system is not suspended, the largest adjustments needed are for inserted (or deleted) leap seconds.

> ### Warning:
>
> To use this mode, ensure that all Erlang code that will execute in both phases are *time warp safe*.
>
> Code executing only in the final phase does not have to be able to cope with the time warp.

### Multi-Time Warp Mode

*Multi-time warp mode in combination with time correction is the preferred configuration*. This as the Erlang runtime system have better performance, scale better, and behave better on almost all platforms. In addition, the accuracy and precision of time measurements are better. Only Erlang runtime systems executing on ancient platforms benefit from another configuration.

The time offset may change at any time without limitations. That is, Erlang system time may perform time warps both forwards and backwards at *any* time. As we align Erlang system time with OS system time by changing the time offset, we can enable a time correction that tries to adjust the frequency of the Erlang monotonic clock to be as correct as possible. This makes time measurements using Erlang monotonic time more accurate and precise.

If time correction is disabled, Erlang monotonic time leaps forward if OS system time leaps forward. If OS system time leaps backwards, Erlang monotonic time stops briefly, but it does not freeze for extended periods of time. This as the time offset is changed to align Erlang system time with OS system time.

> Warning:
>
> To use this mode, ensure that all Erlang code that will execute on the runtime system is *time warp safe*.

### 1.2.7 New Time API

The old time API is based on *`erlang:now/0`*. `erlang:now/0` was intended to be used for many unrelated things. This tied these unrelated operations together and caused issues with performance, scalability, accuracy, and precision for operations that did not need to have such issues. To improve this, the new API spreads different functionality over multiple functions.

To be backwards compatible, `erlang:now/0` remains as is, but *you are strongly discouraged from using it*. Many use cases of `erlang:now/0` prevents you from using the new *multi-time warp mode*, which is an important part of this new time functionality improvement.

Some of the new BIFs on some systems, perhaps surprisingly, return negative integer values on a newly started runtime system. This is not a bug, but a memory use optimization.

The new API consists of the following new BIFs:

- *`erlang:convert_time_unit/3`*
- *`erlang:monotonic_time/0`*
- *`erlang:monotonic_time/1`*
- *`erlang:system_time/0`*
- *`erlang:system_time/1`*
- *`erlang:time_offset/0`*
- *`erlang:time_offset/1`*
- *`erlang:timestamp/0`*
- *`erlang:unique_integer/0`*
- *`erlang:unique_integer/1`*
- *`os:system_time/0`*
- *`os:system_time/1`*

The new API also consists of extensions of the following existing BIFs:

- *`erlang:monitor(time_offset, clock_service)`*
- *`erlang:system_flag(time_offset, finalize)`*
- *`erlang:system_info(os_monotonic_time_source)`*
- *`erlang:system_info(os_system_time_source)`*
- *`erlang:system_info(time_offset)`*
- *`erlang:system_info(time_warp_mode)`*
- *`erlang:system_info(time_correction)`*
- *`erlang:system_info(start_time)`*
- *`erlang:system_info(end_time)`*

### New Erlang Monotonic Time

Erlang monotonic time as such is new as of ERTS 7.0. It is introduced to detach time measurements, such as elapsed time from calendar time. In many use cases there is a need to measure elapsed time or specify a time relative to another point in time without the need to know the involved times in UTC or any other globally defined time scale. By introducing a time scale with a local definition of where it starts, time that do not concern calendar time can be managed on that time scale. Erlang monotonic time uses such a time scale with a locally defined start.

The introduction of Erlang monotonic time allows us to adjust the two Erlang times (Erlang monotonic time and Erlang system time) separately. By doing this, the accuracy of elapsed time does not have to suffer just because the system time happened to be wrong at some point in time. Separate adjustments of the two times are only performed in the time warp modes, and only fully separated in the *multi-time warp mode*. All other modes than the multi-time warp mode are for backwards compatibility reasons. When using these modes, the accuracy of Erlang monotonic time suffer, as the adjustments of Erlang monotonic time in these modes are more or less tied to Erlang system time.

The adjustment of system time could have been made smother than using a time warp approach, but we think that would be a bad choice. As we can express and measure time that is not connected to calendar time by the use of Erlang monotonic time, it is better to expose the change in Erlang system time immediately. This as the Erlang applications executing on the system can react on the change in system time as soon as possible. This is also more or less exactly how most operating systems handle this (OS monotonic time and OS system time). By adjusting system time smoothly, we would just hide the fact that system time changed and make it harder for the Erlang applications to react to the change in a sensible way.

To be able to react to a change in Erlang system time, you must be able to detect that it happened. The change in Erlang system time occurs when current time offset is changed. We have therefore introduced the possibility to monitor the time offset using `erlang:monitor(time_offset, clock_service)`. A process monitoring the time offset is sent a message on the following format when the time offset is changed:

```
{'CHANGE', MonitorReference, time_offset, clock_service, NewTimeOffset}
```

### Unique Values

Besides reporting time, `erlang:now/0` also produces unique and strictly monotonically increasing values. To detach this functionality from time measurements, we have introduced `erlang:unique_integer()`.

### How to Work with the New API

Previously `erlang:now/0` was the only option for doing many things. This section deals with some things that `erlang:now/0` can be used for, and how you are to these using the new API.

**Retrieve Erlang System Time**

#### Don't:

Use `erlang:now/0` to retrieve current Erlang system time.

#### Do:

Use `erlang:system_time/1` to retrieve current Erlang system time on the *time unit* of your choice.

If you want the same format as returned by `erlang:now/0`, use `erlang:timestamp/0`.

### Measure Elapsed Time

Don't:

Take timestamps with `erlang:now/0` and calculate the difference in time with *`timer:now_diff/2`*.

Do:

Take timestamps with *`erlang:monotonic_time/0`* and calculate the time difference using ordinary subtraction. The result will be in `native` *time unit*. If you want to convert the result to another time unit, you can use *`erlang:convert_time_unit/3`*.

An easier way to do this is to use *`erlang:monotonic_time/1`* with the desired time unit. However, you can then lose accuracy and precision.

### Determine Order of Events

Don't:

Determine the order of events by saving a timestamp with `erlang:now/0` when the event occurs.

Do:

Determine the order of events by saving the integer returned by *`erlang:unique_integer([monotonic])`* when the event occurs. These integers will be strictly monotonically ordered on current runtime system instance corresponding to creation time.

### Determine Order of Events with Time of the Event

Don't:

Determine the order of events by saving a timestamp with `erlang:now/0` when the event occurs.

### Do:

Determine the order of events by saving a tuple containing *monotonic time* and a *strictly monotonically increasing integer* as follows:

```
Time = erlang:monotonic_time(),
UMI = erlang:unique_integer([monotonic]),
EventTag = {Time, UMI}
```

These tuples will be strictly monotonically ordered on current runtime system instance according to creation time. It is important that the monotonic time is in the first element (the most significant element when comparing 2-tuples). Using the monotonic time in the tuples, you can calculate time between events.

If you are interested in Erlang system time at the time when the event occurred, you can also save the time offset before or after saving the events using *`erlang:time_offset/0`*. Erlang monotonic time added with the time offset corresponds to Erlang system time.

If you are executing in a mode where time offset can change, and you want to get the actual Erlang system time when the event occurred, you can save the time offset as a third element in the tuple (the least significant element when comparing 3-tuples).

#### Create a Unique Name

### Don't:

Use the values returned from `erlang:now/0` to create a name unique on the current runtime system instance.

### Do:

Use the value returned from *`erlang:unique_integer/0`* to create a name unique on the current runtime system instance. If you only want positive integers, you can use *`erlang:unique_integer([positive])`*.

#### Seed Random Number Generation with a Unique Value

### Don't:

Seed random number generation using `erlang:now()`.

### Do:

Seed random number generation using a combination of *`erlang:monotonic_time()`*, *`erlang:time_offset()`*, *`erlang:unique_integer()`*, and other functionality.

To sum up this section: *Do not use* `erlang:now/0`.

### 1.2.8 Support of Both New and Old OTP Releases

It can be required that your code must run on a variety of OTP installations of different OTP releases. If so, you cannot use the new API out of the box, as it will not be available on old pre OTP 18 releases. The solution is *not* to avoid using the new API, as your code then would not benefit from the scalability and accuracy improvements made. Instead, use the new API when available, and fall back on `erlang:now/0` when the new API is unavailable.

Fortunately most of the new API can easily be implemented using existing primitives, except for:

- *`erlang:system_info(start_time)`*
- *`erlang:system_info(end_time)`*
- *`erlang:system_info(os_monotonic_time_source)`*
- *`erlang:system_info(os_system_time_source)`*)

By wrapping the API with functions that fall back on `erlang:now/0` when the new API is unavailable, and using these wrappers instead of using the API directly, the problem is solved. These wrappers can, for example, be implemented as in **$ERL_TOP/erts/example/time_compat.erl**.

## 1.3 Match specifications in Erlang

A "match specification" (match_spec) is an Erlang term describing a small "program" that will try to match something (either the parameters to a function as used in the `erlang:trace_pattern/2` BIF, or the objects in an ETS table.). The match_spec in many ways works like a small function in Erlang, but is interpreted/compiled by the Erlang runtime system to something much more efficient than calling an Erlang function. The match_spec is also very limited compared to the expressiveness of real Erlang functions.

Match specifications are given to the BIF `erlang:trace_pattern/2` to execute matching of function arguments as well as to define some actions to be taken when the match succeeds (the `MatchBody` part). Match specifications can also be used in ETS, to specify objects to be returned from an `ets:select/2` call (or other select calls). The semantics and restrictions differ slightly when using match specifications for tracing and in ETS, the differences are defined in a separate paragraph below.

The most notable difference between a match_spec and an Erlang fun is of course the syntax. Match specifications are Erlang terms, not Erlang code. A match_spec also has a somewhat strange concept of exceptions. An exception (e.g., `badarg`) in the `MatchCondition` part, which resembles an Erlang guard, will generate immediate failure, while an exception in the `MatchBody` part, which resembles the body of an Erlang function, is implicitly caught and results in the single atom `'EXIT'`.

### 1.3.1 Grammar

A match_spec used in tracing can be described in this *informal* grammar:

- MatchExpression ::= [ MatchFunction, ... ]
- MatchFunction ::= { MatchHead, MatchConditions, MatchBody }
- MatchHead ::= MatchVariable | `'_'` | [ MatchHeadPart, ... ]
- MatchHeadPart ::= term() | MatchVariable | `'_'`
- MatchVariable ::= '$<number>'
- MatchConditions ::= [ MatchCondition, ...] | `[]`
- MatchCondition ::= { GuardFunction } | { GuardFunction, ConditionExpression, ... }
- BoolFunction ::= `is_atom` | `is_float` | `is_integer` | `is_list` | `is_number` | `is_pid` | `is_port` | `is_reference` | `is_tuple` | `is_map` | `is_binary` | `is_function` | `is_record` | `is_seq_trace` | `'and'` | `'or'` | `'not'` | `'xor'` | `andalso` | `orelse`

- ConditionExpression ::= ExprMatchVariable | { GuardFunction } | { GuardFunction, ConditionExpression, ... } | TermConstruct
- ExprMatchVariable ::= MatchVariable (bound in the MatchHead) | `'$_'` | `'$$'`
- TermConstruct = {{}} | {{ ConditionExpression, ... }} | `[]` | [ConditionExpression, ...] | `#{}` | #{term() => ConditionExpression, ...} | NonCompositeTerm | Constant
- NonCompositeTerm ::= term() (not list or tuple or map)
- Constant ::= {`const`, term()}
- GuardFunction ::= BoolFunction | `abs` | `element` | `hd` | `length` | `node` | `round` | `size` | `tl` | `trunc` | `'+'` | `'-'` | `'*'` | `'div'` | `'rem'` | `'band'` | `'bor'` | `'bxor'` | `'bnot'` | `'bsl'` | `'bsr'` | `'>'` | `'>='` | `'<'` | `'=<'` | `'=:='` | `'=='` | `'=/='` | `'/='` | `self` | `get_tcw`
- MatchBody ::= [ ActionTerm ]
- ActionTerm ::= ConditionExpression | ActionCall
- ActionCall ::= {ActionFunction} | {ActionFunction, ActionTerm, ...}
- ActionFunction ::= `set_seq_token` | `get_seq_token` | `message` | `return_trace` | `exception_trace` | `process_dump` | `enable_trace` | `disable_trace` | `trace` | `display` | `caller` | `set_tcw` | `silent`

A match_spec used in ets can be described in this *informal* grammar:

- MatchExpression ::= [ MatchFunction, ... ]
- MatchFunction ::= { MatchHead, MatchConditions, MatchBody }
- MatchHead ::= MatchVariable | `'_'` | { MatchHeadPart, ... }
- MatchHeadPart ::= term() | MatchVariable | `'_'`
- MatchVariable ::= '$<number>'
- MatchConditions ::= [ MatchCondition, ...] | `[]`
- MatchCondition ::= { GuardFunction } | { GuardFunction, ConditionExpression, ... }
- BoolFunction ::= `is_atom` | `is_float` | `is_integer` | `is_list` | `is_number` | `is_pid` | `is_port` | `is_reference` | `is_tuple` | `is_map` | `is_binary` | `is_function` | `is_record` | `is_seq_trace` | `'and'` | `'or'` | `'not'` | `'xor'` | `andalso` | `orelse`
- ConditionExpression ::= ExprMatchVariable | { GuardFunction } | { GuardFunction, ConditionExpression, ... } | TermConstruct
- ExprMatchVariable ::= MatchVariable (bound in the MatchHead) | `'$_'` | `'$$'`
- TermConstruct = {{}} | {{ ConditionExpression, ... }} | `[]` | [ConditionExpression, ...] | #{} | #{term() => ConditionExpression, ...} | NonCompositeTerm | Constant
- NonCompositeTerm ::= term() (not list or tuple or map)
- Constant ::= {`const`, term()}
- GuardFunction ::= BoolFunction | `abs` | `element` | `hd` | `length` | `node` | `round` | `size` | `tl` | `trunc` | `'+'` | `'-'` | `'*'` | `'div'` | `'rem'` | `'band'` | `'bor'` | `'bxor'` | `'bnot'` | `'bsl'` | `'bsr'` | `'>'` | `'>='` | `'<'` | `'=<'` | `'=:='` | `'=='` | `'=/='` | `'/='` | `self` | `get_tcw`
- MatchBody ::= [ ConditionExpression, ... ]

## 1.3.2 Function descriptions

### Functions allowed in all types of match specifications

The different functions allowed in `match_spec` work like this:

*is_atom, is_float, is_integer, is_list, is_number, is_pid, is_port, is_reference, is_tuple, is_map, is_binary, is_function:* Like the corresponding guard tests in Erlang, return `true` or `false`.

*is_record:* Takes an additional parameter, which SHALL be the result of `record_info(size, <record_type>)`, like in `{is_record, '$1', rectype, record_info(size, rectype)}`.

*'not':* Negates its single argument (anything other than `false` gives `false`).

*'and':* Returns `true` if all its arguments (variable length argument list) evaluate to `true`, else `false`. Evaluation order is undefined.

*'or':* Returns `true` if any of its arguments evaluates to `true`. Variable length argument list. Evaluation order is undefined.

*andalso:* Like `'and'`, but quits evaluating its arguments as soon as one argument evaluates to something else than true. Arguments are evaluated left to right.

*orelse:* Like `'or'`, but quits evaluating as soon as one of its arguments evaluates to `true`. Arguments are evaluated left to right.

*'xor':* Only two arguments, of which one has to be true and the other false to return `true`; otherwise `'xor'` returns false.

*abs, element, hd, length, node, round, size, tl, trunc, '+', '-', '*', 'div', 'rem', 'band', 'bor', 'bxor', 'bnot', 'bsl', 'bsr', '>', '>=', '<', '=<', '=:=', '==', '=/=', '/=', self:* Work as the corresponding Erlang bif's (or operators). In case of bad arguments, the result depends on the context. In the `MatchConditions` part of the expression, the test fails immediately (like in an Erlang guard), but in the `MatchBody`, exceptions are implicitly caught and the call results in the atom `'EXIT'`.

## Functions allowed only for tracing

*is_seq_trace:* Returns `true` if a sequential trace token is set for the current process, otherwise `false`.

*set_seq_token:* Works like `seq_trace:set_token/2`, but returns `true` on success and `'EXIT'` on error or bad argument. Only allowed in the `MatchBody` part and only allowed when tracing.

*get_seq_token:* Works just like `seq_trace:get_token/0`, and is only allowed in the `MatchBody` part when tracing.

*message:* Sets an additional message appended to the trace message sent. One can only set one additional message in the body; subsequent calls will replace the appended message. As a special case, `{message, false}` disables sending of trace messages ('call' and 'return_to') for this function call, just like if the match_spec had not matched, which can be useful if only the side effects of the `MatchBody` are desired. Another special case is `{message, true}` which sets the default behavior, as if the function had no match_spec, trace message is sent with no extra information (if no other calls to `message` are placed before `{message, true}`, it is in fact a "noop").

Takes one argument, the message. Returns `true` and can only be used in the `MatchBody` part and when tracing.

*return_trace:* Causes a `return_from` trace message to be sent upon return from the current function. Takes no arguments, returns `true` and can only be used in the `MatchBody` part when tracing. If the process trace flag `silent` is active the `return_from` trace message is inhibited.

NOTE! If the traced function is tail recursive, this match spec function destroys that property. Hence, if a match spec executing this function is used on a perpetual server process, it may only be active for a limited time, or the emulator will eventually use all memory in the host machine and crash. If this match_spec function is inhibited using the `silent` process trace flag tail recursiveness still remains.

*exception_trace:* Same as *return_trace*, plus; if the traced function exits due to an exception, an `exception_from` trace message is generated, whether the exception is caught or not.

*process_dump:* Returns some textual information about the current process as a binary. Takes no arguments and is only allowed in the `MatchBody` part when tracing.

*enable_trace:* With one parameter this function turns on tracing like the Erlang call `erlang:trace(self(), true, [P2])`, where `P2` is the parameter to `enable_trace`. With two parameters, the first parameter should

be either a process identifier or the registered name of a process. In this case tracing is turned on for the designated process in the same way as in the Erlang call `erlang:trace(P1, true, [P2])`, where P1 is the first and P2 is the second argument. The process `P1` gets its trace messages sent to the same tracer as the process executing the statement uses. `P1` can *not* be one of the atoms `all`, `new` or `existing` (unless, of course, they are registered names). `P2` can *not* be `cpu_timestamp` nor `{tracer,_}`. Returns `true` and may only be used in the `MatchBody` part when tracing.

*disable_trace:* With one parameter this function disables tracing like the Erlang call `erlang:trace(self(), false, [P2])`, where `P2` is the parameter to `disable_trace`. With two parameters it works like the Erlang call `erlang:trace(P1, false, [P2])`, where P1 can be either a process identifier or a registered name and is given as the first argument to the match_spec function. `P2` can *not* be `cpu_timestamp` nor `{tracer,_}`. Returns `true` and may only be used in the `MatchBody` part when tracing.

*trace:* With two parameters this function takes a list of trace flags to disable as first parameter and a list of trace flags to enable as second parameter. Logically, the disable list is applied first, but effectively all changes are applied atomically. The trace flags are the same as for `erlang:trace/3` not including `cpu_timestamp` but including `{tracer,_}`. If a tracer is specified in both lists, the tracer in the enable list takes precedence. If no tracer is specified the same tracer as the process executing the match spec is used. With three parameters to this function the first is either a process identifier or the registered name of a process to set trace flags on, the second is the disable list, and the third is the enable list. Returns `true` if any trace property was changed for the trace target process or `false` if not. It may only be used in the `MatchBody` part when tracing.

*caller:* Returns the calling function as a tuple {Module, Function, Arity} or the atom `undefined` if the calling function cannot be determined. May only be used in the `MatchBody` part when tracing.

Note that if a "technically built in function" (i.e. a function not written in Erlang) is traced, the `caller` function will sometimes return the atom `undefined`. The calling Erlang function is not available during such calls.

*display:* For debugging purposes only; displays the single argument as an Erlang term on stdout, which is seldom what is wanted. Returns `true` and may only be used in the `MatchBody` part when tracing.

*get_tcw:* Takes no argument and returns the value of the node's trace control word. The same is done by `erlang:system_info(trace_control_word)`.

The trace control word is a 32-bit unsigned integer intended for generic trace control. The trace control word can be tested and set both from within trace match specifications and with BIFs. This call is only allowed when tracing.

*set_tcw:* Takes one unsigned integer argument, sets the value of the node's trace control word to the value of the argument and returns the previous value. The same is done by `erlang:system_flag(trace_control_word, Value)`. It is only allowed to use `set_tcw` in the `MatchBody` part when tracing.

*silent:* Takes one argument. If the argument is `true`, the call trace message mode for the current process is set to silent for this call and all subsequent, i.e call trace messages are inhibited even if `{message, true}` is called in the `MatchBody` part for a traced function.

This mode can also be activated with the `silent` flag to `erlang:trace/3`.

If the argument is `false`, the call trace message mode for the current process is set to normal (non-silent) for this call and all subsequent.

If the argument is neither `true` nor `false`, the call trace message mode is unaffected.

*Note* that all "function calls" have to be tuples, even if they take no arguments. The value of `self` is the atom() `self`, but the value of `{self}` is the pid() of the current process.

### 1.3.3 Variables and literals

Variables take the form `'$<number>'` where `<number>` is an integer between 0 (zero) and 100000000 (1e+8), the behavior if the number is outside these limits is *undefined*. In the `MatchHead` part, the special variable `'_'` matches

anything, and never gets bound (like _ in Erlang). In the `MatchCondition/MatchBody` parts, no unbound variables are allowed, why `'_'` is interpreted as itself (an atom). Variables can only be bound in the `MatchHead` part. In the `MatchBody` and `MatchCondition` parts, only variables bound previously may be used. As a special case, in the `MatchCondition/MatchBody` parts, the variable `'$_'` expands to the whole expression which matched the `MatchHead` (i.e., the whole parameter list to the possibly traced function or the whole matching object in the ets table) and the variable `'$$'` expands to a list of the values of all bound variables in order (i.e. `['$1','$2', ...]`).

In the `MatchHead` part, all literals (except the variables noted above) are interpreted as is. In the `MatchCondition/MatchBody` parts, however, the interpretation is in some ways different. Literals in the `MatchCondition/MatchBody` can either be written as is, which works for all literals except tuples, or by using the special form `{const, T}`, where `T` is any Erlang term. For tuple literals in the match_spec, one can also use double tuple parentheses, i.e., construct them as a tuple of arity one containing a single tuple, which is the one to be constructed. The "double tuple parenthesis" syntax is useful to construct tuples from already bound variables, like in `{{'$1', [a,b,'$2']}}`. Some examples may be needed:

| Expression | Variable bindings | Result |
|---|---|---|
| {{'$1','$2'}} | '$1' = a, '$2' = b | {a,b} |
| {const, {'$1', '$2'}} | doesn't matter | {'$1', '$2'} |
| a | doesn't matter | a |
| '$1' | '$1' = [] | [] |
| ['$1'] | '$1' = [] | [[]] |
| [{{a}}] | doesn't matter | [{a}] |
| 42 | doesn't matter | 42 |
| "hello" | doesn't matter | "hello" |
| $1 | doesn't matter | 49 (the ASCII value for the character '1') |

**Table 3.1: Literals in the MatchCondition/MatchBody parts of a match_spec**

## 1.3.4 Execution of the match

The execution of the match expression, when the runtime system decides whether a trace message should be sent, goes as follows:

For each tuple in the `MatchExpression` list and while no match has succeeded:

- Match the `MatchHead` part against the arguments to the function, binding the `'$<number>'` variables (much like in `ets:match/2`). If the `MatchHead` cannot match the arguments, the match fails.
- Evaluate each `MatchCondition` (where only `'$<number>'` variables previously bound in the `MatchHead` can occur) and expect it to return the atom `true`. As soon as a condition does not evaluate to `true`, the match fails. If any BIF call generates an exception, also fail.
- - *If the match_spec is executing when tracing:*
    Evaluate each `ActionTerm` in the same way as the `MatchConditions`, but completely ignore the return values. Regardless of what happens in this part, the match has succeeded.

- *If the match_spec is executed when selecting objects from an ETS table:*
  Evaluate the expressions in order and return the value of the last expression (typically there is only one expression in this context)

### 1.3.5 Differences between match specifications in ETS and tracing

ETS match specifications are there to produce a return value. Usually the `MatchBody` contains one single `ConditionExpression` which defines the return value without having any side effects. Calls with side effects are not allowed in the ETS context.

When tracing there is no return value to produce, the match specification either matches or doesn't. The effect when the expression matches is a trace message rather then a returned term. The `ActionTerm`'s are executed as in an imperative language, i.e. for their side effects. Functions with side effects are also allowed when tracing.

In ETS the match head is a `tuple()` (or a single match variable) while it is a list (or a single match variable) when tracing.

### 1.3.6 Examples

Match an argument list of three where the first and third arguments are equal:

```
[{['$1', '_', '$1'],
  [],
  []}]
```

Match an argument list of three where the second argument is a number greater than three:

```
[{['_', '$1', '_'],
  [{ '>', '$1', 3}],
  []}]
```

Match an argument list of three, where the third argument is a tuple containing argument one and two *or* a list beginning with argument one and two (i. e. `[a,b,[a,b,c]]` or `[a,b,{a,b}]`):

```
[{['$1', '$2', '$3'],
  [{orelse,
      {'=:=', '$3', {{'$1','$2'}}},
      {'and',
        {'=:=', '$1', {hd, '$3'}},
        {'=:=', '$2', {hd, {tl, '$3'}}}}}],
  []}]
```

The above problem may also be solved like this:

```
[{['$1', '$2', {'$1', '$2}], [], []},
 {['$1', '$2', ['$1', '$2' | '_']], [], []}]
```

Match two arguments where the first is a tuple beginning with a list which in turn begins with the second argument times two (i. e. [{[4,x],y},2] or [{[8], y, z},4])

```
[{['$1', '$2'],[{'=:=', {'*', 2, '$2'}, {hd, {element, 1, '$1'}}}],
  []}]
```

Match three arguments. When all three are equal and are numbers, append the process dump to the trace message, else let the trace message be as is, but set the sequential trace token label to 4711.

```
[{['$1', '$1', '$1'],
  [{is_number, '$1'}],
  [{message, {process_dump}}]},
 {'_', [], [{set_seq_token, label, 4711}]}]
```

As can be noted above, the parameter list can be matched against a single `MatchVariable` or an `'_'`. To replace the whole parameter list with a single variable is a special case. In all other cases the `MatchHead` has to be a *proper* list.

Match all objects in an ets table where the first element is the atom 'strider' and the tuple arity is 3 and return the whole object.

```
[{{strider,'_','_'},
  [],
  ['$_']}]
```

Match all objects in an ets table with arity > 1 and the first element is 'gandalf', return element 2.

```
[{'$1',
  [{'==', gandalf, {element, 1, '$1'}},{'>=',{size, '$1'},2}],
  [{element,2,'$1'}]}]
```

In the above example, if the first element had been the key, it's much more efficient to match that key in the `MatchHead` part than in the `MatchConditions` part. The search space of the tables is restricted with regards to the `MatchHead` so that only objects with the matching key are searched.

Match tuples of 3 elements where the second element is either 'merry' or 'pippin', return the whole objects.

```
[{{'_',merry,'_'},
  [],
  ['$_']},
 {{'_',pippin,'_'},
  [],
  ['$_']}]
```

The function `ets:test_ms/2` can be useful for testing complicated ets matches.

# 1.4 How to interpret the Erlang crash dumps

This document describes the `erl_crash.dump` file generated upon abnormal exit of the Erlang runtime system.

*Important:* For OTP release R9C the Erlang crash dump has had a major facelift. This means that the information in this document will not be directly applicable for older dumps. However, if you use the Crashdump Viewer tool on older dumps, the crash dumps are translated into a format similar to this.

The system will write the crash dump in the current directory of the emulator or in the file pointed out by the environment variable (whatever that means on the current operating system) ERL_CRASH_DUMP. For a crash dump to be written, there has to be a writable file system mounted.

Crash dumps are written mainly for one of two reasons: either the builtin function `erlang:halt/1` is called explicitly with a string argument from running Erlang code, or else the runtime system has detected an error that cannot be handled. The most usual reason that the system can't handle the error is that the cause is external limitations, such as running out of memory. A crash dump due to an internal error may be caused by the system reaching limits in the emulator itself (like the number of atoms in the system, or too many simultaneous ets tables). Usually the emulator or the operating system can be reconfigured to avoid the crash, which is why interpreting the crash dump correctly is important.

On systems that support OS signals, it is also possible to stop the runtime system and generate a crash dump by sending the SIGUSR1.

The erlang crash dump is a readable text file, but it might not be very easy to read. Using the Crashdump Viewer tool in the `observer` application will simplify the task. This is an wx-widget based tool for browsing Erlang crash dumps.

## 1.4.1 General information

The first part of the dump shows the creation time for the dump, a slogan indicating the reason for the dump, the system version, of the node from which the dump originates, the compile time of the emulator running the originating node, the number of atoms in the atom table and the runtime system thread that caused the crash dump to happen.

### Reasons for crash dumps (slogan)

The reason for the dump is noted in the beginning of the file as *Slogan: <reason>* (the word "slogan" has historical roots). If the system is halted by the BIF `erlang:halt/1`, the slogan is the string parameter passed to the BIF, otherwise it is a description generated by the emulator or the (Erlang) kernel. Normally the message should be enough to understand the problem, but nevertheless some messages are described here. Note however that the suggested reasons for the crash are *only suggestions*. The exact reasons for the errors may vary depending on the local applications and the underlying operating system.

- "<*A*>: Cannot allocate <*N*> bytes of memory (of type "<*T*>")." - The system has run out of memory. <A> is the allocator that failed to allocate memory, <N> is the number of bytes that <A> tried to allocate, and <T> is the memory block type that the memory was needed for. The most common case is that a process stores huge amounts of data. In this case <T> is most often `heap`, `old_heap`, `heap_frag`, or `binary`. For more information on allocators see *erts_alloc(3)*.
- "<*A*>: Cannot reallocate <*N*> bytes of memory (of type "<*T*>")." - Same as above with the exception that memory was being reallocated instead of being allocated when the system ran out of memory.
- "Unexpected op code *N*" - Error in compiled code, `beam` file damaged or error in the compiler.
- "Module *Name* undefined" | "Function *Name* undefined" | "No function *Name*:*Name*/1" | "No function *Name*:start/2" - The kernel/stdlib applications are damaged or the start script is damaged.
- "Driver_select called with too large file descriptor `N`" - The number of file descriptors for sockets exceed 1024 (Unix only). The limit on file-descriptors in some Unix flavors can be set to over 1024, but only 1024 sockets/pipes can be used simultaneously by Erlang (due to limitations in the Unix `select` call). The number of open regular files is not affected by this.

- "Received SIGUSR1" - Sending the SIGUSR1 signal to a Erlang machine (Unix only) forces a crash dump. This slogan reflects that the Erlang machine crash-dumped due to receiving that signal.
- "Kernel pid terminated (*Who*) (*Exit-reason*)" - The kernel supervisor has detected a failure, usually that the `application_controller` has shut down (`Who` = `application_controller`, `Why` = `shutdown`). The application controller may have shut down for a number of reasons, the most usual being that the node name of the distributed Erlang node is already in use. A complete supervisor tree "crash" (i.e., the top supervisors have exited) will give about the same result. This message comes from the Erlang code and not from the virtual machine itself. It is always due to some kind of failure in an application, either within OTP or a "user-written" one. Looking at the error log for your application is probably the first step to take.
- "Init terminating in do_boot ()" - The primitive Erlang boot sequence was terminated, most probably because the boot script has errors or cannot be read. This is usually a configuration error - the system may have been started with a faulty `-boot` parameter or with a boot script from the wrong version of OTP.
- "Could not start kernel pid (*Who*) ()" - One of the kernel processes could not start. This is probably due to faulty arguments (like errors in a `-config` argument) or faulty configuration files. Check that all files are in their correct location and that the configuration files (if any) are not damaged. Usually there are also messages written to the controlling terminal and/or the error log explaining what's wrong.

Other errors than the ones mentioned above may occur, as the `erlang:halt/1` BIF may generate any message. If the message is not generated by the BIF and does not occur in the list above, it may be due to an error in the emulator. There may however be unusual messages that I haven't mentioned, that still are connected to an application failure. There is a lot more information available, so more thorough reading of the crash dump may reveal the crash reason. The size of processes, the number of ets tables and the Erlang data on each process stack can be useful for tracking down the problem.

### Number of atoms

The number of atoms in the system at the time of the crash is shown as *Atoms: <number>*. Some ten thousands atoms is perfectly normal, but more could indicate that the BIF `erlang:list_to_atom/1` is used to dynamically generate a lot of *different* atoms, which is never a good idea.

## 1.4.2 Scheduler information

Under the tag *=scheduler* information about the current state and statistics of the schedulers in the runtime system is displayed. On OSs that do allow instant suspension of other threads, the data within this section will reflect what the runtime system looks like at the moment when the crash happens.

The following fields can exist for a process:

*=scheduler:id*
: Header, states the scheduler identifier.

*Scheduler Sleep Info Flags*
: If empty the scheduler was doing some work. If not empty the scheduler is either in some state of sleep, or suspended. This entry is only present in a SMP enabled emulator

*Scheduler Sleep Info Aux Work*
: If not empty, a scheduler internal auxiliary work is scheduled to be done.

*Current Port*
: The port identifier of the port that is currently being executed by the scheduler.

*Current Process*
: The process identifier of the process that is currently being executed by the scheduler. If there is such a process this entry is followed by the *State,Internal State, Program Counter, CP* of that same process. See *Process Information* for a description what the different entries mean. Keep in mind that this is a snapshot of what the entries are exactly when the crash dump is starting to be generated. Therefore they will most likely be different (and more telling) then the entries for the same processes found in the *=proc* section. If there is no currently running process, only the *Current Process* entry will be printed.

*Current Process Limited Stack Trace*

This entry only shows up if there is a current process. It is very similar to *=proc_stack*, except that only the function frames are printed (i.e. the stack variables are omited). It is also limited to only print the top and bottom part of the stack. If the stack is small (less that 512 slots) then the entire stack will be printed. If not, an entry stating

```
skipping ## slots
```

will be printed where ## is replaced by the number of slots that has been skipped.

*Run Queue*

Displays statistics about how many processes and ports of different priorities are scheduled on this scheduler.

*** crashed ***

This entry is normally not printed. It signifies that getting the rest of the information about this scheduler failed for some reason.

### 1.4.3 Memory information

Under the tag *=memory* you will find information similar to what you can obtain on a living node with *erlang:memory()*.

### 1.4.4 Internal table information

The tags *=hash_table:<table_name>* and *=index_table:<table_name>* presents internal tables. These are mostly of interest for runtime system developers.

### 1.4.5 Allocated areas

Under the tag *=allocated_areas* you will find information similar to what you can obtain on a living node with *erlang:system_info(allocated_areas)*.

### 1.4.6 Allocator

Under the tag *=allocator:<A>* you will find various information about allocator <A>. The information is similar to what you can obtain on a living node with *erlang:system_info({allocator, <A>})*. For more information see the documentation of *erlang:system_info({allocator, <A>})*, and the *erts_alloc(3)* documentation.

### 1.4.7 Process information

The Erlang crashdump contains a listing of each living Erlang process in the system. The process information for one process may look like this (line numbers have been added):

The following fields can exist for a process:

*=proc:<pid>*

Heading, states the process identifier

*State*

The state of the process. This can be one of the following:

- *Scheduled* - The process was scheduled to run but not currently running ("in the run queue").
- *Waiting* - The process was waiting for something (in `receive`).
- *Running* - The process was currently running. If the BIF `erlang:halt/1` was called, this was the process calling it.
- *Exiting* - The process was on its way to exit.

- *Garbing* - This is bad luck, the process was garbage collecting when the crash dump was written, the rest of the information for this process is limited.
- *Suspended* - The process is suspended, either by the BIF `erlang:suspend_process/1` or because it is trying to write to a busy port.

*Registered name*
: The registered name of the process, if any.

*Spawned as*
: The entry point of the process, i.e., what function was referenced in the `spawn` or `spawn_link` call that started the process.

*Last scheduled in for | Current call*
: The current function of the process. These fields will not always exist.

*Spawned by*
: The parent of the process, i.e. the process which executed `spawn` or `spawn_link`.

*Started*
: The date and time when the process was started.

*Message queue length*
: The number of messages in the process' message queue.

*Number of heap fragments*
: The number of allocated heap fragments.

*Heap fragment data*
: Size of fragmented heap data. This is data either created by messages being sent to the process or by the Erlang BIFs. This amount depends on so many things that this field is utterly uninteresting.

*Link list*
: Process id's of processes linked to this one. May also contain ports. If process monitoring is used, this field also tells in which direction the monitoring is in effect, i.e., a link being "to" a process tells you that the "current" process was monitoring the other and a link "from" a process tells you that the other process was monitoring the current one.

*Reductions*
: The number of reductions consumed by the process.

*Stack+heap*
: The size of the stack and heap (they share memory segment)

*OldHeap*
: The size of the "old heap". The Erlang virtual machine uses generational garbage collection with two generations. There is one heap for new data items and one for the data that have survived two garbage collections. The assumption (which is almost always correct) is that data that survive two garbage collections can be "tenured" to a heap more seldom garbage collected, as they will live for a long period. This is a quite usual technique in virtual machines. The sum of the heaps and stack together constitute most of the process's allocated memory.

*Heap unused, OldHeap unused*
: The amount of unused memory on each heap. This information is usually useless.

*Stack*
: If the system uses shared heap, the fields *Stack+heap*, *OldHeap*, *Heap unused* and *OldHeap unused* do not exist. Instead this field presents the size of the process' stack.

*Memory*
: The total memory used by this process. This includes call stack, heap and internal structures. Same as *erlang:process_info(Pid,memory)*.

*Program counter*
: The current instruction pointer. This is only interesting for runtime system developers. The function into which the program counter points is the current function of the process.

*CP*
: The continuation pointer, i.e. the return address for the current call. Usually useless for other than runtime system developers. This may be followed by the function into which the CP points, which is the function calling the current function.

*Arity*
: The number of live argument registers. The argument registers, if any are live, will follow. These may contain the arguments of the function if they are not yet moved to the stack.

*Internal State*
: A more detailed internal represantation of the state of this process.

See also the section about *process data*.

### 1.4.8 Port information

This section lists the open ports, their owners, any linked processed, and the name of their driver or external process.

### 1.4.9 ETS tables

This section contains information about all the ETS tables in the system. The following fields are interesting for each table:

*=ets:<owner>*
: Heading, states the owner of the table (a process identifier)

*Table*
: The identifier for the table. If the table is a `named_table`, this is the name.

*Name*
: The name of the table, regardless of whether it is a `named_table` or not.

*Hash table, Buckets*
: This occurs if the table is a hash table, i.e. if it is not an `ordered_set`.

*Hash table, Chain Length*
: Only applicable for hash tables. Contains statistics about the hash table, such as the max, min and avg chain length. Having a max much larger than the avg, and a std dev much larger that the expected std dev is a sign that the hashing of the terms is behaving badly for some reason.

*Ordered set (AVL tree), Elements*
: This occurs only if the table is an `ordered_set`. (The number of elements is the same as the number of objects in the table.)

*Fixed*
: If the table is fixed using ets:safe_fixtable or some internal mechanism.

*Objects*
: The number of objects in the table

*Words*
: The number of words (usually 4 bytes/word) allocated to data in the table.

*Type*
: The type of the table, i.e. `set`, `bag`, `dublicate_bag` or `ordered_set`.

*Compressed*
: If this table was compressed.

*Protection*
: The protection of this table.

*Write Concurrency*
: If write_concurrency was enabled for this table.

*Read Concurrency*
: If read_concurrency was enabled for this table.

### 1.4.10 Timers

This section contains information about all the timers started with the BIFs `erlang:start_timer/3` and `erlang:send_after/3`. The following fields exists for each timer:

*=timer:<owner>*
: Heading, states the owner of the timer (a process identifier) i.e. the process to receive the message when the timer expires.

*Message*
: The message to be sent.

*Time left*
: Number of milliseconds left until the message would have been sent.

### 1.4.11 Distribution information

If the Erlang node was alive, i.e., set up for communicating with other nodes, this section lists the connections that were active. The following fields can exist:

*=node:<node_name>*
: The name of the node

*no_distribution*
: This will only occur if the node was not distributed.

*=visible_node:<channel>*
: Heading for a visible nodes, i.e. an alive node with a connection to the node that crashed. States the channel number for the node.

*=hidden_node:<channel>*
: Heading for a hidden node. A hidden node is the same as a visible node, except that it is started with the "-hidden" flag. States the channel number for the node.

*=not_connected:<channel>*
: Heading for a node which is has been connected to the crashed node earlier. References (i.e. process or port identifiers) to the not connected node existed at the time of the crash. exist. States the channel number for the node.

*Name*
: The name of the remote node.

*Controller*
: The port which controls the communication with the remote node.

*Creation*
: An integer (1-3) which together with the node name identifies a specific instance of the node.

*Remote monitoring: <local_proc> <remote_proc>*
: The local process was monitoring the remote process at the time of the crash.

*Remotely monitored by: <local_proc> <remote_proc>*
: The remote process was monitoring the local process at the time of the crash.

*Remote link: <local_proc> <remote_proc>*
: A link existed between the local process and the remote process at the time of the crash.

### 1.4.12 Loaded module information

This section contains information about all loaded modules. First, the memory usage by loaded code is summarized. There is one field for "Current code" which is code that is the current latest version of the modules. There is also a field for "Old code" which is code where there exists a newer version in the system, but the old version is not yet purged. The memory usage is in bytes.

All loaded modules are then listed. The following fields exist:

*=mod:<module_name>*
: Heading, and the name of the module.

*Current size*
: Memory usage for the loaded code in bytes

*Old size*
: Memory usage for the old code, if any.

*Current attributes*
: Module attributes for the current code. This field is decoded when looked at by the Crashdump Viewer tool.

*Old attributes*
: Module attributes for the old code, if any. This field is decoded when looked at by the Crashdump Viewer tool.

*Current compilation info*
: Compilation information (options) for the current code. This field is decoded when looked at by the Crashdump Viewer tool.

*Old compilation info*
: Compilation information (options) for the old code, if any. This field is decoded when looked at by the Crashdump Viewer tool.

### 1.4.13 Fun information

In this section, all funs are listed. The following fields exist for each fun:

*=fun*
: Heading

*Module*
: The name of the module where the fun was defined.

*Uniq, Index*
: Identifiers

*Address*
: The address of the fun's code.

*Native_address*
: The address of the fun's code when HiPE is enabled.

*Refc*
: The number of references to the fun.

### 1.4.14 Process Data

For each process there will be at least one *=proc_stack* and one *=proc_heap* tag followed by the raw memory information for the stack and heap of the process.

For each process there will also be a *=proc_messages* tag if the process' message queue is non-empty and a *=proc_dictionary* tag if the process' dictionary (the `put/2` and `get/1` thing) is non-empty.

The raw memory information can be decoded by the Crashdump Viewer tool. You will then be able to see the stack dump, the message queue (if any) and the dictionary (if any).

The stack dump is a dump of the Erlang process stack. Most of the live data (i.e., variables currently in use) are placed on the stack; thus this can be quite interesting. One has to "guess" what's what, but as the information is symbolic, thorough reading of this information can be very useful. As an example we can find the state variable of the Erlang primitive loader on line `(5)` in the example below:

```
(1)  3cac44   Return addr 0x13BF58 (<terminate process normally>)
(2)  y(0)     ["/view/siri_r10_dev/clearcase/otp/erts/lib/kernel/ebin","/view/siri_r10_dev/
(3)  clearcase/otp/erts/lib/stdlib/ebin"]
(4)  y(1)     <0.1.0>
(5)  y(2)     {state,[],none,#Fun<erl_prim_loader.6.7085890>,undefined,#Fun<erl_prim_loader.7.9000327>,#Fun<e
```

```
(6)  y(3)     infinity
```

When interpreting the data for a process, it is helpful to know that anonymous function objects (funs) are given a name constructed from the name of the function in which they are created, and a number (starting with 0) indicating the number of that fun within that function.

### 1.4.15 Atoms

Now all the atoms in the system are written. This is only interesting if one suspects that dynamic generation of atoms could be a problem, otherwise this section can be ignored.

Note that the last created atom is printed first.

### 1.4.16 Disclaimer

The format of the crash dump evolves between releases of OTP. Some information here may not apply to your version. A description as this will never be complete; it is meant as an explanation of the crash dump in general and as a help when trying to find application errors, not as a complete specification.

## 1.5 How to implement an alternative carrier for the Erlang distribution

This document describes how one can implement ones own carrier protocol for the Erlang distribution. The distribution is normally carried by the TCP/IP protocol. What's explained here is the method for replacing TCP/IP with another protocol.

The document is a step by step explanation of the `uds_dist` example application (seated in the kernel applications `examples` directory). The `uds_dist` application implements distribution over Unix domain sockets and is written for the Sun Solaris 2 operating environment. The mechanisms are however general and applies to any operating system Erlang runs on. The reason the C code is not made portable, is simply readability.

> **Note:**
>
> This document was written a long time ago. Most of it is still valid, but some things have changed since it was first written. Most notably the driver interface. There have been some updates to the documentation of the driver presented in this documentation, but more could be done and are planned for the future. The reader is encouraged to also read the *erl_driver*, and the *driver_entry* documentation.

### 1.5.1 Introduction

To implement a new carrier for the Erlang distribution, one must first make the protocol available to the Erlang machine, which involves writing an Erlang driver. There is no way one can use a port program, there *has* to be an Erlang driver. Erlang drivers can either be statically linked to the emulator, which can be an alternative when using the open source distribution of Erlang, or dynamically loaded into the Erlang machines address space, which is the only alternative if a precompiled version of Erlang is to be used.

Writing an Erlang driver is by no means easy. The driver is written as a couple of call-back functions called by the Erlang emulator when data is sent to the driver or the driver has any data available on a file descriptor. As the driver call-back routines execute in the main thread of the Erlang machine, the call-back functions can perform no blocking activity whatsoever. The call-backs should only set up file descriptors for waiting and/or read/write available data. All I/O has to be non blocking. Driver call-backs are however executed in sequence, why a global state can safely be updated within the routines.

When the driver is implemented, one would preferably write an Erlang interface for the driver to be able to test the functionality of the driver separately. This interface can then be used by the distribution module which will cover the details of the protocol from the `net_kernel`. The easiest path is to mimic the `inet` and `inet_tcp` interfaces, but a lot of functionality in those modules need not be implemented. In the example application, only a few of the usual interfaces are implemented, and they are much simplified.

When the protocol is available to Erlang through a driver and an Erlang interface module, a distribution module can be written. The distribution module is a module with well defined call-backs, much like a `gen_server` (there is no compiler support for checking the call-backs though). The details of finding other nodes (i.e. talking to epmd or something similar), creating a listen port (or similar), connecting to other nodes and performing the handshakes/cookie verification are all implemented by this module. There is however a utility module, `dist_util`, that will do most of the hard work of handling handshakes, cookies, timers and ticking. Using `dist_util` makes implementing a distribution module much easier and that's what we are doing in the example application.

The last step is to create boot scripts to make the protocol implementation available at boot time. The implementation can be debugged by starting the distribution when all of the system is running, but in a real system the distribution should start very early, why a boot-script and some command line parameters are necessary. This last step also implies that the Erlang code in the interface and distribution modules is written in such a way that it can be run in the startup phase. Most notably there can be no calls to the `application` module or to any modules not loaded at boot-time (i.e. only `kernel`, `stdlib` and the application itself can be used).

## 1.5.2 The driver

Although Erlang drivers in general may be beyond the scope of this document, a brief introduction seems to be in place.

### Drivers in general

An Erlang driver is a native code module written in C (or assembler) which serves as an interface for some special operating system service. This is a general mechanism that is used throughout the Erlang emulator for all kinds of I/O. An Erlang driver can be dynamically linked (or loaded) to the Erlang emulator at runtime by using the `erl_ddll` Erlang module. Some of the drivers in OTP are however statically linked to the runtime system, but that's more an optimization than a necessity.

The driver data-types and the functions available to the driver writer are defined in the header file `erl_driver.h` (there is also an deprecated version called `driver.h`, don't use that one.) seated in Erlang's include directory (and in $ERL_TOP/erts/emulator/beam in the source code distribution). Refer to that file for function prototypes etc.

When writing a driver to make a communications protocol available to Erlang, one should know just about everything worth knowing about that particular protocol. All operation has to be non blocking and all possible situations should be accounted for in the driver. A non stable driver will affect and/or crash the whole Erlang runtime system, which is seldom what's wanted.

The emulator calls the driver in the following situations:

- When the driver is loaded. This call-back has to have a special name and will inform the emulator of what call-backs should be used by returning a pointer to a `ErlDrvEntry` struct, which should be properly filled in (see below).
- When a port to the driver is opened (by a `open_port` call from Erlang). This routine should set up internal data structures and return an opaque data entity of the type `ErlDrvData`, which is a data-type large enough to hold a pointer. The pointer returned by this function will be the first argument to all other call-backs concerning this particular port. It is usually called the port handle. The emulator only stores the handle and does never try to interpret it, why it can be virtually anything (well anything not larger than a pointer that is) and can point to anything if it is a pointer. Usually this pointer will refer to a structure holding information about the particular port, as i t does in our example.
- When an Erlang process sends data to the port. The data will arrive as a buffer of bytes, the interpretation is not defined, but is up to the implementor. This call-back returns nothing to the caller, answers are sent to the caller

as messages (using a routine called `driver_output` available to all drivers). There is also a way to talk in a synchronous way to drivers, described below. There can be an additional call-back function for handling data that is fragmented (sent in a deep io-list). That interface will get the data in a form suitable for Unix `writev` rather than in a single buffer. There is no need for a distribution driver to implement such a call-back, so we wont.

- When a file descriptor is signaled for input. This call-back is called when the emulator detects input on a file descriptor which the driver has marked for monitoring by using the interface `driver_select`. The mechanism of driver select makes it possible to read non blocking from file descriptors by calling `driver_select` when reading is needed and then do the actual reading in this call-back (when reading is actually possible). The typical scenario is that `driver_select` is called when an Erlang process orders a read operation, and that this routine sends the answer when data is available on the file descriptor.
- When a file descriptor is signaled for output. This call-back is called in a similar way as the previous, but when writing to a file descriptor is possible. The usual scenario is that Erlang orders writing on a file descriptor and that the driver calls `driver_select`. When the descriptor is ready for output, this call-back is called an the driver can try to send the output. There may of course be queuing involved in such operations, and there are some convenient queue routines available to the driver writer to use in such situations.
- When a port is closed, either by an Erlang process or by the driver calling one of the `driver_failure_XXX` routines. This routine should clean up everything connected to one particular port. Note that when other call-backs call a `driver_failure_XXX` routine, this routine will be immediately called and the call-back routine issuing the error can make no more use of the data structures for the port, as this routine surely has freed all associated data and closed all file descriptors. If the queue utility available to driver writes is used, this routine will however *not* be called until the queue is empty.
- When an Erlang process calls `erlang:port_control/3`, which is a synchronous interface to drivers. The control interface is used to set driver options, change states of ports etc. We'll use this interface quite a lot in our example.
- When a timer expires. The driver can set timers with the function `driver_set_timer`. When such timers expire, a specific call-back function is called. We will not use timers in our example.
- When the whole driver is unloaded. Every resource allocated by the driver should be freed.

## The distribution driver's data structures

The driver used for Erlang distribution should implement a reliable, order maintaining, variable length packet oriented protocol. All error correction, re-sending and such need to be implemented in the driver or by the underlying communications protocol. If the protocol is stream oriented (as is the case with both TCP/IP and our streamed Unix domain sockets), some mechanism for packaging is needed. We will use the simple method of having a header of four bytes containing the length of the package in a big endian 32 bit integer (as Unix domain sockets only can be used between processes on the same machine, we actually don't need to code the integer in some special endianess, but I'll do it anyway because in most situation you do need to do it. Unix domain sockets are reliable and order maintaining, so we don't need to implement resends and such in our driver.

Lets start writing our example Unix domain sockets driver by declaring prototypes and filling in a static ErlDrvEntry structure.

```
( 1) #include <stdio.h>
( 2) #include <stdlib.h>
( 3) #include <string.h>
( 4) #include <unistd.h>
( 5) #include <errno.h>
( 6) #include <sys/types.h>
( 7) #include <sys/stat.h>
( 8) #include <sys/socket.h>
( 9) #include <sys/un.h>
(10) #include <fcntl.h>
```

```
(11) #define HAVE_UIO_H
(12) #include "erl_driver.h"

(13) /*
(14) ** Interface routines
(15) */
(16) static ErlDrvData uds_start(ErlDrvPort port, char *buff);
(17) static void uds_stop(ErlDrvData handle);
(18) static void uds_command(ErlDrvData handle, char *buff, int bufflen);
(19) static void uds_input(ErlDrvData handle, ErlDrvEvent event);
(20) static void uds_output(ErlDrvData handle, ErlDrvEvent event);
(21) static void uds_finish(void);
(22) static int uds_control(ErlDrvData handle, unsigned int command,
(23)                       char* buf, int count, char** res, int res_size);

(24) /* The driver entry */
(25) static ErlDrvEntry uds_driver_entry = {
(26)     NULL,                           /* init, N/A */
(27)     uds_start,                      /* start, called when port is opened */
(28)     uds_stop,                       /* stop, called when port is closed */
(29)     uds_command,                    /* output, called when erlang has sent */
(30)     uds_input,                      /* ready_input, called when input
(31)                                        descriptor ready */
(32)     uds_output,                     /* ready_output, called when output
(33)                                        descriptor ready */
(34)     "uds_drv",                      /* char *driver_name, the argument
(35)                                        to open_port */
(36)     uds_finish,                     /* finish, called when unloaded */
(37)     NULL,                           /* void * that is not used (BC) */
(38)     uds_control,                    /* control, port_control callback */
(39)     NULL,                           /* timeout, called on timeouts */
(40)     NULL,                           /* outputv, vector output interface */
(41)     NULL,                           /* ready_async callback */
(42)     NULL,                           /* flush callback */
(43)     NULL,                           /* call callback */
(44)     NULL,                           /* event callback */
(45)     ERL_DRV_EXTENDED_MARKER,        /* Extended driver interface marker */
(46)     ERL_DRV_EXTENDED_MAJOR_VERSION, /* Major version number */
(47)     ERL_DRV_EXTENDED_MINOR_VERSION, /* Minor version number */
(48)     ERL_DRV_FLAG_SOFT_BUSY,         /* Driver flags. Soft busy flag is
(49)                                        required for distribution drivers */
(50)     NULL,                           /* Reserved for internal use */
(51)     NULL,                           /* process_exit callback */
(52)     NULL                            /* stop_select callback */
(53) };
```

On line 1 to 10 we have included the OS headers needed for our driver. As this driver is written for Solaris, we know that the header `uio.h` exists, why we can define the preprocessor variable `HAVE_UIO_H` before we include `erl_driver.h` at line 12. The definition of `HAVE_UIO_H` will make the I/O vectors used in Erlang's driver queues to correspond to the operating systems ditto, which is very convenient.

The different call-back functions are declared ("forward declarations") on line 16 to 23.

The driver structure is similar for statically linked in drivers and dynamically loaded. However some of the fields should be left empty (i.e. initialized to NULL) in the different types of drivers. The first field (the `init` function pointer) is always left blank in a dynamically loaded driver, which can be seen on line 26. The NULL on line 37 should always be there, the field is no longer used and is retained for backward compatibility. We use no timers in this driver, why no call-back for timers is needed. The `outputv` field (line 40) can be used to implement an interface similar to Unix `writev` for output. The Erlang runtime system could previously not use `outputv` for the distribution, but since erts version 5.7.2 it can. Since this driver was written before erts version 5.7.2 it does not use the `outputv`

callback. Using the `outputv` callback is preferred since it reduces copying of data. (We will however use scatter/gather I/O internally in the driver).

As of erts version 5.5.3 the driver interface was extended with version control and the possibility to pass capability information. Capability flags are present at line 48. As of erts version 5.7.4 the *ERL_DRV_FLAG_SOFT_BUSY* flag is required for drivers that are to be used by the distribution. The soft busy flag implies that the driver is capable of handling calls to the `output` and `outputv` callbacks even though it has marked itself as busy. This has always been a requirement on drivers used by the distribution, but there have previously not been any capability information available about this. For more information see *set_busy_port()*).

This driver was written before the runtime system had SMP support. The driver will still function in the runtime system with SMP support, but performance will suffer from lock contention on the driver lock used for the driver. This can be alleviated by reviewing and perhaps rewriting the code so that each instance of the driver safely can execute in parallel. When instances safely can execute in parallel it is safe to enable instance specific locking on the driver. This is done by passing *ERL_DRV_FLAG_USE_PORT_LOCKING* as a driver flag. This is left as an exercise for the reader.

Our defined call-backs thus are:

- uds_start, which shall initiate data for a port. We wont create any actual sockets here, just initialize data structures.
- uds_stop, the function called when a port is closed.
- uds_command, which will handle messages from Erlang. The messages can either be plain data to be sent or more subtle instructions to the driver. We will use this function mostly for data pumping.
- uds_input, this is the call-back which is called when we have something to read from a socket.
- uds_output, this is the function called when we can write to a socket.
- uds_finish, which is called when the driver is unloaded. A distribution driver will actually (or hopefully) never be unloaded, but we include this for completeness. Being able to clean up after oneself is always a good thing.
- uds_control, the `erlang:port_control/2` call-back, which will be used a lot in this implementation.

The ports implemented by this driver will operate in two major modes, which i will call the *command* and *data* modes. In command mode, only passive reading and writing (like gen_tcp:recv/gen_tcp:send) can be done, and this is the mode the port will be in during the distribution handshake. When the connection is up, the port will be switched to data mode and all data will be immediately read and passed further to the Erlang emulator. In data mode, no data arriving to the uds_command will be interpreted, but just packaged and sent out on the socket. The uds_control call-back will do the switching between those two modes.

While the `net_kernel` informs different subsystems that the connection is coming up, the port should accept data to send, but not receive any data, to avoid that data arrives from another node before every kernel subsystem is prepared to handle it. We have a third mode for this intermediate stage, lets call it the *intermediate* mode.

Lets define an enum for the different types of ports we have:

```
( 1) typedef enum {
( 2)     portTypeUnknown,      /* An uninitialized port */
( 3)     portTypeListener,     /* A listening port/socket */
( 4)     portTypeAcceptor,     /* An intermediate stage when accepting
( 5)                              on a listen port */
( 6)     portTypeConnector,    /* An intermediate stage when connecting */
( 7)     portTypeCommand,      /* A connected open port in command mode */
( 8)     portTypeIntermediate, /* A connected open port in special
( 9)                              half active mode */
(10)     portTypeData          /* A connectec open port in data mode */
(11) } PortType;
```

Lets look at the different types:

- portTypeUnknown - The type a port has when it's opened, but not actually bound to any file descriptor.
- portTypeListener - A port that is connected to a listen socket. This port will not do especially much, there will be no data pumping done on this socket, but there will be read data available when one is trying to do an accept on the port.
- portTypeAcceptor - This is a port that is to represent the result of an accept operation. It is created when one wants to accept from a listen socket, and it will be converted to a portTypeCommand when the accept succeeds.
- portTypeConnector - Very similar to portTypeAcceptor, an intermediate stage between the request for a connect operation and that the socket is really connected to an accepting ditto in the other end. As soon as the sockets are connected, the port will switch type to portTypeCommand.
- portTypeCommand - A connected socket (or accepted socket if you want) that is in the command mode mentioned earlier.
- portTypeIntermediate - The intermediate stage for a connected socket. There should be no processing of input for this socket.
- portTypeData - The mode where data is pumped through the port and the uds_command routine will regard every call as a call where sending is wanted. In this mode all input available will be read and sent to Erlang as soon as it arrives on the socket, much like in the active mode of a `gen_tcp` socket.

Now lets look at the state we'll need for our ports. One can note that not all fields are used for all types of ports and that one could save some space by using unions, but that would clutter the code with multiple indirections, so i simply use one struct for all types of ports, for readability.

```
( 1) typedef unsigned char Byte;
( 2) typedef unsigned int Word;

( 3) typedef struct uds_data {
( 4)     int fd;                   /* File descriptor */
( 5)     ErlDrvPort port;          /* The port identifier */
( 6)     int lockfd;               /* The file descriptor for a lock file in
( 7)                                  case of listen sockets */
( 8)     Byte creation;            /* The creation serial derived from the
( 9)                                  lockfile */
(10)     PortType type;            /* Type of port */
(11)     char *name;               /* Short name of socket for unlink */
(12)     Word sent;                /* Bytes sent */
(13)     Word received;            /* Bytes received */
(14)     struct uds_data *partner; /* The partner in an accept/listen pair */
(15)     struct uds_data *next;    /* Next structure in list */
(16)     /* The input buffer and its data */
(17)     int buffer_size;          /* The allocated size of the input buffer */
(18)     int buffer_pos;           /* Current position in input buffer */
(19)     int header_pos;           /* Where the current header is in the
(20)                                  input buffer */
(21)     Byte *buffer;             /* The actual input buffer */
(22) } UdsData;
```

This structure is used for all types of ports although some fields are useless for some types. The least memory consuming solution would be to arrange this structure as a union of structures, but the multiple indirections in the code to access a field in such a structure will clutter the code to much for an example.

Let's look at the fields in our structure:

- fd - The file descriptor of the socket associated with the port.
- port - The port identifier for the port which this structure corresponds to. It is needed for most `driver_XXX` calls from the driver back to the emulator.
- lockfd - If the socket is a listen socket, we use a separate (regular) file for two purposes:

- We want a locking mechanism that gives no race conditions, so that we can be sure of if another Erlang node uses the listen socket name we require or if the file is only left there from a previous (crashed) session.
- We store the *creation* serial number in the file. The *creation* is a number that should change between different instances of different Erlang emulators with the same name, so that process identifiers from one emulator won't be valid when sent to a new emulator with the same distribution name. The creation can be between 0 and 3 (two bits) and is stored in every process identifier sent to another node.

  In a system with TCP based distribution, this data is kept in the *Erlang port mapper daemon* (`epmd`), which is contacted when a distributed node starts. The lock-file and a convention for the UDS listen socket's name will remove the need for `epmd` when using this distribution module. UDS is always restricted to one host, why avoiding a port mapper is easy.

- creation - The creation number for a listen socket, which is calculated as (the value found in the lock-file + 1) rem 4. This creation value is also written back into the lock-file, so that the next invocation of the emulator will found our value in the file.
- type - The current type/state of the port, which can be one of the values declared above.
- name - The name of the socket file (the path prefix removed), which allows for deletion (`unlink`) when the socket is closed.
- sent - How many bytes that have been sent over the socket. This may wrap, but that's no problem for the distribution, as the only thing that interests the Erlang distribution is if this value has changed (the Erlang net_kernel *ticker* uses this value by calling the driver to fetch it, which is done through the `erlang:port_control` routine).
- received - How many bytes that are read (received) from the socket, used in similar ways as `sent`.
- partner - A pointer to another port structure, which is either the listen port from which this port is accepting a connection or the other way around. The "partner relation" is always bidirectional.
- next - Pointer to next structure in a linked list of all port structures. This list is used when accepting connections and when the driver is unloaded.
- buffer_size, buffer_pos, header_pos, buffer - data for input buffering. Refer to the source code (in the kernel/examples directory) for details about the input buffering. That certainly goes beyond the scope of this document.

## Selected parts of the distribution driver implementation

The distribution drivers implementation is not completely covered in this text, details about buffering and other things unrelated to driver writing are not explained. Likewise are some peculiarities of the UDS protocol not explained in detail. The chosen protocol is not important.

Prototypes for the driver call-back routines can be found in the `erl_driver.h` header file.

The driver initialization routine is (usually) declared with a macro to make the driver easier to port between different operating systems (and flavours of systems). This is the only routine that has to have a well defined name. All other call-backs are reached through the driver structure. The macro to use is named `DRIVER_INIT` and takes the driver name as parameter.

```
(1) /* Beginning of linked list of ports */
(2) static UdsData *first_data;


(3) DRIVER_INIT(uds_drv)
(4) {
(5)     first_data = NULL;
(6)     return &uds_driver_entry;
```

```
(7) }
```

The routine initializes the single global data structure and returns a pointer to the driver entry. The routine will be called when `erl_ddll:load_driver` is called from Erlang.

The `uds_start` routine is called when a port is opened from Erlang. In our case, we only allocate a structure and initialize it. Creating the actual socket is left to the `uds_command` routine.

```
( 1) static ErlDrvData uds_start(ErlDrvPort port, char *buff)
( 2) {
( 3)     UdsData *ud;
( 4)
( 5)     ud = ALLOC(sizeof(UdsData));
( 6)     ud->fd = -1;
( 7)     ud->lockfd = -1;
( 8)     ud->creation = 0;
( 9)     ud->port = port;
(10)     ud->type = portTypeUnknown;
(11)     ud->name = NULL;
(12)     ud->buffer_size = 0;
(13)     ud->buffer_pos = 0;
(14)     ud->header_pos = 0;
(15)     ud->buffer = NULL;
(16)     ud->sent = 0;
(17)     ud->received = 0;
(18)     ud->partner = NULL;
(19)     ud->next = first_data;
(20)     first_data = ud;
(21)
(22)     return((ErlDrvData) ud);
(23) }
```

Every data item is initialized, so that no problems will arise when a newly created port is closed (without there being any corresponding socket). This routine is called when `open_port({spawn, "uds_drv"},[])` is called from Erlang.

The `uds_command` routine is the routine called when an Erlang process sends data to the port. All asynchronous commands when the port is in *command mode* as well as the sending of all data when the port is in *data mode* is handled in this9s routine. Let's have a look at it:

```
( 1) static void uds_command(ErlDrvData handle, char *buff, int bufflen)
( 2) {
( 3)     UdsData *ud = (UdsData *) handle;

( 4)     if (ud->type == portTypeData || ud->type == portTypeIntermediate) {
( 5)         DEBUGF(("Passive do_send %d",bufflen));
( 6)         do_send(ud, buff + 1, bufflen - 1); /* XXX */
( 7)         return;
( 8)     }
( 9)     if (bufflen == 0) {
(10)         return;
(11)     }
(12)     switch (*buff) {
(13)     case 'L':
(14)         if (ud->type != portTypeUnknown) {
(15)             driver_failure_posix(ud->port, ENOTSUP);
(16)             return;
(17)         }
(18)         uds_command_listen(ud,buff,bufflen);
```

```
(19)         return;
(20)     case 'A':
(21)         if (ud->type != portTypeUnknown) {
(22)             driver_failure_posix(ud->port, ENOTSUP);
(23)             return;
(24)         }
(25)         uds_command_accept(ud,buff,bufflen);
(26)         return;
(27)     case 'C':
(28)         if (ud->type != portTypeUnknown) {
(29)             driver_failure_posix(ud->port, ENOTSUP);
(30)             return;
(31)         }
(32)         uds_command_connect(ud,buff,bufflen);
(33)         return;
(34)     case 'S':
(35)         if (ud->type != portTypeCommand) {
(36)             driver_failure_posix(ud->port, ENOTSUP);
(37)             return;
(38)         }
(39)         do_send(ud, buff + 1, bufflen - 1);
(40)         return;
(41)     case 'R':
(42)         if (ud->type != portTypeCommand) {
(43)             driver_failure_posix(ud->port, ENOTSUP);
(44)             return;
(45)         }
(46)         do_recv(ud);
(47)         return;
(48)     default:
(49)         return;
(50)     }
(51) }
```

The command routine takes three parameters; the handle returned for the port by `uds_start`, which is a pointer to the internal port structure, the data buffer and the length of the data buffer. The buffer is the data sent from Erlang (a list of bytes) converted to an C array (of bytes).

If Erlang sends i.e. the list `[$a,$b,$c]` to the port, the `bufflen` variable will be `3` ant the `buff` variable will contain `{'a','b','c'}` (no null termination). Usually the first byte is used as an opcode, which is the case in our driver to (at least when the port is in command mode). The opcodes are defined as:

- 'L'<socketname>: Create and listen on socket with the given name.
- 'A'<listennumber as 32 bit bigendian>: Accept from the listen socket identified by the given identification number. The identification number is retrieved with the uds_control routine.
- 'C'<socketname>: Connect to the socket named <socketname>.
- 'S'<data>: Send the data <data> on the connected/accepted socket (in command mode). The sending is acked when the data has left this process.
- 'R': Receive one packet of data.

One may wonder what is meant by "one packet of data" in the 'R' command. This driver always sends data packeted with a 4 byte header containing a big endian 32 bit integer that represents the length of the data in the packet. There is no need for different packet sizes or some kind of streamed mode, as this driver is for the distribution only. One may wonder why the header word is coded explicitly in big endian when an UDS socket is local to the host. The answer simply is that I see it as a good practice when writing a distribution driver, as distribution in practice usually cross the host boundaries.

On line 4-8 we handle the case where the port is in data or intermediate mode, the rest of the routine handles the different commands. We see (first on line 15) that the routine uses the `driver_failure_posix()` routine to report errors. One important thing to remember is that the failure routines make a call to our `uds_stop` routine, which will remove

the internal port data. The handle (and the casted handle `ud`) is therefore *invalid pointers* after a `driver_failure` call and we should *immediately return*. The runtime system will send exit signals to all linked processes.

The uds_input routine gets called when data is available on a file descriptor previously passed to the `driver_select` routine. Typically this happens when a read command is issued and no data is available. Lets look at the `do_recv` routine:

```
( 1) static void do_recv(UdsData *ud)
( 2) {
( 3)     int res;
( 4)     char *ibuf;
( 5)     for(;;) {
( 6)         if ((res = buffered_read_package(ud,&ibuf)) < 0) {
( 7)             if (res == NORMAL_READ_FAILURE) {
( 8)                 driver_select(ud->port, (ErlDrvEvent) ud->fd, DO_READ, 1);
( 9)             } else {
(10)                 driver_failure_eof(ud->port);
(11)             }
(12)             return;
(13)         }
(14)         /* Got a package */
(15)         if (ud->type == portTypeCommand) {
(16)             ibuf[-1] = 'R'; /* There is always room for a single byte
(17)                                opcode before the actual buffer
(18)                                (where the packet header was) */
(19)             driver_output(ud->port,ibuf - 1, res + 1);
(20)             driver_select(ud->port, (ErlDrvEvent) ud->fd, DO_READ,0);
(21)             return;
(22)         } else {
(23)             ibuf[-1] = DIST_MAGIC_RECV_TAG; /* XXX */
(24)             driver_output(ud->port,ibuf - 1, res + 1);
(25)             driver_select(ud->port, (ErlDrvEvent) ud->fd, DO_READ,1);
(26)         }
(27)     }
(28) }
```

The routine tries to read data until a packet is read or the `buffered_read_package` routine returns a `NORMAL_READ_FAILURE` (an internally defined constant for the module that means that the read operation resulted in an `EWOULDBLOCK`). If the port is in command mode, the reading stops when one package is read, but if it is in data mode, the reading continues until the socket buffer is empty (read failure). If no more data can be read and more is wanted (always the case when socket is in data mode) driver_select is called to make the `uds_input` call-back be called when more data is available for reading.

When the port is in data mode, all data is sent to Erlang in a format that suits the distribution, in fact the raw data will never reach any Erlang process, but will be translated/interpreted by the emulator itself and then delivered in the correct format to the correct processes. In the current emulator version, received data should be tagged with a single byte of 100. Thats what the macro `DIST_MAGIC_RECV_TAG` is defined to. The tagging of data in the distribution will possibly change in the future.

The `uds_input` routine will handle other input events (like nonblocking `accept`), but most importantly handle data arriving at the socket by calling `do_recv`:

```
( 1) static void uds_input(ErlDrvData handle, ErlDrvEvent event)
( 2) {
( 3)     UdsData *ud = (UdsData *) handle;

( 4)     if (ud->type == portTypeListener) {
( 5)         UdsData *ad = ud->partner;
```

```
( 6)         struct sockaddr_un peer;
( 7)         int pl = sizeof(struct sockaddr_un);
( 8)         int fd;

( 9)         if ((fd = accept(ud->fd, (struct sockaddr *) &peer, &pl)) < 0) {
(10)             if (errno != EWOULDBLOCK) {
(11)                 driver_failure_posix(ud->port, errno);
(12)                 return;
(13)             }
(14)             return;
(15)         }
(16)         SET_NONBLOCKING(fd);
(17)         ad->fd = fd;
(18)         ad->partner = NULL;
(19)         ad->type = portTypeCommand;
(20)         ud->partner = NULL;
(21)         driver_select(ud->port, (ErlDrvEvent) ud->fd, DO_READ, 0);
(22)         driver_output(ad->port, "Aok",3);
(23)         return;
(24)     }
(25)     do_recv(ud);
(26) }
```

The important line here is the last line in the function, the `do_read` routine is called to handle new input. The rest of the function handles input on a listen socket, which means that there should be possible to do an accept on the socket, which is also recognized as a read event.

The output mechanisms are similar to the input. Lets first look at the `do_send` routine:

```
( 1) static void do_send(UdsData *ud, char *buff, int bufflen)
( 2) {
( 3)     char header[4];
( 4)     int written;
( 5)     SysIOVec iov[2];
( 6)     ErlIOVec eio;
( 7)     ErlDrvBinary *binv[] = {NULL,NULL};

( 8)     put_packet_length(header, bufflen);
( 9)     iov[0].iov_base = (char *) header;
(10)     iov[0].iov_len = 4;
(11)     iov[1].iov_base = buff;
(12)     iov[1].iov_len = bufflen;
(13)     eio.iov = iov;
(14)     eio.binv = binv;
(15)     eio.vsize = 2;
(16)     eio.size = bufflen + 4;
(17)     written = 0;
(18)     if (driver_sizeq(ud->port) == 0) {
(19)         if ((written = writev(ud->fd, iov, 2)) == eio.size) {
(20)             ud->sent += written;
(21)             if (ud->type == portTypeCommand) {
(22)                 driver_output(ud->port, "Sok", 3);
(23)             }
(24)             return;
(25)         } else if (written < 0) {
(26)             if (errno != EWOULDBLOCK) {
(27)                 driver_failure_eof(ud->port);
(28)                 return;
(29)             } else {
(30)                 written = 0;
(31)             }
(32)         } else {
```

```
(33)             ud->sent += written;
(34)         }
(35)         /* Enqueue remaining */
(36)     }
(37)     driver_enqv(ud->port, &eio, written);
(38)     send_out_queue(ud);
(39) }
```

This driver uses the `writev` system call to send data onto the socket. A combination of writev and the driver output queues is very convenient. An *ErlIOVec* structure contains a *SysIOVec* (which is equivalent to the `struct iovec` structure defined in `uio.h`. The ErlIOVec also contains an array of *ErlDrvBinary* pointers, of the same length as the number of buffers in the I/O vector itself. One can use this to allocate the binaries for the queue "manually" in the driver, but we'll just fill the binary array with NULL values (line 7) , which will make the runtime system allocate its own buffers when we call `driver_enqv` (line 37).

The routine builds an I/O vector containing the header bytes and the buffer (the opcode has been removed and the buffer length decreased by the output routine). If the queue is empty, we'll write the data directly to the socket (or at least try to). If any data is left, it is stored in the queue and then we try to send the queue (line 38). An ack is sent when the message is delivered completely (line 22). The `send_out_queue` will send acks if the sending is completed there. If the port is in command mode, the Erlang code serializes the send operations so that only one packet can be waiting for delivery at a time. Therefore the ack can be sent simply whenever the queue is empty.

A short look at the `send_out_queue` routine:

```
( 1) static int send_out_queue(UdsData *ud)
( 2) {
( 3)     for(;;) {
( 4)         int vlen;
( 5)         SysIOVec *tmp = driver_peekq(ud->port, &vlen);
( 6)         int wrote;
( 7)         if (tmp == NULL) {
( 8)             driver_select(ud->port, (ErlDrvEvent) ud->fd, DO_WRITE, 0);
( 9)             if (ud->type == portTypeCommand) {
(10)                 driver_output(ud->port, "Sok", 3);
(11)             }
(12)             return 0;
(13)         }
(14)         if (vlen > IO_VECTOR_MAX) {
(15)             vlen = IO_VECTOR_MAX;
(16)         }
(17)         if ((wrote = writev(ud->fd, tmp, vlen)) < 0) {
(18)             if (errno == EWOULDBLOCK) {
(19)                 driver_select(ud->port, (ErlDrvEvent) ud->fd,
(20)                               DO_WRITE, 1);
(21)                 return 0;
(22)             } else {
(23)                 driver_failure_eof(ud->port);
(24)                 return -1;
(25)             }
(26)         }
(27)         driver_deq(ud->port, wrote);
(28)         ud->sent += wrote;
(29)     }
(30) }
```

What we do is simply to pick out an I/O vector from the queue (which is the whole queue as an *SysIOVec*). If the I/O vector is to long (IO_VECTOR_MAX is defined to 16), the vector length is decreased (line 15), otherwise the `writev` (line 17) call will fail. Writing is tried and anything written is dequeued (line 27). If the write fails with `EWOULDBLOCK`

(note that all sockets are in nonblocking mode), `driver_select` is called to make the `uds_output` routine be called when there is space to write again.

We will continue trying to write until the queue is empty or the writing would block.

The routine above are called from the `uds_output` routine, which looks like this:

```
( 1) static void uds_output(ErlDrvData handle, ErlDrvEvent event)
( 2) {
( 3)    UdsData *ud = (UdsData *) handle;
( 4)    if (ud->type == portTypeConnector) {
( 5)        ud->type = portTypeCommand;
( 6)        driver_select(ud->port, (ErlDrvEvent) ud->fd, DO_WRITE, 0);
( 7)        driver_output(ud->port, "Cok",3);
( 8)        return;
( 9)    }
(10)    send_out_queue(ud);
(11) }
```

The routine is simple, it first handles the fact that the output select will concern a socket in the business of connecting (and the connecting blocked). If the socket is in a connected state it simply sends the output queue, this routine is called when there is possible to write to a socket where we have an output queue, so there is no question what to do.

The driver implements a control interface, which is a synchronous interface called when Erlang calls `erlang:port_control/3`. This is the only interface that can control the driver when it is in data mode and it may be called with the following opcodes:

- 'C': Set port in command mode.
- 'I': Set port in intermediate mode.
- 'D': Set port in data mode.
- 'N': Get identification number for listen port, this identification number is used in an accept command to the driver, it is returned as a big endian 32 bit integer, which happens to be the file identifier for the listen socket.
- 'S': Get statistics, which is the number of bytes received, the number of bytes sent and the number of bytes pending in the output queue. This data is used when the distribution checks that a connection is alive (ticking). The statistics is returned as 3 32 bit big endian integers.
- 'T': Send a tick message, which is a packet of length 0. Ticking is done when the port is in data mode, so the command for sending data cannot be used (besides it ignores zero length packages in command mode). This is used by the ticker to send dummy data when no other traffic is present. *Note* that it is important that the interface for sending ticks is not blocking. This implementation uses `erlang:port_control/3` which does not block the caller. If `erlang:port_command` is used, use `erlang:port_command/3` and pass `[force]` as option list; otherwise, the caller can be blocked indefinitely on a busy port and prevent the system from taking down a connection that is not functioning.
- 'R': Get creation number of listen socket, which is used to dig out the number stored in the lock file to differentiate between invocations of Erlang nodes with the same name.

The control interface gets a buffer to return its value in, but is free to allocate its own buffer is the provided one is to small. Here is the code for `uds_control`:

```
( 1) static int uds_control(ErlDrvData handle, unsigned int command,
( 2)                        char* buf, int count, char** res, int res_size)
( 3) {
( 4) /* Local macro to ensure large enough buffer. */
( 5) #define ENSURE(N)                                  \
( 6)    do {                                           \
( 7)        if (res_size < N) {                        \
```

```
( 8)            *res = ALLOC(N);                    \
( 9)        }                                       \
(10)    } while(0)

(11)    UdsData *ud = (UdsData *) handle;

(12)    switch (command) {
(13)    case 'S':
(14)        {
(15)            ENSURE(13);
(16)            **res = 0;
(17)            put_packet_length((*res) + 1, ud->received);
(18)            put_packet_length((*res) + 5, ud->sent);
(19)            put_packet_length((*res) + 9, driver_sizeq(ud->port));
(20)            return 13;
(21)        }
(22)    case 'C':
(23)        if (ud->type < portTypeCommand) {
(24)            return report_control_error(res, res_size, "einval");
(25)        }
(26)        ud->type = portTypeCommand;
(27)        driver_select(ud->port, (ErlDrvEvent) ud->fd, DO_READ, 0);
(28)        ENSURE(1);
(29)        **res = 0;
(30)        return 1;
(31)    case 'I':
(32)        if (ud->type < portTypeCommand) {
(33)            return report_control_error(res, res_size, "einval");
(34)        }
(35)        ud->type = portTypeIntermediate;
(36)        driver_select(ud->port, (ErlDrvEvent) ud->fd, DO_READ, 0);
(37)        ENSURE(1);
(38)        **res = 0;
(39)        return 1;
(40)    case 'D':
(41)        if (ud->type < portTypeCommand) {
(42)            return report_control_error(res, res_size, "einval");
(43)        }
(44)        ud->type = portTypeData;
(45)        do_recv(ud);
(46)        ENSURE(1);
(47)        **res = 0;
(48)        return 1;
(49)    case 'N':
(50)        if (ud->type != portTypeListener) {
(51)            return report_control_error(res, res_size, "einval");
(52)        }
(53)        ENSURE(5);
(54)        (*res)[0] = 0;
(55)        put_packet_length((*res) + 1, ud->fd);
(56)        return 5;
(57)    case 'T': /* tick */
(58)        if (ud->type != portTypeData) {
(59)            return report_control_error(res, res_size, "einval");
(60)        }
(61)        do_send(ud,"",0);
(62)        ENSURE(1);
(63)        **res = 0;
(64)        return 1;
(65)    case 'R':
(66)        if (ud->type != portTypeListener) {
(67)            return report_control_error(res, res_size, "einval");
(68)        }
(69)        ENSURE(2);
(70)        (*res)[0] = 0;
```

```
(71)        (*res)[1] = ud->creation;
(72)        return 2;
(73)    default:
(74)        return report_control_error(res, res_size, "einval");
(75)    }
(76) #undef ENSURE
(77) }
```

The macro ENSURE (line 5 to 10) is used to ensure that the buffer is large enough for our answer. We switch on the command and take actions, there is not much to say about this routine. Worth noting is that we always has read select active on a port in data mode (achieved by calling `do_recv` on line 45), but turn off read selection in intermediate and command modes (line 27 and 36).

The rest of the driver is more or less UDS specific and not of general interest.

### 1.5.3 Putting it all together

To test the distribution, one can use the `net_kernel:start/1` function, which is useful as it starts the distribution on a running system, where tracing/debugging can be performed. The `net_kernel:start/1` routine takes a list as its single argument. The lists first element should be the node name (without the "@hostname") as an atom, and the second (and last) element should be one of the atoms `shortnames` or `longnames`. In the example case `shortnames` is preferred.

For net kernel to find out which distribution module to use, the command line argument `-proto_dist` is used. The argument is followed by one or more distribution module names, with the "_dist" suffix removed, i.e. uds_dist as a distribution module is specified as `-proto_dist uds`.

If no epmd (TCP port mapper daemon) is used, one should also specify the command line option `-no_epmd`, which will make Erlang skip the epmd startup, both as a OS process and as an Erlang ditto.

The path to the directory where the distribution modules reside must be known at boot, which can either be achieved by specifying `-pa <path>` on the command line or by building a boot script containing the applications used for your distribution protocol (in the uds_dist protocol, it's only the uds_dist application that needs to be added to the script).

The distribution will be started at boot if all the above is specified and an `-sname <name>` flag is present at the command line, here follows two examples:

```
$ erl -pa $ERL_TOP/lib/kernel/examples/uds_dist/ebin -proto_dist uds -no_epmd
Erlang (BEAM) emulator version 5.0

Eshell V5.0  (abort with ^G)
1> net_kernel:start([bing,shortnames]).
{ok,<0.30.0>}
(bing@hador)2>
```

...

```
$ erl -pa $ERL_TOP/lib/kernel/examples/uds_dist/ebin -proto_dist uds \
      -no_epmd -sname bong
Erlang (BEAM) emulator version 5.0

Eshell V5.0  (abort with ^G)
(bong@hador)1>
```

One can utilize the ERL_FLAGS environment variable to store the complicated parameters in:

```
$ ERL_FLAGS=-pa $ERL_TOP/lib/kernel/examples/uds_dist/ebin \
      -proto_dist uds -no_epmd
$ export ERL_FLAGS
$ erl -sname bang
Erlang (BEAM) emulator version 5.0

Eshell V5.0  (abort with ^G)
(bang@hador)1>
```

The ERL_FLAGS should preferably not include the name of the node.

# 1.6 The Abstract Format

This document describes the standard representation of parse trees for Erlang programs as Erlang terms. This representation is known as the *abstract format*. Functions dealing with such parse trees are `compile:forms/[1,2]` and functions in the modules `epp`, `erl_eval`, `erl_lint`, `erl_pp`, `erl_parse`, and `io`. They are also used as input and output for parse transforms (see the module `compile`).

We use the function `Rep` to denote the mapping from an Erlang source construct `C` to its abstract format representation `R`, and write `R = Rep(C)`.

The word `LINE` below represents an integer, and denotes the number of the line in the source file where the construction occurred. Several instances of `LINE` in the same construction may denote different lines.

Since operators are not terms in their own right, when operators are mentioned below, the representation of an operator should be taken to be the atom with a printname consisting of the same characters as the operator.

## 1.6.1 Module Declarations and Forms

A module declaration consists of a sequence of forms that are either function declarations or attributes.

- If D is a module declaration consisting of the forms `F_1`, ..., `F_k`, then Rep(D) = `[Rep(F_1), ..., Rep(F_k)]`.
- If F is an attribute `-module(Mod)`, then Rep(F) = `{attribute,LINE,module,Mod}`.
- If F is an attribute `-behavior(Behavior)`, then Rep(F) = `{attribute,LINE,behavior,Behavior}`.
- If F is an attribute `-behaviour(Behaviour)`, then Rep(F) = `{attribute,LINE,behaviour,Behaviour}`.
- If F is an attribute `-export([Fun_1/A_1, ..., Fun_k/A_k])`, then Rep(F) = `{attribute,LINE,export,[{Fun_1,A_1}, ..., {Fun_k,A_k}]}`.
- If F is an attribute `-import(Mod,[Fun_1/A_1, ..., Fun_k/A_k])`, then Rep(F) = `{attribute,LINE,import,{Mod,[{Fun_1,A_1}, ..., {Fun_k,A_k}]}}`.
- If F is an attribute `-export_type([Type_1/A_1, ..., Type_k/A_k])`, then Rep(F) = `{attribute,LINE,export_type,[{Type_1,A_1}, ..., {Type_k,A_k}]}`.
- If F is an attribute `-compile(Options)`, then Rep(F) = `{attribute,LINE,compile,Options}`.
- If F is an attribute `-file(File,Line)`, then Rep(F) = `{attribute,LINE,file,{File,Line}}`.
- If F is a record declaration `-record(Name,{V_1, ..., V_k})`, then Rep(F) = `{attribute,LINE,record,{Name,[Rep(V_1), ..., Rep(V_k)]}}`. For Rep(V), see below.
- If F is a type declaration `-Type Name(V_1, ..., V_k) :: T`, where `Type` is either the atom `type` or the atom `opaque`, each `V_i` is a variable, and `T` is a type, then Rep(F) = `{attribute,LINE,Type, {Name,Rep(T),[Rep(V_1), ..., Rep(V_k)]}}`.

- If F is a function specification `-Spec Name Ft_1; ...; Ft_k`, where `Spec` is either the atom `spec` or the atom `callback`, and each `Ft_i` is a possibly constrained function type with an argument sequence of the same length `Arity`, then Rep(F) = `{attribute,Line,Spec,{{Name,Arity}, [Rep(Ft_1), ..., Rep(Ft_k)]}}`.
- If F is a function specification `-spec Mod:Name Ft_1; ...; Ft_k`, where each `Ft_i` is a possibly constrained function type with an argument sequence of the same length `Arity`, then Rep(F) = `{attribute,Line,spec,{{Mod,Name,Arity},[Rep(Ft_1), ..., Rep(Ft_k)]}}`.
- If F is a wild attribute `-A(T)`, then Rep(F) = `{attribute,LINE,A,T}`.
- If F is a function declaration `Name Fc_1 ; ... ; Name Fc_k`, where each `Fc_i` is a function clause with a pattern sequence of the same length `Arity`, then Rep(F) = `{function,LINE,Name,Arity, [Rep(Fc_1), ...,Rep(Fc_k)]}`.

### Record Fields

Each field in a record declaration may have an optional explicit default initializer expression, as well as an optional type.

- If V is `A`, then Rep(V) = `{record_field,LINE,Rep(A)}`.
- If V is `A = E`, where `E` is an expression, then Rep(V) = `{record_field,LINE,Rep(A),Rep(E)}`.
- If V is `A :: T`, where `T` is a type and it does not contain `undefined` syntactically, then Rep(V) = `{typed_record_field,{record_field,LINE,Rep(A)},Rep(undefined | T)}`.
- If V is `A :: T`, where `T` is a type, then Rep(V) = `{typed_record_field, {record_field,LINE,Rep(A)},Rep(T)}`.
- If V is `A = E :: T`, where `E` is an expression and `T` is a type, then Rep(V) = `{typed_record_field, {record_field,LINE,Rep(A),Rep(E)},Rep(T)}`.

### Representation of Parse Errors and End-of-file

In addition to the representations of forms, the list that represents a module declaration (as returned by functions in `erl_parse` and `epp`) may contain tuples `{error,E}` and `{warning,W}`, denoting syntactically incorrect forms and warnings, and `{eof,LINE}`, denoting an end-of-stream encountered before a complete form had been parsed.

## 1.6.2 Atomic Literals

There are five kinds of atomic literals, which are represented in the same way in patterns, expressions and guards:

- If L is an integer or character literal, then Rep(L) = `{integer,LINE,L}`.
- If L is a float literal, then Rep(L) = `{float,LINE,L}`.
- If L is a string literal consisting of the characters `C_1`, ..., `C_k`, then Rep(L) = `{string,LINE, [C_1, ..., C_k]}`.
- If L is an atom literal, then Rep(L) = `{atom,LINE,L}`.

Note that negative integer and float literals do not occur as such; they are parsed as an application of the unary negation operator.

## 1.6.3 Patterns

If `Ps` is a sequence of patterns `P_1, ..., P_k`, then Rep(Ps) = `[Rep(P_1), ..., Rep(P_k)]`. Such sequences occur as the list of arguments to a function or fun.

Individual patterns are represented as follows:

- If P is an atomic literal L, then Rep(P) = Rep(L).
- If P is a compound pattern `P_1 = P_2`, then Rep(P) = `{match,LINE,Rep(P_1),Rep(P_2)}`.

- If P is a variable pattern V, then Rep(P) = `{var,LINE,A}`, where A is an atom with a printname consisting of the same characters as V.
- If P is a universal pattern _, then Rep(P) = `{var,LINE,'_'}`.
- If P is a tuple pattern `{P_1, ..., P_k}`, then Rep(P) = `{tuple,LINE,[Rep(P_1), ..., Rep(P_k)]}`.
- If P is a nil pattern `[]`, then Rep(P) = `{nil,LINE}`.
- If P is a cons pattern `[P_h | P_t]`, then Rep(P) = `{cons,LINE,Rep(P_h),Rep(P_t)}`.
- If E is a binary pattern `<<P_1:Size_1/TSL_1, ..., P_k:Size_k/TSL_k>>`, then Rep(E) = `{bin,LINE,[{bin_element,LINE,Rep(P_1),Rep(Size_1),Rep(TSL_1)}, ..., {bin_element,LINE,Rep(P_k),Rep(Size_k),Rep(TSL_k)}]}`. For Rep(TSL), see below. An omitted `Size` is represented by `default`. An omitted `TSL` (type specifier list) is represented by `default`.
- If P is `P_1 Op P_2`, where `Op` is a binary operator (this is either an occurrence of `++` applied to a literal string or character list, or an occurrence of an expression that can be evaluated to a number at compile time), then Rep(P) = `{op,LINE,Op,Rep(P_1),Rep(P_2)}`.
- If P is `Op P_0`, where `Op` is a unary operator (this is an occurrence of an expression that can be evaluated to a number at compile time), then Rep(P) = `{op,LINE,Op,Rep(P_0)}`.
- If P is a record pattern `#Name{Field_1=P_1, ..., Field_k=P_k}`, then Rep(P) = `{record,LINE,Name,[{record_field,LINE,Rep(Field_1),Rep(P_1)}, ..., {record_field,LINE,Rep(Field_k),Rep(P_k)}]}`.
- If P is `#Name.Field`, then Rep(P) = `{record_index,LINE,Name,Rep(Field)}`.
- If P is `( P_0 )`, then Rep(P) = `Rep(P_0)`, that is, patterns cannot be distinguished from their bodies.

Note that every pattern has the same source form as some expression, and is represented the same way as the corresponding expression.

## 1.6.4 Expressions

A body B is a sequence of expressions `E_1, ..., E_k`, and Rep(B) = `[Rep(E_1), ..., Rep(E_k)]`.

An expression E is one of the following alternatives:

- If P is an atomic literal `L`, then Rep(P) = Rep(L).
- If E is `P = E_0`, then Rep(E) = `{match,LINE,Rep(P),Rep(E_0)}`.
- If E is a variable `V`, then Rep(E) = `{var,LINE,A}`, where `A` is an atom with a printname consisting of the same characters as `V`.
- If E is a tuple skeleton `{E_1, ..., E_k}`, then Rep(E) = `{tuple,LINE,[Rep(E_1), ..., Rep(E_k)]}`.
- If E is `[]`, then Rep(E) = `{nil,LINE}`.
- If E is a cons skeleton `[E_h | E_t]`, then Rep(E) = `{cons,LINE,Rep(E_h),Rep(E_t)}`.
- If E is a binary constructor `<<V_1:Size_1/TSL_1, ..., V_k:Size_k/TSL_k>>`, then Rep(E) = `{bin,LINE,[{bin_element,LINE,Rep(V_1),Rep(Size_1),Rep(TSL_1)}, ..., {bin_element,LINE,Rep(V_k),Rep(Size_k),Rep(TSL_k)}]}`. For Rep(TSL), see below. An omitted `Size` is represented by `default`. An omitted `TSL` (type specifier list) is represented by `default`.
- If E is `E_1 Op E_2`, where `Op` is a binary operator, then Rep(E) = `{op,LINE,Op,Rep(E_1),Rep(E_2)}`.
- If E is `Op E_0`, where `Op` is a unary operator, then Rep(E) = `{op,LINE,Op,Rep(E_0)}`.
- If E is `#Name{Field_1=E_1, ..., Field_k=E_k}`, then Rep(E) = `{record,LINE,Name,[{record_field,LINE,Rep(Field_1),Rep(E_1)}, ..., {record_field,LINE,Rep(Field_k),Rep(E_k)}]}`.

- If E is `E_0#Name{Field_1=E_1, ..., Field_k=E_k}`, then Rep(E) = `{record,LINE,Rep(E_0),Name, [{record_field,LINE,Rep(Field_1),Rep(E_1)}, ..., {record_field,LINE,Rep(Field_k),Rep(E_k)}]}`.
- If E is `#Name.Field`, then Rep(E) = `{record_index,LINE,Name,Rep(Field)}`.
- If E is `E_0#Name.Field`, then Rep(E) = `{record_field,LINE,Rep(E_0),Name,Rep(Field)}`.
- If E is `#{W_1, ..., W_k}` where each `W_i` is a map assoc or exact field, then Rep(E) = `{map,LINE, [Rep(W_1), ..., Rep(W_k)]}`. For Rep(W), see below.
- If E is `E_0#{W_1, ..., W_k}` where `W_i` is a map assoc or exact field, then Rep(E) = `{map,LINE,Rep(E_0),[Rep(W_1), ..., Rep(W_k)]}`. For Rep(W), see below.
- If E is `catch E_0`, then Rep(E) = `{'catch',LINE,Rep(E_0)}`.
- If E is `E_0(E_1, ..., E_k)`, then Rep(E) = `{call,LINE,Rep(E_0),[Rep(E_1), ..., Rep(E_k)]}`.
- If E is `E_m:E_0(E_1, ..., E_k)`, then Rep(E) = `{call,LINE, {remote,LINE,Rep(E_m),Rep(E_0)},[Rep(E_1), ..., Rep(E_k)]}`.
- If E is a list comprehension `[E_0 || W_1, ..., W_k]`, where each `W_i` is a generator or a filter, then Rep(E) = `{lc,LINE,Rep(E_0),[Rep(W_1), ..., Rep(W_k)]}`. For Rep(W), see below.
- If E is a binary comprehension `<<E_0 || W_1, ..., W_k>>`, where each `W_i` is a generator or a filter, then Rep(E) = `{bc,LINE,Rep(E_0),[Rep(W_1), ..., Rep(W_k)]}`. For Rep(W), see below.
- If E is `begin B end`, where `B` is a body, then Rep(E) = `{block,LINE,Rep(B)}`.
- If E is `if Ic_1 ; ... ; Ic_k end`, where each `Ic_i` is an if clause then Rep(E) = `{'if',LINE, [Rep(Ic_1), ..., Rep(Ic_k)]}`.
- If E is `case E_0 of Cc_1 ; ... ; Cc_k end`, where `E_0` is an expression and each `Cc_i` is a case clause then Rep(E) = `{'case',LINE,Rep(E_0),[Rep(Cc_1), ..., Rep(Cc_k)]}`.
- If E is `try B catch Tc_1 ; ... ; Tc_k end`, where `B` is a body and each `Tc_i` is a catch clause then Rep(E) = `{'try',LINE,Rep(B),[],[Rep(Tc_1), ..., Rep(Tc_k)],[]}`.
- If E is `try B of Cc_1 ; ... ; Cc_k catch Tc_1 ; ... ; Tc_n end`, where `B` is a body, each `Cc_i` is a case clause and each `Tc_j` is a catch clause then Rep(E) = `{'try',LINE,Rep(B), [Rep(Cc_1), ..., Rep(Cc_k)],[Rep(Tc_1), ..., Rep(Tc_n)],[]}`.
- If E is `try B after A end`, where `B` and `A` are bodies then Rep(E) = `{'try',LINE,Rep(B),[], [],Rep(A)}`.
- If E is `try B of Cc_1 ; ... ; Cc_k after A end`, where `B` and `A` are a bodies and each `Cc_i` is a case clause then Rep(E) = `{'try',LINE,Rep(B),[Rep(Cc_1), ..., Rep(Cc_k)], [],Rep(A)}`.
- If E is `try B catch Tc_1 ; ... ; Tc_k after A end`, where `B` and `A` are bodies and each `Tc_i` is a catch clause then Rep(E) = `{'try',LINE,Rep(B),[],[Rep(Tc_1), ..., Rep(Tc_k)],Rep(A)}`.
- If E is `try B of Cc_1 ; ... ; Cc_k catch Tc_1 ; ... ; Tc_n after A end`, where `B` and `A` are a bodies, each `Cc_i` is a case clause and each `Tc_j` is a catch clause then Rep(E) = `{'try',LINE,Rep(B),[Rep(Cc_1), ..., Rep(Cc_k)],[Rep(Tc_1), ..., Rep(Tc_n)],Rep(A)}`.
- If E is `receive Cc_1 ; ... ; Cc_k end`, where each `Cc_i` is a case clause then Rep(E) = `{'receive',LINE,[Rep(Cc_1), ..., Rep(Cc_k)]}`.
- If E is `receive Cc_1 ; ... ; Cc_k after E_0 -> B_t end`, where each `Cc_i` is a case clause, `E_0` is an expression and `B_t` is a body, then Rep(E) = `{'receive',LINE,[Rep(Cc_1), ..., Rep(Cc_k)],Rep(E_0),Rep(B_t)}`.
- If E is `fun Name / Arity`, then Rep(E) = `{'fun',LINE,{function,Name,Arity}}`.

- If E is `fun Module:Name/Arity`, then Rep(E) = `{'fun',LINE,{function,Rep(Module),Rep(Name),Rep(Arity)}}`. (Before the R15 release: Rep(E) = `{'fun',LINE,{function,Module,Name,Arity}}`.)
- If E is `fun Fc_1 ; ... ; Fc_k end` where each `Fc_i` is a function clause then Rep(E) = `{'fun',LINE,{clauses,[Rep(Fc_1), ..., Rep(Fc_k)]}}`.
- If E is `fun Name Fc_1 ; ... ; Name Fc_k end` where `Name` is a variable and each `Fc_i` is a function clause then Rep(E) = `{named_fun,LINE,Name,[Rep(Fc_1), ..., Rep(Fc_k)]}`.
- If E is `( E_0 )`, then Rep(E) = `Rep(E_0)`, that is, parenthesized expressions cannot be distinguished from their bodies.

### Generators and Filters

When W is a generator or a filter (in the body of a list or binary comprehension), then:

- If W is a generator `P <- E`, where `P` is a pattern and `E` is an expression, then Rep(W) = `{generate,LINE,Rep(P),Rep(E)}`.
- If W is a generator `P <= E`, where `P` is a pattern and `E` is an expression, then Rep(W) = `{b_generate,LINE,Rep(P),Rep(E)}`.
- If W is a filter `E`, which is an expression, then Rep(W) = `Rep(E)`.

### Binary Element Type Specifiers

A type specifier list TSL for a binary element is a sequence of type specifiers `TS_1 - ... - TS_k`. Rep(TSL) = `[Rep(TS_1), ..., Rep(TS_k)]`.

When TS is a type specifier for a binary element, then:

- If TS is an atom `A`, then Rep(TS) = `A`.
- If TS is a couple `A:Value` where `A` is an atom and `Value` is an integer, then Rep(TS) = `{A,Value}`.

### Map Assoc and Exact Fields

When W is an assoc or exact field (in the body of a map), then:

- If W is an assoc field `K => V`, where `K` and `V` are both expressions, then Rep(W) = `{map_field_assoc,LINE,Rep(K),Rep(V)}`.
- If W is an exact field `K := V`, where `K` and `V` are both expressions, then Rep(W) = `{map_field_exact,LINE,Rep(K),Rep(V)}`.

## 1.6.5 Clauses

There are function clauses, if clauses, case clauses and catch clauses.

A clause `C` is one of the following alternatives:

- If C is a function clause `( Ps ) -> B` where `Ps` is a pattern sequence and `B` is a body, then Rep(C) = `{clause,LINE,Rep(Ps),[],Rep(B)}`.
- If C is a function clause `( Ps ) when Gs -> B` where `Ps` is a pattern sequence, `Gs` is a guard sequence and `B` is a body, then Rep(C) = `{clause,LINE,Rep(Ps),Rep(Gs),Rep(B)}`.
- If C is an if clause `Gs -> B` where `Gs` is a guard sequence and `B` is a body, then Rep(C) = `{clause,LINE,[],Rep(Gs),Rep(B)}`.
- If C is a case clause `P -> B` where `P` is a pattern and `B` is a body, then Rep(C) = `{clause,LINE,[Rep(P)],[],Rep(B)}`.
- If C is a case clause `P when Gs -> B` where `P` is a pattern, `Gs` is a guard sequence and `B` is a body, then Rep(C) = `{clause,LINE,[Rep(P)],Rep(Gs),Rep(B)}`.

- If C is a catch clause `P -> B` where `P` is a pattern and `B` is a body, then Rep(C) = `{clause,LINE,[Rep({throw,P,_})],[],Rep(B)}`.
- If C is a catch clause `X : P -> B` where `X` is an atomic literal or a variable pattern, `P` is a pattern and `B` is a body, then Rep(C) = `{clause,LINE,[Rep({X,P,_})],[],Rep(B)}`.
- If C is a catch clause `P when Gs -> B` where `P` is a pattern, `Gs` is a guard sequence and `B` is a body, then Rep(C) = `{clause,LINE,[Rep({throw,P,_})],Rep(Gs),Rep(B)}`.
- If C is a catch clause `X : P when Gs -> B` where `X` is an atomic literal or a variable pattern, `P` is a pattern, `Gs` is a guard sequence and `B` is a body, then Rep(C) = `{clause,LINE,[Rep({X,P,_})],Rep(Gs),Rep(B)}`.

### 1.6.6 Guards

A guard sequence Gs is a sequence of guards `G_1; ...; G_k`, and Rep(Gs) = `[Rep(G_1), ..., Rep(G_k)]`. If the guard sequence is empty, Rep(Gs) = `[]`.

A guard G is a nonempty sequence of guard tests `Gt_1, ..., Gt_k`, and Rep(G) = `[Rep(Gt_1), ..., Rep(Gt_k)]`.

A guard test `Gt` is one of the following alternatives:

- If Gt is an atomic literal L, then Rep(Gt) = Rep(L).
- If Gt is a variable pattern `V`, then Rep(Gt) = `{var,LINE,A}`, where A is an atom with a printname consisting of the same characters as `V`.
- If Gt is a tuple skeleton `{Gt_1, ..., Gt_k}`, then Rep(Gt) = `{tuple,LINE,[Rep(Gt_1), ..., Rep(Gt_k)]}`.
- If Gt is `[]`, then Rep(Gt) = `{nil,LINE}`.
- If Gt is a cons skeleton `[Gt_h | Gt_t]`, then Rep(Gt) = `{cons,LINE,Rep(Gt_h),Rep(Gt_t)}`.
- If Gt is a binary constructor `<<Gt_1:Size_1/TSL_1, ..., Gt_k:Size_k/TSL_k>>`, then Rep(Gt) = `{bin,LINE,[{bin_element,LINE,Rep(Gt_1),Rep(Size_1),Rep(TSL_1)}, ..., {bin_element,LINE,Rep(Gt_k),Rep(Size_k),Rep(TSL_k)}]}`. For Rep(TSL), see above. An omitted `Size` is represented by `default`. An omitted `TSL` (type specifier list) is represented by `default`.
- If Gt is `Gt_1 Op Gt_2`, where `Op` is a binary operator, then Rep(Gt) = `{op,LINE,Op,Rep(Gt_1),Rep(Gt_2)}`.
- If Gt is `Op Gt_0`, where `Op` is a unary operator, then Rep(Gt) = `{op,LINE,Op,Rep(Gt_0)}`.
- If Gt is `#Name{Field_1=Gt_1, ..., Field_k=Gt_k}`, then Rep(E) = `{record,LINE,Name,[{record_field,LINE,Rep(Field_1),Rep(Gt_1)}, ..., {record_field,LINE,Rep(Field_k),Rep(Gt_k)}]}`.
- If Gt is `#Name.Field`, then Rep(Gt) = `{record_index,LINE,Name,Rep(Field)}`.
- If Gt is `Gt_0#Name.Field`, then Rep(Gt) = `{record_field,LINE,Rep(Gt_0),Name,Rep(Field)}`.
- If Gt is `A(Gt_1, ..., Gt_k)`, where `A` is an atom, then Rep(Gt) = `{call,LINE,Rep(A),[Rep(Gt_1), ..., Rep(Gt_k)]}`.
- If Gt is `A_m:A(Gt_1, ..., Gt_k)`, where `A_m` is the atom `erlang` and `A` is an atom or an operator, then Rep(Gt) = `{call,LINE,{remote,LINE,Rep(A_m),Rep(A)},[Rep(Gt_1), ..., Rep(Gt_k)]}`.
- If Gt is `{A_m,A}(Gt_1, ..., Gt_k)`, where `A_m` is the atom `erlang` and `A` is an atom or an operator, then Rep(Gt) = `{call,LINE,Rep({A_m,A}),[Rep(Gt_1), ..., Rep(Gt_k)]}`.
- If Gt is `( Gt_0 )`, then Rep(Gt) = `Rep(Gt_0)`, that is, parenthesized guard tests cannot be distinguished from their bodies.

Note that every guard test has the same source form as some expression, and is represented the same way as the corresponding expression.

### 1.6.7 Types

- If T is an annotated type `Anno :: Type`, where `Anno` is a variable and `Type` is a type, then Rep(T) = `{ann_type,LINE,[Rep(Anno),Rep(Type)]}`.
- If T is an atom or integer literal L, then Rep(T) = Rep(L).
- If T is `L Op R`, where `Op` is a binary operator and `L` and `R` are types (this is an occurrence of an expression that can be evaluated to an integer at compile time), then Rep(T) = `{op,LINE,Op,Rep(L),Rep(R)}`.
- If T is `Op A`, where `Op` is a unary operator and `A` is a type (this is an occurrence of an expression that can be evaluated to an integer at compile time), then Rep(T) = `{op,LINE,Op,Rep(A)}`.
- If T is a bitstring type `<<_:M,_:_*N>>`, where `M` and `N` are singleton integer types, then Rep(T) = `{type,LINE,binary,[Rep(M),Rep(N)]}`.
- If T is the empty list type `[]`, then Rep(T) = `{type,Line,nil,[]}`.
- If T is a fun type `fun()`, then Rep(T) = `{type,LINE,'fun',[]}`.
- If T is a fun type `fun((...) -> B)`, where `B` is a type, then Rep(T) = `{type,LINE,'fun', [{type,LINE,any},Rep(B)]}`.
- If T is a fun type `fun(Ft)`, where `Ft` is a function type, then Rep(T) = `Rep(Ft)`.
- If T is an integer range type `L .. H`, where `L` and `H` are singleton integer types, then Rep(T) = `{type,LINE,range,[Rep(L),Rep(H)]}`.
- If T is a map type `map()`, then Rep(T) = `{type,LINE,map,any}`.
- If T is a map type `#{P_1, ..., P_k}`, where each `P_i` is a map pair type, then Rep(T) = `{type,LINE,map,[Rep(P_1), ..., Rep(P_k)]}`.
- If T is a map pair type `K => V`, where `K` and `V` are types, then Rep(T) = `{type,LINE,map_field_assoc,[Rep(K),Rep(V)]}`.
- If T is a predefined (or built-in) type `N(A_1, ..., A_k)`, where each `A_i` is a type, then Rep(T) = `{type,LINE,N,[Rep(A_1), ..., Rep(A_k)]}`.
- If T is a record type `#Name{F_1, ..., F_k}`, where each `F_i` is a record field type, then Rep(T) = `{type,LINE,record,[Rep(Name),Rep(F_1), ..., Rep(F_k)]}`.
- If T is a record field type `Name :: Type`, where `Type` is a type, then Rep(T) = `{type,LINE,field_type,[Rep(Name),Rep(Type)]}`.
- If T is a remote type `M:N(A_1, ..., A_k)`, where each `A_i` is a type, then Rep(T) = `{remote_type,LINE,[Rep(M),Rep(N),[Rep(A_1), ..., Rep(A_k)]]}`.
- If T is a tuple type `tuple()`, then Rep(T) = `{type,LINE,tuple,any}`.
- If T is a tuple type `{A_1, ..., A_k}`, where each `A_i` is a type, then Rep(T) = `{type,LINE,tuple, [Rep(A_1), ..., Rep(A_k)]}`.
- If T is a type union `T_1 | ... | T_k`, where each `T_i` is a type, then Rep(T) = `{type,LINE,union, [Rep(T_1), ..., Rep(T_k)]}`.
- If T is a type variable `V`, then Rep(T) = `{var,LINE,A}`, where `A` is an atom with a printname consisting of the same characters as `V`. A type variable is any variable except underscore (_).
- If T is a user-defined type `N(A_1, ..., A_k)`, where each `A_i` is a type, then Rep(T) = `{user_type,LINE,N,[Rep(A_1), ..., Rep(A_k)]}`.
- If T is `( T_0 )`, then Rep(T) = `Rep(T_0)`, that is, parenthesized types cannot be distinguished from their bodies.

### Function Types

- If Ft is a constrained function type `Ft_1 when Fc`, where `Ft_1` is a function type and `Fc` is a function constraint, then Rep(T) = `{type,LINE,bounded_fun,[Rep(Ft_1),Rep(Fc)]}`.
- If Ft is a function type `(A_1, ..., A_n) -> B`, where each `A_i` and `B` are types, then Rep(Ft) = `{type,LINE,'fun',[{type,LINE,product,[Rep(A_1), ..., Rep(A_n)]},Rep(B)]}`.

### Function Constraints

A function constraint Fc is a nonempty sequence of constraints `C_1, ..., C_k`, and Rep(Fc) = `[Rep(C_1), ..., Rep(C_k)]`.

- If C is a constraint `is_subtype(V, T)` or `V :: T`, where `V` is a type variable and `T` is a type, then Rep(C) = `{type,LINE,constraint,[{atom,LINE,is_subtype},[Rep(V),Rep(T)]]}`.

## 1.6.8 The Abstract Format After Preprocessing

The compilation option `debug_info` can be given to the compiler to have the abstract code stored in the `abstract_code` chunk in the BEAM file (for debugging purposes).

In OTP R9C and later, the `abstract_code` chunk will contain

`{raw_abstract_v1,AbstractCode}`

where `AbstractCode` is the abstract code as described in this document.

In releases of OTP prior to R9C, the abstract code after some more processing was stored in the BEAM file. The first element of the tuple would be either `abstract_v1` (R7B) or `abstract_v2` (R8B).

# 1.7 tty - A command line interface

`tty` is a simple command line interface program where keystrokes are collected and interpreted. Completed lines are sent to the shell for interpretation. There is a simple history mechanism, which saves previous lines. These can be edited before sending them to the shell. `tty` is started when Erlang is started with the command:

*erl*

`tty` operates in one of two modes:

- *normal mode*, in which lines of text can be edited and sent to the shell.
- *shell break* mode, which allows the user to kill the current shell, start multiple shells etc. Shell break mode is started by typing *Control G*.

## 1.7.1 Normal Mode

In normal mode keystrokes from the user are collected and interpreted by `tty`. Most of the *emacs* line editing commands are supported. The following is a complete list of the supported line editing commands.

*Note:* The notation `C-a` means pressing the control key and the letter `a` simultaneously. `M-f` means pressing the `ESC` key followed by the letter `f`. `Home` and `End` represent the keys with the same name on the keyboard, whereas `Left` and `Right` represent the corresponding arrow keys.

| *Key Sequence* | *Function* |
|---|---|
| Home | Beginning of line |
| C-a | Beginning of line |

| | |
|---|---|
| C-b | Backward character |
| C-Left | Backward word |
| M-b | Backward word |
| C-d | Delete character |
| M-d | Delete word |
| End | End of line |
| C-e | End of line |
| C-f | Forward character |
| C-Right | Forward word |
| M-f | Forward word |
| C-g | Enter shell break mode |
| C-k | Kill line |
| C-u | Backward kill line |
| C-l | Redraw line |
| C-n | Fetch next line from the history buffer |
| C-p | Fetch previous line from the history buffer |
| C-t | Transpose characters |
| C-w | Backward kill word |
| C-y | Insert previously killed text |

**Table 7.1: tty text editing**

## 1.7.2 Shell Break Mode

*tty* enters *shell* break mode when you type *Control G*. In this mode you can:

- Kill or suspend the current shell
- Connect to a suspended shell
- Start a new shell

# 1.8 How to implement a driver

> Note:
>
> This document was written a long time ago. A lot of it is still interesting since it explains important concepts, but it was written for an older driver interface so the examples do not work anymore. The reader is encouraged to read *erl_driver* and the *driver_entry* documentation.

## 1.8.1 Introduction

This chapter tells you how to build your own driver for erlang.

A driver in Erlang is a library written in C, that is linked to the Erlang emulator and called from erlang. Drivers can be used when C is more suitable than Erlang, to speed things up, or to provide access to OS resources not directly accessible from Erlang.

A driver can be dynamically loaded, as a shared library (known as a DLL on windows), or statically loaded, linked with the emulator when it is compiled and linked. Only dynamically loaded drivers are described here, statically linked drivers are beyond the scope of this chapter.

When a driver is loaded it is executed in the context of the emulator, shares the same memory and the same thread. This means that all operations in the driver must be non-blocking, and that any crash in the driver will bring the whole emulator down. In short: you have to be extremely careful!

## 1.8.2 Sample driver

This is a simple driver for accessing a postgres database using the libpq C client library. Postgres is used because it's free and open source. For information on postgres, refer to the website **www.postgres.org**.

The driver is synchronous, it uses the synchronous calls of the client library. This is only for simplicity, and is generally not good, since it will halt the emulator while waiting for the database. This will be improved on below with an asynchronous sample driver.

The code is quite straight-forward: all communication between Erlang and the driver is done with `port_control/3`, and the driver returns data back using the `rbuf`.

An Erlang driver only exports one function: the driver entry function. This is defined with a macro, `DRIVER_INIT`, and returns a pointer to a C `struct` containing the entry points that are called from the emulator. The `struct` defines the entries that the emulator calls to call the driver, with a `NULL` pointer for entries that are not defined and used by the driver.

The `start` entry is called when the driver is opened as a port with `open_port/2`. Here we allocate memory for a user data structure. This user data will be passed every time the emulator calls us. First we store the driver handle, because it is needed in subsequent calls. We allocate memory for the connection handle that is used by LibPQ. We also set the port to return allocated driver binaries, by setting the flag `PORT_CONTROL_FLAG_BINARY`, calling `set_port_control_flags`. (This is because we don't know whether our data will fit in the result buffer of `control`, which has a default size set up by the emulator, currently 64 bytes.)

There is an entry `init` which is called when the driver is loaded, but we don't use this, since it is executed only once, and we want to have the possibility of several instances of the driver.

The `stop` entry is called when the port is closed.

The `control` entry is called from the emulator when the Erlang code calls `port_control/3`, to do the actual work. We have defined a simple set of commands: `connect` to login to the database, `disconnect` to log out and `select` to send a SQL-query and get the result. All results are returned through `rbuf`. The library `ei` in

`erl_interface` is used to encode data in binary term format. The result is returned to the emulator as binary terms, so `binary_to_term` is called in Erlang to convert the result to term form.

The code is available in `pg_sync.c` in the `sample` directory of `erts`.

The driver entry contains the functions that will be called by the emulator. In our simple example, we only provide `start`, `stop` and `control`.

```
/* Driver interface declarations */
static ErlDrvData start(ErlDrvPort port, char *command);
static void stop(ErlDrvData drv_data);
static int control(ErlDrvData drv_data, unsigned int command, char *buf,
                   int len, char **rbuf, int rlen);

static ErlDrvEntry pq_driver_entry = {
    NULL,                       /* init */
    start,
    stop,
    NULL,                       /* output */
    NULL,                       /* ready_input */
    NULL,                       /* ready_output */
    "pg_sync",                  /* the name of the driver */
    NULL,                       /* finish */
    NULL,                       /* handle */
    control,
    NULL,                       /* timeout */
    NULL,                       /* outputv */
    NULL,                       /* ready_async */
    NULL,                       /* flush */
    NULL,                       /* call */
    NULL                        /* event */
};
```

We have a structure to store state needed by the driver, in this case we only need to keep the database connection.

```
typedef struct our_data_s {
    PGconn* conn;
} our_data_t;
```

These are control codes we have defined.

```
/* Keep the following definitions in alignment with the
 * defines in erl_pq_sync.erl
 */

#define DRV_CONNECT             'C'
#define DRV_DISCONNECT          'D'
#define DRV_SELECT              'S'
```

This just returns the driver structure. The macro `DRIVER_INIT` defines the only exported function. All the other functions are static, and will not be exported from the library.

```
```

```
/* INITIALIZATION AFTER LOADING */

/*
 * This is the init function called after this driver has been loaded.
 * It must *not* be declared static. Must return the address to
 * the driver entry.
 */

DRIVER_INIT(pq_drv)
{
    return &pq_driver_entry;
}
```

Here we do some initialization, `start` is called from `open_port`. The data will be passed to `control` and `stop`.

```
/* DRIVER INTERFACE */
static ErlDrvData start(ErlDrvPort port, char *command)
{
    our_data_t* data;

    data = (our_data_t*)driver_alloc(sizeof(our_data_t));
    data->conn = NULL;
    set_port_control_flags(port, PORT_CONTROL_FLAG_BINARY);
    return (ErlDrvData)data;
}
```

We call disconnect to log out from the database. (This should have been done from Erlang, but just in case.)

```
static int do_disconnect(our_data_t* data, ei_x_buff* x);

static void stop(ErlDrvData drv_data)
{
    our_data_t* data = (our_data_t*)drv_data;

    do_disconnect(data, NULL);
    driver_free(data);
}
```

We use the binary format only to return data to the emulator; input data is a string paramater for `connect` and `select`. The returned data consists of Erlang terms.

The functions `get_s` and `ei_x_to_new_binary` are utilities that are used to make the code shorter. `get_s` duplicates the string and zero-terminates it, since the postgres client library wants that. `ei_x_to_new_binary` takes an `ei_x_buff` buffer and allocates a binary and copies the data there. This binary is returned in `*rbuf`. (Note that this binary is freed by the emulator, not by us.)

```
static char* get_s(const char* buf, int len);
static int do_connect(const char *s, our_data_t* data, ei_x_buff* x);
static int do_select(const char* s, our_data_t* data, ei_x_buff* x);

/* Since we are operating in binary mode, the return value from control
 * is irrelevant, as long as it is not negative.
 */
static int control(ErlDrvData drv_data, unsigned int command, char *buf,
```

```
                  int len, char **rbuf, int rlen)
{
    int r;
    ei_x_buff x;
    our_data_t* data = (our_data_t*)drv_data;
    char* s = get_s(buf, len);
    ei_x_new_with_version(&x);
    switch (command) {
        case DRV_CONNECT:    r = do_connect(s, data, &x);  break;
        case DRV_DISCONNECT: r = do_disconnect(data, &x);  break;
        case DRV_SELECT:     r = do_select(s, data, &x);   break;
        default:             r = -1;        break;
    }
    *rbuf = (char*)ei_x_to_new_binary(&x);
    ei_x_free(&x);
    driver_free(s);
    return r;
}
```

`do_connect` is where we log in to the database. If the connection was successful we store the connection handle in our driver data, and return ok. Otherwise, we return the error message from postgres, and store `NULL` in the driver data.

```
static int do_connect(const char *s, our_data_t* data, ei_x_buff* x)
{
    PGconn* conn = PQconnectdb(s);
    if (PQstatus(conn) != CONNECTION_OK) {
        encode_error(x, conn);
        PQfinish(conn);
        conn = NULL;
    } else {
        encode_ok(x);
    }
    data->conn = conn;
    return 0;
}
```

If we are connected (if the connection handle is not `NULL`), we log out from the database. We need to check if we should encode an ok, since we might get here from the `stop` function, which doesn't return data to the emulator.

```
static int do_disconnect(our_data_t* data, ei_x_buff* x)
{
    if (data->conn == NULL)
        return 0;
    PQfinish(data->conn);
    data->conn = NULL;
    if (x != NULL)
        encode_ok(x);
    return 0;
}
```

We execute a query and encode the result. Encoding is done in another C module, `pg_encode.c` which is also provided as sample code.

```
static int do_select(const char* s, our_data_t* data, ei_x_buff* x)
```

```
{
   PGresult* res = PQexec(data->conn, s);
    encode_result(x, res, data->conn);
    PQclear(res);
    return 0;
}
```

Here we simply check the result from postgres, and if it's data we encode it as lists of lists with column data. Everything from postgres is C strings, so we just use `ei_x_encode_string` to send the result as strings to Erlang. (The head of the list contains the column names.)

```
void encode_result(ei_x_buff* x, PGresult* res, PGconn* conn)
{
    int row, n_rows, col, n_cols;
    switch (PQresultStatus(res)) {
    case PGRES_TUPLES_OK:
        n_rows = PQntuples(res);
        n_cols = PQnfields(res);
        ei_x_encode_tuple_header(x, 2);
        encode_ok(x);
        ei_x_encode_list_header(x, n_rows+1);
        ei_x_encode_list_header(x, n_cols);
        for (col = 0; col < n_cols; ++col) {
            ei_x_encode_string(x, PQfname(res, col));
        }
        ei_x_encode_empty_list(x);
        for (row = 0; row < n_rows; ++row) {
            ei_x_encode_list_header(x, n_cols);
            for (col = 0; col < n_cols; ++col) {
                ei_x_encode_string(x, PQgetvalue(res, row, col));
            }
            ei_x_encode_empty_list(x);
        }
        ei_x_encode_empty_list(x);
        break;
    case PGRES_COMMAND_OK:
        ei_x_encode_tuple_header(x, 2);
        encode_ok(x);
        ei_x_encode_string(x, PQcmdTuples(res));
        break;
    default:
        encode_error(x, conn);
        break;
    }
}
```

## 1.8.3 Compiling and linking the sample driver

The driver should be compiled and linked to a shared library (DLL on windows). With gcc this is done with the link flags `-shared` and `-fpic`. Since we use the `ei` library we should include it too. There are several versions of `ei`, compiled for debug or non-debug and multi-threaded or single-threaded. In the makefile for the samples the `obj` directory is used for the `ei` library, meaning that we use the non-debug, single-threaded version.

### 1.8.4 Calling a driver as a port in Erlang

Before a driver can be called from Erlang, it must be loaded and opened. Loading is done using the `erl_ddll` module (the `erl_ddll` driver that loads dynamic driver, is actually a driver itself). If loading is ok the port can be opened with `open_port/2`. The port name must match the name of the shared library and the name in the driver entry structure.

When the port has been opened, the driver can be called. In the `pg_sync` example, we don't have any data from the port, only the return value from the `port_control`.

The following code is the Erlang part of the synchronous postgres driver, `pg_sync.erl`.

```
-module(pg_sync).

-define(DRV_CONNECT, 1).
-define(DRV_DISCONNECT, 2).
-define(DRV_SELECT, 3).

-export([connect/1, disconnect/1, select/2]).

connect(ConnectStr) ->
    case erl_ddll:load_driver(".", "pg_sync") of
        ok -> ok;
        {error, already_loaded} -> ok;
        E -> exit({error, E})
    end,
    Port = open_port({spawn, ?MODULE}, []),
    case binary_to_term(port_control(Port, ?DRV_CONNECT, ConnectStr)) of
        ok -> {ok, Port};
        Error -> Error
    end.

disconnect(Port) ->
    R = binary_to_term(port_control(Port, ?DRV_DISCONNECT, "")),
    port_close(Port),
    R.

select(Port, Query) ->
    binary_to_term(port_control(Port, ?DRV_SELECT, Query)).
```

The API is simple: `connect/1` loads the driver, opens it and logs on to the database, returning the Erlang port if successful, `select/2` sends a query to the driver, and returns the result, `disconnect/1` closes the database connection and the driver. (It does not unload it, however.) The connection string should be a connection string for postgres.

The driver is loaded with `erl_ddll:load_driver/2`, and if this is successful, or if it's already loaded, it is opened. This will call the `start` function in the driver.

We use the `port_control/3` function for all calls into the driver, the result from the driver is returned immediately, and converted to terms by calling `binary_to_term/1`. (We trust that the terms returned from the driver are well-formed, otherwise the `binary_to_term` calls could be contained in a `catch`.)

### 1.8.5 Sample asynchronous driver

Sometimes database queries can take long time to complete, in our `pg_sync` driver, the emulator halts while the driver is doing its job. This is often not acceptable, since no other Erlang process gets a chance to do anything. To improve on our postgres driver, we reimplement it using the asynchronous calls in LibPQ.

The asynchronous version of the driver is in the sample files `pg_async.c` and `pg_asyng.erl`.

```
/* Driver interface declarations */
static ErlDrvData start(ErlDrvPort port, char *command);
static void stop(ErlDrvData drv_data);
static int control(ErlDrvData drv_data, unsigned int command, char *buf,
                   int len, char **rbuf, int rlen);
static void ready_io(ErlDrvData drv_data, ErlDrvEvent event);

static ErlDrvEntry pq_driver_entry = {
    NULL,                       /* init */
    start,
    stop,
    NULL,                       /* output */
    ready_io,                   /* ready_input */
    ready_io,                   /* ready_output */
    "pg_async",                 /* the name of the driver */
    NULL,                       /* finish */
    NULL,                       /* handle */
    control,
    NULL,                       /* timeout */
    NULL,                       /* outputv */
    NULL,                       /* ready_async */
    NULL,                       /* flush */
    NULL,                       /* call */
    NULL                        /* event */
};

typedef struct our_data_t {
    PGconn* conn;
    ErlDrvPort port;
    int socket;
    int connecting;
} our_data_t;
```

Here some things have changed from `pg_sync.c`: we use the entry `ready_io` for `ready_input` and `ready_output` which will be called from the emulator only when there is input to be read from the socket. (Actually, the socket is used in a `select` function inside the emulator, and when the socket is signalled, indicating there is data to read, the `ready_input` entry is called. More on this below.)

Our driver data is also extended, we keep track of the socket used for communication with postgres, and also the port, which is needed when we send data to the port with `driver_output`. We have a flag `connecting` to tell whether the driver is waiting for a connection or waiting for the result of a query. (This is needed since the entry `ready_io` will be called both when connecting and when there is a query result.)

```
static int do_connect(const char *s, our_data_t* data)
{
    PGconn* conn = PQconnectStart(s);
    if (PQstatus(conn) == CONNECTION_BAD) {
        ei_x_buff x;
        ei_x_new_with_version(&x);
        encode_error(&x, conn);
        PQfinish(conn);
        conn = NULL;
        driver_output(data->port, x.buff, x.index);
        ei_x_free(&x);
    }
    PQconnectPoll(conn);
    int socket = PQsocket(conn);
    data->socket = socket;
    driver_select(data->port, (ErlDrvEvent)socket, DO_READ, 1);
```

```
    driver_select(data->port, (ErlDrvEvent)socket, DO_WRITE, 1);
    data->conn = conn;
    data->connecting = 1;
    return 0;
}
```

The `connect` function looks a bit different too. We connect using the asynchronous `PQconnectStart` function. After the connection is started, we retrieve the socket for the connection with `PQsocket`. This socket is used with the `driver_select` function to wait for connection. When the socket is ready for input or for output, the `ready_io` function will be called.

Note that we only return data (with `driver_output`) if there is an error here, otherwise we wait for the connection to be completed, in which case our `ready_io` function will be called.

```
static int do_select(const char* s, our_data_t* data)
{
    data->connecting = 0;
    PGconn* conn = data->conn;
    /* if there's an error return it now */
    if (PQsendQuery(conn, s) == 0) {
        ei_x_buff x;
        ei_x_new_with_version(&x);
        encode_error(&x, conn);
        driver_output(data->port, x.buff, x.index);
        ei_x_free(&x);
    }
    /* else wait for ready_output to get results */
    return 0;
}
```

The `do_select` function initiates a select, and returns if there is no immediate error. The actual result will be returned when `ready_io` is called.

```
static void ready_io(ErlDrvData drv_data, ErlDrvEvent event)
{
    PGresult* res = NULL;
    our_data_t* data = (our_data_t*)drv_data;
    PGconn* conn = data->conn;
    ei_x_buff x;
    ei_x_new_with_version(&x);
    if (data->connecting) {
        ConnStatusType status;
        PQconnectPoll(conn);
        status = PQstatus(conn);
        if (status == CONNECTION_OK)
            encode_ok(&x);
        else if (status == CONNECTION_BAD)
            encode_error(&x, conn);
    } else {
        PQconsumeInput(conn);
        if (PQisBusy(conn))
            return;
        res = PQgetResult(conn);
        encode_result(&x, res, conn);
        PQclear(res);
        for (;;) {
            res = PQgetResult(conn);
```

```
            if (res == NULL)
                break;
            PQclear(res);
        }
    }
    if (x.index > 1) {
        driver_output(data->port, x.buff, x.index);
        if (data->connecting)
            driver_select(data->port, (ErlDrvEvent)data->socket, DO_WRITE, 0);
    }
    ei_x_free(&x);
}
```

The `ready_io` function will be called when the socket we got from postgres is ready for input or output. Here we first check if we are connecting to the database. In that case we check connection status and return ok if the connection is successful, or error if it's not. If the connection is not yet established, we simply return; `ready_io` will be called again.

If we have a result from a connect, indicated by having data in the `x` buffer, we no longer need to select on output (`ready_output`), so we remove this by calling `driver_select`.

If we're not connecting, we're waiting for results from a `PQsendQuery`, so we get the result and return it. The encoding is done with the same functions as in the earlier example.

We should add error handling here, for instance checking that the socket is still open, but this is just a simple example.

The Erlang part of the asynchronous driver consists of the sample file `pg_async.erl`.

```
-module(pg_async).

-define(DRV_CONNECT, $C).
-define(DRV_DISCONNECT, $D).
-define(DRV_SELECT, $S).

-export([connect/1, disconnect/1, select/2]).

connect(ConnectStr) ->
    case erl_ddll:load_driver(".", "pg_async") of
        ok -> ok;
        {error, already_loaded} -> ok;
        _ -> exit({error, could_not_load_driver})
    end,
    Port = open_port({spawn, ?MODULE}, [binary]),
    port_control(Port, ?DRV_CONNECT, ConnectStr),
    case return_port_data(Port) of
        ok ->
            {ok, Port};
        Error ->
            Error
    end.

disconnect(Port) ->
    port_control(Port, ?DRV_DISCONNECT, ""),
    R = return_port_data(Port),
    port_close(Port),
    R.

select(Port, Query) ->
    port_control(Port, ?DRV_SELECT, Query),
    return_port_data(Port).

return_port_data(Port) ->
```

```
    receive
        {Port, {data, Data}} ->
            binary_to_term(Data)
    end.
```

The Erlang code is slightly different, this is because we don't return the result synchronously from `port_control`, instead we get it from `driver_output` as data in the message queue. The function `return_port_data` above receives data from the port. Since the data is in binary format, we use `binary_to_term/1` to convert it to an Erlang term. Note that the driver is opened in binary mode (`open_port/2` is called with the option `[binary]`). This means that data sent from the driver to the emulator is sent as binaries. Without the `binary` option, they would have been lists of integers.

### 1.8.6 An asynchronous driver using driver_async

As a final example we demonstrate the use of `driver_async`. We also use the driver term interface. The driver is written in C++. This enables us to use an algorithm from STL. We will use the `next_permutation` algorithm to get the next permutation of a list of integers. For large lists (more than 100000 elements), this will take some time, so we will perform this as an asynchronous task.

The asynchronous API for drivers is quite complicated. First of all, the work must be prepared. In our example we do this in `output`. We could have used `control` just as well, but we want some variation in our examples. In our driver, we allocate a structure that contains anything that's needed for the asynchronous task to do the work. This is done in the main emulator thread. Then the asynchronous function is called from a driver thread, separate from the main emulator thread. Note that the driver-functions are not reentrant, so they shouldn't be used. Finally, after the function is completed, the driver callback `ready_async` is called from the main emulator thread, this is where we return the result to Erlang. (We can't return the result from within the asynchronous function, since we can't call the driver-functions.)

The code below is from the sample file `next_perm.cc`.

The driver entry looks like before, but also contains the call-back `ready_async`.

```
static ErlDrvEntry next_perm_driver_entry = {
    NULL,                       /* init */
    start,
    NULL,                       /* stop */
    output,
    NULL,                       /* ready_input */
    NULL,                       /* ready_output */
    "next_perm",                /* the name of the driver */
    NULL,                       /* finish */
    NULL,                       /* handle */
    NULL,                       /* control */
    NULL,                       /* timeout */
    NULL,                       /* outputv */
    ready_async,
    NULL,                       /* flush */
    NULL,                       /* call */
    NULL                        /* event */
};
```

The `output` function allocates the work-area of the asynchronous function. Since we use C++, we use a struct, and stuff the data in it. We have to copy the original data, it is not valid after we have returned from the `output` function, and the `do_perm` function will be called later, and from another thread. We return no data here, instead it will be sent later from the `ready_async` call-back.

The `async_data` will be passed to the `do_perm` function. We do not use a `async_free` function (the last argument to `driver_async`), it's only used if the task is cancelled programmatically.

```
struct our_async_data {
    bool prev;
    vector<int> data;
    our_async_data(ErlDrvPort p, int command, const char* buf, int len);
};

our_async_data::our_async_data(ErlDrvPort p, int command,
                               const char* buf, int len)
    : prev(command == 2),
      data((int*)buf, (int*)buf + len / sizeof(int))
{
}

static void do_perm(void* async_data);

static void output(ErlDrvData drv_data, char *buf, int len)
{
    if (*buf < 1 || *buf > 2) return;
    ErlDrvPort port = reinterpret_cast<ErlDrvPort>(drv_data);
    void* async_data = new our_async_data(port, *buf, buf+1, len);
    driver_async(port, NULL, do_perm, async_data, do_free);
}
```

In the `do_perm` we simply do the work, operating on the structure that was allocated in `output`.

```
static void do_perm(void* async_data)
{
    our_async_data* d = reinterpret_cast<our_async_data*>(async_data);
    if (d->prev)
        prev_permutation(d->data.begin(), d->data.end());
    else
        next_permutation(d->data.begin(), d->data.end());
}
```

In the `ready_async` function, the output is sent back to the emulator. We use the driver term format instead of `ei`. This is the only way to send Erlang terms directly to a driver, without having the Erlang code to call `binary_to_term/1`. In our simple example this works well, and we don't need to use `ei` to handle the binary term format.

When the data is returned we deallocate our data.

```
static void ready_async(ErlDrvData drv_data, ErlDrvThreadData async_data)
{
    ErlDrvPort port = reinterpret_cast<ErlDrvPort>(drv_data);
    our_async_data* d = reinterpret_cast<our_async_data*>(async_data);
    int n = d->data.size(), result_n = n*2 + 3;
    ErlDrvTermData *result = new ErlDrvTermData[result_n], *rp = result;
    for (vector<int>::iterator i = d->data.begin();
         i != d->data.end(); ++i) {
        *rp++ = ERL_DRV_INT;
        *rp++ = *i;
    }
```

```
    *rp++ = ERL_DRV_NIL;
    *rp++ = ERL_DRV_LIST;
    *rp++ = n+1;
    driver_output_term(port, result, result_n);
    delete[] result;
    delete d;
}
```

This driver is called like the others from Erlang, however, since we use `driver_output_term`, there is no need to call binary_to_term. The Erlang code is in the sample file `next_perm.erl`.

The input is changed into a list of integers and sent to the driver.

```
-module(next_perm).

-export([next_perm/1, prev_perm/1, load/0, all_perm/1]).

load() ->
    case whereis(next_perm) of
        undefined ->
            case erl_ddll:load_driver(".", "next_perm") of
                ok -> ok;
                {error, already_loaded} -> ok;
                E -> exit(E)
            end,
            Port = open_port({spawn, "next_perm"}, []),
            register(next_perm, Port);
        _ ->
            ok
    end.

list_to_integer_binaries(L) ->
    [<<I:32/integer-native>> || I <- L].

next_perm(L) ->
    next_perm(L, 1).

prev_perm(L) ->
    next_perm(L, 2).

next_perm(L, Nxt) ->
    load(),
    B = list_to_integer_binaries(L),
    port_control(next_perm, Nxt, B),
    receive
        Result ->
            Result
    end.

all_perm(L) ->
    New = prev_perm(L),
    all_perm(New, L, [New]).

all_perm(L, L, Acc) ->
    Acc;
all_perm(L, Orig, Acc) ->
    New = prev_perm(L),
    all_perm(New, Orig, [New | Acc]).
```

# 1.9 Inet configuration

## 1.9.1 Introduction

This chapter tells you how the Erlang runtime system is configured for IP communication. It also explains how you may configure it for your own particular needs by means of a configuration file. The information here is mainly intended for users with special configuration needs or problems. There should normally be no need for specific settings for Erlang to function properly on a correctly IP configured platform.

When Erlang starts up it will read the kernel variable `inetrc` which, if defined, should specify the location and name of a user configuration file. Example:

```
% erl -kernel inetrc '"./cfg_files/erl_inetrc"'
```

Note that the usage of a `.inetrc` file, which was supported in earlier Erlang versions, is now obsolete.

A second way to specify the configuration file is to set the environment variable `ERL_INETRC` to the full name of the file. Example (bash):

```
% export ERL_INETRC=./cfg_files/erl_inetrc
```

Note that the kernel variable `inetrc` overrides this environment variable.

If no user configuration file is specified and Erlang is started in non-distributed or short name distributed mode, Erlang will use default configuration settings and a native lookup method that should work correctly under most circumstances. Erlang will not read any information from system inet configuration files (like /etc/host.conf, /etc/nsswitch.conf, etc) in these modes, except for /etc/resolv.conf and /etc/hosts that is read and monitored for changes on Unix platforms for the internal DNS client *inet_res*.

If Erlang is started in long name distributed mode, it needs to get the domain name from somewhere and will read system inet configuration files for this information. Any hosts and resolver information found then is also recorded, but not used as long as Erlang is configured for native lookups. (The information becomes useful if the lookup method is changed to `'file'` or `'dns'`, see below).

Native lookup (system calls) is always the default resolver method. This is true for all platforms except VxWorks and OSE Delta where `'file'` or `'dns'` is used (in that order of priority).

On Windows platforms, Erlang will search the system registry rather than look for configuration files when started in long name distributed mode.

## 1.9.2 Configuration Data

Erlang records the following data in a local database if found in system inet configuration files (or system registry):

- Host names and addresses
- Domain name
- Nameservers
- Search domains
- Lookup method

This data may also be specified explicitly in the user configuration file. The configuration file should contain lines of configuration parameters (each terminated with a full stop). Some parameters add data to the configuration (e.g. host and nameserver), others overwrite any previous settings (e.g. domain and lookup). The user configuration file is always examined last in the configuration process, making it possible for the user to override any default values or previously made settings. Call `inet:get_rc()` to view the state of the inet configuration database.

These are the valid configuration parameters:

```
{file, Format, File}.
```

```
Format = atom()
File = string()
```

Specify a system file that Erlang should read configuration data from. `Format` tells the parser how the file should be interpreted: `resolv` (Unix resolv.conf), `host_conf_freebsd` (FreeBSD host.conf), `host_conf_bsdos` (BSDOS host.conf), `host_conf_linux` (Linux host.conf), `nsswitch_conf` (Unix nsswitch.conf) or `hosts` (Unix hosts). `File` should specify the name of the file with full path.

*`{resolv_conf, File}.`*

```
File = string()
```

Specify a system file that Erlang should read resolver configuration from for the internal DNS client *inet_res*, and monitor for changes, even if it does not exist. The path must be absolute.

This may override the configuration parameters `nameserver` and `search` depending on the contents of the specified file. They may also change any time in the future reflecting the file contents.

If the file is specified as an empty string "", no file is read nor monitored in the future. This emulates the old behaviour of not configuring the DNS client when the node is started in short name distributed mode.

If this parameter is not specified it defaults to `/etc/resolv.conf` unless the environment variable `ERL_INET_ETC_DIR` is set which defines the directory for this file to some maybe other than `/etc`.

*`{hosts_file, File}.`*

```
File = string()
```

Specify a system file that Erlang should read resolver configuration from for the internal hosts file resolver and monitor for changes, even if it does not exist. The path must be absolute.

These host entries are searched after all added with `{file, hosts, File}` above or `{host, IP, Aliases}` below when the lookup option `file` is used.

If the file is specified as an empty string "", no file is read nor monitored in the future. This emulates the old behaviour of not configuring the DNS client when the node is started in short name distributed mode.

If this parameter is not specified it defaults to `/etc/hosts` unless the environment variable `ERL_INET_ETC_DIR` is set which defines the directory for this file to some maybe other than `/etc`.

*`{registry, Type}.`*

```
Type = atom()
```

Specify a system registry that Erlang should read configuration data from. Currently, `win32` is the only valid option.

*`{host, IP, Aliases}.`*

```
IP = tuple()
Aliases = [string()]
```

Add host entry to the hosts table.

*`{domain, Domain}.`*

```
Domain = string()
```

Set domain name.

*{nameserver, IP [,Port]}.*

```
IP = tuple()
Port = integer()
```

Add address (and port, if other than default) of primary nameserver to use for *inet_res*.

*{alt_nameserver, IP [,Port]}.*

```
IP = tuple()
Port = integer()
```

Add address (and port, if other than default) of secondary nameserver for *inet_res*.

*{search, Domains}.*

```
Domains = [string()]
```

Add search domains for *inet_res*.

*{lookup, Methods}.*

```
Methods = [atom()]
```

Specify lookup methods and in which order to try them. The valid methods are: `native` (use system calls), `file` (use host data retrieved from system configuration files and/or the user configuration file) or `dns` (use the Erlang DNS client *inet_res* for nameserver queries).

The lookup method `string` tries to parse the hostname as a IPv4 or IPv6 string and return the resulting IP address. It is automatically tried first when `native` is *not* in the `Methods` list. To skip it in this case the pseudo lookup method `nostring` can be inserted anywhere in the `Methods` list.

*{cache_size, Size}.*

```
Size = integer()
```

Set size of resolver cache. Default is 100 DNS records.

*{cache_refresh, Time}.*

```
Time = integer()
```

Set how often (in millisec) the resolver cache for *inet_res*. is refreshed (i.e. expired DNS records are deleted). Default is 1 h.

*{timeout, Time}.*

```
Time = integer()
```

Set the time to wait until retry (in millisec) for DNS queries made by *inet_res*. Default is 2 sec.

*{retry, N}.*

```
N = integer()
```

Set the number of DNS queries *inet_res* will try before giving up. Default is 3.

*{inet6, Bool}.*

```
Bool = true | false
```

Tells the DNS client *inet_res* to look up IPv6 addresses. Default is false.

*{usevc, Bool}.*

```
Bool = true | false
```

Tells the DNS client *inet_res* to use TCP (Virtual Circuit) instead of UDP. Default is false.

*{edns, Version}.*

```
Version = false | 0
```

Sets the EDNS version that *inet_res* will use. The only allowed is zero. Default is false which means to not use EDNS.

*{udp_payload_size, Size}.*

```
N = integer()
```

Sets the allowed UDP payload size *inet_res* will advertise in EDNS queries. Also sets the limit when the DNS query will be deemed too large for UDP forcing a TCP query instead, which is not entirely correct since the advertised UDP payload size of the individual nameserver is what should be used, but this simple strategy will do until a more intelligent (probing, caching) algorithm need be implemented. The default is 1280 which stems from the standard Ethernet MTU size.

*{udp, Module}.*

```
Module = atom()
```

Tell Erlang to use other primitive UDP module than inet_udp.

*{tcp, Module}.*

```
Module = atom()
```

Tell Erlang to use other primitive TCP module than inet_tcp.

*clear_hosts.*

Clear the hosts table.

*clear_ns.*

Clear the list of recorded nameservers (primary and secondary).

*clear_search.*

Clear the list of search domains.

### 1.9.3 User Configuration Example

Here follows a user configuration example.

Assume a user does not want Erlang to use the native lookup method, but wants Erlang to read all information necessary from start and use that for resolving names and addresses. In case lookup fails, Erlang should request the data from a nameserver (using the Erlang DNS client, set to use EDNS allowing larger responses). The resolver configuration will be updated when its configuration file changes, furthermore, DNS records should never be cached. The user configuration file (in this example named `erl_inetrc`, stored in directory `./cfg_files`) could then look like this (Unix):

```
%% -- ERLANG INET CONFIGURATION FILE --
%% read the hosts file
{file, hosts, "/etc/hosts"}.
%% add a particular host
{host, {134,138,177,105}, ["finwe"]}.
%% do not monitor the hosts file
{hosts_file, ""}.
%% read and monitor nameserver config from here
{resolv_conf, "/usr/local/etc/resolv.conf"}.
%% enable EDNS
{edns,0}.
%% disable caching
{cache_size, 0}.
%% specify lookup method
{lookup, [file, dns]}.
```

And Erlang could, for example, be started like this:

```
% erl -sname my_node -kernel inetrc '"./cfg_files/erl_inetrc"'
```

## 1.10 External Term Format

### 1.10.1 Introduction

The external term format is mainly used in the distribution mechanism of Erlang.

Since Erlang has a fixed number of types, there is no need for a programmer to define a specification for the external format used within some application. All Erlang terms has an external representation and the interpretation of the different terms are application specific.

In Erlang the BIF *term_to_binary/1,2* is used to convert a term into the external format. To convert binary data encoding a term the BIF *binary_to_term/1* is used.

The distribution does this implicitly when sending messages across node boundaries.

The overall format of the term format is:

| 1 | 1 | N |
|---|---|---|
| 131 | Tag | Data |

**Table 10.1:**

> Note:
>
> When messages are *passed between connected nodes* and a *distribution header* is used, the first byte containing the version number (131) is omitted from the terms that follow the distribution header. This since the version number is implied by the version number in the distribution header.

A compressed term looks like this:

| 1 | 1 | 4 | N |
|---|---|---|---|
| 131 | 80 | UncompressedSize | Zlib-compressedData |

**Table 10.2:**

Uncompressed Size (unsigned 32 bit integer in big-endian byte order) is the size of the data before it was compressed. The compressed data has the following format when it has been expanded:

| 1 | Uncompressed Size |
|---|---|
| Tag | Data |

**Table 10.3:**

> Note:
>
> As of ERTS version 5.10 (OTP-R16) support for UTF-8 encoded atoms has been introduced in the external format. However, only characters that can be encoded using Latin1 (ISO-8859-1) are currently supported in atoms. The support for UTF-8 encoded atoms in the external format has been implemented in order to be able to support all Unicode characters in atoms in *some future release*. Until full Unicode support for atoms has been introduced, it is an *error* to pass atoms containing characters that cannot be encoded in Latin1, and *the behavior is undefined*.
>
> When the *`DFLAG_UTF8_ATOMS`* distribution flag has been exchanged between both nodes in the *distribution handshake*, all atoms in the distribution header will be encoded in UTF-8; otherwise, all atoms in the distribution header will be encoded in Latin1. The two new tags *ATOM_UTF8_EXT*, and *SMALL_ATOM_UTF8_EXT* will only be used if the `DFLAG_UTF8_ATOMS` distribution flag has been exchanged between nodes, or if an atom containing characters that cannot be encoded in Latin1 is encountered.
>
> The maximum number of allowed characters in an atom is 255. In the UTF-8 case each character may need 4 bytes to be encoded.

## 1.10.2 Distribution header

As of erts version 5.7.2 the old atom cache protocol was dropped and a new one was introduced. This atom cache protocol introduced the distribution header. Nodes with erts versions earlier than 5.7.2 can still communicate with new nodes, but no distribution header and no atom cache will be used.

The distribution header currently only contains an atom cache reference section, but could in the future contain more information. The distribution header precedes one or more Erlang terms on the external format. For more information see the documentation of the *protocol between connected nodes* in the *distribution protocol* documentation.

*ATOM_CACHE_REF* entries with corresponding `AtomCacheReferenceIndex` in terms encoded on the external format following a distribution header refers to the atom cache references made in the distribution header. The range is 0 <= `AtomCacheReferenceIndex` < 255, i.e., at most 255 different atom cache references from the following terms can be made.

The distribution header format is:

| 1 | 1 | 1 | NumberOfAtomCacheRefs/2+1 \| 0 | N \| 0 |
|---|---|---|---|---|
| 131 | 68 | NumberOfAtomCacheRefs | Flags | AtomCacheRefs |

**Table 10.4:**

`Flags` consists of `NumberOfAtomCacheRefs/2+1` bytes, unless `NumberOfAtomCacheRefs` is `0`. If `NumberOfAtomCacheRefs` is `0`, `Flags` and `AtomCacheRefs` are omitted. Each atom cache reference have a half byte flag field. Flags corresponding to a specific `AtomCacheReferenceIndex`, are located in flag byte number `AtomCacheReferenceIndex/2`. Flag byte 0 is the first byte after the `NumberOfAtomCacheRefs` byte. Flags for an even `AtomCacheReferenceIndex` are located in the least significant half byte and flags for an odd `AtomCacheReferenceIndex` are located in the most significant half byte.

The flag field of an atom cache reference has the following format:

| 1 bit | 3 bits |
|---|---|
| NewCacheEntryFlag | SegmentIndex |

**Table 10.5:**

The most significant bit is the `NewCacheEntryFlag`. If set, the corresponding cache reference is new. The three least significant bits are the `SegmentIndex` of the corresponding atom cache entry. An atom cache consists of 8 segments each of size 256, i.e., an atom cache can contain 2048 entries.

After flag fields for atom cache references, another half byte flag field is located which has the following format:

| 3 bits | 1 bit |
|---|---|
| CurrentlyUnused | LongAtoms |

**Table 10.6:**

The least significant bit in that half byte is the `LongAtoms` flag. If it is set, 2 bytes are used for atom lengths instead of 1 byte in the distribution header.

After the `Flags` field follow the `AtomCacheRefs`. The first `AtomCacheRef` is the one corresponding to `AtomCacheReferenceIndex` 0. Higher indices follows in sequence up to index `NumberOfAtomCacheRefs - 1`.

If the `NewCacheEntryFlag` for the next `AtomCacheRef` has been set, a `NewAtomCacheRef` on the following format will follow:

| 1 | 1 \| 2 | Length |
|---|---|---|
| InternalSegmentIndex | Length | AtomText |

**Table 10.7:**

`InternalSegmentIndex` together with the `SegmentIndex` completely identify the location of an atom cache entry in the atom cache. `Length` is number of bytes that `AtomText` consists of. Length is a two byte big endian integer if the `LongAtoms` flag has been set, otherwise a one byte integer. When the *`DFLAG_UTF8_ATOMS`* distribution flag has been exchanged between both nodes in the *distribution handshake*, characters in `AtomText` is encoded in UTF-8; otherwise, encoded in Latin1. Subsequent `CachedAtomRef`s with the same `SegmentIndex` and `InternalSegmentIndex` as this `NewAtomCacheRef` will refer to this atom until a new `NewAtomCacheRef` with the same `SegmentIndex` and `InternalSegmentIndex` appear.

For more information on encoding of atoms, see *note on UTF-8 encoded atoms* in the beginning of this document.

If the `NewCacheEntryFlag` for the next `AtomCacheRef` has not been set, a `CachedAtomRef` on the following format will follow:

| 1 |
|---|
| InternalSegmentIndex |

**Table 10.8:**

`InternalSegmentIndex` together with the `SegmentIndex` identify the location of the atom cache entry in the atom cache. The atom corresponding to this `CachedAtomRef` is the latest `NewAtomCacheRef` preceding this `CachedAtomRef` in another previously passed distribution header.

## 1.10.3 ATOM_CACHE_REF

| 1 | 1 |
|---|---|
| 82 | AtomCacheReferenceIndex |

**Table 10.9:**

Refers to the atom with `AtomCacheReferenceIndex` in the *distribution header*.

## 1.10.4 SMALL_INTEGER_EXT

| 1 | 1 |
|---|---|
| 97 | Int |

**Table 10.10:**

Unsigned 8 bit integer.

### 1.10.5 INTEGER_EXT

| 1 | 4 |
|---|---|
| 98 | Int |

**Table 10.11:**

Signed 32 bit integer in big-endian format (i.e. MSB first)

### 1.10.6 FLOAT_EXT

| 1 | 31 |
|---|---|
| 99 | Float String |

**Table 10.12:**

A float is stored in string format. the format used in sprintf to format the float is "%.20e" (there are more bytes allocated than necessary). To unpack the float use sscanf with format "%lf".

This term is used in minor version 0 of the external format; it has been superseded by *NEW_FLOAT_EXT* .

### 1.10.7 ATOM_EXT

| 1 | 2 | Len |
|---|---|---|
| `100` | `Len` | `AtomName` |

**Table 10.13:**

An atom is stored with a 2 byte unsigned length in big-endian order, followed by `Len` numbers of 8 bit Latin1 characters that forms the `AtomName`. *Note*: The maximum allowed value for `Len` is 255.

### 1.10.8 REFERENCE_EXT

| 1 | N | 4 | 1 |
|---|---|---|---|
| `101` | `Node` | `ID` | `Creation` |

**Table 10.14:**

Encode a reference object (an object generated with `make_ref/0`). The `Node` term is an encoded atom, i.e. *ATOM_EXT*, *SMALL_ATOM_EXT* or *ATOM_CACHE_REF*. The `ID` field contains a big-endian unsigned integer, but *should be regarded as uninterpreted data* since this field is node specific. `Creation` is a byte containing a node serial number that makes it possible to separate old (crashed) nodes from a new one.

In `ID`, only 18 bits are significant; the rest should be 0. In `Creation`, only 2 bits are significant; the rest should be 0. See *NEW_REFERENCE_EXT*.

### 1.10.9 PORT_EXT

| 1 | N | 4 | 1 |
|---|---|---|---|
| 102 | Node | ID | Creation |

**Table 10.15:**

Encode a port object (obtained form `open_port/2`). The `ID` is a node specific identifier for a local port. Port operations are not allowed across node boundaries. The `Creation` works just like in *REFERENCE_EXT*.

### 1.10.10 PID_EXT

| 1 | N | 4 | 4 | 1 |
|---|---|---|---|---|
| 103 | Node | ID | Serial | Creation |

**Table 10.16:**

Encode a process identifier object (obtained from `spawn/3` or friends). The `ID` and `Creation` fields works just like in *REFERENCE_EXT*, while the `Serial` field is used to improve safety. In `ID`, only 15 bits are significant; the rest should be 0.

### 1.10.11 SMALL_TUPLE_EXT

| 1 | 1 | N |
|---|---|---|
| 104 | Arity | Elements |

**Table 10.17:**

`SMALL_TUPLE_EXT` encodes a tuple. The `Arity` field is an unsigned byte that determines how many element that follows in the `Elements` section.

### 1.10.12 LARGE_TUPLE_EXT

| 1 | 4 | N |
|---|---|---|
| 105 | Arity | Elements |

**Table 10.18:**

Same as *SMALL_TUPLE_EXT* with the exception that `Arity` is an unsigned 4 byte integer in big endian format.

## 1.10.13 MAP_EXT

| 1 | 4 | N |
|---|---|---|
| 116 | Arity | Pairs |

**Table 10.19:**

`MAP_EXT` encodes a map. The `Arity` field is an unsigned 4 byte integer in big endian format that determines the number of key-value pairs in the map. Key and value pairs (`Ki => Vi`) are encoded in the `Pairs` section in the following order: `K1, V1, K2, V2,..., Kn, Vn`. Duplicate keys are *not allowed* within the same map.

*Since:* OTP 17.0

## 1.10.14 NIL_EXT

| 1 |
|---|
| 106 |

**Table 10.20:**

The representation for an empty list, i.e. the Erlang syntax `[]`.

## 1.10.15 STRING_EXT

| 1 | 2 | Len |
|---|---|---|
| 107 | Length | Characters |

**Table 10.21:**

String does NOT have a corresponding Erlang representation, but is an optimization for sending lists of bytes (integer in the range 0-255) more efficiently over the distribution. Since the `Length` field is an unsigned 2 byte integer (big endian), implementations must make sure that lists longer than 65535 elements are encoded as *LIST_EXT*.

## 1.10.16 LIST_EXT

| 1 | 4 | | |
|---|---|---|---|
| 108 | Length | Elements | Tail |

**Table 10.22:**

`Length` is the number of elements that follows in the `Elements` section. `Tail` is the final tail of the list; it is *NIL_EXT* for a proper list, but may be anything type if the list is improper (for instance `[a|b]`).

## 1.10.17 BINARY_EXT

| 1 | 4 | Len |
|---|---|---|
| 109 | Len | Data |

**Table 10.23:**

Binaries are generated with bit syntax expression or with *list_to_binary/1*, *term_to_binary/1*, or as input from binary ports. The `Len` length field is an unsigned 4 byte integer (big endian).

## 1.10.18 SMALL_BIG_EXT

| 1 | 1 | 1 | n |
|---|---|---|---|
| 110 | n | Sign | d(0) ... d(n-1) |

**Table 10.24:**

Bignums are stored in unary form with a `Sign` byte that is 0 if the binum is positive and 1 if is negative. The digits are stored with the LSB byte stored first. To calculate the integer the following formula can be used:
B = 256
(d0*B^0 + d1*B^1 + d2*B^2 + ... d(N-1)*B^(n-1))

## 1.10.19 LARGE_BIG_EXT

| 1 | 4 | 1 | n |
|---|---|---|---|
| 111 | n | Sign | d(0) ... d(n-1) |

**Table 10.25:**

Same as *SMALL_BIG_EXT* with the difference that the length field is an unsigned 4 byte integer.

## 1.10.20 NEW_REFERENCE_EXT

| 1 | 2 | N | 1 | N' |
|---|---|---|---|---|
| 114 | Len | Node | Creation | ID ... |

**Table 10.26:**

Node and Creation are as in *REFERENCE_EXT*.

`ID` contains a sequence of big-endian unsigned integers (4 bytes each, so `N'` is a multiple of 4), but should be regarded as uninterpreted data.

`N'` = 4 * `Len`.

In the first word (four bytes) of `ID`, only 18 bits are significant, the rest should be 0. In `Creation`, only 2 bits are significant, the rest should be 0.

NEW_REFERENCE_EXT was introduced with distribution version 4. In version 4, `N'` should be at most 12.

See *REFERENCE_EXT*).

## 1.10.21 SMALL_ATOM_EXT

| 1 | 1 | Len |
|---|---|---|
| `115` | `Len` | `AtomName` |

**Table 10.27:**

An atom is stored with a 1 byte unsigned length, followed by `Len` numbers of 8 bit Latin1 characters that forms the `AtomName`. Longer atoms can be represented by *ATOM_EXT*. *Note* the `SMALL_ATOM_EXT` was introduced in erts version 5.7.2 and require an exchange of the *`DFLAG_SMALL_ATOM_TAGS`* distribution flag in the *distribution handshake*.

## 1.10.22 FUN_EXT

| 1 | 4 | N1 | N2 | N3 | N4 | N5 |
|---|---|---|---|---|---|---|
| 117 | NumFree | Pid | Module | Index | Uniq | Free vars ... |

**Table 10.28:**

`Pid`
: is a process identifier as in *PID_EXT*. It represents the process in which the fun was created.

`Module`
: is an encoded as an atom, using *ATOM_EXT*, *SMALL_ATOM_EXT* or *ATOM_CACHE_REF*. This is the module that the fun is implemented in.

`Index`
: is an integer encoded using *SMALL_INTEGER_EXT* or *INTEGER_EXT*. It is typically a small index into the module's fun table.

`Uniq`
: is an integer encoded using *SMALL_INTEGER_EXT* or *INTEGER_EXT*. `Uniq` is the hash value of the parse for the fun.

`Free vars`
: is `NumFree` number of terms, each one encoded according to its type.

## 1.10.23 NEW_FUN_EXT

| 1 | 4 | 1 | 16 | 4 | 4 | N1 | N2 | N3 | N4 | N5 |
|---|---|---|---|---|---|---|---|---|---|---|
| 112 | Size | Arity | Uniq | Index | NumFree | Module | OldIndex | OldUniq | Pid | Free Vars |

**Table 10.29:**

This is the new encoding of internal funs: `fun F/A` and `fun(Arg1,..) -> ... end`.

`Size`
is the total number of bytes, including the `Size` field.

`Arity`
is the arity of the function implementing the fun.

`Uniq`
is the 16 bytes MD5 of the significant parts of the Beam file.

`Index`
is an index number. Each fun within a module has an unique index. `Index` is stored in big-endian byte order.

`NumFree`
is the number of free variables.

`Module`
is an encoded as an atom, using *ATOM_EXT*, *SMALL_ATOM_EXT* or *ATOM_CACHE_REF*. This is the module that the fun is implemented in.

`OldIndex`
is an integer encoded using *SMALL_INTEGER_EXT* or *INTEGER_EXT*. It is typically a small index into the module's fun table.

`OldUniq`
is an integer encoded using *SMALL_INTEGER_EXT* or *INTEGER_EXT*. `Uniq` is the hash value of the parse tree for the fun.

`Pid`
is a process identifier as in *PID_EXT*. It represents the process in which the fun was created.

`Free vars`
is `NumFree` number of terms, each one encoded according to its type.

## 1.10.24 EXPORT_EXT

| 1 | N1 | N2 | N3 |
|---|---|---|---|
| 113 | Module | Function | Arity |

**Table 10.30:**

This term is the encoding for external funs: `fun M:F/A`.

`Module` and `Function` are atoms (encoded using *ATOM_EXT*, *SMALL_ATOM_EXT* or *ATOM_CACHE_REF*).

`Arity` is an integer encoded using *SMALL_INTEGER_EXT*.

## 1.10.25 BIT_BINARY_EXT

| 1 | 4 | 1 | Len |
|---|---|---|---|
| 77 | Len | Bits | Data |

**Table 10.31:**

This term represents a bitstring whose length in bits does not have to be a multiple of 8. The `Len` field is an unsigned 4 byte integer (big endian). The `Bits` field is the number of bits (1-8) that are used in the last byte in the data field, counting from the most significant bit towards the least significant.

### 1.10.26 NEW_FLOAT_EXT

| 1 | 8 |
|---|---|
| 70 | IEEE float |

**Table 10.32:**

A float is stored as 8 bytes in big-endian IEEE format.

This term is used in minor version 1 of the external format.

### 1.10.27 ATOM_UTF8_EXT

| 1 | 2 | Len |
|---|---|---|
| `118` | `Len` | `AtomName` |

**Table 10.33:**

An atom is stored with a 2 byte unsigned length in big-endian order, followed by `Len` bytes containing the `AtomName` encoded in UTF-8.

For more information on encoding of atoms, see *note on UTF-8 encoded atoms* in the beginning of this document.

### 1.10.28 SMALL_ATOM_UTF8_EXT

| 1 | 1 | Len |
|---|---|---|
| `119` | `Len` | `AtomName` |

**Table 10.34:**

An atom is stored with a 1 byte unsigned length, followed by `Len` bytes containing the `AtomName` encoded in UTF-8. Longer atoms encoded in UTF-8 can be represented using *ATOM_UTF8_EXT*.

For more information on encoding of atoms, see *note on UTF-8 encoded atoms* in the beginning of this document.

## 1.11 Distribution Protocol

The description here is far from complete and will therefore be further refined in upcoming releases. The protocols both from Erlang nodes towards EPMD (Erlang Port Mapper Daemon) and between Erlang nodes, however, are stable since many years.

The distribution protocol can be divided into four (4) parts:

- 1. Low level socket connection.
- 2. Handshake, interchange node name and authenticate.
- 3. Authentication (done by net_kernel).
- 4. Connected.

A node fetches the Port number of another node through the EPMD (at the other host) in order to initiate a connection request.

For each host where a distributed Erlang node is running there should also be an EPMD running. The EPMD can be started explicitly or automatically as a result of the Erlang node startup.

By default EPMD listens on port 4369.

3 and 4 are performed at the same level but the net_kernel disconnects the other node if it communicates using an invalid cookie (after one (1) second).

The integers in all multi-byte fields are in big-endian order.

## 1.11.1 EPMD Protocol

The requests served by the EPMD (Erlang Port Mapper Daemon) are summarized in the figure below.

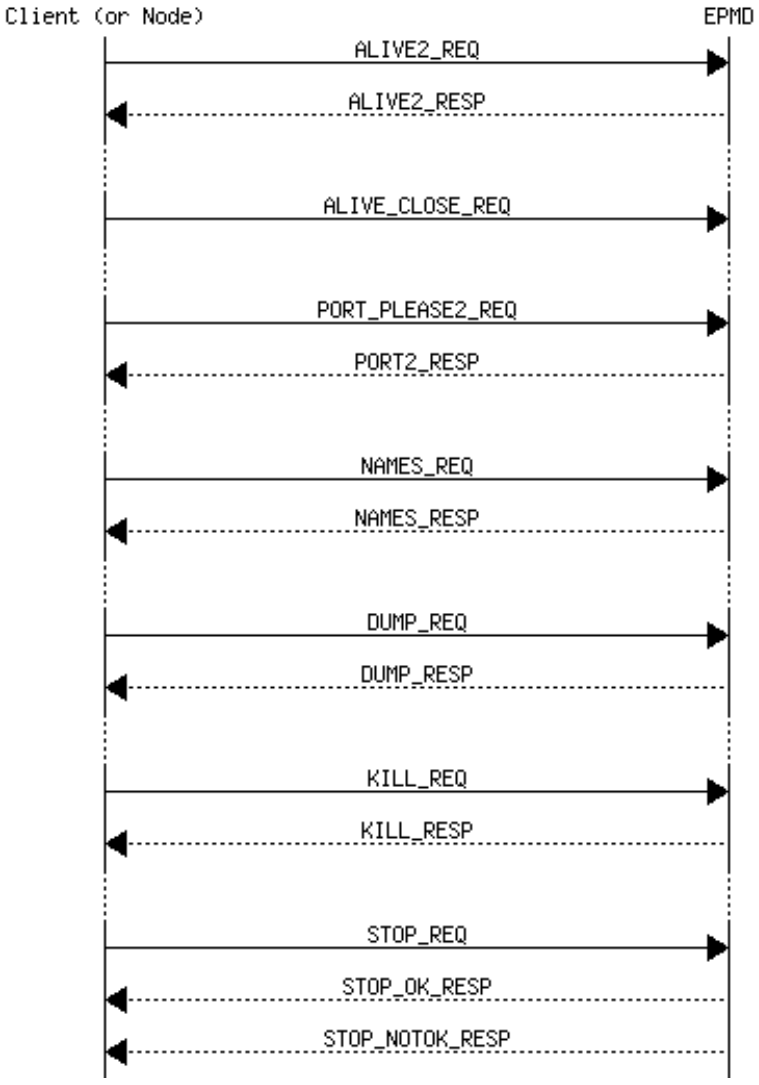


**Figure 11.1: Summary of EPMD requests.**

Each request `*_REQ` is preceded by a two-byte length field. Thus, the overall request format is:

| 2 | n |
|---|---|
| Length | Request |

**Table 11.1:**

## Register a node in the EPMD

When a distributed node is started it registers itself in EPMD. The message ALIVE2_REQ described below is sent from the node towards EPMD. The response from EPMD is ALIVE2_RESP.

| 1 | 2 | 1 | 1 | 2 | 2 | 2 | Nlen | 2 | Elen |
|---|---|---|---|---|---|---|---|---|---|
| 120 | PortNo | NodeType | Protocol | HighestVersion | LowestVersion | Nlen | NodeName | Elen | Extra |

**Table 11.2: ALIVE2_REQ (120)**

`PortNo`
The port number on which the node accept connection requests.

`NodeType`
77 = normal Erlang node, 72 = hidden node (C-node),...

`Protocol`
0 = tcp/ip-v4, ...

`HighestVersion`
The highest distribution version that this node can handle. The value in R6B and later is 5.

`LowestVersion`
The lowest distribution version that this node can handle. The value in R6B and later is 5.

`Nlen`
The length (in bytes) of the `NodeName` field.

`NodeName`
The NodeName as an UTF-8 encoded string of `Nlen` bytes.

`Elen`
The length of the `Extra` field.

`Extra`
Extra field of `Elen` bytes.

The connection created to the EPMD must be kept as long as the node is a distributed node. When the connection is closed the node is automatically unregistered from the EPMD.

The response message ALIVE2_RESP is described below.

| 1 | 1 | 2 |
|---|---|---|
| 121 | Result | Creation |

**Table 11.3: ALIVE2_RESP (121)**

Result = 0 -> ok, Result > 0 -> error

### Unregister a node from the EPMD

A node unregisters itself from the EPMD by simply closing the TCP connection towards EPMD established when the node was registered.

### Get the distribution port of another node

When one node wants to connect to another node it starts with a PORT_PLEASE2_REQ request towards EPMD on the host where the node resides in order to get the distribution port that the node listens to.

| 1 | N |
|---|---|
| 122 | NodeName |

**Table 11.4: PORT_PLEASE2_REQ (122)**

where N = Length - 1

| 1 | 1 |
|---|---|
| 119 | Result |

**Table 11.5: PORT2_RESP (119) response indicating error, Result > 0.**

Or

| 1 | 1 | 2 | 1 | 1 | 2 | 2 | 2 | Nlen | 2 | Elen |
|---|---|---|---|---|---|---|---|---|---|---|
| 119 | Result | PortNo | NodeType | Protocol | HighestVersion | LowestVersion | Nlen | NodeName | Elen | Extra |

**Table 11.6: PORT2_RESP when Result = 0.**

If Result > 0, the packet only consists of [119, Result].

EPMD will close the socket as soon as it has sent the information.

### Get all registered names from EPMD

This request is used via the Erlang function `net_adm:names/1,2`. A TCP connection is opened towards EPMD and this request is sent.

| 1 |
|---|
| 110 |

**Table 11.7: NAMES_REQ (110)**

The response for a `NAMES_REQ` looks like this:

| 4 | |
|---|---|

| | |
|---|---|
| EPMDPortNo | NodeInfo* |

**Table 11.8: NAMES_RESP**

NodeInfo is a string written for each active node. When all NodeInfo has been written the connection is closed by EPMD.

NodeInfo is, as expressed in Erlang:

```
io:format("name ~ts at port ~p~n", [NodeName, Port]).
```

### Dump all data from EPMD

This request is not really used, it should be regarded as a debug feature.

| |
|---|
| 1 |
| 100 |

**Table 11.9: DUMP_REQ**

The response for a `DUMP_REQ` looks like this:

| | |
|---|---|
| 4 | |
| EPMDPortNo | NodeInfo* |

**Table 11.10: DUMP_RESP**

NodeInfo is a string written for each node kept in EPMD. When all NodeInfo has been written the connection is closed by EPMD.

NodeInfo is, as expressed in Erlang:

```
io:format("active name     ~ts at port ~p, fd = ~p ~n",
          [NodeName, Port, Fd]).
```

or

```
io:format("old/unused name ~ts at port ~p, fd = ~p~n",
          [NodeName, Port, Fd]).
```

### Kill the EPMD

This request will kill the running EPMD. It is almost never used.

| 1 |
| --- |
| 107 |

**Table 11.11: KILL_REQ**

The response fo a `KILL_REQ` looks like this:

| 2 |
| --- |
| OKString |

**Table 11.12: KILL_RESP**

where `OKString` is "OK".

## STOP_REQ (Not Used)

| 1 | n |
| --- | --- |
| 115 | NodeName |

**Table 11.13: STOP_REQ**

where n = Length - 1

The current implementation of Erlang does not care if the connection to the EPMD is broken.

The response for a `STOP_REQ` looks like this.

| 7 |
| --- |
| OKString |

**Table 11.14: STOP_RESP**

where OKString is "STOPPED".

A negative response can look like this.

| 7 |
| --- |
| NOKString |

**Table 11.15: STOP_NOTOK_RESP**

where NOKString is "NOEXIST".

## 1.11.2 Distribution Handshake

This section describes the distribution handshake protocol introduced in the OTP-R6 release of Erlang/OTP. This description was previously located in `$ERL_TOP/lib/kernel/internal_doc/distribution_handshake.txt`, and has more or less been copied and "formatted" here. It has been more or less unchanged since the year 1999, but the handshake should not have changed much since then either.

### General

The TCP/IP distribution uses a handshake which expects a connection based protocol, i.e. the protocol does not include any authentication after the handshake procedure.

This is not entirely safe, as it is vulnerable against takeover attacks, but it is a tradeoff between fair safety and performance.

The cookies are never sent in cleartext and the handshake procedure expects the client (called A) to be the first one to prove that it can generate a sufficient digest. The digest is generated with the MD5 message digest algorithm and the challenges are expected to be very random numbers.

### Definitions

A challenge is a 32 bit integer number in big endian order. Below the function `gen_challenge()` returns a random 32 bit integer used as a challenge.

A digest is a (16 bytes) MD5 hash of the Challenge (as text) concatenated with the cookie (as text). Below, the function `gen_digest(Challenge, Cookie)` generates a digest as described above.

An out_cookie is the cookie used in outgoing communication to a certain node, so that A's out_cookie for B should correspond with B's in_cookie for A and the other way around. A's out_cookie for B and A's in_cookie for B need *NOT* be the same. Below the function `out_cookie(Node)` returns the current node's out_cookie for `Node`.

An in_cookie is the cookie expected to be used by another node when communicating with us, so that A's in_cookie for B corresponds with B's out_cookie for A. Below the function `in_cookie(Node)` returns the current node's `in_cookie` for `Node`.

The cookies are text strings that can be viewed as passwords.

Every message in the handshake starts with a 16 bit big endian integer which contains the length of the message (not counting the two initial bytes). In erlang this corresponds to the `gen_tcp` option `{packet, 2}`. Note that after the handshake, the distribution switches to 4 byte packet headers.

### The Handshake in Detail

Imagine two nodes, node A, which initiates the handshake and node B, which accepts the connection.

1) connect/accept

A connects to B via TCP/IP and B accepts the connection.

2) send_name/receive_name

A sends an initial identification to B. B receives the message. The message looks like this (every "square" being one byte and the packet header removed):

```
+---+--------+--------+-----+-----+-----+-----+-----+-----+-...-+-----+
|'n'|Version0|Version1|Flag0|Flag1|Flag2|Flag3|Name0|Name1| ... |NameN|
+---+--------+--------+-----+-----+-----+-----+-----+-----+-... +-----+
```

The 'n' is just a message tag. Version0 and Version1 is the distribution version selected by node A, based on information from EPMD. (16 bit big endian) Flag0 ... Flag3 are capability flags, the capabilities defined in

`$ERL_TOP/lib/kernel/include/dist.hrl`. (32 bit big endian) Name0 ... NameN is the full nodename of A, as a string of bytes (the packet length denotes how long it is).

3) recv_status/send_status

B sends a status message to A, which indicates if the connection is allowed. The following status codes are defined:

`ok`
: The handshake will continue.

`ok_simultaneous`
: The handshake will continue, but A is informed that B has another ongoing connection attempt that will be shut down (simultaneous connect where A's name is greater than B's name, compared literally).

`nok`
: The handshake will not continue, as B already has an ongoing handshake which it itself has initiated. (simultaneous connect where B's name is greater than A's).

`not_allowed`
: The connection is disallowed for some (unspecified) security reason.

`alive`
: A connection to the node is already active, which either means that node A is confused or that the TCP connection breakdown of a previous node with this name has not yet reached node B. See 3B below.

This is the format of the status message:

```
+---+-------+-------+-...-+-------+
|'s'|Status0|Status1| ... |StatusN|
+---+-------+-------+-...-+-------+
```

's' is the message tag Status0 ... StatusN is the status as a string (not terminated)

3B) send_status/recv_status

If status was 'alive', node A will answer with another status message containing either 'true' which means that the connection should continue (The old connection from this node is broken), or `'false'`, which simply means that the connection should be closed, the connection attempt was a mistake.

4) recv_challenge/send_challenge

If the status was `ok` or `ok_simultaneous`, The handshake continues with B sending A another message, the challenge. The challenge contains the same type of information as the "name" message initially sent from A to B, with the addition of a 32 bit challenge:

```
+---+--------+--------+-----+-----+-----+-----+-----+-----+-----+-----+-----+-...-+-----+
|'n'|Version0|Version1|Flag0|Flag1|Flag2|Flag3|Chal0|Chal1|Chal2|Chal3|Name0|Name1| ... |NameN|
+---+--------+--------+-----+-----+-----+-----+-----+-----+-----+-----+-----+-... +-----+
```

Where Chal0 ... Chal3 is the challenge as a 32 bit big endian integer and the other fields are B's version, flags and full nodename.

5) send_challenge_reply/recv_challenge_reply

Now A has generated a digest and its own challenge. Those are sent together in a package to B:

```
+---+-----+-----+-----+-----+-----+-----+-----+-----+-...-+------+
|'r'|Chal0|Chal1|Chal2|Chal3|Dige0|Dige1|Dige2|Dige3| ... |Dige15|
+---+-----+-----+-----+-----+-----+-----+-----+-----+-...-+------+
```

Where 'r' is the tag, Chal0 ... Chal3 is A's challenge for B to handle and Dige0 ... Dige15 is the digest that A constructed from the challenge B sent in the previous step.

6) recv_challenge_ack/send_challenge_ack

B checks that the digest received from A is correct and generates a digest from the challenge received from A. The digest is then sent to A. The message looks like this:

```
+---+-----+-----+-----+-----+-...-+------+
|'a'|Dige0|Dige1|Dige2|Dige3| ... |Dige15|
+---+-----+-----+-----+-----+-...-+------+
```

Where 'a' is the tag and Dige0 ... Dige15 is the digest calculated by B for A's challenge.

7)

A checks the digest from B and the connection is up.

## Semigraphic View

```
A (initiator)      B (acceptor)

TCP connect ------------------------------------------>
       TCP accept

send_name   ------------------------------------------>
       recv_name

     <------------------------------------- send_status
recv_status
(if status was 'alive'
 send_status - - - - - - - - - - - - - - - - - - - ->
       recv_status)
       ChB = gen_challenge()
            (ChB)
     <-------------------------------------- send_challenge
recv_challenge

ChA = gen_challenge(),
OCA = out_cookie(B),
DiA = gen_digest(ChB,OCA)
     (ChA, DiA)
send_challenge_reply ------------------------------->
       recv_challenge_reply
       ICB = in_cookie(A),
       check:
       DiA == gen_digest
        (ChB, ICB) ?
       - if OK:
            OCB = out_cookie(A),
        DiB = gen_digest
   (DiB)     (ChA, OCB)
     <---------------------------------------  send_challenge_ack
recv_challenge_ack      DONE
ICA = in_cookie(B),                                    - else
check:                                                  CLOSE
DiB == gen_digest(ChA,ICA) ?
- if OK
 DONE
- else
```

```
CLOSE
```

### The Currently Defined Distribution Flags

Currently (OTP-R16) the following capability flags are defined:

```
%% The node should be published and part of the global namespace
-define(DFLAG_PUBLISHED,1).

%% The node implements an atom cache (obsolete)
-define(DFLAG_ATOM_CACHE,2).

%% The node implements extended (3 * 32 bits) references. This is
%% required today. If not present connection will be refused.
-define(DFLAG_EXTENDED_REFERENCES,4).

%% The node implements distributed process monitoring.
-define(DFLAG_DIST_MONITOR,8).

%% The node uses separate tag for fun's (lambdas) in the distribution protocol.
-define(DFLAG_FUN_TAGS,16#10).

%% The node implements distributed named process monitoring.
-define(DFLAG_DIST_MONITOR_NAME,16#20).

%% The (hidden) node implements atom cache (obsolete)
-define(DFLAG_HIDDEN_ATOM_CACHE,16#40).

%% The node understand new fun-tags
-define(DFLAG_NEW_FUN_TAGS,16#80).

%% The node is capable of handling extended pids and ports. This is
%% required today. If not present connection will be refused.
-define(DFLAG_EXTENDED_PIDS_PORTS,16#100).

%%
-define(DFLAG_EXPORT_PTR_TAG,16#200).

%%
-define(DFLAG_BIT_BINARIES,16#400).

%% The node understands new float format
-define(DFLAG_NEW_FLOATS,16#800).

%%
-define(DFLAG_UNICODE_IO,16#1000).

%% The node implements atom cache in distribution header.
-define(DFLAG_DIST_HDR_ATOM_CACHE,16#2000).

%% The node understand the SMALL_ATOM_EXT tag
-define(DFLAG_SMALL_ATOM_TAGS, 16#4000).

%% The node understand UTF-8 encoded atoms
-define(DFLAG_UTF8_ATOMS, 16#10000).
```

## 1.11.3 Protocol between connected nodes

As of erts version 5.7.2 the runtime system passes a distribution flag in the handshake stage that enables the use of a *distribution header* on all messages passed. Messages passed between nodes are in this case on the following format:

| 4 | d | n | m |
|---|---|---|---|
| Length | DistributionHeader | ControlMessage | Message |

**Table 11.16:**

where:

`Length` is equal to d + n + m

`ControlMessage` is a tuple passed using the external format of Erlang.

`Message` is the message sent to another node using the '!' (in external format). Note that `Message` is only passed in combination with a `ControlMessage` encoding a send ('!').

Also note that *the version number is omitted from the terms that follow a distribution header*.

Nodes with an erts version less than 5.7.2 does not pass the distribution flag that enables the distribution header. Messages passed between nodes are in this case on the following format:

| 4 | 1 | n | m |
|---|---|---|---|
| Length | Type | ControlMessage | Message |

**Table 11.17:**

where:

`Length` is equal to 1 + n + m

Type is: 112 (pass through)

`ControlMessage` is a tuple passed using the external format of Erlang.

`Message` is the message sent to another node using the '!' (in external format). Note that `Message` is only passed in combination with a `ControlMessage` encoding a send ('!').

The `ControlMessage` is a tuple, where the first element indicates which distributed operation it encodes.

`LINK`

```
{1, FromPid, ToPid}
```

`SEND`

```
{2, Cookie, ToPid}
```

*Note* followed by `Message`

`EXIT`

```
{3, FromPid, ToPid, Reason}
```

`UNLINK`

```
{4, FromPid, ToPid}
```

`NODE_LINK`

```
{5}
```

`REG_SEND`

`{6, FromPid, Cookie, ToName}`

*Note* followed by `Message`

`GROUP_LEADER`

`{7, FromPid, ToPid}`

`EXIT2`

`{8, FromPid, ToPid, Reason}`

### 1.11.4 New Ctrlmessages for distrvsn = 1 (OTP R4)

`SEND_TT`

`{12, Cookie, ToPid, TraceToken}`

*Note* followed by `Message`

`EXIT_TT`

`{13, FromPid, ToPid, TraceToken, Reason}`

`REG_SEND_TT`

`{16, FromPid, Cookie, ToName, TraceToken}`

*Note* followed by `Message`

`EXIT2_TT`

`{18, FromPid, ToPid, TraceToken, Reason}`

### 1.11.5 New Ctrlmessages for distrvsn = 2

distrvsn 2 was never used.

### 1.11.6 New Ctrlmessages for distrvsn = 3 (OTP R5C)

None, but the version number was increased anyway.

### 1.11.7 New Ctrlmessages for distrvsn = 4 (OTP R6)

These are only recognized by Erlang nodes, not by hidden nodes.

`MONITOR_P`

`{19, FromPid, ToProc, Ref}` `FromPid` = monitoring process `ToProc` = monitored process pid or name (atom)

`DEMONITOR_P`

`{20, FromPid, ToProc, Ref}` We include the FromPid just in case we want to trace this. `FromPid` = monitoring process `ToProc` = monitored process pid or name (atom)

`MONITOR_P_EXIT`

`{21, FromProc, ToPid, Ref, Reason}` `FromProc` = monitored process pid or name (atom) `ToPid` = monitoring process `Reason` = exit reason for the monitored process

# 2 Reference Manual

The Erlang Runtime System Application *ERTS*.

> **Note:**
>
> By default, the `erts` is only guaranteed to be compatible with other Erlang/OTP components from the same release as the `erts` itself. See the documentation of the system flag *+R* on how to communicate with Erlang/OTP components from earlier releases.

# erl_prim_loader

Erlang module

`erl_prim_loader` is used to load all Erlang modules into the system. The start script is also fetched with this low level loader.

`erl_prim_loader` knows about the environment and how to fetch modules.

The `-loader Loader` command line flag can be used to choose the method used by the `erl_prim_loader`. Two `Loader` methods are supported by the Erlang runtime system: `efile` and `inet`.

> ### Warning:
>
> The support for loading of code from archive files is experimental. The sole purpose of releasing it before it is ready is to obtain early feedback. The file format, semantics, interfaces etc. may be changed in a future release. The functions `list_dir/1` and `read_file_info/1` as well as the flag `-loader_debug` are also experimental

## Data Types

**`host() = atom()`**

## Exports

**`start(Id, Loader, Hosts) -> {ok, Pid} | {error, What}`**

Types:

**`Id = term()`**
**`Loader = atom() | string()`**
**`Hosts = Host | [Host]`**
**`Host = host()`**
**`Pid = pid()`**
**`What = term()`**

Starts the Erlang low level loader. This function is called by the `init` process (and module). The `init` process reads the command line flags `-id Id`, `-loader Loader`, and `-hosts Hosts`. These are the arguments supplied to the `start/3` function.

If `-loader` is not given, the default loader is `efile` which tells the system to read from the file system.

If `-loader` is `inet`, the `-id Id`, `-hosts Hosts`, and `-setcookie Cookie` flags must also be supplied. `Hosts` identifies hosts which this node can contact in order to load modules. One Erlang runtime system with a `erl_boot_server` process must be started on each of hosts given in `Hosts` in order to answer the requests. See *erl_boot_server(3)*.

**`get_file(Filename) -> {ok, Bin, FullName} | error`**

Types:

**Filename = atom() | string()**
**Bin = binary()**
**FullName = string()**

This function fetches a file using the low level loader. `Filename` is either an absolute file name or just the name of the file, for example `"lists.beam"`. If an internal path is set to the loader, this path is used to find the file. If a user supplied loader is used, the path can be stripped off if it is obsolete, and the loader does not use a path. `FullName` is the complete name of the fetched file. `Bin` is the contents of the file as a binary.

The `Filename` can also be a file in an archive. For example `$OTPROOT/lib/mnesia-4.4.7.ez/mnesia-4.4.7/ebin/mnesia.beam`. See *code(3)* about archive files.

**get_path() -> {ok, Path}**

Types:

**Path = [Dir :: string()]**

This function gets the path set in the loader. The path is set by the `init` process according to information found in the start script.

**list_dir(Dir) -> {ok, Filenames} | error**

Types:

**Dir = string()**
**Filenames = [Filename :: string()]**

Lists all the files in a directory. Returns `{ok, Filenames}` if successful. Otherwise, it returns `error`. `Filenames` is a list of the names of all the files in the directory. The names are not sorted.

The `Dir` can also be a directory in an archive. For example `$OTPROOT/lib/mnesia-4.4.7.ez/mnesia-4.4.7/ebin`. See *code(3)* about archive files.

**read_file_info(Filename) -> {ok, FileInfo} | error**

Types:

**Filename = string()**
**FileInfo = *file:file_info()***

Retrieves information about a file. Returns `{ok, FileInfo}` if successful, otherwise `error`. `FileInfo` is a record `file_info`, defined in the Kernel include file `file.hrl`. Include the following directive in the module from which the function is called:

```
-include_lib("kernel/include/file.hrl").
```

See *file(3)* for more info about the record `file_info`.

The `Filename` can also be a file in an archive. For example `$OTPROOT/lib/mnesia-4.4.7.ez/mnesia-4.4.7/ebin/mnesia`. See *code(3)* about archive files.

**read_link_info(Filename) -> {ok, FileInfo} | error**

Types:

**Filename = string()**
**FileInfo = *file:file_info()***

This function works like *read_file_info/1* except that if `Filename` is a symbolic link, information about the link will be returned in the `file_info` record and the `type` field of the record will be set to `symlink`.

If `Filename` is not a symbolic link, this function returns exactly the same result as `read_file_info/1`. On platforms that do not support symbolic links, this function is always equivalent to `read_file_info/1`.

**set_path(Path) -> ok**

Types:

**Path = [Dir :: string()]**

This function sets the path of the loader if `init` interprets a `path` command in the start script.

## Command Line Flags

The `erl_prim_loader` module interprets the following command line flags:

`-loader Loader`

Specifies the name of the loader used by `erl_prim_loader`. `Loader` can be `efile` (use the local file system) or `inet` (load using the `boot_server` on another Erlang node).

If the `-loader` flag is omitted, it defaults to `efile`.

`-loader_debug`

Makes the `efile` loader write some debug information, such as the reason for failures, while it handles files.

`-hosts Hosts`

Specifies which other Erlang nodes the `inet` loader can use. This flag is mandatory if the `-loader inet` flag is present. On each host, there must be on Erlang node with the `erl_boot_server` which handles the load requests. `Hosts` is a list of IP addresses (hostnames are not acceptable).

`-id Id`

Specifies the identity of the Erlang runtime system. If the system runs as a distributed node, `Id` must be identical to the name supplied with the `-sname` or `-name` distribution flags.

`-setcookie Cookie`

Specifies the cookie of the Erlang runtime system. This flag is mandatory if the `-loader inet` flag is present.

## SEE ALSO

*init(3)*, *erl_boot_server(3)*

# erlang

Erlang module

By convention, most Built-In Functions (BIFs) are seen as being in this module. Some of the BIFs are viewed more or less as part of the Erlang programming language and are *auto-imported*. Thus, it is not necessary to specify the module name. For example, the calls `atom_to_list(Erlang)` and `erlang:atom_to_list(Erlang)` are identical.

Auto-imported BIFs are listed without module prefix. BIFs listed with module prefix are not auto-imported.

BIFs can fail for various reasons. All BIFs fail with reason `badarg` if they are called with arguments of an incorrect type. The other reasons are described in the description of each individual BIF.

Some BIFs can be used in guard tests and are marked with "Allowed in guard tests".

## Data Types

**`ext_binary()`**

A binary data object, structured according to the Erlang external term format.

```
timestamp() =
    {MegaSecs :: integer() >= 0,
     Secs :: integer() >= 0,
     MicroSecs :: integer() >= 0}
```

See *erlang:timestamp/0*.

```
time_unit() =
    integer() >= 1 |
    seconds |
    milli_seconds |
    micro_seconds |
    nano_seconds |
    native
```

Supported time unit representations:

`PartsPerSecond :: integer() >= 1`

Time unit expressed in parts per second. That is, the time unit equals `1/PartsPerSecond` second.

`seconds`

Symbolic representation of the time unit represented by the integer `1`.

`milli_seconds`

Symbolic representation of the time unit represented by the integer `1000`.

`micro_seconds`

Symbolic representation of the time unit represented by the integer `1000000`.

`nano_seconds`

Symbolic representation of the time unit represented by the integer `1000000000`.

`native`

Symbolic representation of the native time unit used by the Erlang runtime system.

The `native` time unit is determined at runtime system start, and remains the same until the runtime system terminates. If a runtime system is stopped and then started again (even on the same machine), the `native` time unit of the new runtime system instance can differ from the `native` time unit of the old runtime system instance.

One can get an approximation of the `native` time unit by calling `erlang:convert_time_unit(1, seconds, native)`. The result equals the number of whole `native` time units per second. In case the number of `native` time units per second does not add up to a whole number, the result is rounded downwards.

> **Note:**
>
> The value of the `native` time unit gives you more or less no information at all about the quality of time values. It sets a limit for the *resolution* as well as for the *precision* of time values, but it gives absolutely no information at all about the *accuracy* of time values. The resolution of the `native` time unit and the resolution of time values can differ significantly.

The `time_unit/0` type may be extended. Use *`erlang:convert_time_unit/3`* in order to convert time values between time units.

## Exports

**`abs(Float) -> float()`**

**`abs(Int) -> integer() >= 0`**

Types:

**`Int = integer()`**

Types:

**`Float = float()`**

**`Int = integer()`**

Returns an integer or float that is the arithmetical absolute value of `Float` or `Int`, for example:

```
> abs(-3.33).
3.33
> abs(-3).
3
```

Allowed in guard tests.

**`erlang:adler32(Data) -> integer() >= 0`**

Types:

**`Data = iodata()`**

Computes and returns the adler32 checksum for `Data`.

**`erlang:adler32(OldAdler, Data) -> integer() >= 0`**

Types:

**OldAdler = integer() >= 0**
**Data = iodata()**

Continues computing the adler32 checksum by combining the previous checksum, `OldAdler`, with the checksum of `Data`.

The following code:

```
X = erlang:adler32(Data1),
Y = erlang:adler32(X,Data2).
```

assigns the same value to `Y` as this:

```
Y = erlang:adler32([Data1,Data2]).
```

**erlang:adler32_combine(FirstAdler, SecondAdler, SecondSize) ->**
**integer() >= 0**

Types:

**FirstAdler = SecondAdler = SecondSize = integer() >= 0**

Combines two previously computed adler32 checksums. This computation requires the size of the data object for the second checksum to be known.

The following code:

```
Y = erlang:adler32(Data1),
Z = erlang:adler32(Y,Data2).
```

assigns the same value to `Z` as this:

```
X = erlang:adler32(Data1),
Y = erlang:adler32(Data2),
Z = erlang:adler32_combine(X,Y,iolist_size(Data2)).
```

**erlang:append_element(Tuple1, Term) -> Tuple2**

Types:

**Tuple1 = Tuple2 = tuple()**
**Term = term()**

Returns a new tuple that has one element more than `Tuple1`, and contains the elements in `Tuple1` followed by `Term` as the last element. Semantically equivalent to `list_to_tuple(tuple_to_list(Tuple1) ++ [Term])`, but much faster.

Example:

```
> erlang:append_element({one, two}, three).
{one,two,three}
```

**apply(Fun, Args) -> term()**

Types:

**Fun = function()**

**Args = [term()]**

Calls a fun, passing the elements in `Args` as arguments.

If the number of elements in the arguments are known at compile time, the call is better written as `Fun(Arg1, Arg2, ... ArgN)`.

> Warning:
>
> Earlier, `Fun` could also be given as `{Module, Function}`, equivalent to `apply(Module, Function, Args)`. This use is deprecated and will stop working in a future release.

**apply(Module, Function, Args) -> term()**

Types:

**Module = module()**

**Function = atom()**

**Args = [term()]**

Returns the result of applying `Function` in `Module` to `Args`. The applied function must be exported from `Module`. The arity of the function is the length of `Args`.

Example:

```
> apply(lists, reverse, [[a, b, c]]).
[c,b,a]
> apply(erlang, atom_to_list, ['Erlang']).
"Erlang"
```

If the number of arguments are known at compile time, the call is better written as `Module:Function(Arg1, Arg2, ..., ArgN)`.

Failure: `error_handler:undefined_function/3` is called if the applied function is not exported. The error handler can be redefined (see *process_flag/2*). If `error_handler` is undefined, or if the user has redefined the default `error_handler` so the replacement module is undefined, an error with the reason `undef` is generated.

**atom_to_binary(Atom, Encoding) -> binary()**

Types:

**Atom = atom()**

**Encoding = latin1 | unicode | utf8**

Returns a binary corresponding to the text representation of `Atom`. If `Encoding` is `latin1`, there is one byte for each character in the text representation. If `Encoding` is `utf8` or `unicode`, the characters are encoded using UTF-8 (that is, characters from 128 through 255 are encoded in two bytes).

> Note:
>
> `atom_to_binary(Atom, latin1)` never fails because the text representation of an atom can only contain characters from 0 through 255. In a future release, the text representation of atoms can be allowed to contain any Unicode character and `atom_to_binary(Atom, latin1)` will then fail if the text representation for `Atom` contains a Unicode character greater than 255.

Example:

```
> atom_to_binary('Erlang', latin1).
<<"Erlang">>
```

**`atom_to_list(Atom) -> string()`**

Types:

**`Atom = atom()`**

Returns a string corresponding to the text representation of `Atom`, for example:

```
> atom_to_list('Erlang').
"Erlang"
```

**`binary_part(Subject, PosLen) -> binary()`**

Types:

**`Subject = binary()`**

**`PosLen = {Start :: integer() >= 0, Length :: integer()}`**

Extracts the part of the binary described by `PosLen`.

Negative length can be used to extract bytes at the end of a binary, for example:

```
1> Bin = <<1,2,3,4,5,6,7,8,9,10>>.
2> binary_part(Bin,{byte_size(Bin), -5}).
<<6,7,8,9,10>>
```

Failure: `badarg` if `PosLen` in any way references outside the binary.

`Start` is zero-based, that is:

```
1> Bin = <<1,2,3>>
2> binary_part(Bin,{0,2}).
<<1,2>>
```

For details about the `PosLen` semantics, see the *binary* manual page in `STDLIB`.

Allowed in guard tests.

**binary_part(Subject, Start, Length) -> binary()**

Types:

**Subject = binary()**
**Start = integer() >= 0**
**Length = integer()**

The same as `binary_part(Subject, {Start, Length})`.

Allowed in guard tests.

**binary_to_atom(Binary, Encoding) -> atom()**

Types:

**Binary = binary()**
**Encoding = latin1 | unicode | utf8**

Returns the atom whose text representation is `Binary`. If `Encoding` is `latin1`, no translation of bytes in the binary is done. If `Encoding` is `utf8` or `unicode`, the binary must contain valid UTF-8 sequences. Only Unicode characters up to 255 are allowed.

> Note:
>
> `binary_to_atom(Binary, utf8)` fails if the binary contains Unicode characters greater than 255. In a future release, such Unicode characters can be allowed and `binary_to_atom(Binary, utf8)` does then not fail. For more information on Unicode support in atoms, see the *note on UTF-8 encoded atoms* in Section "External Term Format" in the User's Guide.

Examples:

```
> binary_to_atom(<<"Erlang">>, latin1).
'Erlang'
> binary_to_atom(<<1024/utf8>>, utf8).
** exception error: bad argument
     in function  binary_to_atom/2
        called as binary_to_atom(<<208,128>>,utf8)
```

**binary_to_existing_atom(Binary, Encoding) -> atom()**

Types:

**Binary = binary()**
**Encoding = latin1 | unicode | utf8**

As *binary_to_atom/2*, but the atom must exist.

Failure: `badarg` if the atom does not exist.

**binary_to_float(Binary) -> float()**

Types:

**Binary = binary()**

Returns the float whose text representation is `Binary`, for example:

```
> binary_to_float(<<"2.2017764e+0">>).
2.2017764
```

Failure: `badarg` if `Binary` contains a bad representation of a float.

### binary_to_integer(Binary) -> integer()

Types:

**Binary = binary()**

Returns an integer whose text representation is `Binary`, for example:

```
> binary_to_integer(<<"123">>).
123
```

Failure: `badarg` if `Binary` contains a bad representation of an integer.

### binary_to_integer(Binary, Base) -> integer()

Types:

**Binary = binary()**

**Base = 2..36**

Returns an integer whose text representation in base `Base` is `Binary`, for example:

```
> binary_to_integer(<<"3FF">>, 16).
1023
```

Failure: `badarg` if `Binary` contains a bad representation of an integer.

### binary_to_list(Binary) -> [byte()]

Types:

**Binary = binary()**

Returns a list of integers corresponding to the bytes of `Binary`.

### binary_to_list(Binary, Start, Stop) -> [byte()]

Types:

**Binary = binary()**

**Start = Stop = integer() >= 1**

1..byte_size(`Binary`)

As `binary_to_list/1`, but returns a list of integers corresponding to the bytes from position `Start` to position `Stop` in `Binary`. The positions in the binary are numbered starting from 1.

> Note:
>
> The one-based indexing for binaries used by this function is deprecated. New code is to use *binary:bin_to_list/3* in `STDLIB` instead. All functions in module `binary` consistently use zero-based indexing.

**`bitstring_to_list(Bitstring) -> [byte() | bitstring()]`**

Types:

**`Bitstring = bitstring()`**

Returns a list of integers corresponding to the bytes of `Bitstring`. If the number of bits in the binary is not divisible by 8, the last element of the list is a bitstring containing the remaining 1-7 bits.

**`binary_to_term(Binary) -> term()`**

Types:

**`Binary = ext_binary()`**

Returns an Erlang term that is the result of decoding binary object `Binary`, which must be encoded according to the Erlang external term format.

> Warning:
>
> When decoding binaries from untrusted sources, consider using `binary_to_term/2` to prevent Denial of Service attacks.

See also *term_to_binary/1* and *binary_to_term/2*.

**`binary_to_term(Binary, Opts) -> term()`**

Types:

**`Binary = ext_binary()`**

**`Opts = [safe]`**

As `binary_to_term/1`, but takes options that affect decoding of the binary.

`safe`

Use this option when receiving binaries from an untrusted source.

When enabled, it prevents decoding data that can be used to attack the Erlang system. In the event of receiving unsafe data, decoding fails with a `badarg` error.

This prevents creation of new atoms directly, creation of new atoms indirectly (as they are embedded in certain structures, such as process identifiers, refs, and funs), and creation of new external function references. None of those resources are garbage collected, so unchecked creation of them can exhaust available memory.

Failure: `badarg` if `safe` is specified and unsafe data is decoded.

See also *term_to_binary/1*, *binary_to_term/1*, and *list_to_existing_atom/1*.

**`bit_size(Bitstring) -> integer() >= 0`**

Types:

**Bitstring = bitstring()**

Returns an integer that is the size in bits of `Bitstring`, for example:

```
> bit_size(<<433:16,3:3>>).
19
> bit_size(<<1,2,3>>).
24
```

Allowed in guard tests.

### erlang:bump_reductions(Reductions) -> true

Types:

**Reductions = integer() >= 1**

This implementation-dependent function increments the reduction counter for the calling process. In the Beam emulator, the reduction counter is normally incremented by one for each function and BIF call. A context switch is forced when the counter reaches the maximum number of reductions for a process (2000 reductions in OTP R12B).

> Warning:
>
> This BIF can be removed in a future version of the Beam machine without prior warning. It is unlikely to be implemented in other Erlang implementations.

### byte_size(Bitstring) -> integer() >= 0

Types:

**Bitstring = bitstring()**

Returns an integer that is the number of bytes needed to contain `Bitstring`. That is, if the number of bits in `Bitstring` is not divisible by 8, the resulting number of bytes is rounded *up*.

Examples:

```
> byte_size(<<433:16,3:3>>).
3
> byte_size(<<1,2,3>>).
3
```

Allowed in guard tests.

### erlang:cancel_timer(TimerRef, Options) -> Result | ok

Types:

```
TimerRef = reference()
Async = Info = boolean()
Option = {async, Async} | {info, Info}
Options = [Option]
Time = integer() >= 0
Result = Time | false
```

Cancels a timer that has been created by *erlang:start_timer()*, or *erlang:send_after()*. TimerRef identifies the timer, and was returned by the BIF that created the timer.

Available Options:

{async, Async}

Asynchronous request for cancellation. Async defaults to false which will cause the cancellation to be performed synchronously. When Async is set to true, the cancel operation is performed asynchronously. That is, erlang:cancel_timer() will send an asynchronous request for cancellation to the timer service that manages the timer, and then return ok.

{info, Info}

Request information about the Result of the cancellation. Info defaults to true which means the Result is given. When Info is set to false, no information about the result of the cancellation is given. When the operation is performed

synchronously

If Info is true, the Result is returned by erlang:cancel_timer(); otherwise, ok is returned.

asynchronously

If Info is true, a message on the form {cancel_timer, TimerRef, Result} is sent to the caller of erlang:cancel_timer() when the cancellation operation has been performed; otherwise, no message is sent.

More Options may be added in the future.

If Result is an integer, it represents the time in milli-seconds left until the canceled timer would have expired.

If Result is false, a timer corresponding to TimerRef could not be found. This can be either because the timer had expired, already had been canceled, or because TimerRef never corresponded to a timer. Even if the timer had expired, it does not tell you whether or not the timeout message has arrived at its destination yet.

> ### Note:
>
> The timer service that manages the timer may be co-located with another scheduler than the scheduler that the calling process is executing on. If this is the case, communication with the timer service takes much longer time than if it is located locally. If the calling process is in critical path, and can do other things while waiting for the result of this operation, or is not interested in the result of the operation, you want to use option {async, true}. If using option {async, false}, the calling process blocks until the operation has been performed.

See also *erlang:send_after/4*, *erlang:start_timer/4*, and *erlang:read_timer/2*.

**erlang:cancel_timer(TimerRef) -> Result**

Types:

```
TimerRef = reference()
Time = integer() >= 0
Result = Time | false
```

Cancels a timer. The same as calling *erlang:cancel_timer(TimerRef, [])*.

**check_old_code(Module) -> boolean()**

Types:

```
Module = module()
```

Returns `true` if `Module` has old code, otherwise `false`.

See also *code(3)*.

**check_process_code(Pid, Module) -> CheckResult**

Types:

```
Pid = pid()
Module = module()
CheckResult = boolean()
```

The same as *erlang:check_process_code(Pid, Module, [])*.

**check_process_code(Pid, Module, OptionList) -> CheckResult | async**

Types:

```
Pid = pid()
Module = module()
RequestId = term()
Option = {async, RequestId} | {allow_gc, boolean()}
OptionList = [Option]
CheckResult = boolean() | aborted
```

Checks if the node local process identified by `Pid` executes old code for `Module`.

The available `Option`s are as follows:

`{allow_gc, boolean()}`

Determines if garbage collection is allowed when performing the operation. If `{allow_gc, false}` is passed, and a garbage collection is needed to determine the result of the operation, the operation is aborted (see information on `CheckResult` in the following). The default is to allow garbage collection, that is, `{allow_gc, true}`.

`{async, RequestId}`

The function `check_process_code/3` returns the value `async` immediately after the request has been sent. When the request has been processed, the process that called this function is passed a message on the form `{check_process_code, RequestId, CheckResult}`.

If `Pid` equals `self()`, and no `async` option has been passed, the operation is performed at once. Otherwise a request for the operation is sent to the process identified by `Pid`, and is handled when appropriate. If no `async` option has been passed, the caller blocks until `CheckResult` is available and can be returned.

`CheckResult` informs about the result of the request as follows:

`true`

The process identified by `Pid` executes old code for `Module`. That is, the current call of the process executes old code for this module, or the process has references to old code for this module, or the process contains funs that references old code for this module.

`false`

The process identified by `Pid` does not execute old code for `Module`.

`aborted`

The operation was aborted, as the process needed to be garbage collected to determine the operation result, and the operation was requested by passing option `{allow_gc, false}`.

See also *code(3)*.

Failures:

`badarg`
If `Pid` is not a node local process identifier.
`badarg`
If `Module` is not an atom.
`badarg`
If `OptionList` is an invalid list of options.

**`erlang:convert_time_unit(Time, FromUnit, ToUnit) -> ConvertedTime`**

Types:

**`Time = ConvertedTime = integer()`**
**`FromUnit = ToUnit = time_unit()`**

Converts the `Time` value of time unit `FromUnit` to the corresponding `ConvertedTime` value of time unit `ToUnit`. The result is rounded using the floor function.

> Warning:
>
> You may lose accuracy and precision when converting between time units. In order to minimize such loss, collect all data at `native` time unit and do the conversion on the end result.

**`erlang:crc32(Data) -> integer() >= 0`**

Types:

**`Data = iodata()`**

Computes and returns the crc32 (IEEE 802.3 style) checksum for `Data`.

**`erlang:crc32(OldCrc, Data) -> integer() >= 0`**

Types:

**`OldCrc = integer() >= 0`**
**`Data = iodata()`**

Continues computing the crc32 checksum by combining the previous checksum, `OldCrc`, with the checksum of `Data`.

The following code:

```
      X = erlang:crc32(Data1),
      Y = erlang:crc32(X,Data2).
```

assigns the same value to Y as this:

```
      Y = erlang:crc32([Data1,Data2]).
```

**erlang:crc32_combine(FirstCrc, SecondCrc, SecondSize) ->**
**integer() >= 0**

Types:

**FirstCrc = SecondCrc = SecondSize = integer() >= 0**

Combines two previously computed crc32 checksums. This computation requires the size of the data object for the second checksum to be known.

The following code:

```
      Y = erlang:crc32(Data1),
      Z = erlang:crc32(Y,Data2).
```

assigns the same value to Z as this:

```
      X = erlang:crc32(Data1),
      Y = erlang:crc32(Data2),
      Z = erlang:crc32_combine(X,Y,iolist_size(Data2)).
```

**date() -> Date**

Types:

**Date = *calendar:date()***

Returns the current date as `{Year, Month, Day}`.

The time zone and Daylight Saving Time correction depend on the underlying OS.

Example:

```
> date().
{1995,2,19}
```

**erlang:decode_packet(Type, Bin, Options) ->**
**{ok, Packet, Rest} |**
**{more, Length} |**
**{error, Reason}**

Types:

**Type =**
**raw |**

```
    0 |
    1 |
    2 |
    4 |
    asn1 |
    cdr |
    sunrm |
    fcgi |
    tpkt |
    line |
    http |
    http_bin |
    httph |
    httph_bin
Bin = binary()
Options = [Opt]
Opt =
    {packet_size, integer() >= 0} |
    {line_length, integer() >= 0}
Packet = binary() | HttpPacket
Rest = binary()
Length = integer() >= 0 | undefined
Reason = term()
HttpPacket =
    HttpRequest | HttpResponse | HttpHeader | http_eoh | HttpError
HttpRequest = {http_request, HttpMethod, HttpUri, HttpVersion}
HttpResponse =
    {http_response, HttpVersion, integer(), HttpString}
HttpHeader =
    {http_header,
     integer(),
     HttpField,
     Reserved :: term(),
     Value :: HttpString}
HttpError = {http_error, HttpString}
HttpMethod =
    'OPTIONS' |
    'GET' |
    'HEAD' |
    'POST' |
    'PUT' |
    'DELETE' |
    'TRACE' |
    HttpString
HttpUri =
    '*' |
    {absoluteURI,
     http | https,
     Host :: HttpString,
```

```
       Port :: inet:port_number() | undefined,
       Path :: HttpString} |
      {scheme, Scheme :: HttpString, HttpString} |
      {abs_path, HttpString} |
      HttpString
  HttpVersion =
      {Major :: integer() >= 0, Minor :: integer() >= 0}
  HttpField =
      'Cache-Control' |
      'Connection' |
      'Date' |
      'Pragma' |
      'Transfer-Encoding' |
      'Upgrade' |
      'Via' |
      'Accept' |
      'Accept-Charset' |
      'Accept-Encoding' |
      'Accept-Language' |
      'Authorization' |
      'From' |
      'Host' |
      'If-Modified-Since' |
      'If-Match' |
      'If-None-Match' |
      'If-Range' |
      'If-Unmodified-Since' |
      'Max-Forwards' |
      'Proxy-Authorization' |
      'Range' |
      'Referer' |
      'User-Agent' |
      'Age' |
      'Location' |
      'Proxy-Authenticate' |
      'Public' |
      'Retry-After' |
      'Server' |
      'Vary' |
      'Warning' |
      'Www-Authenticate' |
      'Allow' |
      'Content-Base' |
      'Content-Encoding' |
      'Content-Language' |
      'Content-Length' |
      'Content-Location' |
      'Content-Md5' |
      'Content-Range' |
      'Content-Type' |
      'Etag' |
      'Expires' |
```

```
        'Last-Modified' |
        'Accept-Ranges' |
        'Set-Cookie' |
        'Set-Cookie2' |
        'X-Forwarded-For' |
        'Cookie' |
        'Keep-Alive' |
        'Proxy-Connection' |
        HttpString
   HttpString = string() | binary()
```

Decodes the binary `Bin` according to the packet protocol specified by `Type`. Similar to the packet handling done by sockets with option {packet,Type}.

If an entire packet is contained in `Bin`, it is returned together with the remainder of the binary as `{ok,Packet,Rest}`.

If `Bin` does not contain the entire packet, `{more,Length}` is returned. `Length` is either the expected *total size* of the packet, or `undefined` if the expected packet size is unknown. `decode_packet` can then be called again with more data added.

If the packet does not conform to the protocol format, `{error,Reason}` is returned.

The following `Type`s are valid:

`raw | 0`

No packet handling is done. The entire binary is returned unless it is empty.

`1 | 2 | 4`

Packets consist of a header specifying the number of bytes in the packet, followed by that number of bytes. The length of the header can be one, two, or four bytes; the order of the bytes is big-endian. The header is stripped off when the packet is returned.

`line`

A packet is a line terminated by a delimiter byte, default is the latin1 newline character. The delimiter byte is included in the returned packet unless the line was truncated according to option `line_length`.

`asn1 | cdr | sunrm | fcgi | tpkt`

The header is *not* stripped off.

The meanings of the packet types are as follows:

`asn1` - ASN.1 BER
`sunrm` - Sun's RPC encoding
`cdr` - CORBA (GIOP 1.1)
`fcgi` - Fast CGI
`tpkt` - TPKT format [RFC1006]

`http | httph | http_bin | httph_bin`

The Hypertext Transfer Protocol. The packets are returned with the format according to `HttpPacket` described earlier. A packet is either a request, a response, a header, or an end of header mark. Invalid lines are returned as `HttpError`.

Recognized request methods and header fields are returned as atoms. Others are returned as strings. Strings of unrecognized header fields are formatted with only capital letters first and after hyphen characters, for example, `"Sec-Websocket-Key"`.

The protocol type `http` is only to be used for the first line when an `HttpRequest` or an `HttpResponse` is expected. The following calls are to use `httph` to get `HttpHeader`s until `http_eoh` is returned, which marks the end of the headers and the beginning of any following message body.

The variants `http_bin` and `httph_bin` return strings (`HttpString`) as binaries instead of lists.

The following options are available:

`{packet_size, integer() >= 0}`

Sets the maximum allowed size of the packet body. If the packet header indicates that the length of the packet is longer than the maximum allowed length, the packet is considered invalid. Default is 0, which means no size limit.

`{line_length, integer() >= 0}`

For packet type `line`, lines longer than the indicated length are truncated.

Option `line_length` also applies to `http*` packet types as an alias for option `packet_size` if `packet_size` itself is not set. This use is only intended for backward compatibility.

`{line_delimiter, 0 =< byte() =< 255}`

For packet type `line`, sets the delimiting byte. Default is the latin1 character `$\n`.

Examples:

```
> erlang:decode_packet(1,<<3,"abcd">>,[]).
{ok,<<"abc">>,<<"d">>}
> erlang:decode_packet(1,<<5,"abcd">>,[]).
{more,6}
```

**`erlang:delete_element(Index, Tuple1) -> Tuple2`**

Types:

**`Index = integer() >= 1`**

1..tuple_size(Tuple1)

**`Tuple1 = Tuple2 = tuple()`**

Returns a new tuple with element at `Index` removed from tuple `Tuple1`, for example:

```
> erlang:delete_element(2, {one, two, three}).
{one,three}
```

**`delete_module(Module) -> true | undefined`**

Types:

**`Module = module()`**

Makes the current code for `Module` become old code, and deletes all references for this module from the export table. Returns `undefined` if the module does not exist, otherwise `true`.

> Warning:
>
> This BIF is intended for the code server (see *code(3)*) and is not to be used elsewhere.

Failure: `badarg` if there already is an old version of `Module`.

**`demonitor(MonitorRef) -> true`**

Types:

**`MonitorRef = reference()`**

If `MonitorRef` is a reference that the calling process obtained by calling *monitor/2*, this monitoring is turned off. If the monitoring is already turned off, nothing happens.

Once `demonitor(MonitorRef)` has returned, it is guaranteed that no `{'DOWN', MonitorRef, _, _, _}` message, because of the monitor, will be placed in the caller message queue in the future. A `{'DOWN', MonitorRef, _, _, _}` message can have been placed in the caller message queue before the call, though. It is therefore usually advisable to remove such a `'DOWN'` message from the message queue after monitoring has been stopped. *`demonitor(MonitorRef, [flush])`* can be used instead of `demonitor(MonitorRef)` if this cleanup is wanted.

> ### Note:
>
> Prior to OTP release R11B (ERTS version 5.5) `demonitor/1` behaved completely asynchronously, i.e., the monitor was active until the "demonitor signal" reached the monitored entity. This had one undesirable effect. You could never know when you were guaranteed *not* to receive a `DOWN` message due to the monitor.
>
> Current behavior can be viewed as two combined operations: asynchronously send a "demonitor signal" to the monitored entity and ignore any future results of the monitor.

Failure: It is an error if `MonitorRef` refers to a monitoring started by another process. Not all such cases are cheap to check. If checking is cheap, the call fails with `badarg` for example, if `MonitorRef` is a remote reference.

**`demonitor(MonitorRef, OptionList) -> boolean()`**

Types:

**`MonitorRef = reference()`**

**`OptionList = [Option]`**

**`Option = flush | info`**

The returned value is `true` unless `info` is part of `OptionList`.

`demonitor(MonitorRef, [])` is equivalent to *`demonitor(MonitorRef)`*.

The available `Option`s are as follows:

`flush`

Removes (one) `{_, MonitorRef, _, _, _}` message, if there is one, from the caller message queue after monitoring has been stopped.

Calling `demonitor(MonitorRef, [flush])` is equivalent to the following, but more efficient:

```
demonitor(MonitorRef),
receive
    {_, MonitorRef, _, _, _} ->
        true
after 0 ->
        true
```

```
    end
```

`info`

The returned value is one of the following:

`true`
The monitor was found and removed. In this case, no `'DOWN'` message corresponding to this monitor has been delivered and will not be delivered.

`false`
The monitor was not found and could not be removed. This probably because someone already has placed a `'DOWN'` message corresponding to this monitor in the caller message queue.

If option `info` is combined with option `flush`, `false` is returned if a flush was needed, otherwise `true`.

> **Note:**
> More options can be added in a future release.

Failures:

`badarg`
If `OptionList` is not a list.

`badarg`
If `Option` is an invalid option.

`badarg`
The same failure as for *demonitor/1*.

**`disconnect_node(Node) -> boolean() | ignored`**

Types:

**`Node = node()`**

Forces the disconnection of a node. This appears to the node `Node` as if the local node has crashed. This BIF is mainly used in the Erlang network authentication protocols.

Returns `true` if disconnection succeeds, otherwise `false`. If the local node is not alive, `ignored` is returned.

**`erlang:display(Term) -> true`**

Types:

**`Term = term()`**

Prints a text representation of `Term` on the standard output. On OSE, the term is printed to the ramlog.

> **Warning:**
> This BIF is intended for debugging only.

**`element(N, Tuple) -> term()`**

Types:

**N = integer() >= 1**

1..tuple_size(Tuple)

**Tuple = tuple()**

Returns the Nth element (numbering from 1) of `Tuple`, for example:

```
> element(2, {a, b, c}).
b
```

Allowed in guard tests.

### erase() -> [{Key, Val}]

Types:

**Key = Val = term()**

Returns the process dictionary and deletes it, for example:

```
> put(key1, {1, 2, 3}),
put(key2, [a, b, c]),
erase().
[{key1,{1,2,3}},{key2,[a,b,c]}]
```

### erase(Key) -> Val | undefined

Types:

**Key = Val = term()**

Returns the value `Val` associated with `Key` and deletes it from the process dictionary. Returns `undefined` if no value is associated with `Key`.

Example:

```
> put(key1, {merry, lambs, are, playing}),
X = erase(key1),
{X, erase(key1)}.
{{merry,lambs,are,playing},undefined}
```

### error(Reason) -> no_return()

Types:

**Reason = term()**

Stops the execution of the calling process with the reason `Reason`, where `Reason` is any term. The exit reason is `{Reason, Where}`, where `Where` is a list of the functions most recently called (the current function first). Since evaluating this function causes the process to terminate, it has no return value.

Example:

```
> catch error(foobar).
{'EXIT',{foobar,[{erl_eval,do_apply,5},
                 {erl_eval,expr,5},
```

```
                {shell,exprs,6},
                {shell,eval_exprs,6},
                {shell,eval_loop,3}]}}
```

**error(Reason, Args) -> no_return()**

Types:

**Reason = term()**

**Args = [term()]**

Stops the execution of the calling process with the reason `Reason`, where `Reason` is any term. The exit reason is `{Reason, Where}`, where `Where` is a list of the functions most recently called (the current function first). `Args` is expected to be the list of arguments for the current function; in Beam it is used to provide the arguments for the current function in the term `Where`. Since evaluating this function causes the process to terminate, it has no return value.

**exit(Reason) -> no_return()**

Types:

**Reason = term()**

Stops the execution of the calling process with exit reason `Reason`, where `Reason` is any term. Since evaluating this function causes the process to terminate, it has no return value.

Example:

```
> exit(foobar).
** exception exit: foobar
> catch exit(foobar).
{'EXIT',foobar}
```

**exit(Pid, Reason) -> true**

Types:

**Pid = pid() | port()**

**Reason = term()**

Sends an exit signal with exit reason `Reason` to the process or port identified by `Pid`.

The following behavior applies if `Reason` is any term, except `normal` or `kill`:

- If `Pid` is not trapping exits, `Pid` itself exits with exit reason `Reason`.
- If `Pid` is trapping exits, the exit signal is transformed into a message `{'EXIT', From, Reason}` and delivered to the message queue of `Pid`.
- `From` is the process identifier of the process that sent the exit signal. See also *process_flag/2*.

If `Reason` is the atom `normal`, `Pid` does not exit. If it is trapping exits, the exit signal is transformed into a message `{'EXIT', From, normal}` and delivered to its message queue.

If `Reason` is the atom `kill`, that is, if `exit(Pid, kill)` is called, an untrappable exit signal is sent to `Pid`, which unconditionally exits with exit reason `killed`.

**erlang:external_size(Term) -> integer() >= 0**

Types:

**Term = term()**

Calculates, without doing the encoding, the maximum byte size for a term encoded in the Erlang external term format. The following condition applies always:

```
> Size1 = byte_size(term_to_binary()),
> Size2 = erlang:external_size(),
> true = Size1 =< Size2.
true
```

This is equivalent to a call to:

```
erlang:external_size(, [])
```

**erlang:external_size(Term, Options) -> integer() >= 0**

Types:

**Term = term()**

**Options = [{minor_version, Version :: integer() >= 0}]**

Calculates, without doing the encoding, the maximum byte size for a term encoded in the Erlang external term format. The following condition applies always:

```
> Size1 = byte_size(term_to_binary(, )),
> Size2 = erlang:external_size(, ),
> true = Size1 =< Size2.
true
```

Option `{minor_version, Version}` specifies how floats are encoded. For a detailed description, see *term_to_binary/2*.

**float(Number) -> float()**

Types:

**Number = number()**

Returns a float by converting `Number` to a float, for example:

```
> float(55).
55.0
```

Allowed in guard tests.

> Note:
>
> If used on the top level in a guard, it tests whether the argument is a floating point number; for clarity, use *is_float/1* instead.
>
> When `float/1` is used in an expression in a guard, such as '`float(A) == 4.0`', it converts a number as described earlier.

**float_to_binary(Float) -> binary()**

Types:

**Float = float()**

The same as `float_to_binary(Float,[{scientific,20}])`.

**float_to_binary(Float, Options) -> binary()**

Types:

```
Float = float()
Options = [Option]
Option =
    {decimals, Decimals :: 0..253} |
    {scientific, Decimals :: 0..249} |
    compact
```

Returns a binary corresponding to the text representation of `Float` using fixed decimal point formatting. `Options` behaves in the same way as *float_to_list/2*.

Examples:

```
> float_to_binary(7.12, [{decimals, 4}]).
<<"7.1200">>
> float_to_binary(7.12, [{decimals, 4}, compact]).
<<"7.12">>
```

**float_to_list(Float) -> string()**

Types:

**Float = float()**

The same as `float_to_list(Float,[{scientific,20}])`.

**float_to_list(Float, Options) -> string()**

Types:

```
Float = float()
Options = [Option]
Option =
    {decimals, Decimals :: 0..253} |
    {scientific, Decimals :: 0..249} |
    compact
```

Returns a string corresponding to the text representation of `Float` using fixed decimal point formatting. The options are as follows:

- If option `decimals` is specified, the returned value contains at most `Decimals` number of digits past the decimal point. If the number does not fit in the internal static buffer of 256 bytes, the function throws `badarg`.
- If option `compact` is provided, the trailing zeros at the end of the list are truncated. This option is only meaningful together with option `decimals`.
- If option `scientific` is provided, the float is formatted using scientific notation with `Decimals` digits of precision.
- If `Options` is `[]`, the function behaves as *float_to_list/1*.

Examples:

```
> float_to_list(7.12, [{decimals, 4}]).
"7.1200"
> float_to_list(7.12, [{decimals, 4}, compact]).
"7.12"
```

**erlang:fun_info(Fun) -> [{Item, Info}]**

Types:

```
Fun = function()
Item =
    arity |
    env |
    index |
    name |
    module |
    new_index |
    new_uniq |
    pid |
    type |
    uniq
Info = term()
```

Returns a list with information about the fun `Fun`. Each list element is a tuple. The order of the tuples is undefined, and more tuples can be added in a future release.

> ### Warning:
>
> This BIF is mainly intended for debugging, but it can sometimes be useful in library functions that need to verify, for example, the arity of a fun.

Two types of funs have slightly different semantics:

- A fun created by `fun M:F/A` is called an *external* fun. Calling it will always call the function `F` with arity `A` in the latest code for module `M`. Notice that module `M` does not even need to be loaded when the fun `fun M:F/A` is created.
- All other funs are called *local*. When a local fun is called, the same version of the code that created the fun is called (even if a newer version of the module has been loaded).

The following elements are always present in the list for both local and external funs:

`{type, Type}`

`Type` is `local` or `external`.

`{module, Module}`

`Module` (an atom) is the module name.

If `Fun` is a local fun, `Module` is the module in which the fun is defined.

If `Fun` is an external fun, `Module` is the module that the fun refers to.

`{name, Name}`

`Name` (an atom) is a function name.

If `Fun` is a local fun, `Name` is the name of the local function that implements the fun. (This name was generated by the compiler, and is only of informational use. As it is a local function, it cannot be called directly.) If no code is currently loaded for the fun, `[]` is returned instead of an atom.

If `Fun` is an external fun, `Name` is the name of the exported function that the fun refers to.

`{arity, Arity}`

`Arity` is the number of arguments that the fun is to be called with.

`{env, Env}`

`Env` (a list) is the environment or free variables for the fun. For external funs, the returned list is always empty.

The following elements are only present in the list if `Fun` is local:

`{pid, Pid}`

`Pid` is the process identifier of the process that originally created the fun.

`{index, Index}`

`Index` (an integer) is an index into the module fun table.

`{new_index, Index}`

`Index` (an integer) is an index into the module fun table.

`{new_uniq, Uniq}`

`Uniq` (a binary) is a unique value for this fun. It is calculated from the compiled code for the entire module.

`{uniq, Uniq}`

`Uniq` (an integer) is a unique value for this fun. As from OTP R15, this integer is calculated from the compiled code for the entire module. Before OTP R15, this integer was based on only the body of the fun.

**`erlang:fun_info(Fun, Item) -> {Item, Info}`**

Types:

```
Fun = function()
Item = fun_info_item()
Info = term()
fun_info_item() =
    arity |
    env |
    index |
    name |
    module |
    new_index |
    new_uniq |
    pid |
    type |
    uniq
```

Returns information about `Fun` as specified by `Item`, in the form `{Item,Info}`.

For any fun, `Item` can be any of the atoms `module`, `name`, `arity`, `env`, or `type`.

For a local fun, `Item` can also be any of the atoms `index`, `new_index`, `new_uniq`, `uniq`, and `pid`. For an external fun, the value of any of these items is always the atom `undefined`.

See *erlang:fun_info/1*.

**`erlang:fun_to_list(Fun) -> string()`**

Types:

**`Fun = function()`**

Returns a string corresponding to the text representation of `Fun`.

**`erlang:function_exported(Module, Function, Arity) -> boolean()`**

Types:

**`Module = module()`**
**`Function = atom()`**
**`Arity = arity()`**

Returns `true` if the module `Module` is loaded and contains an exported function `Function/Arity`, or if there is a BIF (a built-in function implemented in C) with the given name, otherwise returns `false`.

> Note:
>
> This function used to return false for built-in functions before the 18.0 release.

**`garbage_collect() -> true`**

Forces an immediate garbage collection of the executing process. The function is not to be used unless it has been noticed (or there are good reasons to suspect) that the spontaneous garbage collection will occur too late or not at all.

> Warning:
>
> Improper use can seriously degrade system performance.

**`garbage_collect(Pid) -> GCResult`**

Types:

**`Pid = pid()`**
**`GCResult = boolean()`**

The same as *`garbage_collect(Pid, [])`*.

**`garbage_collect(Pid, OptionList) -> GCResult | async`**

Types:

```
Pid = pid()
RequestId = term()
Option = {async, RequestId}
OptionList = [Option]
GCResult = boolean()
```

Garbage collects the node local process identified by `Pid`.

The available `Option`s are as follows:

`{async, RequestId}`
: The function `garbage_collect/2` returns the value `async` immediately after the request has been sent. When the request has been processed, the process that called this function is passed a message on the form `{garbage_collect, RequestId, GCResult}`.

If `Pid` equals `self()`, and no `async` option has been passed, the garbage collection is performed at once, that is, the same as calling *garbage_collect/0*. Otherwise a request for garbage collection is sent to the process identified by `Pid`, and will be handled when appropriate. If no `async` option has been passed, the caller blocks until `GCResult` is available and can be returned.

`GCResult` informs about the result of the garbage collection request as follows:

`true`
: The process identified by `Pid` has been garbage collected.

`false`
: No garbage collection was performed, as the process identified by `Pid` terminated before the request could be satisfied.

Notice that the same caveats apply as for *garbage_collect/0*.

Failures:

`badarg`
: If `Pid` is not a node local process identifier.

`badarg`
: If `OptionList` is an invalid list of options.

### get() -> [{Key, Val}]

Types:

```
Key = Val = term()
```

Returns the process dictionary as a list of `{Key, Val}` tuples, for example:

```
> put(key1, merry),
put(key2, lambs),
put(key3, {are, playing}),
get().
[{key1,merry},{key2,lambs},{key3,{are,playing}}]
```

### get(Key) -> Val | undefined

Types:

```
Key = Val = term()
```

Returns the value `Val` associated with `Key` in the process dictionary, or `undefined` if `Key` does not exist.

Example:

```
> put(key1, merry),
put(key2, lambs),
put({any, [valid, term]}, {are, playing}),
get({any, [valid, term]}).
{are,playing}
```

**erlang:get_cookie() -> Cookie | nocookie**

Types:

**Cookie = atom()**

Returns the magic cookie of the local node if the node is alive, otherwise the atom `nocookie`.

**get_keys() -> [Key]**

Types:

**Key = term()**

Returns a list of keys all keys present in the process dictionary.

```
> put(dog, {animal,1}),
put(cow, {animal,2}),
put(lamb, {animal,3}),
get_keys().
[dog,cow,lamb]
```

**get_keys(Val) -> [Key]**

Types:

**Val = Key = term()**

Returns a list of keys that are associated with the value `Val` in the process dictionary, for example:

```
> put(mary, {1, 2}),
put(had, {1, 2}),
put(a, {1, 2}),
put(little, {1, 2}),
put(dog, {1, 3}),
put(lamb, {1, 2}),
get_keys({1, 2}).
[mary,had,a,little,lamb]
```

**erlang:get_stacktrace() -> [*stack_item()*]**

Types:

```
stack_item() =
    {Module :: module(),
     Function :: atom(),
     Arity :: arity() | (Args :: [term()]),
     Location ::
         [{file, Filename :: string()} |
```

**{line, Line :: integer() >= 1}]}**

Gets the call stack back-trace (*stacktrace*) of the last exception in the calling process as a list of `{Module,Function,Arity,Location}` tuples. Field `Arity` in the first tuple can be the argument list of that function call instead of an arity integer, depending on the exception.

If there has not been any exceptions in a process, the stacktrace is `[]`. After a code change for the process, the stacktrace can also be reset to `[]`.

The stacktrace is the same data as the `catch` operator returns, for example:

```
{'EXIT',{badarg,Stacktrace}} = catch abs(x)
```

`Location` is a (possibly empty) list of two-tuples that can indicate the location in the source code of the function. The first element is an atom describing the type of information in the second element. The following items can occur:

`file`
: The second element of the tuple is a string (list of characters) representing the file name of the source file of the function.

`line`
: The second element of the tuple is the line number (an integer greater than zero) in the source file where the exception occurred or the function was called.

See also *erlang:error/1* and *erlang:error/2*.

### group_leader() -> pid()

Returns the process identifier of the group leader for the process evaluating the function.

Every process is a member of some process group and all groups have a *group leader*. All I/O from the group is channeled to the group leader. When a new process is spawned, it gets the same group leader as the spawning process. Initially, at system start-up, `init` is both its own group leader and the group leader of all processes.

### group_leader(GroupLeader, Pid) -> true

Types:

**GroupLeader = Pid = pid()**

Sets the group leader of `Pid` to `GroupLeader`. Typically, this is used when a process started from a certain shell is to have another group leader than `init`.

See also *group_leader/0*.

### halt() -> no_return()

The same as *`halt(0, [])`*.

Example:

```
> halt().
os_prompt%
```

### halt(Status) -> no_return()

Types:

**Status = integer() >= 0 | abort | string()**

The same as *`halt(Status, [])`*.

Example:

```
> halt(17).
os_prompt% echo $?
17
os_prompt%
```

**halt(Status, Options) -> no_return()**

Types:

**Status = integer() >= 0 | abort | string()**
**Options = [Option]**
**Option = {flush, boolean()}**

`Status` must be a non-negative integer, a string, or the atom `abort`. Halts the Erlang runtime system. Has no return value. Depending on `Status`, the following occurs:

integer()
: The runtime system exits with integer value `Status` as status code to the calling environment (OS).

string()
: An Erlang crash dump is produced with `Status` as slogan. Then the runtime system exits with status code `1`.

`abort`
: The runtime system aborts producing a core dump, if that is enabled in the OS.

> ### Note:
>
> On many platforms, the OS supports only status codes 0-255. A too large status code will be truncated by clearing the high bits.

For integer `Status`, the Erlang runtime system closes all ports and allows async threads to finish their operations before exiting. To exit without such flushing, use `Option` as `{flush,false}`.

For statuses `string()` and `abort`, option `flush` is ignored and flushing is *not* done.

**erlang:hash(Term, Range) -> integer() >= 1**

Types:

**Term = term()**
**Range = integer() >= 1**

Returns a hash value for `Term` within the range `1..Range`. The maximum range is 1..2^27-1.

> ### Warning:
>
> This BIF is deprecated, as the hash value can differ on different architectures. The hash values for integer terms higher than 2^27 and large binaries are poor. The BIF is retained for backward compatibility reasons (it can have been used to hash records into a file), but all new code is to use one of the BIFs `erlang:phash/2` or `erlang:phash2/1,2` instead.

**hd(List) -> term()**

Types:

**List = [term(), ...]**

Returns the head of `List`, that is, the first element, for example:

```
> hd([1,2,3,4,5]).
1
```

Allowed in guard tests.

Failure: `badarg` if `List` is the empty list `[]`.

**erlang:hibernate(Module, Function, Args) -> no_return()**

Types:

**Module = module()**

**Function = atom()**

**Args = [term()]**

Puts the calling process into a wait state where its memory allocation has been reduced as much as possible. This is useful if the process does not expect to receive any messages soon.

The process is awaken when a message is sent to it, and control resumes in `Module:Function` with the arguments given by `Args` with the call stack emptied, meaning that the process terminates when that function returns. Thus `erlang:hibernate/3` never returns to its caller.

If the process has any message in its message queue, the process is awakened immediately in the same way as described earlier.

In more technical terms, what `erlang:hibernate/3` does is the following. It discards the call stack for the process, and then garbage collects the process. After this, all live data is in one continuous heap. The heap is then shrunken to the exact same size as the live data that it holds (even if that size is less than the minimum heap size for the process).

If the size of the live data in the process is less than the minimum heap size, the first garbage collection occurring after the process is awakened ensures that the heap size is changed to a size not smaller than the minimum heap size.

Notice that emptying the call stack means that any surrounding `catch` is removed and must be reinserted after hibernation. One effect of this is that processes started using `proc_lib` (also indirectly, such as `gen_server` processes), are to use *proc_lib:hibernate/3* instead, to ensure that the exception handler continues to work when the process wakes up.

**erlang:insert_element(Index, Tuple1, Term) -> Tuple2**

Types:

**Index = integer() >= 1**

1..tuple_size(Tuple1) + 1

**Tuple1 = Tuple2 = tuple()**

**Term = term()**

Returns a new tuple with element `Term` inserted at position `Index` in tuple `Tuple1`. All elements from position `Index` and upwards are pushed one step higher in the new tuple `Tuple2`.

Example:

```
> erlang:insert_element(2, {one, two, three}, new).
{one,new,two,three}
```

**integer_to_binary(Integer) -> binary()**

Types:

**Integer = integer()**

Returns a binary corresponding to the text representation of `Integer`, for example:

```
> integer_to_binary(77).
<<"77">>
```

**integer_to_binary(Integer, Base) -> binary()**

Types:

**Integer = integer()**

**Base = 2..36**

Returns a binary corresponding to the text representation of `Integer` in base `Base`, for example:

```
> integer_to_binary(1023, 16).
<<"3FF">>
```

**integer_to_list(Integer) -> string()**

Types:

**Integer = integer()**

Returns a string corresponding to the text representation of `Integer`, for example:

```
> integer_to_list(77).
"77"
```

**integer_to_list(Integer, Base) -> string()**

Types:

**Integer = integer()**

**Base = 2..36**

Returns a string corresponding to the text representation of `Integer` in base `Base`, for example:

```
> integer_to_list(1023, 16).
"3FF"
```

**iolist_to_binary(IoListOrBinary) -> binary()**

Types:

**IoListOrBinary = iolist() | binary()**

Returns a binary that is made from the integers and binaries in `IoListOrBinary`, for example:

```
> Bin1 = <<1,2,3>>.
<<1,2,3>>
> Bin2 = <<4,5>>.
<<4,5>>
> Bin3 = <<6>>.
<<6>>
> iolist_to_binary([Bin1,1,[2,3,Bin2],4|Bin3]).
<<1,2,3,1,2,3,4,5,4,6>>
```

### iolist_size(Item) -> integer() >= 0

Types:

**Item = iolist() | binary()**

Returns an integer that is the size in bytes of the binary that would be the result of `iolist_to_binary(Item)`, for example:

```
> iolist_size([1,2|<<3,4>>]).
4
```

### is_alive() -> boolean()

Returns `true` if the local node is alive (that is, if the node can be part of a distributed system), otherwise `false`.

### is_atom(Term) -> boolean()

Types:

**Term = term()**

Returns `true` if `Term` is an atom, otherwise `false`.

Allowed in guard tests.

### is_binary(Term) -> boolean()

Types:

**Term = term()**

Returns `true` if `Term` is a binary, otherwise `false`.

A binary always contains a complete number of bytes.

Allowed in guard tests.

### is_bitstring(Term) -> boolean()

Types:

**Term = term()**

Returns `true` if `Term` is a bitstring (including a binary), otherwise `false`.

Allowed in guard tests.

**`is_boolean(Term) -> boolean()`**

Types:

**`Term = term()`**

Returns `true` if `Term` is the atom `true` or the atom `false` (that is, a boolean). Otherwise returns `false`.

Allowed in guard tests.

**`erlang:is_builtin(Module, Function, Arity) -> boolean()`**

Types:

**`Module = module()`**
**`Function = atom()`**
**`Arity = arity()`**

This BIF is useful for builders of cross-reference tools.

Returns `true` if `Module:Function/Arity` is a BIF implemented in C, otherwise `false`.

**`is_float(Term) -> boolean()`**

Types:

**`Term = term()`**

Returns `true` if `Term` is a floating point number, otherwise `false`.

Allowed in guard tests.

**`is_function(Term) -> boolean()`**

Types:

**`Term = term()`**

Returns `true` if `Term` is a fun, otherwise `false`.

Allowed in guard tests.

**`is_function(Term, Arity) -> boolean()`**

Types:

**`Term = term()`**
**`Arity = arity()`**

Returns `true` if `Term` is a fun that can be applied with `Arity` number of arguments, otherwise `false`.

Allowed in guard tests.

**`is_integer(Term) -> boolean()`**

Types:

**`Term = term()`**

Returns `true` if `Term` is an integer, otherwise `false`.

Allowed in guard tests.

**`is_list(Term) -> boolean()`**

Types:

**Term = term()**

Returns `true` if `Term` is a list with zero or more elements, otherwise `false`.

Allowed in guard tests.

### is_map(Term) -> boolean()

Types:

**Term = term()**

Returns `true` if `Term` is a map, otherwise `false`.

Allowed in guard tests.

### is_number(Term) -> boolean()

Types:

**Term = term()**

Returns `true` if `Term` is an integer or a floating point number. Otherwise returns `false`.

Allowed in guard tests.

### is_pid(Term) -> boolean()

Types:

**Term = term()**

Returns `true` if `Term` is a process identifier, otherwise `false`.

Allowed in guard tests.

### is_port(Term) -> boolean()

Types:

**Term = term()**

Returns `true` if `Term` is a port identifier, otherwise `false`.

Allowed in guard tests.

### is_process_alive(Pid) -> boolean()

Types:

**Pid = pid()**

`Pid` must refer to a process at the local node.

Returns `true` if the process exists and is alive, that is, is not exiting and has not exited. Otherwise returns `false`.

### is_record(Term, RecordTag) -> boolean()

Types:

**Term = term()**

**RecordTag = atom()**

Returns `true` if `Term` is a tuple and its first element is `RecordTag`. Otherwise returns `false`.

> Note:
>
> Normally the compiler treats calls to `is_record/2` specially. It emits code to verify that `Term` is a tuple, that its first element is `RecordTag`, and that the size is correct. However, if `RecordTag` is not a literal atom, the BIF `is_record/2` is called instead and the size of the tuple is not verified.

Allowed in guard tests, if `RecordTag` is a literal atom.

**`is_record(Term, RecordTag, Size) -> boolean()`**

Types:

**`Term = term()`**
**`RecordTag = atom()`**
**`Size = integer() >= 0`**

`RecordTag` must be an atom.

Returns `true` if `Term` is a tuple, its first element is `RecordTag`, and its size is `Size`. Otherwise returns `false`.

Allowed in guard tests if `RecordTag` is a literal atom and `Size` is a literal integer.

> Note:
>
> This BIF is documented for completeness. Usually `is_record/2` is to be used.

**`is_reference(Term) -> boolean()`**

Types:

**`Term = term()`**

Returns `true` if `Term` is a reference, otherwise `false`.

Allowed in guard tests.

**`is_tuple(Term) -> boolean()`**

Types:

**`Term = term()`**

Returns `true` if `Term` is a tuple, otherwise `false`.

Allowed in guard tests.

**`length(List) -> integer() >= 0`**

Types:

**`List = [term()]`**

Returns the length of `List`, for example:

```
> length([1,2,3,4,5,6,7,8,9]).
9
```

Allowed in guard tests.

### link(PidOrPort) -> true

Types:

**PidOrPort = pid() | port()**

Creates a link between the calling process and another process (or port) `PidOrPort`, if there is not such a link already. If a process attempts to create a link to itself, nothing is done. Returns `true`.

If `PidOrPort` does not exist, the behavior of the BIF depends on if the calling process is trapping exits or not (see *process_flag/2*):

- If the calling process is not trapping exits, and checking `PidOrPort` is cheap (that is, if `PidOrPort` is local), `link/1` fails with reason `noproc`.
- Otherwise, if the calling process is trapping exits, and/or `PidOrPort` is remote, `link/1` returns `true`, but an exit signal with reason `noproc` is sent to the calling process.

### list_to_atom(String) -> atom()

Types:

**String = string()**

Returns the atom whose text representation is `String`.

`String` can only contain ISO-latin-1 characters (that is, numbers less than 256) as the implementation does not allow unicode characters equal to or above 256 in atoms. For more information on Unicode support in atoms, see *note on UTF-8 encoded atoms* in Section "External Term Format" in the User's Guide.

Example:

```
> list_to_atom("Erlang").
'Erlang'
```

### list_to_binary(IoList) -> binary()

Types:

**IoList = iolist()**

Returns a binary that is made from the integers and binaries in `IoList`, for example:

```
> Bin1 = <<1,2,3>>.
<<1,2,3>>
> Bin2 = <<4,5>>.
<<4,5>>
> Bin3 = <<6>>.
<<6>>
> list_to_binary([Bin1,1,[2,3,Bin2],4|Bin3]).
<<1,2,3,1,2,3,4,5,4,6>>
```

### list_to_bitstring(BitstringList) -> bitstring()

Types:

**BitstringList = *bitstring_list()***

**bitstring_list() =**

**maybe_improper_list(byte() | bitstring() | *bitstring_list()*, bitstring() | [])**

Returns a bitstring that is made from the integers and bitstrings in `BitstringList`. (The last tail in `BitstringList` is allowed to be a bitstring.)

Example:

```
> Bin1 = <<1,2,3>>.
<<1,2,3>>
> Bin2 = <<4,5>>.
<<4,5>>
> Bin3 = <<6,7:4>>.
<<6,7:4>>
> list_to_bitstring([Bin1,1,[2,3,Bin2],4|Bin3]).
<<1,2,3,1,2,3,4,5,4,6,7:4>>
```

**list_to_existing_atom(String) -> atom()**

Types:

**String = string()**

Returns the atom whose text representation is `String`, but only if there already exists such atom.

Failure: `badarg` if there does not already exist an atom whose text representation is `String`.

**list_to_float(String) -> float()**

Types:

**String = string()**

Returns the float whose text representation is `String`, for example:

```
> list_to_float("2.2017764e+0").
2.2017764
```

Failure: `badarg` if `String` contains a bad representation of a float.

**list_to_integer(String) -> integer()**

Types:

**String = string()**

Returns an integer whose text representation is `String`, for example:

```
> list_to_integer("123").
123
```

Failure: `badarg` if `String` contains a bad representation of an integer.

**list_to_integer(String, Base) -> integer()**

Types:

**String = string()**
**Base = 2..36**

Returns an integer whose text representation in base `Base` is `String`, for example:

```
> list_to_integer("3FF", 16).
1023
```

Failure: `badarg` if `String` contains a bad representation of an integer.

### list_to_pid(String) -> pid()

Types:

**String = string()**

Returns a process identifier whose text representation is a `String`, for example:

```
> list_to_pid("<0.4.1>").
<0.4.1>
```

Failure: `badarg` if `String` contains a bad representation of a process identifier.

> Warning:
>
> This BIF is intended for debugging and is not to be used in application programs.

### list_to_tuple(List) -> tuple()

Types:

**List = [term()]**

Returns a tuple corresponding to `List`, for example

```
> list_to_tuple([share, ['Ericsson_B', 163]]).
{share, ['Ericsson_B', 163]}
```

`List` can contain any Erlang terms.

### load_module(Module, Binary) -> {module, Module} | {error, Reason}

Types:

**Module = module()**
**Binary = binary()**
**Reason = badfile | not_purged | on_load**

If `Binary` contains the object code for module `Module`, this BIF loads that object code. If the code for module `Module` already exists, all export references are replaced so they point to the newly loaded code. The previously loaded code is kept in the system as old code, as there can still be processes executing that code.

Returns either `{module, Module}`, or `{error, Reason}` if loading fails. `Reason` is any of the following:

`badfile`

The object code in `Binary` has an incorrect format *or* the object code contains code for another module than `Module`.

`not_purged`

`Binary` contains a module that cannot be loaded because old code for this module already exists.

> ### Warning:
>
> This BIF is intended for the code server (see *code(3)*) and is not to be used elsewhere.

**`erlang:load_nif(Path, LoadInfo) -> ok | Error`**

Types:

```
Path = string()
LoadInfo = term()
Error = {error, {Reason, Text :: string()}}
Reason =
    load_failed | bad_lib | load | reload | upgrade | old_code
```

> ### Note:
>
> Before OTP R14B, NIFs were an experimental feature. Versions before OTP R14B can have different and possibly incompatible NIF semantics and interfaces. For example, in OTP R13B03 the return value on failure was `{error,Reason,Text}`.

Loads and links a dynamic library containing native implemented functions (NIFs) for a module. `Path` is a file path to the shareable object/dynamic library file minus the OS-dependent file extension (`.so` for Unix and `.dll` for Windows. For information on how to implement a NIF library, see *erl_nif*.

`LoadInfo` can be any term. It is passed on to the library as part of the initialization. A good practice is to include a module version number to support future code upgrade scenarios.

The call to `load_nif/2` must be made *directly* from the Erlang code of the module that the NIF library belongs to. It returns either `ok`, or `{error,{Reason,Text}}` if loading fails. `Reason` is one of the following atoms while `Text` is a human readable string that can give more information about the failure:

`load_failed`
The OS failed to load the NIF library.

`bad_lib`
The library did not fulfill the requirements as a NIF library of the calling module.

`load | reload | upgrade`
The corresponding library callback was unsuccessful.

`old_code`
The call to `load_nif/2` was made from the old code of a module that has been upgraded; this is not allowed.

**`erlang:loaded() -> [Module]`**

Types:

**Module = module()**

Returns a list of all loaded Erlang modules (current and old code), including preloaded modules.

See also *code(3)*.

### erlang:localtime() -> DateTime

Types:

**DateTime = *calendar:datetime()***

Returns the current local date and time, `{{Year, Month, Day}, {Hour, Minute, Second}}`, for example:

```
> erlang:localtime().
{{1996,11,6},{14,45,17}}
```

The time zone and Daylight Saving Time correction depend on the underlying OS.

### erlang:localtime_to_universaltime(Localtime) -> Universaltime

Types:

**Localtime = Universaltime = *calendar:datetime()***

Converts local date and time to Universal Time Coordinated (UTC), if supported by the underlying OS. Otherwise no conversion is done and `Localtime` is returned.

Example:

```
> erlang:localtime_to_universaltime({{1996,11,6},{14,45,17}}).
{{1996,11,6},{13,45,17}}
```

Failure: `badarg` if `Localtime` denotes an invalid date and time.

### erlang:localtime_to_universaltime(Localtime, IsDst) -> Universaltime

Types:

**Localtime = Universaltime = *calendar:datetime()***
**IsDst = true | false | undefined**

Converts local date and time to Universal Time Coordinated (UTC) as `erlang:localtime_to_universaltime/1`, but the caller decides if Daylight Saving Time is active.

If `IsDst == true`, `Localtime` is during Daylight Saving Time, if `IsDst == false` it is not. If `IsDst == undefined`, the underlying OS can guess, which is the same as calling `erlang:localtime_to_universaltime(Localtime)`.

Examples:

```
> erlang:localtime_to_universaltime({{1996,11,6},{14,45,17}}, true).
{{1996,11,6},{12,45,17}}
> erlang:localtime_to_universaltime({{1996,11,6},{14,45,17}}, false).
{{1996,11,6},{13,45,17}}
> erlang:localtime_to_universaltime({{1996,11,6},{14,45,17}}, undefined).
```

```
{{1996,11,6},{13,45,17}}
```

Failure: `badarg` if `Localtime` denotes an invalid date and time.

### make_ref() -> reference()

Returns a *unique reference*. The reference is unique among connected nodes.

> Warning:
>
> Known issue: When a node is restarted multiple times with the same node name, references created on a newer node can be mistaken for a reference created on an older node with the same node name.

### erlang:make_tuple(Arity, InitialValue) -> tuple()

Types:

```
Arity = arity()
InitialValue = term()
```

Creates a new tuple of the given `Arity`, where all elements are `InitialValue`, for example:

```
> erlang:make_tuple(4, []).
{[],[],[],[]}
```

### erlang:make_tuple(Arity, DefaultValue, InitList) -> tuple()

Types:

```
Arity = arity()
DefaultValue = term()
InitList = [{Position :: integer() >= 1, term()}]
```

Creates a tuple of size `Arity`, where each element has value `DefaultValue`, and then fills in values from `InitList`. Each list element in `InitList` must be a two-tuple, where the first element is a position in the newly created tuple and the second element is any term. If a position occurs more than once in the list, the term corresponding to the last occurrence is used.

Example:

```
> erlang:make_tuple(5, [], [{2,ignored},{5,zz},{2,aa}]).
{{[],aa,[],[],zz}
```

### map_size(Map) -> integer() >= 0

Types:

```
Map = #{}
```

Returns an integer, which is the number of key-value pairs in `Map`, for example:

```
> map_size(#{a=>1, b=>2, c=>3}).
```

```
3
```

Allowed in guard tests.

**`max(Term1, Term2) -> Maximum`**

Types:

**`Term1 = Term2 = Maximum = term()`**

Returns the largest of `Term1` and `Term2`. If the terms are equal, `Term1` is returned.

**`erlang:md5(Data) -> Digest`**

Types:

**`Data = iodata()`**

**`Digest = binary()`**

Computes an MD5 message digest from `Data`, where the length of the digest is 128 bits (16 bytes). `Data` is a binary or a list of small integers and binaries.

For more information about MD5, see RFC 1321 - The MD5 Message-Digest Algorithm.

> Warning:
>
> The MD5 Message-Digest Algorithm is *not* considered safe for code-signing or software-integrity purposes.

**`erlang:md5_final(Context) -> Digest`**

Types:

**`Context = Digest = binary()`**

Finishes the update of an MD5 `Context` and returns the computed `MD5` message digest.

**`erlang:md5_init() -> Context`**

Types:

**`Context = binary()`**

Creates an MD5 context, to be used in subsequent calls to `md5_update/2`.

**`erlang:md5_update(Context, Data) -> NewContext`**

Types:

**`Context = binary()`**

**`Data = iodata()`**

**`NewContext = binary()`**

Updates an MD5 `Context` with `Data` and returns a `NewContext`.

**`erlang:memory() -> [{Type, Size}]`**

Types:

```
Type = memory_type()
Size = integer() >= 0
memory_type() =
    total |
    processes |
    processes_used |
    system |
    atom |
    atom_used |
    binary |
    code |
    ets |
    low |
    maximum
```

Returns a list with information about memory dynamically allocated by the Erlang emulator. Each list element is a tuple `{Type, Size}`. The first element `Type` is an atom describing memory type. The second element `Size` is the memory size in bytes.

The memory types are as follows:

`total`

The total amount of memory currently allocated. This is the same as the sum of the memory size for `processes` and `system`.

`processes`

The total amount of memory currently allocated for the Erlang processes.

`processes_used`

The total amount of memory currently used by the Erlang processes. This is part of the memory presented as `processes` memory.

`system`

The total amount of memory currently allocated for the emulator that is not directly related to any Erlang process. Memory presented as `processes` is not included in this memory.

`atom`

The total amount of memory currently allocated for atoms. This memory is part of the memory presented as `system` memory.

`atom_used`

The total amount of memory currently used for atoms. This memory is part of the memory presented as `atom` memory.

`binary`

The total amount of memory currently allocated for binaries. This memory is part of the memory presented as `system` memory.

`code`

The total amount of memory currently allocated for Erlang code. This memory is part of the memory presented as `system` memory.

`ets`

The total amount of memory currently allocated for ets tables. This memory is part of the memory presented as `system` memory.

`low`

Only on 64-bit halfword emulator. The total amount of memory allocated in low memory areas that are restricted to less than 4 GB, although the system can have more memory.

Can be removed in a future release of the halfword emulator.

`maximum`

The maximum total amount of memory allocated since the emulator was started. This tuple is only present when the emulator is run with instrumentation.

For information on how to run the emulator with instrumentation, see *instrument(3)* and/or *erl(1)*.

> Note:
>
> The `system` value is not complete. Some allocated memory that is to be part of this value is not.
>
> When the emulator is run with instrumentation, the `system` value is more accurate, but memory directly allocated for `malloc` (and friends) is still not part of the `system` value. Direct calls to `malloc` are only done from OS-specific runtime libraries and perhaps from user-implemented Erlang drivers that do not use the memory allocation functions in the driver interface.
>
> As the `total` value is the sum of `processes` and `system`, the error in `system` propagates to the `total` value.
>
> The different amounts of memory that are summed are *not* gathered atomically, which introduces an error in the result.

The different values have the following relation to each other. Values beginning with an uppercase letter is not part of the result.

```
total = processes + system
processes = processes_used + ProcessesNotUsed
system = atom + binary + code + ets + OtherSystem
atom = atom_used + AtomNotUsed
RealTotal = processes + RealSystem
RealSystem = system + MissedSystem
```

More tuples in the returned list can be added in a future release.

> Note:
>
> The `total` value is supposed to be the total amount of memory dynamically allocated by the emulator. Shared libraries, the code of the emulator itself, and the emulator stacks are not supposed to be included. That is, the `total` value is *not* supposed to be equal to the total size of all pages mapped to the emulator.
>
> Furthermore, because of fragmentation and prereservation of memory areas, the size of the memory segments containing the dynamically allocated memory blocks can be much larger than the total size of the dynamically allocated memory blocks.

> Note:
>
> As from `ERTS` 5.6.4, `erlang:memory/0` requires that all *erts_alloc(3)* allocators are enabled (default behavior).

Failure: `notsup` if an *erts_alloc(3)* allocator has been disabled.

```
erlang:memory(Type :: memory_type()) -> integer() >= 0
erlang:memory(TypeList :: [memory_type()]) ->
                [{memory_type(), integer() >= 0}]
```

Types:

```
   memory_type() =
       total |
       processes |
       processes_used |
       system |
       atom |
       atom_used |
       binary |
       code |
       ets |
       low |
       maximum
```

Returns the memory size in bytes allocated for memory of type `Type`. The argument can also be given as a list of `memory_type()` atoms, in which case a corresponding list of `{memory_type(), Size :: integer >= 0}` tuples is returned.

> Note:
>
> As from `ERTS` version 5.6.4, `erlang:memory/1` requires that all *erts_alloc(3)* allocators are enabled (default behavior).

Failures:

`badarg`
: If `Type` is not one of the memory types listed in the description of *erlang:memory/0*.

`badarg`
If `maximum` is passed as `Type` and the emulator is not run in instrumented mode.

`notsup`
If an *erts_alloc(3)* allocator has been disabled.

See also *erlang:memory/0*.

**`min(Term1, Term2) -> Minimum`**

Types:

**`Term1 = Term2 = Minimum = term()`**

Returns the smallest of `Term1` and `Term2`. If the terms are equal, `Term1` is returned.

**`module_loaded(Module) -> boolean()`**

Types:

**`Module = module()`**

Returns `true` if the module `Module` is loaded, otherwise `false`. It does not attempt to load the module.

> Warning:
>
> This BIF is intended for the code server (see *code(3)*) and is not to be used elsewhere.

**`monitor(Type :: process, Item :: monitor_process_identifier()) ->`**
**`MonitorRef`**
**`monitor(Type :: time_offset, Item :: clock_service) -> MonitorRef`**

Types:

**`MonitorRef = reference()`**
**`registered_name() = atom()`**
**`registered_process_identifier() =`**
**`registered_name() | {registered_name(), node()}`**
**`monitor_process_identifier() =`**
**`pid() | registered_process_identifier()`**

Send a monitor request of type `Type` to the entity identified by `Item`. The caller of `monitor/2` will later be notified by a monitor message on the following format if the monitored state is changed:

```
{Tag, , , Object, Info}
```

> Note:
>
> The monitor request is an asynchronous signal. That is, it takes time before the signal reaches its destination.

Valid `Type`s:

`process`

Monitor the existence of the process identified by `Item`. Valid `Item`s in combination with the `process Type` can be any of the following:

`pid()`

The process identifier of the process to monitor.

`{RegisteredName, Node}`

A tuple consisting of a registered name of a process and a node name. The process residing on the node `Node` with the registered name `{RegisteredName, Node}` will be monitored.

`RegisteredName`

The process locally registered as `RegisteredName` will become monitored.

> **Note:**
>
> When a registered name is used, the process that has the registered name when the monitor request reach its destination will be monitored. The monitor is not effected if the registered name is unregistered, or unregistered and later registered on another process.

The monitor is triggered either when the monitored process terminates, is non existing, or if the connection to it is lost. In the case the connection to it is lost, we do not know if it still exist or not. After this type of monitor has been triggered, the monitor is automatically removed.

When the monitor is triggered a `'DOWN'` message is sent to the monitoring process. A `'DOWN'` message has the following pattern:

```
{'DOWN', MonitorRef, Type, Object, Info}
```

Here `MonitorRef` and `Type` are the same as described earlier, and:

`Object`

equals:

`Item`
If `Item` is specified by a process identifier.

`{RegisteredName, Node}`
If `Item` is specified as `RegisteredName`, or `{RegisteredName, Node}` where `Node` corresponds to the node that the monitored process resides on.

`Info`

Either the exit reason of the process, `noproc` (non-existing process), or `noconnection` (no connection to the node where the monitored process resides).

The monitoring is turned off when the `'DOWN'` message is sent or when *demonitor/1* is called.

If an attempt is made to monitor a process on an older node (where remote process monitoring is not implemented or where remote process monitoring by registered name is not implemented), the call fails with `badarg`.

> Note:
>
> The format of the `'DOWN'` message changed in ERTS version 5.2 (OTP R9B) for monitoring *by registered name*. Element `Object` of the `'DOWN'` message could in earlier versions sometimes be the process identifier of the monitored process and sometimes be the registered name. Now element `Object` is always a tuple consisting of the registered name and the node name. Processes on new nodes (ERTS version 5.2 or higher) always get `'DOWN'` messages on the new format even if they are monitoring processes on old nodes. Processes on old nodes always get `'DOWN'` messages on the old format.

`time_offset`

Monitor changes in *time offset* between *Erlang monotonic time* and *Erlang system time*. There is only one valid `Item` in combination with the `time_offset Type`, namely the atom `clock_service`. Note that the atom `clock_service` is *not* the registered name of a process. In this specific case it serves as an identifier of the runtime system internal clock service at current runtime system instance.

The monitor is triggered when the time offset is changed. This either if the time offset value is changed, or if the offset is changed from preliminary to final during *finalization of the time offset* when the *single time warp mode* is used. When a change from preliminary to final time offset is made, the monitor will be triggered once regardless of whether the time offset value was actually changed or not.

If the runtime system is in *multi time warp mode*, the time offset will be changed when the runtime system detects that the *OS system time* has changed. The runtime system will, however, not detect this immediately when it happens. A task checking the time offset is scheduled to execute at least once a minute, so under normal operation this should be detected within a minute, but during heavy load it might take longer time.

The monitor will *not* be automatically removed after it has been triggered. That is, repeated changes of the time offset will trigger the monitor repeatedly.

When the monitor is triggered a `'CHANGE'` message will be sent to the monitoring process. A `'CHANGE'` message has the following pattern:

```
{'CHANGE', MonitorRef, Type, Item, NewTimeOffset}
```

where `MonitorRef`, `Type`, and `Item` are the same as described above, and `NewTimeOffset` is the new time offset.

When the `'CHANGE'` message has been received you are guaranteed not to retrieve the old time offset when calling *`erlang:time_offset()`*. Note that you can observe the change of the time offset when calling `erlang:time_offset()` before you get the `'CHANGE'` message.

Making several calls to `monitor/2` for the same `Item` and/or `Type` is not an error; it results in as many independent monitoring instances.

The monitor functionality is expected to be extended. That is, other `Type`s and `Item`s are expected to be supported in a future release.

> Note:
>
> If or when `monitor/2` is extended, other possible values for `Tag`, `Object` and `Info` in the monitor message will be introduced.

**monitor_node(Node, Flag) -> true**

Types:

**Node = node()**
**Flag = boolean()**

Monitors the status of the node `Node`. If `Flag` is `true`, monitoring is turned on. If `Flag` is `false`, monitoring is turned off.

Making several calls to `monitor_node(Node, true)` for the same `Node` is not an error; it results in as many independent monitoring instances.

If `Node` fails or does not exist, the message `{nodedown, Node}` is delivered to the process. If a process has made two calls to `monitor_node(Node, true)` and `Node` terminates, two `nodedown` messages are delivered to the process. If there is no connection to `Node`, an attempt is made to create one. If this fails, a `nodedown` message is delivered.

Nodes connected through hidden connections can be monitored as any other nodes.

Failure: `badarg` if the local node is not alive.

**erlang:monitor_node(Node, Flag, Options) -> true**

Types:

**Node = node()**
**Flag = boolean()**
**Options = [Option]**
**Option = allow_passive_connect**

Behaves as *monitor_node/2* except that it allows an extra option to be given, namely `allow_passive_connect`. This option allows the BIF to wait the normal network connection time-out for the *monitored node* to connect itself, even if it cannot be actively connected from this node (that is, it is blocked). The state where this can be useful can only be achieved by using the `Kernel` option `dist_auto_connect once`. If that option is not used, option `allow_passive_connect` has no effect.

> Note:
>
> Option `allow_passive_connect` is used internally and is seldom needed in applications where the network topology and the `Kernel` options in effect are known in advance.

Failure: `badarg` if the local node is not alive or the option list is malformed.

**erlang:monotonic_time() -> integer()**

Returns the current *Erlang monotonic time* in `native` *time unit*. This is a monotonically increasing time since some unspecified point in time.

> Note:
>
> This is a *monotonically increasing* time, but *not* a *strictly monotonically increasing* time. That is, consecutive calls to `erlang:monotonic_time/0` can produce the same result.
>
> Different runtime system instances will use different unspecified points in time as base for their Erlang monotonic clocks. That is, it is *pointless* comparing monotonic times from different runtime system instances. Different runtime system instances may also place this unspecified point in time different relative runtime system start. It may be placed in the future (time at start is a negative value), the past (time at start is a positive value), or the runtime system start (time at start is zero). The monotonic time at runtime system start can be retrieved by calling *`erlang:system_info(start_time)`*.

**`erlang:monotonic_time(Unit) -> integer()`**

Types:

**`Unit = time_unit()`**

Returns the current *Erlang monotonic time* converted into the `Unit` passed as argument.

Same as calling *`erlang:convert_time_unit`*`(`*`erlang:monotonic_time()`*`, native, Unit)` however optimized for commonly used `Unit`s.

**`erlang:nif_error(Reason) -> no_return()`**

Types:

**`Reason = term()`**

Works exactly like *erlang:error/1*, but `Dialyzer` thinks that this BIF will return an arbitrary term. When used in a stub function for a NIF to generate an exception when the NIF library is not loaded, `Dialyzer` does not generate false warnings.

**`erlang:nif_error(Reason, Args) -> no_return()`**

Types:

**`Reason = term()`**

**`Args = [term()]`**

Works exactly like *erlang:error/2*, but `Dialyzer` thinks that this BIF will return an arbitrary term. When used in a stub function for a NIF to generate an exception when the NIF library is not loaded, `Dialyzer` does not generate false warnings.

**`node() -> Node`**

Types:

**`Node = node()`**

Returns the name of the local node. If the node is not alive, `nonode@nohost` is returned instead.

Allowed in guard tests.

**`node(Arg) -> Node`**

Types:

```
Arg = pid() | port() | reference()
Node = node()
```

Returns the node where `Arg` originates. `Arg` can be a process identifier, a reference, or a port. If the local node is not alive, `nonode@nohost` is returned.

Allowed in guard tests.

**`nodes() -> Nodes`**

Types:

```
Nodes = [node()]
```

Returns a list of all visible nodes in the system, except the local node. Same as `nodes(visible)`.

**`nodes(Arg) -> Nodes`**

Types:

```
Arg = NodeType | [NodeType]
NodeType = visible | hidden | connected | this | known
Nodes = [node()]
```

Returns a list of nodes according to the argument given. The returned result when the argument is a list, is the list of nodes satisfying the disjunction(s) of the list elements.

`NodeType` can be any of the following:

`visible`

Nodes connected to this node through normal connections.

`hidden`

Nodes connected to this node through hidden connections.

`connected`

All nodes connected to this node.

`this`

This node.

`known`

Nodes that are known to this node. That is, connected nodes and nodes referred to by process identifiers, port identifiers and references located on this node. The set of known nodes is garbage collected. Notice that this garbage collection can be delayed. For more information, see *delayed_node_table_gc*.

Some equalities: `[node()] = nodes(this)`, `nodes(connected) = nodes([visible, hidden])`, and `nodes() = nodes(visible)`.

**`now() -> Timestamp`**

Types:

```
Timestamp = timestamp()
timestamp() =
    {MegaSecs :: integer() >= 0,
     Secs :: integer() >= 0,
```

```
      MicroSecs :: integer() >= 0}
```

> Warning:
>
> *This function is deprecated! Do not use it!* See the users guide chapter *Time and Time Correction* for more information. Specifically the *Dos and Dont's* section for information on what to use instead of `erlang:now/0`.

Returns the tuple `{MegaSecs, Secs, MicroSecs}` which is the elapsed time since 00:00 GMT, January 1, 1970 (zero hour), on the assumption that the underlying OS supports this. Otherwise some other point in time is chosen. It is also guaranteed that subsequent calls to this BIF return continuously increasing values. Hence, the return value from `now()` can be used to generate unique time-stamps. If it is called in a tight loop on a fast machine, the time of the node can become skewed.

Can only be used to check the local time of day if the time-zone information of the underlying OS is properly configured.

**`open_port(PortName, PortSettings) -> port()`**

Types:

```
PortName =
    {spawn, Command :: string() | binary()} |
    {spawn_driver, Command :: string() | binary()} |
    {spawn_executable, FileName :: file:name()} |
    {fd, In :: integer() >= 0, Out :: integer() >= 0}
PortSettings = [Opt]
Opt =
    {packet, N :: 1 | 2 | 4} |
    stream |
    {line, L :: integer() >= 0} |
    {cd, Dir :: string() | binary()} |
    {env, Env :: [{Name :: string(), Val :: string() | false}]} |
    {args, [string() | binary()]} |
    {arg0, string() | binary()} |
    exit_status |
    use_stdio |
    nouse_stdio |
    stderr_to_stdout |
    in |
    out |
    binary |
    eof |
    {parallelism, Boolean :: boolean()} |
    hide
```

Returns a port identifier as the result of opening a new Erlang port. A port can be seen as an external Erlang process.

The name of the executable as well as the arguments given in `cd`, `env`, `args`, and `arg0` are subject to Unicode file name translation if the system is running in Unicode file name mode. To avoid translation or to force, for example UTF-8, supply the executable and/or arguments as a binary in the correct encoding. For details, see the module *file*, the function *file:native_name_encoding/0*, and the *STDLIB* User's Guide.

> **Note:**
>
> The characters in the name (if given as a list) can only be higher than 255 if the Erlang Virtual Machine is started in Unicode file name translation mode. Otherwise the name of the executable is limited to the ISO-latin-1 character set.

`PortName` can be any of the following:

`{spawn, Command}`

Starts an external program. `Command` is the name of the external program to be run. `Command` runs outside the Erlang work space unless an Erlang driver with the name `Command` is found. If found, that driver is started. A driver runs in the Erlang work space, which means that it is linked with the Erlang runtime system.

When starting external programs on Solaris, the system call `vfork` is used in preference to `fork` for performance reasons, although it has a history of being less robust. If there are problems using `vfork`, setting environment variable `ERL_NO_VFORK` to any value causes `fork` to be used instead.

For external programs, `PATH` is searched (or an equivalent method is used to find programs, depending on OS). This is done by invoking the shell on certain platforms. The first space-separated token of the command is considered as the name of the executable (or driver). This (among other things) makes this option unsuitable for running programs having spaces in file names or directory names. If spaces in executable file names are desired, use `{spawn_executable, Command}` instead.

`{spawn_driver, Command}`

Works like `{spawn, Command}`, but demands the first (space-separated) token of the command to be the name of a loaded driver. If no driver with that name is loaded, a `badarg` error is raised.

`{spawn_executable, FileName}`

Works like `{spawn, FileName}`, but only runs external executables. `FileName` in its whole is used as the name of the executable, including any spaces. If arguments are to be passed, the `PortSettings` `args` and `arg0` can be used.

The shell is usually not invoked to start the program, it is executed directly. `PATH` (or equivalent) is not searched. To find a program in `PATH` to execute, use *os:find_executable/1*.

Only if a shell script or `.bat` file is executed, the appropriate command interpreter is invoked implicitly, but there is still no command argument expansion or implicit `PATH` search.

If `FileName` cannot be run, an error exception is raised, with the POSIX error code as the reason. The error reason can differ between OSs. Typically the error `enoent` is raised when an attempt is made to run a program that is not found and `eacces` is raised when the given file is not executable.

`{fd, In, Out}`

Allows an Erlang process to access any currently opened file descriptors used by Erlang. The file descriptor `In` can be used for standard input, and the file descriptor `Out` for standard output. It is only used for various servers in the Erlang OS (`shell` and `user`). Hence, its use is limited.

`PortSettings` is a list of settings for the port. The valid settings are as follows:

`{packet, N}`

Messages are preceded by their length, sent in `N` bytes, with the most significant byte first. The valid values for `N` are 1, 2, and 4.

`stream`

Output messages are sent without packet lengths. A user-defined protocol must be used between the Erlang process and the external object.

`{line, L}`

Messages are delivered on a per line basis. Each line (delimited by the OS-dependent new line sequence) is delivered in a single message. The message data format is `{Flag, Line}`, where `Flag` is `eol` or `noeol`, and `Line` is the data delivered (without the new line sequence).

`L` specifies the maximum line length in bytes. Lines longer than this are delivered in more than one message, with `Flag` set to `noeol` for all but the last message. If end of file is encountered anywhere else than immediately following a new line sequence, the last line is also delivered with `Flag` set to `noeol`. Otherwise lines are delivered with `Flag` set to `eol`.

The `{packet, N}` and `{line, L}` settings are mutually exclusive.

`{cd, Dir}`

Only valid for `{spawn, Command}` and `{spawn_executable, FileName}`. The external program starts using `Dir` as its working directory. `Dir` must be a string.

`{env, Env}`

Only valid for `{spawn, Command}` and `{spawn_executable, FileName}`. The environment of the started process is extended using the environment specifications in `Env`.

`Env` is to be a list of tuples `{Name, Val}`, where `Name` is the name of an environment variable, and `Val` is the value it is to have in the spawned port process. Both `Name` and `Val` must be strings. The one exception is `Val` being the atom `false` (in analogy with `os:getenv/1`), which removes the environment variable.

`{args, [ string() | binary() ]}`

Only valid for `{spawn_executable, FileName}` and specifies arguments to the executable. Each argument is given as a separate string and (on Unix) eventually ends up as one element each in the argument vector. On other platforms, a similar behavior is mimicked.

The arguments are not expanded by the shell before being supplied to the executable. Most notably this means that file wild card expansion does not happen. To expand wild cards for the arguments, use *filelib:wildcard/1*. Notice that even if the program is a Unix shell script, meaning that the shell ultimately is invoked, wild card expansion does not happen, and the script is provided with the untouched arguments. On Windows, wild card expansion is always up to the program itself, therefore this is not an issue issue.

The executable name (also known as `argv[0]`) is not to be given in this list. The proper executable name is automatically used as argv[0], where applicable.

If you explicitly want to set the program name in the argument vector, option `arg0` can be used.

`{arg0, string() | binary()}`

Only valid for `{spawn_executable, FileName}` and explicitly specifies the program name argument when running an executable. This can in some circumstances, on some OSs, be desirable. How the program responds to this is highly system-dependent and no specific effect is guaranteed.

`exit_status`

Only valid for `{spawn, Command}`, where `Command` refers to an external program, and for `{spawn_executable, FileName}`.

When the external process connected to the port exits, a message of the form `{Port, {exit_status,Status}}` is sent to the connected process, where `Status` is the exit status of the external process. If the program aborts on Unix, the same convention is used as the shells do (that is, 128+signal).

If option `eof` is also given, the messages `eof` and `exit_status` appear in an unspecified order.

If the port program closes its `stdout` without exiting, option `exit_status` does not work.

`use_stdio`

Only valid for `{spawn, Command}` and `{spawn_executable, FileName}`. It allows the standard input and output (file descriptors 0 and 1) of the spawned (Unix) process for communication with Erlang.

`nouse_stdio`

The opposite of `use_stdio`. It uses file descriptors 3 and 4 for communication with Erlang.

`stderr_to_stdout`

Affects ports to external programs. The executed program gets its standard error file redirected to its standard output file. `stderr_to_stdout` and `nouse_stdio` are mutually exclusive.

`overlapped_io`

Affects ports to external programs on Windows only. The standard input and standard output handles of the port program are, if this option is supplied, opened with flag `FILE_FLAG_OVERLAPPED`, so that the port program can (and must) do overlapped I/O on its standard handles. This is not normally the case for simple port programs, but an option of value for the experienced Windows programmer. *On all other platforms, this option is silently discarded.*

`in`

The port can only be used for input.

`out`

The port can only be used for output.

`binary`

All I/O from the port is binary data objects as opposed to lists of bytes.

`eof`

The port is not closed at the end of the file and does not produce an exit signal. Instead, it remains open and a `{Port, eof}` message is sent to the process holding the port.

`hide`

When running on Windows, suppresses creation of a new console window when spawning the port program. (This option has no effect on other platforms.)

`{parallelism, Boolean}`

Sets scheduler hint for port parallelism. If set to `true`, the Virtual Machine schedules port tasks; when doing so, it improves parallelism in the system. If set to `false`, the Virtual Machine tries to perform port tasks immediately, improving latency at the expense of parallelism. The default can be set at system startup by passing command-line argument *+spp* to `erl(1)`.

Default is `stream` for all port types and `use_stdio` for spawned ports.

Failure: If the port cannot be opened, the exit reason is `badarg`, `system_limit`, or the POSIX error code that most closely describes the error, or `einval` if no POSIX code is appropriate:

`badarg`
Bad input arguments to `open_port`.

`system_limit`
All available ports in the Erlang emulator are in use.

`enomem`
Not enough memory to create the port.

`eagain`
: No more available OS processes.

`enametoolong`
: Too long external command.

`emfile`
: No more available file descriptors (for the OS process that the Erlang emulator runs in).

`enfile`
: Full file table (for the entire OS).

`eacces`
: `Command` given in `{spawn_executable, Command}` does not point out an executable file.

`enoent`
: `FileName` given in `{spawn_executable, FileName}` does not point out an existing file.

During use of a port opened using `{spawn, Name}`, `{spawn_driver, Name}`, or `{spawn_executable, Name}`, errors arising when sending messages to it are reported to the owning process using signals of the form `{'EXIT', Port, PosixCode}`. For the possible values of `PosixCode`, see the *file(3)* manual page in `Kernel`.

The maximum number of ports that can be open at the same time can be configured by passing command-line flag `+Q` to `erl(1)`.

**`erlang:phash(Term, Range) -> Hash`**

Types:

**`Term = term()`**

**`Range = Hash = integer() >= 1`**

Range = 1..2^32, Hash = 1..Range

Portable hash function that gives the same hash for the same Erlang term regardless of machine architecture and `ERTS` version (the BIF was introduced in `ERTS` 4.9.1.1). The function returns a hash value for `Term` within the range `1..Range`. The maximum value for `Range` is 2^32.

This BIF can be used instead of the old deprecated BIF `erlang:hash/2`, as it calculates better hashes for all data types, but consider using `phash2/1,2` instead.

**`erlang:phash2(Term) -> Hash`**

**`erlang:phash2(Term, Range) -> Hash`**

Types:

**`Term = term()`**

**`Range = integer() >= 1`**

1..2^32

**`Hash = integer() >= 0`**

0..Range-1

Portable hash function that gives the same hash for the same Erlang term regardless of machine architecture and `ERTS` version (the BIF was introduced in `ERTS` 5.2). The function returns a hash value for `Term` within the range `0..Range-1`. The maximum value for `Range` is 2^32. When without argument `Range`, a value in the range 0..2^27-1 is returned.

This BIF is always to be used for hashing terms. It distributes small integers better than `phash/2`, and it is faster for bignums and binaries.

Notice that the range `0..Range-1` is different from the range of `phash/2`, which is `1..Range`.

**pid_to_list(Pid) -> string()**

Types:

**Pid = pid()**

Returns a string corresponding to the text representation of `Pid`.

> Warning:
>
> This BIF is intended for debugging and is not to be used in application programs.

**port_close(Port) -> true**

Types:

**Port = port() | atom()**

Closes an open port. Roughly the same as `Port ! {self(), close}` except for the error behavior (see the following), being synchronous, and that the port does *not* reply with `{Port, closed}`. Any process can close a port with `port_close/1`, not only the port owner (the connected process). If the calling process is linked to the port identified by `Port`, the exit signal from the port is guaranteed to be delivered before `port_close/1` returns.

For comparison: `Port ! {self(), close}` only fails with `badarg` if `Port` does not refer to a port or a process. If `Port` is a closed port, nothing happens. If `Port` is an open port and the calling process is the port owner, the port replies with `{Port, closed}` when all buffers have been flushed and the port really closes. If the calling process is not the port owner, the *port owner* fails with `badsig`.

Notice that any process can close a port using `Port ! {PortOwner, close}` as if it itself was the port owner, but the reply always goes to the port owner.

As from OTP R16, `Port ! {PortOwner, close}` is truly asynchronous. Notice that this operation has always been documented as an asynchronous operation, while the underlying implementation has been synchronous. `port_close/1` is however still fully synchronous. This because of its error behavior.

Failure: `badarg` if `Port` is not an identifier of an open port, or the registered name of an open port. If the calling process was previously linked to the closed port, identified by `Port`, the exit signal from the port is guaranteed to be delivered before this `badarg` exception occurs.

**port_command(Port, Data) -> true**

Types:

**Port = port() | atom()**
**Data = iodata()**

Sends data to a port. Same as `Port ! {PortOwner, {command, Data}}` except for the error behavior and being synchronous (see the following). Any process can send data to a port with `port_command/2`, not only the port owner (the connected process).

For comparison: `Port ! {PortOwner, {command, Data}}` only fails with `badarg` if `Port` does not refer to a port or a process. If `Port` is a closed port, the data message disappears without a sound. If `Port` is open and the calling process is not the port owner, the *port owner* fails with `badsig`. The port owner fails with `badsig` also if `Data` is an invalid I/O list.

Notice that any process can send to a port using `Port ! {PortOwner, {command, Data}}` as if it itself was the port owner.

If the port is busy, the calling process is suspended until the port is not busy any more.

As from OTP-R16, `Port ! {PortOwner, {command, Data}}` is truly asynchronous. Notice that this operation has always been documented as an asynchronous operation, while the underlying implementation has been synchronous. `port_command/2` is however still fully synchronous. This because of its error behavior.

Failures:

`badarg`
: If `Port` is not an identifier of an open port, or the registered name of an open port. If the calling process was previously linked to the closed port, identified by `Port`, the exit signal from the port is guaranteed to be delivered before this `badarg` exception occurs.

`badarg`
: If `Data` is an invalid I/O list.

**`port_command(Port, Data, OptionList) -> boolean()`**

Types:

```
Port = port() | atom()
Data = iodata()
Option = force | nosuspend
OptionList = [Option]
```

Sends data to a port. `port_command(Port, Data, [])` equals `port_command(Port, Data)`.

If the port command is aborted, `false` is returned, otherwise `true`.

If the port is busy, the calling process is suspended until the port is not busy any more.

The following `Option`s are valid:

`force`
: The calling process is not suspended if the port is busy, instead the port command is forced through. The call fails with a `notsup` exception if the driver of the port does not support this. For more information, see driver flag *ERL_DRV_FLAG_SOFT_BUSY*.

`nosuspend`
: The calling process is not suspended if the port is busy, instead the port command is aborted and `false` is returned.

> **Note:**
>
> More options can be added in a future release.

Failures:

`badarg`
: If `Port` is not an identifier of an open port, or the registered name of an open port. If the calling process was previously linked to the closed port, identified by `Port`, the exit signal from the port is guaranteed to be delivered before this `badarg` exception occurs.

`badarg`
: If `Data` is an invalid I/O list.

`badarg`
: If `OptionList` is an invalid option list.

`notsup`
: If option `force` has been passed, but the driver of the port does not allow forcing through a busy port.

**port_connect(Port, Pid) -> true**

Types:

**Port = port() | atom()**

**Pid = pid()**

Sets the port owner (the connected port) to `Pid`. Roughly the same as `Port ! {Owner, {connect, Pid}}` except for the following:

- The error behavior differs, see the following.
- The port does *not* reply with `{Port,connected}`.
- `port_connect/1` is synchronous, see the following.
- The new port owner gets linked to the port.

The old port owner stays linked to the port and must call `unlink(Port)` if this is not desired. Any process can set the port owner to be any process with `port_connect/2`.

For comparison: `Port ! {self(), {connect, Pid}}` only fails with `badarg` if `Port` does not refer to a port or a process. If `Port` is a closed port, nothing happens. If `Port` is an open port and the calling process is the port owner, the port replies with `{Port, connected}` to the old port owner. Notice that the old port owner is still linked to the port, while the new is not. If `Port` is an open port and the calling process is not the port owner, the *port owner* fails with `badsig`. The port owner fails with `badsig` also if `Pid` is not an existing local process identifier.

Notice that any process can set the port owner using `Port ! {PortOwner, {connect, Pid}}` as if it itself was the port owner, but the reply always goes to the port owner.

As from OTP-R16, `Port ! {PortOwner, {connect, Pid}}` is truly asynchronous. Notice that this operation has always been documented as an asynchronous operation, while the underlying implementation has been synchronous. `port_connect/2` is however still fully synchronous. This because of its error behavior.

Failures:

`badarg`
: If `Port` is not an identifier of an open port, or the registered name of an open port. If the calling process was previously linked to the closed port, identified by `Port`, the exit signal from the port is guaranteed to be delivered before this `badarg` exception occurs.

`badarg`
: If process identified by `Pid` is not an existing local process.

**port_control(Port, Operation, Data) -> iodata() | binary()**

Types:

**Port = port() | atom()**

**Operation = integer()**

**Data = iodata()**

Performs a synchronous control operation on a port. The meaning of `Operation` and `Data` depends on the port, that is, on the port driver. Not all port drivers support this control feature.

Returns a list of integers in the range 0..255, or a binary, depending on the port driver. The meaning of the returned data also depends on the port driver.

Failures:

`badarg`
: If `Port` is not an open port or the registered name of an open port.

`badarg`
: If `Operation` cannot fit in a 32-bit integer.

badarg
: If the port driver does not support synchronous control operations.

badarg
: If the port driver so decides for any reason (probably something wrong with `Operation` or `Data`).

**`erlang:port_call(Port, Operation, Data) -> term()`**

Types:

```
Port = port() | atom()
Operation = integer()
Data = term()
```

Performs a synchronous call to a port. The meaning of `Operation` and `Data` depends on the port, that is, on the port driver. Not all port drivers support this feature.

`Port` is a port identifier, referring to a driver.

`Operation` is an integer, which is passed on to the driver.

`Data` is any Erlang term. This data is converted to binary term format and sent to the port.

Returns a term from the driver. The meaning of the returned data also depends on the port driver.

Failures:

badarg
: If `Port` is not an identifier of an open port, or the registered name of an open port. If the calling process was previously linked to the closed port, identified by `Port`, the exit signal from the port is guaranteed to be delivered before this `badarg` exception occurs.

badarg
: If `Operation` does not fit in a 32-bit integer.

badarg
: If the port driver does not support synchronous control operations.

badarg
: If the port driver so decides for any reason (probably something wrong with `Operation` or `Data`).

**`erlang:port_info(Port) -> Result`**

Types:

```
Port = port() | atom()
ResultItem =
    {registered_name, RegisteredName :: atom()} |
    {id, Index :: integer() >= 0} |
    {connected, Pid :: pid()} |
    {links, Pids :: [pid()]} |
    {name, String :: string()} |
    {input, Bytes :: integer() >= 0} |
    {output, Bytes :: integer() >= 0} |
    {os_pid, OsPid :: integer() >= 0 | undefined}
Result = [ResultItem] | undefined
```

Returns a list containing tuples with information about `Port`, or `undefined` if the port is not open. The order of the tuples is undefined, and all the tuples are not mandatory. If the port is closed and the calling process was previously linked to the port, the exit signal from the port is guaranteed to be delivered before `port_info/1` returns `undefined`.

The result contains information about the following `Item`s:

- `registered_name` (if the port has a registered name)
- `id`
- `connected`
- `links`
- `name`
- `input`
- `output`

For more information about the different `Item`s, see *port_info/2*.

Failure: `badarg` if `Port` is not a local port identifier, or an atom.

**`erlang:port_info(Port, Item :: connected) ->`**
**`                  {connected, Pid} | undefined`**

Types:

**`Port = port() | atom()`**
**`Pid = pid()`**

`Pid` is the process identifier of the process connected to the port.

If the port identified by `Port` is not open, `undefined` is returned. If the port is closed and the calling process was previously linked to the port, the exit signal from the port is guaranteed to be delivered before `port_info/2` returns `undefined`.

Failure: `badarg` if `Port` is not a local port identifier, or an atom.

**`erlang:port_info(Port, Item :: id) -> {id, Index} | undefined`**

Types:

**`Port = port() | atom()`**
**`Index = integer() >= 0`**

`Index` is the internal index of the port. This index can be used to separate ports.

If the port identified by `Port` is not open, `undefined` is returned. If the port is closed and the calling process was previously linked to the port, the exit signal from the port is guaranteed to be delivered before `port_info/2` returns `undefined`.

Failure: `badarg` if `Port` is not a local port identifier, or an atom.

**`erlang:port_info(Port, Item :: input) ->`**
**`                  {input, Bytes} | undefined`**

Types:

**`Port = port() | atom()`**
**`Bytes = integer() >= 0`**

`Bytes` is the total number of bytes read from the port.

If the port identified by `Port` is not open, `undefined` is returned. If the port is closed and the calling process was previously linked to the port, the exit signal from the port is guaranteed to be delivered before `port_info/2` returns `undefined`.

Failure: `badarg` if `Port` is not a local port identifier, or an atom.

**erlang:port_info(Port, Item :: links) -> {links, Pids} | undefined**

Types:

```
Port = port() | atom()
Pids = [pid()]
```

`Pids` is a list of the process identifiers of the processes that the port is linked to.

If the port identified by `Port` is not open, `undefined` is returned. If the port is closed and the calling process was previously linked to the port, the exit signal from the port is guaranteed to be delivered before `port_info/2` returns `undefined`.

Failure: `badarg` if `Port` is not a local port identifier, or an atom.

**erlang:port_info(Port, Item :: locking) ->**
**{locking, Locking} | undefined**

Types:

```
Port = port() | atom()
Locking = false | port_level | driver_level
```

`Locking` is one of the following:

- `false` (emulator without SMP support)
- `port_level` (port-specific locking)
- `driver_level` (driver-specific locking)

Notice that these results are highly implementation-specific and can change in a future release.

If the port identified by `Port` is not open, `undefined` is returned. If the port is closed and the calling process was previously linked to the port, the exit signal from the port is guaranteed to be delivered before `port_info/2` returns `undefined`.

Failure: `badarg` if `Port` is not a local port identifier, or an atom.

**erlang:port_info(Port, Item :: memory) ->**
**{memory, Bytes} | undefined**

Types:

```
Port = port() | atom()
Bytes = integer() >= 0
```

`Bytes` is the total number of bytes allocated for this port by the runtime system. The port itself can have allocated memory that is not included in `Bytes`.

If the port identified by `Port` is not open, `undefined` is returned. If the port is closed and the calling process was previously linked to the port, the exit signal from the port is guaranteed to be delivered before `port_info/2` returns `undefined`.

Failure: `badarg` if `Port` is not a local port identifier, or an atom.

**erlang:port_info(Port, Item :: monitors) ->**
**{monitors, Monitors} | undefined**

Types:

```
Port = port() | atom()
Monitors = [{process, pid()}]
```

`Monitors` represent processes that this port monitors.

If the port identified by `Port` is not open, `undefined` is returned. If the port is closed and the calling process was previously linked to the port, the exit signal from the port is guaranteed to be delivered before `port_info/2` returns `undefined`.

Failure: `badarg` if `Port` is not a local port identifier, or an atom.

**`erlang:port_info(Port, Item :: name) -> {name, Name} | undefined`**

Types:

```
Port = port() | atom()
Name = string()
```

`Name` is the command name set by *open_port/2*.

If the port identified by `Port` is not open, `undefined` is returned. If the port is closed and the calling process was previously linked to the port, the exit signal from the port is guaranteed to be delivered before `port_info/2` returns `undefined`.

Failure: `badarg` if `Port` is not a local port identifier, or an atom.

**`erlang:port_info(Port, Item :: os_pid) ->`**
**`{os_pid, OsPid} | undefined`**

Types:

```
Port = port() | atom()
OsPid = integer() >= 0 | undefined
```

`OsPid` is the process identifier (or equivalent) of an OS process created with *open_port({spawn | spawn_executable, Command}, Options)*. If the port is not the result of spawning an OS process, the value is `undefined`.

If the port identified by `Port` is not open, `undefined` is returned. If the port is closed and the calling process was previously linked to the port, the exit signal from the port is guaranteed to be delivered before `port_info/2` returns `undefined`.

Failure: `badarg` if `Port` is not a local port identifier, or an atom.

**`erlang:port_info(Port, Item :: output) ->`**
**`{output, Bytes} | undefined`**

Types:

```
Port = port() | atom()
Bytes = integer() >= 0
```

`Bytes` is the total number of bytes written to the port from Erlang processes using *port_command/2*, *port_command/3*, or `Port ! {Owner, {command, Data}`.

If the port identified by `Port` is not open, `undefined` is returned. If the port is closed and the calling process was previously linked to the port, the exit signal from the port is guaranteed to be delivered before `port_info/2` returns `undefined`.

Failure: `badarg` if `Port` is not a local port identifier, or an atom.

**`erlang:port_info(Port, Item :: parallelism) ->`**
**`{parallelism, Boolean} | undefined`**

Types:

```
Port = port() | atom()
Boolean = boolean()
```

`Boolean` corresponds to the port parallelism hint being used by this port. For more information, see option *parallelism* of *open_port/2*.

```
erlang:port_info(Port, Item :: queue_size) ->
                    {queue_size, Bytes} | undefined
```

Types:

```
Port = port() | atom()
Bytes = integer() >= 0
```

`Bytes` is the total number of bytes queued by the port using the ERTS driver queue implementation.

If the port identified by `Port` is not open, `undefined` is returned. If the port is closed and the calling process was previously linked to the port, the exit signal from the port is guaranteed to be delivered before `port_info/2` returns `undefined`.

Failure: `badarg` if `Port` is not a local port identifier, or an atom.

```
erlang:port_info(Port, Item :: registered_name) ->
                    {registered_name, RegisteredName} |
                    [] |
                    undefined
```

Types:

```
Port = port() | atom()
RegisteredName = atom()
```

`RegisteredName` is the registered name of the port. If the port has no registered name, `[]` is returned.

If the port identified by `Port` is not open, `undefined` is returned. If the port is closed and the calling process was previously linked to the port, the exit signal from the port is guaranteed to be delivered before `port_info/2` returns `undefined`.

Failure: `badarg` if `Port` is not a local port identifier, or an atom.

```
erlang:port_to_list(Port) -> string()
```

Types:

```
Port = port()
```

Returns a string corresponding to the text representation of the port identifier `Port`.

> Warning:
>
> This BIF is intended for debugging. It is not to be used in application programs.

```
erlang:ports() -> [port()]
```

Returns a list of port identifiers corresponding to all the ports existing on the local node.

Notice that an exiting port exists, but is not open.

**pre_loaded() -> [module()]**

Returns a list of Erlang modules that are preloaded in the system. As all loading of code is done through the file system, the file system must have been loaded previously. Hence, at least the module `init` must be preloaded.

**erlang:process_display(Pid, Type) -> true**

Types:

**Pid = pid()**
**Type = backtrace**

Writes information about the local process `Pid` on standard error. The only allowed value for the atom `Type` is `backtrace`, which shows the contents of the call stack, including information about the call chain, with the current function printed first. The format of the output is not further defined.

**process_flag(Flag :: trap_exit, Boolean) -> OldBoolean**

Types:

**Boolean = OldBoolean = boolean()**

When `trap_exit` is set to `true`, exit signals arriving to a process are converted to `{'EXIT', From, Reason}` messages, which can be received as ordinary messages. If `trap_exit` is set to `false`, the process exits if it receives an exit signal other than `normal` and the exit signal is propagated to its linked processes. Application processes are normally not to trap exits.

Returns the old value of the flag.

See also *exit/2*.

**process_flag(Flag :: error_handler, Module) -> OldModule**

Types:

**Module = OldModule = atom()**

Used by a process to redefine the error handler for undefined function calls and undefined registered processes. Inexperienced users are not to use this flag, as code auto-loading depends on the correct operation of the error handling module.

Returns the old value of the flag.

**process_flag(Flag :: min_heap_size, MinHeapSize) -> OldMinHeapSize**

Types:

**MinHeapSize = OldMinHeapSize = integer() >= 0**

Changes the minimum heap size for the calling process.

Returns the old value of the flag.

**process_flag(Flag :: min_bin_vheap_size, MinBinVHeapSize) ->**
**OldMinBinVHeapSize**

Types:

**MinBinVHeapSize = OldMinBinVHeapSize = integer() >= 0**

Changes the minimum binary virtual heap size for the calling process.

Returns the old value of the flag.

**process_flag(Flag :: priority, Level) -> OldLevel**

Types:

**Level = OldLevel = *priority_level()***
**priority_level() = low | normal | high | max**

Sets the process priority. `Level` is an atom. There are four priority levels: `low`, `normal`, `high`, and `max`. Default is `normal`.

> Note:
>
> Priority level `max` is reserved for internal use in the Erlang runtime system, and is *not* to be used by others.

Internally in each priority level, processes are scheduled in a round robin fashion.

Execution of processes on priority `normal` and `low` are interleaved. Processes on priority `low` are selected for execution less frequently than processes on priority `normal`.

When there are runnable processes on priority `high`, no processes on priority `low` or `normal` are selected for execution. Notice however, that this does *not* mean that no processes on priority `low` or `normal` can run when there are processes running on priority `high`. On the runtime system with SMP support, more processes can be running in parallel than processes on priority `high`, that is, a `low` and a `high` priority process can execute at the same time.

When there are runnable processes on priority `max`, no processes on priority `low`, `normal`, or `high` are selected for execution. As with priority `high`, processes on lower priorities can execute in parallel with processes on priority `max`.

Scheduling is preemptive. Regardless of priority, a process is preempted when it has consumed more than a certain number of reductions since the last time it was selected for execution.

> Note:
>
> Do not depend on the scheduling to remain exactly as it is today. Scheduling, at least on the runtime system with SMP support, is likely to be changed in a future release to use available processor cores better.

There is *no* automatic mechanism for avoiding priority inversion, such as priority inheritance or priority ceilings. When using priorities, take this into account and handle such scenarios by yourself.

Making calls from a `high` priority process into code that you have no control over can cause the `high` priority process to wait for a process with lower priority. That is, effectively decreasing the priority of the `high` priority process during the call. Even if this is not the case with one version of the code that you have no control over, it can be the case in a future version of it. This can, for example, occur if a `high` priority process triggers code loading, as the code server runs on priority `normal`.

Other priorities than `normal` are normally not needed. When other priorities are used, use them with care, *especially* priority `high`. A process on priority `high` is only to perform work for short periods. Busy looping for long periods in a `high` priority process does most likely cause problems, as important OTP servers run on priority `normal`.

Returns the old value of the flag.

**process_flag(Flag :: save_calls, N) -> OldN**

Types:

**N = OldN = 0..10000**

N must be an integer in the interval 0..10000. If N is greater than 0, call saving is made active for the process. This means that information about the N most recent global function calls, BIF calls, sends, and receives made by the process are saved in a list, which can be retrieved with `process_info(Pid, last_calls)`. A global function call is one in which the module of the function is explicitly mentioned. Only a fixed amount of information is saved, as follows:

- A tuple `{Module, Function, Arity}` for function calls
- The atoms `send`, `'receive'`, and `timeout` for sends and receives (`'receive'` when a message is received and `timeout` when a receive times out)

If N = 0, call saving is disabled for the process, which is the default. Whenever the size of the call saving list is set, its contents are reset.

Returns the old value of the flag.

**process_flag(Flag :: sensitive, Boolean) -> OldBoolean**

Types:

**Boolean = OldBoolean = boolean()**

Sets or clears flag `sensitive` for the current process. When a process has been marked as sensitive by calling `process_flag(sensitive, true)`, features in the runtime system that can be used for examining the data or inner working of the process are silently disabled.

Features that are disabled include (but are not limited to) the following:

- Tracing: Trace flags can still be set for the process, but no trace messages of any kind are generated. (If flag `sensitive` is turned off, trace messages are again generated if any trace flags are set.)
- Sequential tracing: The sequential trace token is propagated as usual, but no sequential trace messages are generated.

`process_info/1,2` cannot be used to read out the message queue or the process dictionary (both are returned as empty lists).

Stack back-traces cannot be displayed for the process.

In crash dumps, the stack, messages, and the process dictionary are omitted.

If `{save_calls,N}` has been set for the process, no function calls are saved to the call saving list. (The call saving list is not cleared. Furthermore, send, receive, and timeout events are still added to the list.)

Returns the old value of the flag.

**process_flag(Pid, Flag, Value) -> OldValue**

Types:

**Pid = pid()**

**Flag = save_calls**

**Value = OldValue = integer() >= 0**

Sets certain flags for the process `Pid`, in the same manner as *process_flag/2*. Returns the old value of the flag. The valid values for `Flag` are only a subset of those allowed in `process_flag/2`, namely `save_calls`.

Failure: `badarg` if `Pid` is not a local process.

**process_info(Pid) -> Info**

Types:

```
Pid = pid()
Info = [InfoTuple] | undefined
InfoTuple = process_info_result_item()
process_info_result_item() =
    {backtrace, Bin :: binary()} |
    {binary,
     BinInfo ::
         [{integer() >= 0,
           integer() >= 0,
           integer() >= 0}]} |
    {catchlevel, CatchLevel :: integer() >= 0} |
    {current_function,
     {Module :: module(), Function :: atom(), Arity :: arity()}} |
    {current_location,
     {Module :: module(),
      Function :: atom(),
      Arity :: arity(),
      Location ::
          [{file, Filename :: string()} |
           {line, Line :: integer() >= 1}]}} |
    {current_stacktrace, Stack :: [stack_item()]} |
    {dictionary, Dictionary :: [{Key :: term(), Value :: term()}]} |
    {error_handler, Module :: module()} |
    {garbage_collection, GCInfo :: [{atom(), integer() >= 0}]} |
    {group_leader, GroupLeader :: pid()} |
    {heap_size, Size :: integer() >= 0} |
    {initial_call, mfa()} |
    {links, PidsAndPorts :: [pid() | port()]} |
    {last_calls, false | (Calls :: [mfa()])} |
    {memory, Size :: integer() >= 0} |
    {message_queue_len, MessageQueueLen :: integer() >= 0} |
    {messages, MessageQueue :: [term()]} |
    {min_heap_size, MinHeapSize :: integer() >= 0} |
    {min_bin_vheap_size, MinBinVHeapSize :: integer() >= 0} |
    {monitored_by, Pids :: [pid()]} |
    {monitors,
     Monitors ::
         [{process,
           Pid :: pid() | {RegName :: atom(), Node :: node()}}]} |
    {priority, Level :: priority_level()} |
    {reductions, Number :: integer() >= 0} |
    {registered_name, Atom :: atom()} |
    {sequential_trace_token,
     [] | (SequentialTraceToken :: term())} |
    {stack_size, Size :: integer() >= 0} |
    {status,
     Status ::
         exiting |
         garbage_collecting |
         waiting |
         running |
```

```
          runnable |
          suspended} |
      {suspending,
       SuspendeeList ::
          [{Suspendee :: pid(),
            ActiveSuspendCount :: integer() >= 0,
            OutstandingSuspendCount :: integer() >= 0}]} |
      {total_heap_size, Size :: integer() >= 0} |
      {trace, InternalTraceFlags :: integer() >= 0} |
      {trap_exit, Boolean :: boolean()}
priority_level() = low | normal | high | max
stack_item() =
      {Module :: module(),
       Function :: atom(),
       Arity :: arity() | (Args :: [term()]),
       Location ::
          [{file, Filename :: string()} |
           {line, Line :: integer() >= 1}]}
```

Returns a list containing `InfoTuple`s with miscellaneous information about the process identified by `Pid`, or `undefined` if the process is not alive.

The order of the `InfoTuple`s is undefined and all `InfoTuple`s are not mandatory. The `InfoTuple`s part of the result can be changed without prior notice.

The `InfoTuple`s with the following items are part of the result:

- `current_function`
- `initial_call`
- `status`
- `message_queue_len`
- `messages`
- `links`
- `dictionary`
- `trap_exit`
- `error_handler`
- `priority`
- `group_leader`
- `total_heap_size`
- `heap_size`
- `stack_size`
- `reductions`
- `garbage_collection`

If the process identified by `Pid` has a registered name, also an `InfoTuple` with item `registered_name` appears.

For information about specific `InfoTuple`s, see *process_info/2*.

> Warning:
>
> This BIF is intended for *debugging only*. For all other purposes, use *process_info/2*.

Failure: `badarg` if `Pid` is not a local process.

```
process_info(Pid, Item) -> InfoTuple | [] | undefined
process_info(Pid, ItemList) -> InfoTupleList | [] | undefined
```

Types:

```
   Pid = pid()
   ItemList = [Item]
   Item = process_info_item()
   InfoTupleList = [InfoTuple]
   InfoTuple = process_info_result_item()
   process_info_item() =
       backtrace |
       binary |
       catchlevel |
       current_function |
       current_location |
       current_stacktrace |
       dictionary |
       error_handler |
       garbage_collection |
       group_leader |
       heap_size |
       initial_call |
       links |
       last_calls |
       memory |
       message_queue_len |
       messages |
       min_heap_size |
       min_bin_vheap_size |
       monitored_by |
       monitors |
       priority |
       reductions |
       registered_name |
       sequential_trace_token |
       stack_size |
       status |
       suspending |
       total_heap_size |
       trace |
       trap_exit
   process_info_result_item() =
       {backtrace, Bin :: binary()} |
       {binary,
```

```
 BinInfo ::
     [{integer() >= 0,
       integer() >= 0,
       integer() >= 0}]} |
{catchlevel, CatchLevel :: integer() >= 0} |
{current_function,
 {Module :: module(), Function :: atom(), Arity :: arity()}} |
{current_location,
 {Module :: module(),
  Function :: atom(),
  Arity :: arity(),
  Location ::
      [{file, Filename :: string()} |
       {line, Line :: integer() >= 1}]}} |
{current_stacktrace, Stack :: [stack_item()]} |
{dictionary, Dictionary :: [{Key :: term(), Value :: term()}]} |
{error_handler, Module :: module()} |
{garbage_collection, GCInfo :: [{atom(), integer() >= 0}]} |
{group_leader, GroupLeader :: pid()} |
{heap_size, Size :: integer() >= 0} |
{initial_call, mfa()} |
{links, PidsAndPorts :: [pid() | port()]} |
{last_calls, false | (Calls :: [mfa()])} |
{memory, Size :: integer() >= 0} |
{message_queue_len, MessageQueueLen :: integer() >= 0} |
{messages, MessageQueue :: [term()]} |
{min_heap_size, MinHeapSize :: integer() >= 0} |
{min_bin_vheap_size, MinBinVHeapSize :: integer() >= 0} |
{monitored_by, Pids :: [pid()]} |
{monitors,
 Monitors ::
     [{process,
       Pid :: pid() | {RegName :: atom(), Node :: node()}}]} |
{priority, Level :: priority_level()} |
{reductions, Number :: integer() >= 0} |
{registered_name, Atom :: atom()} |
{sequential_trace_token,
 [] | (SequentialTraceToken :: term())} |
{stack_size, Size :: integer() >= 0} |
{status,
 Status ::
     exiting |
     garbage_collecting |
     waiting |
     running |
     runnable |
     suspended} |
{suspending,
 SuspendeeList ::
     [{Suspendee :: pid(),
       ActiveSuspendCount :: integer() >= 0,
       OutstandingSuspendCount :: integer() >= 0}]} |
```

```
      {total_heap_size, Size :: integer() >= 0} |
      {trace, InternalTraceFlags :: integer() >= 0} |
      {trap_exit, Boolean :: boolean()}
  stack_item() =
      {Module :: module(),
       Function :: atom(),
       Arity :: arity() | (Args :: [term()]),
       Location ::
           [{file, Filename :: string()} |
            {line, Line :: integer() >= 1}]}
  priority_level() = low | normal | high | max
```

Returns information about the process identified by `Pid`, as specified by `Item` or `ItemList`. Returns `undefined` if the process is not alive.

If the process is alive and a single `Item` is given, the returned value is the corresponding `InfoTuple`, unless `Item =:= registered_name` and the process has no registered name. In this case, `[]` is returned. This strange behavior is because of historical reasons, and is kept for backward compatibility.

If `ItemList` is given, the result is `InfoTupleList`. The `InfoTuple`s in `InfoTupleList` appear with the corresponding `Item`s in the same order as the `Item`s appeared in `ItemList`. Valid `Item`s can appear multiple times in `ItemList`.

> **Note:**
>
> If `registered_name` is part of `ItemList` and the process has no name registered a `{registered_name, []}`, `InfoTuple` *will* appear in the resulting `InfoTupleList`. This behavior is different when a single `Item =:= registered_name` is given, and when `process_info/1` is used.

The following `InfoTuple`s with corresponding `Item`s are valid:

`{backtrace, Bin}`

Binary `Bin` contains the same information as the output from `erlang:process_display(Pid, backtrace)`. Use `binary_to_list/1` to obtain the string of characters from the binary.

`{binary, BinInfo}`

`BinInfo` is a list containing miscellaneous information about binaries currently being referred to by this process. This `InfoTuple` can be changed or removed without prior notice.

`{catchlevel, CatchLevel}`

`CatchLevel` is the number of currently active catches in this process. This `InfoTuple` can be changed or removed without prior notice.

`{current_function, {Module, Function, Arity}}`

`Module`, `Function`, `Arity` is the current function call of the process.

`{current_location, {Module, Function, Arity, Location}}`

`Module`, `Function`, `Arity` is the current function call of the process. `Location` is a list of two-tuples describing the location in the source code.

`{current_stacktrace, Stack}`

Returns the current call stack back-trace (*stacktrace*) of the process. The stack has the same format as returned by *erlang:get_stacktrace/0*.

`{dictionary, Dictionary}`

`Dictionary` is the process dictionary.

`{error_handler, Module}`

`Module` is the error handler module used by the process (for undefined function calls, for example).

`{garbage_collection, GCInfo}`

`GCInfo` is a list containing miscellaneous information about garbage collection for this process. The content of `GCInfo` can be changed without prior notice.

`{group_leader, GroupLeader}`

`GroupLeader` is group leader for the I/O of the process.

`{heap_size, Size}`

`Size` is the size in words of the youngest heap generation of the process. This generation includes the process stack. This information is highly implementation-dependent, and can change if the implementation changes.

`{initial_call, {Module, Function, Arity}}`

`Module`, `Function`, `Arity` is the initial function call with which the process was spawned.

`{links, PidsAndPorts}`

`PidsAndPorts` is a list of process identifiers and port identifiers, with processes or ports to which the process has a link.

`{last_calls, false|Calls}`

The value is `false` if call saving is not active for the process (see *process_flag/3*). If call saving is active, a list is returned, in which the last element is the most recent called.

`{memory, Size}`

`Size` is the size in bytes of the process. This includes call stack, heap, and internal structures.

`{message_queue_len, MessageQueueLen}`

`MessageQueueLen` is the number of messages currently in the message queue of the process. This is the length of the list `MessageQueue` returned as the information item `messages` (see the following).

`{messages, MessageQueue}`

`MessageQueue` is a list of the messages to the process, which have not yet been processed.

`{min_heap_size, MinHeapSize}`

`MinHeapSize` is the minimum heap size for the process.

`{min_bin_vheap_size, MinBinVHeapSize}`

`MinBinVHeapSize` is the minimum binary virtual heap size for the process.

`{monitored_by, Pids}`

A list of process identifiers monitoring the process (with `monitor/2`).

`{monitors, Monitors}`

A list of monitors (started by `monitor/2`) that are active for the process. For a local process monitor or a remote process monitor by a process identifier, the list item is `{process, Pid}`. For a remote process monitor by name, the list item is `{process, {RegName, Node}}`.

`{priority, Level}`

`Level` is the current priority level for the process. For more information on priorities, see *process_flag(priority, Level)*.

`{reductions, Number}`

`Number` is the number of reductions executed by the process.

`{registered_name, Atom}`

`Atom` is the registered name of the process. If the process has no registered name, this tuple is not present in the list.

`{sequential_trace_token, [] | SequentialTraceToken}`

`SequentialTraceToken` is the sequential trace token for the process. This `InfoTuple` can be changed or removed without prior notice.

`{stack_size, Size}`

`Size` is the stack size, in words, of the process.

`{status, Status}`

`Status` is the status of the process and is one of the following:

- `exiting`
- `garbage_collecting`
- `waiting` (for a message)
- `running`
- `runnable` (ready to run, but another process is running)
- `suspended` (suspended on a "busy" port or by the BIF `erlang:suspend_process/[1,2]`)

`{suspending, SuspendeeList}`

`SuspendeeList` is a list of `{Suspendee, ActiveSuspendCount, OutstandingSuspendCount}` tuples. `Suspendee` is the process identifier of a process that has been, or is to be, suspended by the process identified by `Pid` through one of the following BIFs:

- *erlang:suspend_process/2*
- *erlang:suspend_process/1*

`ActiveSuspendCount` is the number of times `Suspendee` has been suspended by `Pid`. `OutstandingSuspendCount` is the number of not yet completed suspend requests sent by `Pid`, that is:

- If `ActiveSuspendCount =/= 0`, `Suspendee` is currently in the suspended state.
- If `OutstandingSuspendCount =/= 0`, option `asynchronous` of `erlang:suspend_process/2` has been used and the suspendee has not yet been suspended by `Pid`.

Notice that `ActiveSuspendCount` and `OutstandingSuspendCount` are not the total suspend count on `Suspendee`, only the parts contributed by `Pid`.

`{total_heap_size, Size}`

`Size` is the total size, in words, of all heap fragments of the process. This includes the process stack.

`{trace, InternalTraceFlags}`

`InternalTraceFlags` is an integer representing the internal trace flag for this process. This `InfoTuple` can be changed or removed without prior notice.

`{trap_exit, Boolean}`

`Boolean` is `true` if the process is trapping exits, otherwise `false`.

Notice that not all implementations support all these `Item`s.

Failures:

`badarg`
If `Pid` is not a local process.

`badarg`
If `Item` is an invalid item.

### processes() -> [pid()]

Returns a list of process identifiers corresponding to all the processes currently existing on the local node.

Notice that an exiting process exists, but is not alive. That is, `is_process_alive/1` returns `false` for an exiting process, but its process identifier is part of the result returned from `processes/0`.

Example:

```
> processes().
[<0.0.0>,<0.2.0>,<0.4.0>,<0.5.0>,<0.7.0>,<0.8.0>]
```

### purge_module(Module) -> true

Types:

**Module = atom()**

Removes old code for `Module`. Before this BIF is used, `erlang:check_process_code/2` is to be called to check that no processes execute old code in the module.

> Warning:
>
> This BIF is intended for the code server (see *code(3)*) and is not to be used elsewhere.

Failure: `badarg` if there is no old code for `Module`.

### put(Key, Val) -> term()

Types:

**Key = Val = term()**

Adds a new `Key` to the process dictionary, associated with the value `Val`, and returns `undefined`. If `Key` exists, the old value is deleted and replaced by `Val`, and the function returns the old value.

Example:

```
> X = put(name, walrus), Y = put(name, carpenter),
Z = get(name),
{X, Y, Z}.
{undefined,walrus,carpenter}
```

> Note:
>
> The values stored when `put` is evaluated within the scope of a `catch` are not retracted if a `throw` is evaluated, or if an error occurs.

**`erlang:raise(Class, Reason, Stacktrace) -> no_return()`**

Types:

```
Class = error | exit | throw
Reason = term()
Stacktrace = raise_stacktrace()
raise_stacktrace() =
    [{module(), atom(), arity() | [term()]} |
     {function(), [term()]}] |
    [{module(), atom(), arity() | [term()], [{atom(), term()}]} |
     {function(), [term()], [{atom(), term()}]}]
```

Stops the execution of the calling process with an exception of given class, reason, and call stack backtrace (*stacktrace*).

> Warning:
>
> This BIF is intended for debugging. Avoid to use it in applications, unless you really know what you are doing.

`Class` is `error`, `exit`, or `throw`. So, if it were not for the stacktrace, `erlang:raise(Class, Reason, Stacktrace)` is equivalent to `erlang:Class(Reason)`.

`Reason` is any term. `Stacktrace` is a list as returned from `get_stacktrace()`, that is, a list of four-tuples `{Module, Function, Arity | Args, Location}`, where `Module` and `Function` are atoms, and the third element is an integer arity or an argument list. The stacktrace can also contain `{Fun, Args, Location}` tuples, where `Fun` is a local fun and `Args` is an argument list.

Element `Location` at the end is optional. Omitting it is equivalent to specifying an empty list.

The stacktrace is used as the exception stacktrace for the calling process; it is truncated to the current maximum stacktrace depth.

Since evaluating this function causes the process to terminate, it has no return value unless the arguments are invalid, in which case the function *returns the error reason* `badarg`. If you want to be sure not to return, you can call `error(erlang:raise(Class, Reason, Stacktrace))` and hope to distinguish exceptions later.

**`erlang:read_timer(TimerRef, Options) -> Result | ok`**

Types:

```
TimerRef = reference()
Async = boolean()
Option = {async, Async}
Options = [Option]
Time = integer() >= 0
Result = Time | false
```

Read the state of a timer that has been created by either *`erlang:start_timer()`*, or *`erlang:send_after()`*. `TimerRef` identifies the timer, and was returned by the BIF that created the timer.

Available `Options`:

`{async, Async}`

Asynchronous request for state information. `Async` defaults to `false` which will cause the operation to be performed synchronously. In this case, the `Result` is returned by `erlang:read_timer()`. When `Async` is `true`, `erlang:read_timer()` sends an asynchronous request for the state information to the timer service that manages the timer, and then returns `ok`. A message on the format `{read_timer, TimerRef, Result}` is sent to the caller of `erlang:read_timer()` when the operation has been processed.

More `Option`s may be added in the future.

If `Result` is an integer, it represents the time in milli-seconds left until the timer expires.

If `Result` is `false`, a timer corresponding to `TimerRef` could not be found. This can be because the timer had expired, it had been canceled, or because `TimerRef` never has corresponded to a timer. Even if the timer has expired, it does not tell you whether or not the timeout message has arrived at its destination yet.

> ### Note:
>
> The timer service that manages the timer may be co-located with another scheduler than the scheduler that the calling process is executing on. If this is the case, communication with the timer service takes much longer time than if it is located locally. If the calling process is in critical path, and can do other things while waiting for the result of this operation, you want to use option `{async, true}`. If using option `{async, false}`, the calling process will be blocked until the operation has been performed.

See also *`erlang:send_after/4`*, *`erlang:start_timer/4`*, and *`erlang:cancel_timer/2`*.

**`erlang:read_timer(TimerRef) -> Result`**

Types:

```
TimerRef = reference()
Time = integer() >= 0
Result = Time | false
```

Read the state of a timer. The same as calling *`erlang:read_timer(TimerRef, [])`*.

**`erlang:ref_to_list(Ref) -> string()`**

Types:

```
Ref = reference()
```

Returns a string corresponding to the text representation of `Ref`.

> Warning:
>
> This BIF is intended for debugging and is not to be used in application programs.

**`register(RegName, PidOrPort) -> true`**

Types:

**`RegName = atom()`**

**`PidOrPort = port() | pid()`**

Associates the name `RegName` with a process identifier (pid) or a port identifier. `RegName`, which must be an atom, can be used instead of the pid or port identifier in send operator (`RegName ! Message`).

Example:

```
> register(db, Pid).
true
```

Failures:

`badarg`
: If `PidOrPort` is not an existing local process or port.

`badarg`
: If `RegName` is already in use.

`badarg`
: If the process or port is already registered (already has a name).

`badarg`
: If `RegName` is the atom `undefined`.

**`registered() -> [RegName]`**

Types:

**`RegName = atom()`**

Returns a list of names that have been registered using *register/2*, for example:

```
> registered().
[code_server, file_server, init, user, my_db]
```

**`erlang:resume_process(Suspendee) -> true`**

Types:

**`Suspendee = pid()`**

Decreases the suspend count on the process identified by `Suspendee`. `Suspendee` is previously to have been suspended through *erlang:suspend_process/2* or *erlang:suspend_process/1* by the process calling `erlang:resume_process(Suspendee)`. When the suspend count on `Suspendee` reaches zero, `Suspendee` is resumed, that is, its state is changed from suspended into the state it had before it was suspended.

> Warning:
>
> This BIF is intended for debugging only.

Failures:

`badarg`
: If `Suspendee` is not a process identifier.

`badarg`
: If the process calling `erlang:resume_process/1` had not previously increased the suspend count on the process identified by `Suspendee`.

`badarg`
: If the process identified by `Suspendee` is not alive.

**`round(Number) -> integer()`**

Types:

**`Number = number()`**

Returns an integer by rounding `Number`, for example:

```
round(5.5).
6
```

Allowed in guard tests.

**`self() -> pid()`**

Returns the process identifier of the calling process, for example:

```
> self().
<0.26.0>
```

Allowed in guard tests.

**`erlang:send(Dest, Msg) -> Msg`**

Types:

**`Dest = dst()`**

**`Msg = term()`**

**`dst() =`**
**`    pid() |`**
**`    port() |`**
**`    (RegName :: atom()) |`**
**`    {RegName :: atom(), Node :: node()}`**

Sends a message and returns `Msg`. This is the same as `Dest ! Msg`.

`Dest` can be a remote or local process identifier, a (local) port, a locally registered name, or a tuple `{RegName, Node}` for a registered name at another node.

**erlang:send(Dest, Msg, Options) -> Res**

Types:

```
Dest = dst()
Msg = term()
Options = [nosuspend | noconnect]
Res = ok | nosuspend | noconnect
dst() =
    pid() |
    port() |
    (RegName :: atom()) |
    {RegName :: atom(), Node :: node()}
```

Either sends a message and returns `ok`, or does not send the message but returns something else (see the following). Otherwise the same as *erlang:send/2*. For more detailed explanation and warnings, see *erlang:send_nosuspend/2,3*.

The options are as follows:

`nosuspend`

If the sender would have to be suspended to do the send, `nosuspend` is returned instead.

`noconnect`

If the destination node would have to be auto-connected to do the send, `noconnect` is returned instead.

> Warning:
>
> As with `erlang:send_nosuspend/2,3`: use with extreme care.

**erlang:send_after(Time, Dest, Msg, Options) -> TimerRef**

Types:

```
Time = integer()
Dest = pid() | atom()
Msg = term()
Options = [Option]
Abs = boolean()
Option = {abs, Abs}
TimerRef = reference()
```

Starts a timer. When the timer expires, the message `Msg` is sent to the process identified by `Dest`. Apart from the format of the timeout message, `erlang:send_after/4` works exactly as *`erlang:start_timer/4`*.

**erlang:send_after(Time, Dest, Msg) -> TimerRef**

Types:

```
Time = integer() >= 0
Dest = pid() | atom()
Msg = term()
TimerRef = reference()
```

Starts a timer. The same as calling *`erlang:send_after(Time, Dest, Msg, [])`*.

**erlang:send_nosuspend(Dest, Msg) -> boolean()**

Types:

```
Dest = dst()
Msg = term()
dst() =
    pid() |
    port() |
    (RegName :: atom()) |
    {RegName :: atom(), Node :: node()}
```

The same as *erlang:send(Dest, Msg, [nosuspend])*, but returns `true` if the message was sent and `false` if the message was not sent because the sender would have had to be suspended.

This function is intended for send operations to an unreliable remote node without ever blocking the sending (Erlang) process. If the connection to the remote node (usually not a real Erlang node, but a node written in C or Java) is overloaded, this function *does not send the message* and returns `false`.

The same occurs if `Dest` refers to a local port that is busy. For all other destinations (allowed for the ordinary send operator `'!'`), this function sends the message and returns `true`.

This function is only to be used in rare circumstances where a process communicates with Erlang nodes that can disappear without any trace, causing the TCP buffers and the drivers queue to be over-full before the node is shut down (because of tick time-outs) by `net_kernel`. The normal reaction to take when this occurs is some kind of premature shutdown of the other node.

Notice that ignoring the return value from this function would result in an *unreliable* message passing, which is contradictory to the Erlang programming model. The message is *not* sent if this function returns `false`.

In many systems, transient states of overloaded queues are normal. The fact that this function returns `false` does not mean that the other node is guaranteed to be non-responsive, it could be a temporary overload. Also, a return value of `true` does only mean that the message can be sent on the (TCP) channel without blocking, the message is not guaranteed to arrive at the remote node. For a disconnected non-responsive node, the return value is `true` (mimics the behavior of operator `!`). The expected behavior and the actions to take when the function returns `false` are application- and hardware-specific.

> Warning:
>
> Use with extreme care.

**erlang:send_nosuspend(Dest, Msg, Options) -> boolean()**

Types:

```
Dest = dst()
Msg = term()
Options = [noconnect]
dst() =
    pid() |
    port() |
    (RegName :: atom()) |
    {RegName :: atom(), Node :: node()}
```

The same as *erlang:send(Dest, Msg, [nosuspend | Options])*, but with a Boolean return value.

This function behaves like *erlang:send_nosuspend/2*, but takes a third parameter, a list of options. The only option is `noconnect`, which makes the function return `false` if the remote node is not currently reachable by the local node. The normal behavior is to try to connect to the node, which can stall the process during a short period. The use of option `noconnect` makes it possible to be sure not to get the slightest delay when sending to a remote process. This is especially useful when communicating with nodes that expect to always be the connecting part (that is, nodes written in C or Java).

Whenever the function returns `false` (either when a suspend would occur or when `noconnect` was specified and the node was not already connected), the message is guaranteed *not* to have been sent.

> Warning:
>
> Use with extreme care.

**`erlang:set_cookie(Node, Cookie) -> true`**

Types:

**`Node = node()`**

**`Cookie = atom()`**

Sets the magic cookie of `Node` to the atom `Cookie`. If `Node` is the local node, the function also sets the cookie of all other unknown nodes to `Cookie` (see Section *Distributed Erlang* in the Erlang Reference Manual in System Documentation).

Failure: `function_clause` if the local node is not alive.

**`setelement(Index, Tuple1, Value) -> Tuple2`**

Types:

**`Index = integer() >= 1`**

1..tuple_size(Tuple1

**`Tuple1 = Tuple2 = tuple()`**

**`Value = term()`**

Returns a tuple that is a copy of argument `Tuple1` with the element given by integer argument `Index` (the first element is the element with index 1) replaced by argument `Value`, for example:

```
> setelement(2, {10, green, bottles}, red).
{10,red,bottles}
```

**`size(Item) -> integer() >= 0`**

Types:

**`Item = tuple() | binary()`**

Returns the number of elements in a tuple or the number of bytes in a binary or bitstring, for example:

```
> size({morni, mulle, bwange}).
3
> size(<<11, 22, 33>>).
3
```

For bitstrings the number of whole bytes is returned. That is, if the number of bits in the bitstring is not divisible by 8, the resulting number of bytes is rounded *down*.

Allowed in guard tests.

See also *tuple_size/1*, *byte_size/1* and *bit_size/1*.

**spawn(Fun) -> pid()**

Types:

**Fun = function()**

Returns the process identifier of a new process started by the application of Fun to the empty list []. Otherwise works like *spawn/3*.

**spawn(Node, Fun) -> pid()**

Types:

**Node = node()**

**Fun = function()**

Returns the process identifier of a new process started by the application of Fun to the empty list [] on Node. If Node does not exist, a useless pid is returned. Otherwise works like *spawn/3*.

**spawn(Module, Function, Args) -> pid()**

Types:

**Module = module()**

**Function = atom()**

**Args = [term()]**

Returns the process identifier of a new process started by the application of Module:Function to Args.

error_handler:undefined_function(Module, Function, Args) is evaluated by the new process if Module:Function/Arity does not exist (where Arity is the length of Args). The error handler can be redefined (see *process_flag/2*). If error_handler is undefined, or the user has redefined the default error_handler and its replacement is undefined, a failure with reason undef occurs.

Example:

```
> spawn(speed, regulator, [high_speed, thin_cut]).
<0.13.1>
```

**spawn(Node, Module, Function, Args) -> pid()**

Types:

**Node = node()**

**Module = module()**

**Function = atom()**

**Args = [term()]**

Returns the process identifier (pid) of a new process started by the application of Module:Function to Args on Node. If Node does not exist, a useless pid is returned. Otherwise works like *spawn/3*.

**spawn_link(Fun) -> pid()**

Types:

**Fun = function()**

Returns the process identifier of a new process started by the application of Fun to the empty list [] . A link is created between the calling process and the new process, atomically. Otherwise works like *spawn/3*.

**spawn_link(Node, Fun) -> pid()**

Types:

**Node = node()**

**Fun = function()**

Returns the process identifier (pid) of a new process started by the application of Fun to the empty list [] on Node. A link is created between the calling process and the new process, atomically. If Node does not exist, a useless pid is returned and an exit signal with reason noconnection is sent to the calling process. Otherwise works like *spawn/3*.

**spawn_link(Module, Function, Args) -> pid()**

Types:

**Module = module()**

**Function = atom()**

**Args = [term()]**

Returns the process identifier of a new process started by the application of Module:Function to Args. A link is created between the calling process and the new process, atomically. Otherwise works like *spawn/3*.

**spawn_link(Node, Module, Function, Args) -> pid()**

Types:

**Node = node()**

**Module = module()**

**Function = atom()**

**Args = [term()]**

Returns the process identifier (pid) of a new process started by the application of Module:Function to Args on Node. A link is created between the calling process and the new process, atomically. If Node does not exist, a useless pid is returned and an exit signal with reason noconnection is sent to the calling process. Otherwise works like *spawn/3*.

**spawn_monitor(Fun) -> {pid(), reference()}**

Types:

**Fun = function()**

Returns the process identifier of a new process, started by the application of Fun to the empty list [], and a reference for a monitor created to the new process. Otherwise works like *spawn/3*.

**spawn_monitor(Module, Function, Args) -> {pid(), reference()}**

Types:

```
Module = module()
Function = atom()
Args = [term()]
```

A new process is started by the application of `Module:Function` to `Args`. The process is monitored at the same time. Returns the process identifier and a reference for the monitor. Otherwise works like *spawn/3*.

```
spawn_opt(Fun, Options) -> pid() | {pid(), reference()}
```

Types:

```
Fun = function()
Options = [Option]
Option =
    link |
    monitor |
    {priority, Level :: priority_level()} |
    {fullsweep_after, Number :: integer() >= 0} |
    {min_heap_size, Size :: integer() >= 0} |
    {min_bin_vheap_size, VSize :: integer() >= 0}
priority_level() = low | normal | high | max
```

Returns the process identifier (pid) of a new process started by the application of `Fun` to the empty list `[]`. Otherwise works like *spawn_opt/4*.

If option `monitor` is given, the newly created process is monitored, and both the pid and reference for the monitor is returned.

```
spawn_opt(Node, Fun, Options) -> pid() | {pid(), reference()}
```

Types:

```
Node = node()
Fun = function()
Options = [Option]
Option =
    link |
    monitor |
    {priority, Level :: priority_level()} |
    {fullsweep_after, Number :: integer() >= 0} |
    {min_heap_size, Size :: integer() >= 0} |
    {min_bin_vheap_size, VSize :: integer() >= 0}
priority_level() = low | normal | high | max
```

Returns the process identifier (pid) of a new process started by the application of `Fun` to the empty list `[]` on `Node`. If `Node` does not exist, a useless pid is returned. Otherwise works like *spawn_opt/4*.

```
spawn_opt(Module, Function, Args, Options) ->
             pid() | {pid(), reference()}
```

Types:

```
Module = module()
Function = atom()
Args = [term()]
Options = [Option]
Option =
    link |
    monitor |
    {priority, Level :: priority_level()} |
    {fullsweep_after, Number :: integer() >= 0} |
    {min_heap_size, Size :: integer() >= 0} |
    {min_bin_vheap_size, VSize :: integer() >= 0}
priority_level() = low | normal | high | max
```

Works as *spawn/3*, except that an extra option list is given when creating the process.

If option `monitor` is given, the newly created process is monitored, and both the pid and reference for the monitor is returned.

The options are as follows:

`link`

Sets a link to the parent process (like `spawn_link/3` does).

`monitor`

Monitors the new process (like *monitor/2* does).

`{priority, Level`

Sets the priority of the new process. Equivalent to executing *process_flag(priority, Level)* in the start function of the new process, except that the priority is set before the process is selected for execution for the first time. For more information on priorities, see *process_flag(priority, Level)*.

`{fullsweep_after, Number}`

Useful only for performance tuning. Do not use this option unless you know that there is problem with execution times or memory consumption, and ensure that the option improves matters.

The Erlang runtime system uses a generational garbage collection scheme, using an "old heap" for data that has survived at least one garbage collection. When there is no more room on the old heap, a fullsweep garbage collection is done.

Option `fullsweep_after` makes it possible to specify the maximum number of generational collections before forcing a fullsweep, even if there is room on the old heap. Setting the number to zero disables the general collection algorithm, that is, all live data is copied at every garbage collection.

A few cases when it can be useful to change `fullsweep_after`:

- If binaries that are no longer used are to be thrown away as soon as possible. (Set `Number` to zero.)
- A process that mostly have short-lived data is fullsweeped seldom or never, that is, the old heap contains mostly garbage. To ensure a fullsweep occasionally, set `Number` to a suitable value, such as 10 or 20.
- In embedded systems with a limited amount of RAM and no virtual memory, you might want to preserve memory by setting `Number` to zero. (The value can be set globally, see *erlang:system_flag/2*.)

`{min_heap_size, Size}`

Useful only for performance tuning. Do not use this option unless you know that there is problem with execution times or memory consumption, and ensure that the option improves matters.

Gives a minimum heap size, in words. Setting this value higher than the system default can speed up some processes because less garbage collection is done. However, setting a too high value can waste memory and slow down the system because of worse data locality. Therefore, use this option only for fine-tuning an application and to measure the execution time with various `Size` values.

`{min_bin_vheap_size, VSize}`

Useful only for performance tuning. Do not use this option unless you know that there is problem with execution times or memory consumption, and ensure that the option improves matters.

Gives a minimum binary virtual heap size, in words. Setting this value higher than the system default can speed up some processes because less garbage collection is done. However, setting a too high value can waste memory. Therefore, use this option only for fine-tuning an application and to measure the execution time with various `VSize` values.

```
spawn_opt(Node, Module, Function, Args, Options) ->
             pid() | {pid(), reference()}
```

Types:

```
Node = node()
Module = module()
Function = atom()
Args = [term()]
Options = [Option]
Option =
    link |
    monitor |
    {priority, Level :: priority_level()} |
    {fullsweep_after, Number :: integer() >= 0} |
    {min_heap_size, Size :: integer() >= 0} |
    {min_bin_vheap_size, VSize :: integer() >= 0}
priority_level() = low | normal | high | max
```

Returns the process identifier (pid) of a new process started by the application of `Module:Function` to `Args` on `Node`. If `Node` does not exist, a useless pid is returned. Otherwise works like *spawn_opt/4*.

> **Note:**
>
> Option `monitor` is not supported by `spawn_opt/5`.

```
split_binary(Bin, Pos) -> {binary(), binary()}
```

Types:

```
Bin = binary()
Pos = integer() >= 0
```

0..byte_size(Bin)

Returns a tuple containing the binaries that are the result of splitting `Bin` into two parts at position `Pos`. This is not a destructive operation. After the operation, there are three binaries altogether.

Example:

```
> B = list_to_binary("0123456789").
<<"0123456789">>
> byte_size(B).
10
> {B1, B2} = split_binary(B,3).
{<<"012">>,<<"3456789">>}
> byte_size(B1).
3
> byte_size(B2).
7
```

**erlang:start_timer(Time, Dest, Msg, Options) -> TimerRef**

Types:

**Time = integer()**
**Dest = pid() | atom()**
**Msg = term()**
**Options = [Option]**
**Abs = boolean()**
**Option = {abs, Abs}**
**TimerRef = reference()**

Starts a timer. When the timer expires, the message `{timeout, TimerRef, Msg}` is sent to the process identified by `Dest`.

Available `Option`s:

`{abs, false}`

This is the default. It means the `Time` value is interpreted as a time in milli-seconds *relative* current *Erlang monotonic time*.

`{abs, true}`

Absolute `Time` value. The `Time` value is interpreted as an absolute Erlang monotonic time in milli-seconds.

More `Option`s may be added in the future.

The absolute point in time, the timer is set to expire on, has to be in the interval [*`erlang:system_info(start_time)`*, *`erlang:system_info(end_time)`*]. Further, if a relative time is specified, the `Time` value is not allowed to be negative.

If `Dest` is a `pid()`, it must be a `pid()` of a process created on the current runtime system instance. This process may or may not have terminated. If `Dest` is an `atom()`, it is interpreted as the name of a locally registered process. The process referred to by the name is looked up at the time of timer expiration. No error is given if the name does not refer to a process.

If `Dest` is a `pid()`, the timer is automatically canceled if the process referred to by the `pid()` is not alive, or if the process exits. This feature was introduced in ERTS version 5.4.11. Notice that timers are not automatically canceled when `Dest` is an `atom()`.

See also *`erlang:send_after/4`*, *`erlang:cancel_timer/2`*, and *`erlang:read_timer/2`*.

Failure: `badarg` if the arguments do not satisfy the requirements specified here.

**erlang:start_timer(Time, Dest, Msg) -> TimerRef**

Types:

```
Time = integer() >= 0
Dest = pid() | atom()
Msg = term()
TimerRef = reference()
```

Starts a timer. The same as calling *erlang:start_timer(Time, Dest, Msg, [])*.

**statistics(Item :: active_tasks) -> [ActiveTasks]**

Types:

```
ActiveTasks = integer() >= 0
```

Returns a list where each element represents the amount of active processes and ports on each run queue and its associated scheduler. That is, the number of processes and ports that are ready to run, or are currently running. The element location in the list corresponds to the scheduler and its run queue. The first element corresponds to scheduler number 1 and so on. The information is *not* gathered atomically. That is, the result is not necessarily a consistent snapshot of the state, but instead quite efficiently gathered. See also, *statistics(total_active_tasks)*, *statistics(run_queue_lengths)*, and *statistics(total_run_queue_lengths)*.

**statistics(Item :: context_switches) -> {ContextSwitches, 0}**

Types:

```
ContextSwitches = integer() >= 0
```

Returns the total number of context switches since the system started.

```
statistics(Item :: exact_reductions) ->
              {Total_Exact_Reductions,
               Exact_Reductions_Since_Last_Call}
```

Types:

```
Total_Exact_Reductions = Exact_Reductions_Since_Last_Call = integer() >= 0
```

Returns the number of exact reductions.

> Note:
>
> `statistics(exact_reductions)` is a more expensive operation than *statistics(reductions)*, especially on an Erlang machine with SMP support.

```
statistics(Item :: garbage_collection) ->
              {Number_of_GCs, Words_Reclaimed, 0}
```

Types:

```
Number_of_GCs = Words_Reclaimed = integer() >= 0
```

Returns information about garbage collection, for example:

```
> statistics(garbage_collection).
{85,23961,0}
```

This information can be invalid for some implementations.

**statistics(Item :: io) -> {{input, Input}, {output, Output}}**

Types:

**Input = Output = integer() >= 0**

Returns `Input`, which is the total number of bytes received through ports, and `Output`, which is the total number of bytes output to ports.

**statistics(Item :: reductions) ->**
**{Total_Reductions, Reductions_Since_Last_Call}**

Types:

**Total_Reductions = Reductions_Since_Last_Call = integer() >= 0**

Returns information about reductions, for example:

```
> statistics(reductions).
{2046,11}
```

Note:

As from `ERTS` 5.5 (OTP R11B), this value does not include reductions performed in current time slices of currently scheduled processes. If an exact value is wanted, use *statistics(exact_reductions)*.

**statistics(Item :: run_queue) -> integer() >= 0**

Returns the total length of the run-queues. That is, the number of processes and ports that are ready to run on all available run-queues. The information is gathered atomically. That is, the result is a consistent snapshot of the state, but this operation is much more expensive compared to *`statistics(total_run_queue_lengths)`*. This especially when a large amount of schedulers is used.

**statistics(Item :: run_queue_lengths) -> [RunQueueLenght]**

Types:

**RunQueueLenght = integer() >= 0**

Returns a list where each element represents the amount of processes and ports ready to run for each run queue. The element location in the list corresponds to the run queue of a scheduler. The first element corresponds to the run queue of scheduler number 1 and so on. The information is *not* gathered atomically. That is, the result is not necessarily a consistent snapshot of the state, but instead quite efficiently gathered. See also, *`statistics(total_run_queue_lengths)`*, *`statistics(active_tasks)`*, and *`statistics(total_active_tasks)`*.

**statistics(Item :: runtime) ->**
**{Total_Run_Time, Time_Since_Last_Call}**

Types:

**Total_Run_Time = Time_Since_Last_Call = integer() >= 0**

Returns information about runtime, in milliseconds.

This is the sum of the runtime for all threads in the Erlang runtime system and can therefore be greater than the wall clock time.

Example:

```
> statistics(runtime).
{1690,1620}
```

**statistics(Item :: scheduler_wall_time) ->**
**[{SchedulerId, ActiveTime, TotalTime}] | undefined**

Types:

**SchedulerId = integer() >= 1**

**ActiveTime = TotalTime = integer() >= 0**

Returns a list of tuples with `{SchedulerId, ActiveTime, TotalTime}`, where `SchedulerId` is an integer ID of the scheduler, `ActiveTime` is the duration the scheduler has been busy, and `TotalTime` is the total time duration since *scheduler_wall_time* activation. The time unit is undefined and can be subject to change between releases, OSs, and system restarts. `scheduler_wall_time` is only to be used to calculate relative values for scheduler-utilization. `ActiveTime` can never exceed `TotalTime`.

The definition of a busy scheduler is when it is not idle and is not scheduling (selecting) a process or port, that is:

- Executing process code
- Executing linked-in-driver or NIF code
- Executing built-in-functions, or any other runtime handling
- Garbage collecting
- Handling any other memory management

Notice that a scheduler can also be busy even if the OS has scheduled out the scheduler thread.

Returns `undefined` if system flag *scheduler_wall_time* is turned off.

The list of scheduler information is unsorted and can appear in different order between calls.

Using `scheduler_wall_time` to calculate scheduler-utilization:

```
> erlang:system_flag(scheduler_wall_time, true).
false
> Ts0 = lists:sort(erlang:statistics(scheduler_wall_time)), ok.
ok
```

Some time later the user takes another snapshot and calculates scheduler-utilization per scheduler, for example:

```
> Ts1 = lists:sort(erlang:statistics(scheduler_wall_time)), ok.
ok
> lists:map(fun({{I, A0, T0}, {I, A1, T1}}) ->
 {I, (A1 - A0)/(T1 - T0)} end, lists:zip(Ts0,Ts1)).
[{1,0.9743474730177548},
 {2,0.9744843782751444},
 {3,0.9995902361669045},
 {4,0.9738012596572161},
 {5,0.9717956667018103},
 {6,0.9739235846420741},
 {7,0.973237033077876},
 {8,0.9741297293248656}]
```

Using the same snapshots to calculate a total scheduler-utilization:

```
> {A, T} = lists:foldl(fun({{_, A0, T0}, {_, A1, T1}}, {Ai,Ti}) ->
 {Ai + (A1 - A0), Ti + (T1 - T0)} end, {0, 0}, lists:zip(Ts0,Ts1)), A/T.
0.9769136803764825
```

> Note:
> `scheduler_wall_time` is by default disabled. To enable it, use `erlang:system_flag(scheduler_wall_time, true)`.

**`statistics(Item :: total_active_tasks) -> ActiveTasks`**

Types:

**`ActiveTasks = integer() >= 0`**

Returns the total amount of active processes and ports in the system. That is, the number of processes and ports that are ready to run, or are currently running. The information is *not* gathered atomically. That is, the result is not necessarily a consistent snapshot of the state, but instead quite efficiently gathered. See also, *`statistics(active_tasks)`*, *`statistics(run_queue_lengths)`*, and *`statistics(total_run_queue_lengths)`*.

**`statistics(Item :: total_run_queue_lengths) ->`**
**`TotalRunQueueLenghts`**

Types:

**`TotalRunQueueLenghts = integer() >= 0`**

Returns the total length of the run-queues. That is, the number of processes and ports that are ready to run on all available run-queues. The information is *not* gathered atomically. That is, the result is not necessarily a consistent snapshot of the state, but much more efficiently gathered compared to *`statistics(run_queue)`*. See also, *`statistics(run_queue_lengths)`*, *`statistics(total_active_tasks)`*, and *`statistics(active_tasks)`*.

**`statistics(Item :: wall_clock) ->`**
**`{Total_Wallclock_Time,`**
**`Wallclock_Time_Since_Last_Call}`**

Types:

**`Total_Wallclock_Time = Wallclock_Time_Since_Last_Call = integer() >= 0`**

Returns information about wall clock. `wall_clock` can be used in the same manner as `runtime`, except that real time is measured as opposed to runtime or CPU time.

**`erlang:suspend_process(Suspendee, OptList) -> boolean()`**

Types:

**`Suspendee = pid()`**

**`OptList = [Opt]`**

**`Opt = unless_suspending | asynchronous`**

Increases the suspend count on the process identified by `Suspendee` and puts it in the suspended state if it is not already in that state. A suspended process will not be scheduled for execution until the process has been resumed.

A process can be suspended by multiple processes and can be suspended multiple times by a single process. A suspended process does not leave the suspended state until its suspend count reaches zero. The suspend count of `Suspendee` is decreased when *erlang:resume_process(Suspendee)* is called by the same process that called `erlang:suspend_process(Suspendee)`. All increased suspend counts on other processes acquired by a process are automatically decreased when the process terminates.

The options (`Opts`) are as follows:

`asynchronous`
: A suspend request is sent to the process identified by `Suspendee`. `Suspendee` eventually suspends unless it is resumed before it could suspend. The caller of `erlang:suspend_process/2` returns immediately, regardless of whether `Suspendee` has suspended yet or not. The point in time when `Suspendee` suspends cannot be deduced from other events in the system. It is only guaranteed that `Suspendee` *eventually* suspends (unless it is resumed). If option `asynchronous` has *not* been passed, the caller of `erlang:suspend_process/2` is blocked until `Suspendee` has suspended.

`unless_suspending`
: The process identified by `Suspendee` is suspended unless the calling process already is suspending `Suspendee`. If `unless_suspending` is combined with option `asynchronous`, a suspend request is sent unless the calling process already is suspending `Suspendee` or if a suspend request already has been sent and is in transit. If the calling process already is suspending `Suspendee`, or if combined with option `asynchronous` and a send request already is in transit, `false` is returned and the suspend count on `Suspendee` remains unchanged.

If the suspend count on the process identified by `Suspendee` is increased, `true` is returned, otherwise `false`.

> **Warning:**
>
> This BIF is intended for debugging only.

Failures:

`badarg`
: If `Suspendee` is not a process identifier.

`badarg`
: If the process identified by `Suspendee` is the same process as the process calling `erlang:suspend_process/2`.

`badarg`
: If the process identified by `Suspendee` is not alive.

`badarg`
: If the process identified by `Suspendee` resides on another node.

`badarg`
: If `OptList` is not a proper list of valid `Opts`.

`system_limit`
: If the process identified by `Suspendee` has been suspended more times by the calling process than can be represented by the currently used internal data structures. The system limit is higher than 2,000,000,000 suspends and will never be lower.

**`erlang:suspend_process(Suspendee) -> true`**

Types:

**`Suspendee = pid()`**

Suspends the process identified by `Suspendee`. The same as calling *erlang:suspend_process(Suspendee, [])*.

> Warning:
>
> This BIF is intended for debugging only.

**erlang:system_flag(Flag :: backtrace_depth, Depth) -> OldDepth**

Types:

**Depth = OldDepth = integer() >= 0**

Sets the maximum depth of call stack back-traces in the exit reason element of `'EXIT'` tuples.

Returns the old value of the flag.

**erlang:system_flag(Flag :: cpu_topology, CpuTopology) ->**
**OldCpuTopology**

Types:

```
CpuTopology = OldCpuTopology = cpu_topology()
cpu_topology() = [LevelEntry :: level_entry()] | undefined
level_entry() =
    {LevelTag :: level_tag(), SubLevel :: sub_level()} |
    {LevelTag :: level_tag(),
     InfoList :: info_list(),
     SubLevel :: sub_level()}
level_tag() = core | node | processor | thread
sub_level() =
    [LevelEntry :: level_entry()] |
    (LogicalCpuId :: {logical, integer() >= 0})
info_list() = []
```

> Warning:
>
> This argument is *deprecated* and scheduled for removal in ERTS 5.10/OTP R16. Instead of using this argument, use command-line argument *+sct* in `erl(1)`.
>
> When this argument is removed, a final CPU topology to use is determined at emulator boot time.

Sets the user-defined `CpuTopology`. The user-defined CPU topology overrides any automatically detected CPU topology. By passing `undefined` as `CpuTopology`, the system reverts to the CPU topology automatically detected. The returned value equals the value returned from `erlang:system_info(cpu_topology)` before the change was made.

Returns the old value of the flag.

The CPU topology is used when binding schedulers to logical processors. If schedulers are already bound when the CPU topology is changed, the schedulers are sent a request to rebind according to the new CPU topology.

The user-defined CPU topology can also be set by passing command-line argument *+sct* to `erl(1)`.

For information on type `CpuTopology` and more, see *erlang:system_info(cpu_topology)* as well as the command-line flags *+sct* and *+sbt* in `erl(1)`.

```
erlang:system_flag(Flag :: dirty_cpu_schedulers_online,
                   DirtyCPUSchedulersOnline) ->
                      OldDirtyCPUSchedulersOnline
```

Types:

```
DirtyCPUSchedulersOnline = OldDirtyCPUSchedulersOnline = integer() >= 1
```

Sets the number of dirty CPU schedulers online. Range is 1 <= DirtyCPUSchedulersOnline <= N, where `N` is the smallest of the return values of `erlang:system_info(dirty_cpu_schedulers)` and `erlang:system_info(schedulers_online)`.

Returns the old value of the flag.

The number of dirty CPU schedulers online can change if the number of schedulers online changes. For example, if 12 schedulers and 6 dirty CPU schedulers are online, and `system_flag/2` is used to set the number of schedulers online to 6, then the number of dirty CPU schedulers online is automatically decreased by half as well, down to 3. Similarly, the number of dirty CPU schedulers online increases proportionally to increases in the number of schedulers online.

> Note:
>
> The dirty schedulers functionality is experimental. Enable support for dirty schedulers when building OTP to try out the functionality.

For more information, see *erlang:system_info(dirty_cpu_schedulers)* and *erlang:system_info(dirty_cpu_schedulers_online)*.

```
erlang:system_flag(Flag :: fullsweep_after, Number) -> OldNumber
```

Types:

```
Number = OldNumber = integer() >= 0
```

Sets system flag `fullsweep_after`. `Number` is a non-negative integer indicating how many times generational garbage collections can be done without forcing a fullsweep collection. The value applies to new processes, while processes already running are not affected.

Returns the old value of the flag.

In low-memory systems (especially without virtual memory), setting the value to `0` can help to conserve memory.

This value can also be set through (OS) environment variable `ERL_FULLSWEEP_AFTER`.

```
erlang:system_flag(Flag :: min_heap_size, MinHeapSize) ->
                      OldMinHeapSize
```

Types:

```
MinHeapSize = OldMinHeapSize = integer() >= 0
```

Sets the default minimum heap size for processes. The size is given in words. The new `min_heap_size` effects only processes spawned after the change of `min_heap_size` has been made. `min_heap_size` can be set for individual processes by using *spawn_opt/N* or *process_flag/2*.

Returns the old value of the flag.

```
erlang:system_flag(Flag :: min_bin_vheap_size, MinBinVHeapSize) ->
                      OldMinBinVHeapSize
```

Types:

```
MinBinVHeapSize = OldMinBinVHeapSize = integer() >= 0
```

Sets the default minimum binary virtual heap size for processes. The size is given in words. The new `min_bin_vhheap_size` effects only processes spawned after the change of `min_bin_vhheap_size` has been made. `min_bin_vheap_size` can be set for individual processes by using *spawn_opt/N* or *process_flag/2*.

Returns the old value of the flag.

```
erlang:system_flag(Flag :: multi_scheduling, BlockState) ->
                      OldBlockState
```

Types:

```
BlockState = block | unblock
OldBlockState = block | unblock | enabled
```

If multi-scheduling is enabled, more than one scheduler thread is used by the emulator. Multi-scheduling can be blocked. When multi-scheduling is blocked, only one scheduler thread schedules Erlang processes.

If `BlockState =:= block`, multi-scheduling is blocked. If `BlockState =:= unblock` and no one else blocks multi-scheduling, and this process has blocked only once, multi-scheduling is unblocked.

One process can block multi-scheduling multiple times. If a process has blocked multiple times, it must unblock exactly as many times as it has blocked before it has released its multi-scheduling block. If a process that has blocked multi-scheduling exits, it releases its blocking of multi-scheduling.

The return values are `disabled`, `blocked`, or `enabled`. The returned value describes the state just after the call to `erlang:system_flag(multi_scheduling, BlockState)` has been made. For information about the return values, see *erlang:system_info(multi_scheduling)*.

> **Note:**
>
> Blocking of multi-scheduling is normally not needed. If you feel that you need to block multi-scheduling, consider it a few more times again. Blocking multi-scheduling is only to be used as a last resort, as it is most likely a *very inefficient* way to solve the problem.

See also *erlang:system_info(multi_scheduling)*, *erlang:system_info(multi_scheduling_blockers)*, and *erlang:system_info(schedulers)*.

```
erlang:system_flag(Flag :: scheduler_bind_type, How) ->
                      OldBindType
```

Types:

```
How = scheduler_bind_type() | default_bind
OldBindType = scheduler_bind_type()
scheduler_bind_type() =
    no_node_processor_spread |
    no_node_thread_spread |
    no_spread |
    processor_spread |
    spread |
    thread_spread |
    thread_no_node_processor_spread |
```

**unbound**

> ### Warning:
>
> This argument is *deprecated* and scheduled for removal in ERTS 5.10/OTP R16. Instead of using this argument, use command-line argument *+sbt* in `erl(1)`. When this argument is removed, a final scheduler bind type to use is determined at emulator boot time.

Controls if and how schedulers are bound to logical processors.

When `erlang:system_flag(scheduler_bind_type, How)` is called, an asynchronous signal is sent to all schedulers online, causing them to try to bind or unbind as requested.

> ### Note:
>
> If a scheduler fails to bind, this is often silently ignored, as it is not always possible to verify valid logical processor identifiers. If an error is reported, it is reported to `error_logger`. To verify that the schedulers have bound as requested, call *erlang:system_info(scheduler_bindings).*

Schedulers can be bound on newer Linux, Solaris, FreeBSD, and Windows systems, but more systems will be supported in future releases.

In order for the runtime system to be able to bind schedulers, the CPU topology must be known. If the runtime system fails to detect the CPU topology automatically, it can be defined. For more information on how to define the CPU topology, see command-line flag *+sct* in `erl(1)`.

The runtime system does by default *not* bind schedulers to logical processors.

> ### Note:
>
> If the Erlang runtime system is the only OS process binding threads to logical processors, this improves the performance of the runtime system. However, if other OS processes (for example, another Erlang runtime system) also bind threads to logical processors, there can be a performance penalty instead. Sometimes this performance penalty can be severe. If so, it is recommended to not bind the schedulers.

Schedulers can be bound in different ways. Argument `How` determines how schedulers are bound and can be any of the following:

`unbound`

Same as command-line argument *+sbt u* in `erl(1)`.

`no_spread`

Same as command-line argument *+sbt ns* in `erl(1)`.

`thread_spread`

Same as command-line argument *+sbt ts* in `erl(1)`.

`processor_spread`

Same as command-line argument *+sbt ps* in `erl(1)`.

`spread`

Same as command-line argument *+sbt s* in `erl(1)`.

`no_node_thread_spread`

Same as command-line argument *+sbt nnts* in `erl(1)`.

`no_node_processor_spread`

Same as command-line argument *+sbt nnps* in `erl(1)`.

`thread_no_node_processor_spread`

Same as command-line argument *+sbt tnnps* in `erl(1)`.

`default_bind`

Same as command-line argument *+sbt db* in `erl(1)`.

The returned value equals `How` before flag `scheduler_bind_type` was changed.

Failures:

`notsup`

If binding of schedulers is not supported.

`badarg`

If `How` is not one of the documented alternatives.

`badarg`

If CPU topology information is unavailable.

The scheduler bind type can also be set by passing command-line argument *+sbt* to `erl(1)`.

For more information, see *erlang:system_info(scheduler_bind_type)*, *erlang:system_info(scheduler_bindings)*, as well as command-line flags *+sbt* and *+sct* in `erl(1)`.

**`erlang:system_flag(Flag :: scheduler_wall_time, Boolean) ->`**
**`OldBoolean`**

Types:

**`Boolean = OldBoolean = boolean()`**

Turns on or off scheduler wall time measurements.

For more information, see *erlang:statistics(scheduler_wall_time)*.

**`erlang:system_flag(Flag :: schedulers_online, SchedulersOnline) ->`**
**`OldSchedulersOnline`**

Types:

**`SchedulersOnline = OldSchedulersOnline = integer() >= 1`**

Sets the number of schedulers online. Range is 1 <= SchedulersOnline <= erlang:system_info(schedulers).

Returns the old value of the flag.

If the emulator was built with support for *dirty schedulers*, changing the number of schedulers online can also change the number of dirty CPU schedulers online. For example, if 12 schedulers and 6 dirty CPU schedulers are online, and `system_flag/2` is used to set the number of schedulers online to 6, then the number of dirty CPU schedulers online is automatically decreased by half as well, down to 3. Similarly, the number of dirty CPU schedulers online increases proportionally to increases in the number of schedulers online.

For more information, see *erlang:system_info(schedulers)* and *erlang:system_info(schedulers_online)*.

**erlang:system_flag(Flag :: trace_control_word, TCW) -> OldTCW**

Types:

**TCW = OldTCW = integer() >= 0**

Sets the value of the node trace control word to `TCW`, which is to be an unsigned integer. For more information, see the function *set_tcw* in Section "Match Specifications in Erlang" in the User's Guide.

Returns the old value of the flag.

**erlang:system_flag(Flag :: time_offset, Value :: finalize) ->**
**OldState**

Types:

**OldState = preliminary | final | volatile**

Finalizes the *time offset* when *single time warp mode* is used. If another time warp mode is used, the time offset state is left unchanged.

Returns the old state identifier. That is:

- If `preliminary` is returned, finalization was performed and the time offset is now final.
- If `final` is returned, the time offset was already in the final state. This either because another `erlang:system_flag(time_offset, finalize)` call, or because *no time warp mode* is used.
- If `volatile` is returned, the time offset cannot be finalized because *multi time warp mode* is used.

**erlang:system_info(Item :: allocated_areas) -> [tuple()]**
**erlang:system_info(Item :: allocator) ->**
**{Allocator, Version, Features, Settings}**
**erlang:system_info(Item :: alloc_util_allocators) -> [Alloc]**
**erlang:system_info(Item :: {allocator, Alloc}) -> [term()]**
**erlang:system_info(Item :: {allocator_sizes, Alloc}) -> [term()]**

Types:

```
Allocator = undefined | glibc
Version = [integer() >= 0]
Features = [atom()]
Settings =
    [{Subsystem :: atom(),
      [{Parameter :: atom(), Value :: term()}]}]
Alloc = atom()
```

Returns various information about the allocators of the current system (emulator) as specified by `Item`:

`allocated_areas`

Returns a list of tuples with information about miscellaneous allocated memory areas.

Each tuple contains an atom describing the type of memory as first element and the amount of allocated memory in bytes as second element. When information about allocated and used memory is present, also a third element is present, containing the amount of used memory in bytes.

`erlang:system_info(allocated_areas)` is intended for debugging, and the content is highly implementation-dependent. The content of the results therefore changes when needed without prior notice.

Notice that the sum of these values is *not* the total amount of memory allocated by the emulator. Some values are part of other values, and some memory areas are not part of the result. For information about the total amount of memory allocated by the emulator, see *erlang:memory/0,1*.

`allocator`

Returns `{Allocator, Version, Features, Settings}`, where:

- `Allocator` corresponds to the `malloc()` implementation used. If `Allocator` equals `undefined`, the `malloc()` implementation used cannot be identified. `glibc` can be identified.
- `Version` is a list of integers (but not a string) representing the version of the `malloc()` implementation used.
- `Features` is a list of atoms representing the allocation features used.
- `Settings` is a list of subsystems, their configurable parameters, and used values. Settings can differ between different combinations of platforms, allocators, and allocation features. Memory sizes are given in bytes.

See also "System Flags Effecting erts_alloc" in *erts_alloc(3)*.

`alloc_util_allocators`

Returns a list of the names of all allocators using the `ERTS` internal `alloc_util` framework as atoms. For more information, see Section *"The alloc_util framework" in erts_alloc(3)*.

`{allocator, Alloc}`

Returns information about the specified allocator. As from `ERTS` 5.6.1, the return value is a list of `{instance, InstanceNo, InstanceInfo}` tuples, where `InstanceInfo` contains information about a specific instance of the allocator. As from `ERTS` 5.10.4, the returned list when calling `erlang:system_info({allocator, mseg_alloc})` also includes an `{erts_mmap, _}` tuple as one element in the list. If `Alloc` is not a recognized allocator, `undefined` is returned. If `Alloc` is disabled, `false` is returned.

Notice that the information returned is highly implementation-dependent and can be changed or removed at any time without prior notice. It was initially intended as a tool when developing new allocators, but as it can be of interest for others it has been briefly documented.

The recognized allocators are listed in *erts_alloc(3)*. After reading the `erts_alloc(3)` documentation, the returned information more or less speaks for itself, but it can be worth explaining some things. Call counts are presented by two values, the first value is giga calls, and the second value is calls. `mbcs` and `sbcs` denote multi-block carriers, and single-block carriers, respectively. Sizes are presented in bytes. When a size is not presented, it is the amount of something. Sizes and amounts are often presented by three values:

- The first is the current value.
- The second is the maximum value since the last call to `erlang:system_info({allocator, Alloc})`.
- The third is the maximum value since the emulator was started.

If only one value is present, it is the current value. `fix_alloc` memory block types are presented by two values. The first value is the memory pool size and the second value is the used memory size.

`{allocator_sizes, Alloc}`

Returns various size information for the specified allocator. The information returned is a subset of the information returned by *`erlang:system_info({allocator, Alloc})`*.

```
erlang:system_info(Item :: cpu_topology) -> CpuTopology
erlang:system_info(Item ::
                       {cpu_topology, defined | detected | used}) ->
```

**CpuTopology**

Types:

```
CpuTopology = cpu_topology()
cpu_topology() = [LevelEntry :: level_entry()] | undefined
```

All `LevelEntry`s of a list must contain the same `LevelTag`, except on the top level where both `node` and `processor` `LevelTag`s can coexist.

```
level_entry() =
    {LevelTag :: level_tag(), SubLevel :: sub_level()} |
    {LevelTag :: level_tag(),
     InfoList :: info_list(),
     SubLevel :: sub_level()}
{LevelTag, SubLevel} == {LevelTag, [], SubLevel}
level_tag() = core | node | processor | thread
```

More `LevelTag`s can be introduced in a future release.

```
sub_level() =
    [LevelEntry :: level_entry()] |
    (LogicalCpuId :: {logical, integer() >= 0})
info_list() = []
```

The `info_list()` can be extended in a future release.

Returns various information about the CPU topology of the current system (emulator) as specified by `Item`:

`cpu_topology`

Returns the `CpuTopology` currently used by the emulator. The CPU topology is used when binding schedulers to logical processors. The CPU topology used is the *user-defined CPU topology*, if such exists, otherwise the *automatically detected CPU topology*, if such exists. If no CPU topology exists, `undefined` is returned.

`node` refers to Non-Uniform Memory Access (NUMA) nodes. `thread` refers to hardware threads (for example, Intel hyper-threads).

A level in term `CpuTopology` can be omitted if only one entry exists and `InfoList` is empty.

`thread` can only be a sub level to `core`. `core` can be a sub level to `processor` or `node`. `processor` can be on the top level or a sub level to `node`. `node` can be on the top level or a sub level to `processor`. That is, NUMA nodes can be processor internal or processor external. A CPU topology can consist of a mix of processor internal and external NUMA nodes, as long as each logical CPU belongs to *one* NUMA node. Cache hierarchy is not part of the `CpuTopology` type, but will be in a future release. Other things can also make it into the CPU topology in a future release. In other words, expect the `CpuTopology` type to change.

`{cpu_topology, defined}`

Returns the user-defined `CpuTopology`. For more information, see command-line flag *+sct* in `erl(1)` and argument *cpu_topology*.

`{cpu_topology, detected}`

Returns the automatically detected `CpuTopologyy`. The emulator detects the CPU topology on some newer Linux, Solaris, FreeBSD, and Windows systems. On Windows system with more than 32 logical processors, the CPU topology is not detected.

For more information, see argument *cpu_topology*.

`{cpu_topology, used}`

Returns `CpuTopology` used by the emulator. For more information, see argument *cpu_topology*.

```
erlang:system_info(Item :: build_type) ->
                      opt |
                      debug |
                      purify |
                      quantify |
                      purecov |
                      gcov |
                      valgrind |
                      gprof |
                      lcnt |
                      frmptr
erlang:system_info(Item :: c_compiler_used) -> {atom(), term()}
erlang:system_info(Item :: check_io) -> [term()]
erlang:system_info(Item :: compat_rel) -> integer()
erlang:system_info(Item :: creation) -> integer()
erlang:system_info(Item :: debug_compiled) -> boolean()
erlang:system_info(Item :: delayed_node_table_gc) ->
                      infinity | integer() >= 0
erlang:system_info(Item :: dirty_cpu_schedulers) ->
                      integer() >= 0
erlang:system_info(Item :: dirty_cpu_schedulers_online) ->
                      integer() >= 0
erlang:system_info(Item :: dirty_io_schedulers) ->
                      integer() >= 0
erlang:system_info(Item :: dist) -> binary()
erlang:system_info(Item :: dist_buf_busy_limit) ->
                      integer() >= 0
erlang:system_info(Item :: dist_ctrl) ->
                      {Node :: node(),
                       ControllingEntity :: port() | pid()}
erlang:system_info(Item :: driver_version) -> string()
erlang:system_info(Item :: dynamic_trace) ->
                      none | dtrace | systemtap
erlang:system_info(Item :: dynamic_trace_probes) -> boolean()
erlang:system_info(Item :: elib_malloc) -> false
erlang:system_info(Item :: eager_check_io) -> boolean()
erlang:system_info(Item :: ets_limit) -> integer() >= 1
erlang:system_info(Item :: fullsweep_after) ->
                      {fullsweep_after, integer() >= 0}
erlang:system_info(Item :: garbage_collection) ->
                      [{atom(), integer()}]
erlang:system_info(Item :: heap_sizes) -> [integer() >= 0]
erlang:system_info(Item :: heap_type) -> private
erlang:system_info(Item :: info) -> binary()
erlang:system_info(Item :: kernel_poll) -> boolean()
erlang:system_info(Item :: loaded) -> binary()
erlang:system_info(Item ::
```

```
                       logical_processors |
                       logical_processors_available |
                       logical_processors_online) ->
                      unknown | integer() >= 1
erlang:system_info(Item :: machine) -> string()
erlang:system_info(Item :: min_heap_size) ->
                      {min_heap_size,
                       MinHeapSize :: integer() >= 1}
erlang:system_info(Item :: min_bin_vheap_size) ->
                      {min_bin_vheap_size,
                       MinBinVHeapSize :: integer() >= 1}
erlang:system_info(Item :: modified_timing_level) ->
                      integer() | undefined
erlang:system_info(Item :: multi_scheduling) ->
                      disabled | blocked | enabled
erlang:system_info(Item :: multi_scheduling_blockers) ->
                      [Pid :: pid()]
erlang:system_info(Item :: nif_version) -> string()
erlang:system_info(Item :: otp_release) -> string()
erlang:system_info(Item :: os_monotonic_time_source) ->
                      [{atom(), term()}]
erlang:system_info(Item :: os_system_time_source) ->
                      [{atom(), term()}]
erlang:system_info(Item :: port_count) -> integer() >= 0
erlang:system_info(Item :: port_limit) -> integer() >= 1
erlang:system_info(Item :: process_count) -> integer() >= 1
erlang:system_info(Item :: process_limit) -> integer() >= 1
erlang:system_info(Item :: procs) -> binary()
erlang:system_info(Item :: scheduler_bind_type) ->
                      spread |
                      processor_spread |
                      thread_spread |
                      thread_no_node_processor_spread |
                      no_node_processor_spread |
                      no_node_thread_spread |
                      no_spread |
                      unbound
erlang:system_info(Item :: scheduler_bindings) -> tuple()
erlang:system_info(Item :: scheduler_id) ->
                      SchedulerId :: integer() >= 1
erlang:system_info(Item :: schedulers | schedulers_online) ->
```

```
                      integer() >= 1
erlang:system_info(Item :: smp_support) -> boolean()
erlang:system_info(Item :: start_time) -> integer()
erlang:system_info(Item :: system_version) -> string()
erlang:system_info(Item :: system_architecture) -> string()
erlang:system_info(Item :: threads) -> boolean()
erlang:system_info(Item :: thread_pool_size) -> integer() >= 0
erlang:system_info(Item :: time_correction) -> true | false
erlang:system_info(Item :: time_offset) ->
                      preliminary | final | volatile
erlang:system_info(Item :: time_warp_mode) ->
                      no_time_warp |
                      single_time_warp |
                      multi_time_warp
erlang:system_info(Item :: tolerant_timeofday) ->
                      enabled | disabled
erlang:system_info(Item :: trace_control_word) ->
                      integer() >= 0
erlang:system_info(Item :: update_cpu_info) -> changed | unchanged
erlang:system_info(Item :: version) -> string()
erlang:system_info(Item ::
                       wordsize |
                       {wordsize, internal} |
                       {wordsize, external}) ->
                      4 | 8
```

Returns various information about the current system (emulator) as specified by `Item`:

`allocated_areas`, `allocator`, `alloc_util_allocators`, `allocator_sizes`

See *above*.

`build_type`

Returns an atom describing the build type of the runtime system. This is normally the atom `opt` for optimized. Other possible return values are `debug`, `purify`, `quantify`, `purecov`, `gcov`, `valgrind`, `gprof`, and `lcnt`. Possible return values can be added or removed at any time without prior notice.

`c_compiler_used`

Returns a two-tuple describing the C compiler used when compiling the runtime system. The first element is an atom describing the name of the compiler, or `undefined` if unknown. The second element is a term describing the version of the compiler, or `undefined` if unknown.

`check_io`

Returns a list containing miscellaneous information about the emulators internal I/O checking. Notice that the content of the returned list can vary between platforms and over time. It is only guaranteed that a list is returned.

`compat_rel`

Returns the compatibility mode of the local node as an integer. The integer returned represents the Erlang/OTP release that the current emulator has been set to be backward compatible with. The compatibility mode can be configured at startup by using command-line flag *+R* in `erl(1)`.

`cpu_topology`

See *above*.

`creation`

Returns the creation of the local node as an integer. The creation is changed when a node is restarted. The creation of a node is stored in process identifiers, port identifiers, and references. This makes it (to some extent) possible to distinguish between identifiers from different incarnations of a node. The valid creations are integers in the range 1..3, but this will probably change in a future release. If the node is not alive, `0` is returned.

`debug_compiled`

Returns `true` if the emulator has been debug compiled, otherwise `false`.

`delayed_node_table_gc`

Returns the amount of time in seconds garbage collection of an entry in a node table is delayed. This limit can be set on startup by passing the command line flag *+zdntgc* to `erl`. For more information see the documentation of the command line flag.

`dirty_cpu_schedulers`

Returns the number of dirty CPU scheduler threads used by the emulator. Dirty CPU schedulers execute CPU-bound native functions, such as NIFs, linked-in driver code, and BIFs that cannot be managed cleanly by the normal emulator schedulers.

The number of dirty CPU scheduler threads is determined at emulator boot time and cannot be changed after that. However, the number of dirty CPU scheduler threads online can be changed at any time. The number of dirty CPU schedulers can be set at startup by passing command-line flag *+SDcpu* or *+SDPcpu* in `erl(1)`.

Notice that the dirty schedulers functionality is experimental. Enable support for dirty schedulers when building OTP to try out the functionality.

See also *erlang:system_flag(dirty_cpu_schedulers_online, DirtyCPUSchedulersOnline)*, *erlang:system_info(dirty_cpu_schedulers_online)*, *erlang:system_info(dirty_io_schedulers)*, *erlang:system_info(schedulers)*, *erlang:system_info(schedulers_online)*, and *erlang:system_flag(schedulers_online, SchedulersOnline)*.

`dirty_cpu_schedulers_online`

Returns the number of dirty CPU schedulers online. The return value satisfies `1 <= DirtyCPUSchedulersOnline <= N`, where `N` is the smallest of the return values of `erlang:system_info(dirty_cpu_schedulers)` and `erlang:system_info(schedulers_online)`.

The number of dirty CPU schedulers online can be set at startup by passing command-line flag *+SDcpu* in `erl(1)`.

Notice that the dirty schedulers functionality is experimental. Enable support for dirty schedulers when building OTP to try out the functionality.

For more information, see *erlang:system_info(dirty_cpu_schedulers)*, *erlang:system_info(dirty_io_schedulers)*, *erlang:system_info(schedulers_online)*, and *erlang:system_flag(dirty_cpu_schedulers_online, DirtyCPUSchedulersOnline)*.

`dirty_io_schedulers`

Returns the number of dirty I/O schedulers as an integer. Dirty I/O schedulers execute I/O-bound native functions, such as NIFs and linked-in driver code, which cannot be managed cleanly by the normal emulator schedulers.

This value can be set at startup by passing command-line argument *+SDio* in `erl(1)`.

Notice that the dirty schedulers functionality is experimental. Enable support for dirty schedulers when building OTP to try out the functionality.

For more information, see *erlang:system_info(dirty_cpu_schedulers)*, *erlang:system_info(dirty_cpu_schedulers_online)*, and *erlang:system_flag(dirty_cpu_schedulers_online, DirtyCPUSchedulersOnline)*.

`dist`

Returns a binary containing a string of distribution information formatted as in Erlang crash dumps. For more information, see Section *"How to interpret the Erlang crash dumps"* in the User's Guide.

`dist_buf_busy_limit`

Returns the value of the distribution buffer busy limit in bytes. This limit can be set at startup by passing command-line flag *+zdbbl* to `erl`.

`dist_ctrl`

Returns a list of tuples `{Node, ControllingEntity}`, one entry for each connected remote node. `Node` is the node name and `ControllingEntity` is the port or process identifier responsible for the communication to that node. More specifically, `ControllingEntity` for nodes connected through TCP/IP (the normal case) is the socket used in communication with the specific node.

`driver_version`

Returns a string containing the Erlang driver version used by the runtime system. It has the form *"<major ver>.<minor ver>"*.

`dynamic_trace`

Returns an atom describing the dynamic trace framework compiled into the virtual machine. It can be `dtrace`, `systemtap`, or `none`. For a commercial or standard build, it is always `none`. The other return values indicate a custom configuration (for example, `./configure --with-dynamic-trace=dtrace`). For more information about dynamic tracing, see the *dyntrace* manual page and the `README.dtrace`/`README.systemtap` files in the Erlang source code top directory.

`dynamic_trace_probes`

Returns a `boolean()` indicating if dynamic trace probes (`dtrace` or `systemtap`) are built into the emulator. This can only be `true` if the Virtual Machine was built for dynamic tracing (that is, `system_info(dynamic_trace)` returns `dtrace` or `systemtap`).

`end_time`

The last *Erlang monotonic time* in `native` *time unit* that can be represented internally in the current Erlang runtime system instance. The time between the *start time* and the end time is at least a quarter of a millennium.

`elib_malloc`

This option will be removed in a future release. The return value will always be `false`, as the `elib_malloc` allocator has been removed.

`eager_check_io`

Returns the value of the `erl` command line flag *+secio* which is either `true` or `false`. See the documentation of the command line flag for information about the different values.

`ets_limit`

Returns the maximum number of ETS tables allowed. This limit can be increased at startup by passing command-line flag *+e* to `erl(1)` or by setting environment variable `ERL_MAX_ETS_TABLES` before starting the Erlang runtime system.

`fullsweep_after`

Returns `{fullsweep_after, integer() >= 0}`, which is the `fullsweep_after` garbage collection setting used by default. For more information, see `garbage_collection` described in the following.

`garbage_collection`

Returns a list describing the default garbage collection settings. A process spawned on the local node by a `spawn` or `spawn_link` uses these garbage collection settings. The default settings can be changed by using *system_flag/2*. *spawn_opt/4* can spawn a process that does not use the default settings.

`heap_sizes`

Returns a list of integers representing valid heap sizes in words. All Erlang heaps are sized from sizes in this list.

`heap_type`

Returns the heap type used by the current emulator. One heap type exists:

`private`

Each process has a heap reserved for its use and no references between heaps of different processes are allowed. Messages passed between processes are copied between heaps.

`info`

Returns a binary containing a string of miscellaneous system information formatted as in Erlang crash dumps. For more information, see Section *"How to interpret the Erlang crash dumps"* in the User's Guide.

`kernel_poll`

Returns `true` if the emulator uses some kind of kernel-poll implementation, otherwise `false`.

`loaded`

Returns a binary containing a string of loaded module information formatted as in Erlang crash dumps. For more information, see Section *"How to interpret the Erlang crash dumps"* in the User's Guide.

`logical_processors`

Returns the detected number of logical processors configured in the system. The return value is either an integer, or the atom `unknown` if the emulator cannot detect the configured logical processors.

`logical_processors_available`

Returns the detected number of logical processors available to the Erlang runtime system. The return value is either an integer, or the atom `unknown` if the emulator cannot detect the available logical processors. The number of available logical processors is less than or equal to the number of *logical processors online*.

`logical_processors_online`

Returns the detected number of logical processors online on the system. The return value is either an integer, or the atom `unknown` if the emulator cannot detect logical processors online. The number of logical processors online is less than or equal to the number of *logical processors configured*.

`machine`

Returns a string containing the Erlang machine name.

`min_heap_size`

Returns `{min_heap_size, MinHeapSize}`, where `MinHeapSize` is the current system-wide minimum heap size for spawned processes.

`min_bin_vheap_size`

Returns `{min_bin_vheap_size, MinBinVHeapSize}`, where `MinBinVHeapSize` is the current system-wide minimum binary virtual heap size for spawned processes.

`modified_timing_level`

Returns the modified timing-level (an integer) if modified timing is enabled, otherwise, `undefined`. For more information about modified timing, see command-line flag *+T* in `erl(1)`

`multi_scheduling`

Returns `disabled`, `blocked`, or `enabled`:

`disabled`

The emulator has only one scheduler thread. The emulator does not have SMP support, or have been started with only one scheduler thread.

`blocked`

The emulator has more than one scheduler thread, but all scheduler threads except one are blocked, that is, only one scheduler thread schedules Erlang processes and executes Erlang code.

`enabled`

The emulator has more than one scheduler thread, and no scheduler threads are blocked, that is, all available scheduler threads schedule Erlang processes and execute Erlang code.

See also *erlang:system_flag(multi_scheduling, BlockState)*, *erlang:system_info(multi_scheduling_blockers)*, and *erlang:system_info(schedulers)*.

`multi_scheduling_blockers`

Returns a list of `Pid`s when multi-scheduling is blocked, otherwise the empty list is returned. The `Pid`s in the list represent all the processes currently blocking multi-scheduling. A `Pid` occurs only once in the list, even if the corresponding process has blocked multiple times.

See also *erlang:system_flag(multi_scheduling, BlockState)*, *erlang:system_info(multi_scheduling)*, and *erlang:system_info(schedulers)*.

`nif_version`

Returns a string containing the version of the Erlang NIF interface used by the runtime system. It is on the form "<major ver>.<minor ver>".

`otp_release`

Returns a string containing the OTP release number of the OTP release that the currently executing `ERTS` application is part of.

As from OTP 17, the OTP release number corresponds to the major OTP version number. No `erlang:system_info()` argument gives the exact OTP version. This is because the exact OTP version in the general case is difficult to determine. For more information, see the description of versions in *System principles* in System Documentation.

`os_monotonic_time_source`

Returns a list containing information about the source of *OS monotonic time* that is used by the runtime system.

If `[]` is returned, no OS monotonic time is available. The list contains two-tuples with `Key`s as first element, and `Value`s as second element. The order of these tuples is undefined. The following tuples can be part of the list, but more tuples can be introduced in the future:

`{function, Function}`

`Function` is the name of the function used. This tuple always exist if OS monotonic time is available to the runtime system.

`{clock_id, ClockId}`

This tuple only exist if `Function` can be used with different clocks. `ClockId` corresponds to the clock identifier used when calling `Function`.

`{resolution, OsMonotonicTimeResolution}`

Highest possible *resolution* of current OS monotonic time source as parts per second. If no resolution information can be retrieved from the OS, `OsMonotonicTimeResolution` is set to the resolution of the time unit of `Function`s return value. That is, the actual resolution can be lower than `OsMonotonicTimeResolution`. Also note that the resolution does not say anything about the *accuracy*, and whether the *precision* do align with the resolution. You do, however, know that the precision is not better than `OsMonotonicTimeResolution`.

`{extended, Extended}`

`Extended` equals `yes` if the range of time values has been extended; otherwise, `Extended` equals `no`. The range needs to be extended if `Function` returns values that wrap fast. This typically is the case when the return value is a 32-bit value.

`{parallel, Parallel}`

`Parallel` equals `yes` if `Function` is called in parallel from multiple threads. If it is not called in parallel, because calls needs to be serialized, `Parallel` equals `no`.

`{time, OsMonotonicTime}`

`OsMonotonicTime` equals current OS monotonic time in `native` *time unit*.

`os_system_time_source`

Returns a list containing information about the source of *OS system time* that is used by the runtime system.

The list contains two-tuples with `Key`s as first element, and `Value`s as second element. The order if these tuples is undefined. The following tuples can be part of the list, but more tuples can be introduced in the future:

`{function, Function}`

`Function` is the name of the funcion used.

`{clock_id, ClockId}`

This tuple only exist if `Function` can be used with different clocks. `ClockId` corresponds to the clock identifier used when calling `Function`.

`{resolution, OsSystemTimeResolution}`

Highest possible *resolution* of current OS system time source as parts per second. If no resolution information can be retrieved from the OS, `OsSystemTimeResolution` is set to the resolution of the time unit of `Function`s return value. That is, the actual resolution may be lower than `OsSystemTimeResolution`. Also note that the resolution does not say anything about the *accuracy*, and whether the *precision* do align with the resolution. You do, however, know that the precision is not better than `OsSystemTimeResolution`.

`{parallel, Parallel}`

`Parallel` equals `yes` if `Function` is called in parallel from multiple threads. If it is not called in parallel, because calls needs to be serialized, `Parallel` equals `no`.

`{time, OsSystemTime}`

`OsSystemTime` equals current OS system time in `native` *time unit*.

`port_parallelism`

Returns the default port parallelism scheduling hint used. For more information, see command-line argument *+spp* in `erl(1)`.

`port_count`

Returns the number of ports currently existing at the local node. The value is given as an integer. This is the same value as returned by `length(erlang:ports())`, but more efficient.

`port_limit`

Returns the maximum number of simultaneously existing ports at the local node as an integer. This limit can be configured at startup by using command-line flag *+Q* in `erl(1)`.

`process_count`

Returns the number of processes currently existing at the local node. The value is given as an integer. This is the same value as returned by `length(processes())`, but more efficient.

`process_limit`

Returns the maximum number of simultaneously existing processes at the local node. The value is given as an integer. This limit can be configured at startup by using command-line flag *+P* in `erl(1)`.

`procs`

Returns a binary containing a string of process and port information formatted as in Erlang crash dumps. For more information, see Section *"How to interpret the Erlang crash dumps"* in the User's Guide.

`scheduler_bind_type`

Returns information about how the user has requested schedulers to be bound or not bound.

Notice that even though a user has requested schedulers to be bound, they can silently have failed to bind. To inspect the scheduler bindings, call *erlang:system_info(scheduler_bindings)*.

For more information, see command-line argument *+sbt* in `erl(1)` and *erlang:system_info(scheduler_bindings)*.

`scheduler_bindings`

Returns information about the currently used scheduler bindings.

A tuple of a size equal to *erlang:system_info(schedulers)* is returned. The tuple elements are integers or the atom `unbound`. Logical processor identifiers are represented as integers. The `N`th element of the tuple equals the current binding for the scheduler with the scheduler identifier equal to `N`. For example, if the schedulers are bound, `element(erlang:system_info(scheduler_id), erlang:system_info(scheduler_bindings))` returns the identifier of the logical processor that the calling process is executing on.

Notice that only schedulers online can be bound to logical processors.

For more information, see command-line argument *+sbt* in `erl(1)` and *erlang:system_info(schedulers_online)*.

`scheduler_id`

Returns the scheduler ID (`SchedulerId`) of the scheduler thread that the calling process is executing on. `SchedulerId` is a positive integer, where `1 <= SchedulerId <= erlang:system_info(schedulers)`. See also *erlang:system_info(schedulers)*.

`schedulers`

Returns the number of scheduler threads used by the emulator. Scheduler threads online schedules Erlang processes and Erlang ports, and execute Erlang code and Erlang linked-in driver code.

The number of scheduler threads is determined at emulator boot time and cannot be changed later. However, the number of schedulers online can be changed at any time.

See also *erlang:system_flag(schedulers_online, SchedulersOnline)*, *erlang:system_info(schedulers_online)*, *erlang:system_info(scheduler_id)*, *erlang:system_flag(multi_scheduling, BlockState)*, *erlang:system_info(multi_scheduling)*, and *erlang:system_info(multi_scheduling_blockers)*.

`schedulers_online`

Returns the number of schedulers online. The scheduler identifiers of schedulers online satisfy the relationship `1 <= SchedulerId <= erlang:system_info(schedulers_online)`.

For more information, see *erlang:system_info(schedulers)* and *erlang:system_flag(schedulers_online, SchedulersOnline)*.

`smp_support`

Returns `true` if the emulator has been compiled with SMP support, otherwise `false` is returned.

`start_time`

The *Erlang monotonic time* in `native` *time unit* at the time when current Erlang runtime system instance started. See also *`erlang:system_info(end_time)`*.

`system_version`

Returns a string containing version number and some important properties, such as the number of schedulers.

`system_architecture`

Returns a string containing the processor and OS architecture the emulator is built for.

`threads`

Returns `true` if the emulator has been compiled with thread support, otherwise `false` is returned.

`thread_pool_size`

Returns the number of async threads in the async thread pool used for asynchronous driver calls (*driver_async()*). The value is given as an integer.

`time_correction`

Returns a boolean value indicating whether *time correction* is enabled or not.

`time_offset`

Returns the state of the time offset:

`preliminary`

The time offset is preliminary, and will be changed at a later time when being finalized. The preliminary time offset is used during the preliminary phase of the *single time warp mode*.

`final`

The time offset is final. This either because *no time warp mode* is used, or because the time offset have been finalized when *single time warp mode* is used.

`volatile`

The time offset is volatile. That is, it can change at any time. This is because *multi time warp mode* is used.

`time_warp_mode`

Returns a value identifying the *time warp mode* being used:

`no_time_warp`

The *no time warp mode* is used.

`single_time_warp`

The *single time warp mode* is used.

`multi_time_warp`

The *multi time warp mode* is used.

`tolerant_timeofday`

Returns whether a pre erts-7.0 backwards compatible compensation for sudden changes of system time is `enabled` or `disabled`. Such compensation is `enabled` when the *time offset* is `final`, and *time correction* is enabled.

`trace_control_word`

Returns the value of the node trace control word. For more information, see function `get_tcw` in Section *Match Specifications in Erlang* in the User's Guide.

`update_cpu_info`

The runtime system rereads the CPU information available and updates its internally stored information about the *detected CPU topology* and the number of logical processors *configured*, *online*, and *available*.

If the CPU information has changed since the last time it was read, the atom `changed` is returned, otherwise the atom `unchanged`. If the CPU information has changed, you probably want to *adjust the number of schedulers online*. You typically want to have as many schedulers online as *logical processors available*.

`version`

Returns a string containing the version number of the emulator.

`wordsize`

Same as `{wordsize, internal}`.

`{wordsize, internal}`

Returns the size of Erlang term words in bytes as an integer, that is, 4 is returned on a 32-bit architecture, and 8 is returned on a pure 64-bit architecture. On a halfword 64-bit emulator, 4 is returned, as the Erlang terms are stored using a virtual word size of half the system word size.

`{wordsize, external}`

Returns the true word size of the emulator, that is, the size of a pointer. The value is given in bytes as an integer. On a pure 32-bit architecture, 4 is returned. On both a half word and on a pure 64-bit architecture, 8 is returned.

> ### Note:
>
> Argument `scheduler` has changed name to `scheduler_id` to avoid mix up with argument `schedulers`. Argument `scheduler` was introduced in ERTS 5.5 and renamed in ERTS 5.5.1.

**`erlang:system_monitor() -> MonSettings`**

Types:

```
MonSettings = undefined | {MonitorPid, Options}
MonitorPid = pid()
Options = [system_monitor_option()]
system_monitor_option() =
    busy_port |
    busy_dist_port |
    {long_gc, integer() >= 0} |
    {long_schedule, integer() >= 0} |
    {large_heap, integer() >= 0}
```

Returns the current system monitoring settings set by *erlang:system_monitor/2* as `{MonitorPid, Options}`, or `undefined` if there are no settings. The order of the options can be different from the one that was set.

**erlang:system_monitor(Arg) -> MonSettings**

Types:

```
Arg = MonSettings = undefined | {MonitorPid, Options}
MonitorPid = pid()
Options = [system_monitor_option()]
system_monitor_option() =
    busy_port |
    busy_dist_port |
    {long_gc, integer() >= 0} |
    {long_schedule, integer() >= 0} |
    {large_heap, integer() >= 0}
```

When called with argument `undefined`, all system performance monitoring settings are cleared.

Calling the function with `{MonitorPid, Options}` as argument is the same as calling *erlang:system_monitor(MonitorPid, Options)*.

Returns the previous system monitor settings just like *erlang:system_monitor/0*.

**erlang:system_monitor(MonitorPid, Options) -> MonSettings**

Types:

```
MonitorPid = pid()
Options = [system_monitor_option()]
MonSettings = undefined | {OldMonitorPid, OldOptions}
OldMonitorPid = pid()
OldOptions = [system_monitor_option()]
system_monitor_option() =
    busy_port |
    busy_dist_port |
    {long_gc, integer() >= 0} |
    {long_schedule, integer() >= 0} |
    {large_heap, integer() >= 0}
```

Sets the system performance monitoring options. `MonitorPid` is a local process identifier (pid) receiving system monitor messages. The second argument is a list of monitoring options:

`{long_gc, Time}`

If a garbage collection in the system takes at least `Time` wall clock milliseconds, a message `{monitor, GcPid, long_gc, Info}` is sent to `MonitorPid`. `GcPid` is the pid that was garbage collected. `Info` is a list of two-element tuples describing the result of the garbage collection.

One of the tuples is `{timeout, GcTime}`, where `GcTime` is the time for the garbage collection in milliseconds. The other tuples are tagged with `heap_size`, `heap_block_size stack_size`, `mbuf_size`, `old_heap_size`, and `old_heap_block_size`. These tuples are explained in the description of trace message *gc_start* (see *erlang:trace/3*). New tuples can be added, and the order of the tuples in the `Info` list can be changed at any time without prior notice.

`{long_schedule, Time}`

If a process or port in the system runs uninterrupted for at least `Time` wall clock milliseconds, a message `{monitor, PidOrPort, long_schedule, Info}` is sent to `MonitorPid`. `PidOrPort` is the process or port that was running. `Info` is a list of two-element tuples describing the event.

If a `pid()`, the tuples `{timeout, Millis}`, `{in, Location}`, and `{out, Location}` are present, where `Location` is either an MFA (`{Module, Function, Arity}`) describing the function where the process was scheduled in/out, or the atom `undefined`.

If a `port()`, the tuples `{timeout, Millis}` and `{port_op,Op}` are present. `Op` is one of `proc_sig`, `timeout`, `input`, `output`, `event`, or `dist_cmd`, depending on which driver callback was executing.

`proc_sig` is an internal operation and is never to appear, while the others represent the corresponding driver callbacks `timeout`, `ready_input`, `ready_output`, `event`, and `outputv` (when the port is used by distribution). Value `Millis` in the `timeout` tuple informs about the uninterrupted execution time of the process or port, which always is equal to or higher than the `Time` value supplied when starting the trace. New tuples can be added to the `Info` list in a future release. The order of the tuples in the list can be changed at any time without prior notice.

This can be used to detect problems with NIFs or drivers that take too long to execute. 1 ms is considered a good maximum time for a driver callback or a NIF. However, a time-sharing system is usually to consider everything below 100 ms as "possible" and fairly "normal". However, longer schedule times can indicate swapping or a misbehaving NIF/driver. Misbehaving NIFs and drivers can cause bad resource utilization and bad overall system performance.

`{large_heap, Size}`

If a garbage collection in the system results in the allocated size of a heap being at least `Size` words, a message `{monitor, GcPid, large_heap, Info}` is sent to `MonitorPid`. `GcPid` and `Info` are the same as for `long_gc` earlier, except that the tuple tagged with `timeout` is not present.

As of ERTS 5.6, the monitor message is sent if the sum of the sizes of all memory blocks allocated for all heap generations is equal to or higher than `Size`. Previously the monitor message was sent if the memory block allocated for the youngest generation was equal to or higher than `Size`.

`busy_port`

If a process in the system gets suspended because it sends to a busy port, a message `{monitor, SusPid, busy_port, Port}` is sent to `MonitorPid`. `SusPid` is the pid that got suspended when sending to `Port`.

`busy_dist_port`

If a process in the system gets suspended because it sends to a process on a remote node whose inter-node communication was handled by a busy port, a message `{monitor, SusPid, busy_dist_port, Port}` is sent to `MonitorPid`. `SusPid` is the pid that got suspended when sending through the inter-node communication port `Port`.

Returns the previous system monitor settings just like *erlang:system_monitor/0*.

> Note:
>
> If a monitoring process gets so large that it itself starts to cause system monitor messages when garbage collecting, the messages enlarge the process message queue and probably make the problem worse.
>
> Keep the monitoring process neat and do not set the system monitor limits too tight.

Failures:

`badarg`
If `MonitorPid` does not exist.

`badarg`
If `MonitorPid` is not a local process.

**`erlang:system_profile() -> ProfilerSettings`**

Types:

```
ProfilerSettings = undefined | {ProfilerPid, Options}
ProfilerPid = pid() | port()
Options = [system_profile_option()]
system_profile_option() =
    exclusive |
    runnable_ports |
    runnable_procs |
    scheduler |
    timestamp |
    monotonic_timestamp |
    strict_monotonic_timestamp
```

Returns the current system profiling settings set by *erlang:system_profile/2* as `{ProfilerPid, Options}`, or `undefined` if there are no settings. The order of the options can be different from the one that was set.

**`erlang:system_profile(ProfilerPid, Options) -> ProfilerSettings`**

Types:

```
ProfilerPid = pid() | port() | undefined
Options = [system_profile_option()]
ProfilerSettings =
    undefined | {pid() | port(), [system_profile_option()]}
system_profile_option() =
    exclusive |
    runnable_ports |
    runnable_procs |
    scheduler |
    timestamp |
    monotonic_timestamp |
    strict_monotonic_timestamp
```

Sets system profiler options. `ProfilerPid` is a local process identifier (pid) or port receiving profiling messages. The receiver is excluded from all profiling. The second argument is a list of profiling options:

`exclusive`

If a synchronous call to a port from a process is done, the calling process is considered not runnable during the call runtime to the port. The calling process is notified as `inactive`, and later `active` when the port callback returns.

`monotonic_timestamp`

Timestamps in profile messages will use *Erlang monotonic time*. The time-stamp (Ts) has the same format and value as produced by `erlang:monotonic_time(nano_seconds)`.

`runnable_procs`

If a process is put into or removed from the run queue, a message, `{profile, Pid, State, Mfa, Ts}`, is sent to `ProfilerPid`. Running processes that are reinserted into the run queue after having been preempted do not trigger this message.

`runnable_ports`

If a port is put into or removed from the run queue, a message, `{profile, Port, State, 0, Ts}`, is sent to `ProfilerPid`.

`scheduler`

If a scheduler is put to sleep or awoken, a message, `{profile, scheduler, Id, State, NoScheds, Ts}`, is sent to `ProfilerPid`.

`strict_monotonic_timestamp`

Timestamps in profile messages will consisting of *Erlang monotonic time* and a monotonically increasing integer. The time-stamp (Ts) has the same format and value as produced by `{erlang:monotonic_time(nano_seconds), erlang:unique_integer([monotonic])}`.

`timestamp`

Timestamps in profile messages will include a time-stamp (Ts) that has the same form as returned by `erlang:now()`. This is also the default if no timestamp flag is given. If `cpu_timestamp` has been enabled via `erlang:trace/3`, this will also effect the timestamp produced in profiling messages when `timestamp` flag is enabled.

> Note:
>
> `erlang:system_profile` is considered experimental and its behavior can change in a future release.

**`erlang:system_time() -> integer()`**

Returns current *Erlang system time* in `native` *time unit*.

Calling `erlang:system_time()` is equivalent to: *`erlang:monotonic_time()`* `+` *`erlang:time_offset()`*.

> Note:
>
> This time is *not* a monotonically increasing time in the general case. For more information, see the documentation of *time warp modes* in the ERTS User's Guide.

**`erlang:system_time(Unit) -> integer()`**

Types:

**`Unit = time_unit()`**

Returns current *Erlang system time* converted into the `Unit` passed as argument.

Calling `erlang:system_time(Unit)` is equivalent to: `erlang:convert_time_unit(erlang:system_time(), native, Unit)`.

> Note:
>
> This time is *not* a monotonically increasing time in the general case. For more information, see the documentation of *time warp modes* in the ERTS User's Guide.

**`term_to_binary(Term) -> ext_binary()`**

Types:

**`Term = term()`**

Returns a binary data object that is the result of encoding `Term` according to the Erlang external term format.

This can be used for various purposes, for example, writing a term to a file in an efficient way, or sending an Erlang term to some type of communications channel not supported by distributed Erlang.

See also *binary_to_term/1*.

**`term_to_binary(Term, Options) -> ext_binary()`**

Types:

```
Term = term()
Options =
    [compressed |
     {compressed, Level :: 0..9} |
     {minor_version, Version :: 0..1}]
```

Returns a binary data object that is the result of encoding `Term` according to the Erlang external term format.

If option `compressed` is provided, the external term format is compressed. The compressed format is automatically recognized by `binary_to_term/1` as from Erlang R7B.

A compression level can be specified by giving option `{compressed, Level}`. `Level` is an integer with range 0..9, where:

- `0` - No compression is done (it is the same as giving no `compressed` option).
- `1` - Takes least time but may not compress as well as the higher levels.
- `6` - Default level when option `compressed` is provided.
- `9` - Takes most time and tries to produce a smaller result. Notice "tries" in the preceding sentence; depending on the input term, level 9 compression either does or does not produce a smaller result than level 1 compression.

Option `{minor_version, Version}` can be used to control some encoding details. This option was introduced in OTP R11B-4. The valid values for `Version` are `0` and `1`.

As from OTP 17.0, `{minor_version, 1}` is the default. It forces any floats in the term to be encoded in a more space-efficient and exact way (namely in the 64-bit IEEE format, rather than converted to a textual representation).

As from OTP R11B-4, `binary_to_term/1` can decode this representation.

`{minor_version, 0}` means that floats are encoded using a textual representation. This option is useful to ensure that releases before OTP R11B-4 can decode resulting binary.

See also *binary_to_term/1*.

### `throw(Any) -> no_return()`

Types:

**`Any = term()`**

A non-local return from a function. If evaluated within a `catch`, `catch` returns value `Any`.

Example:

```
> catch throw({hello, there}).
{hello,there}
```

Failure: `nocatch` if not evaluated within a catch.

### `time() -> Time`

Types:

**`Time = calendar:time()`**

Returns the current time as `{Hour, Minute, Second}`.

The time zone and Daylight Saving Time correction depend on the underlying OS.

Example:

```
> time().
{9,42,44}
```

### `erlang:time_offset() -> integer()`

Returns the current time offset between *Erlang monotonic time* and *Erlang system time* in `native` *time unit*. Current time offset added to an Erlang monotonic time gives corresponding Erlang system time.

The time offset may or may not change during operation depending on the *time warp mode* used.

> **Note:**
>
> A change in time offset may be observed at slightly different points in time by different processes.
>
> If the runtime system is in *multi time warp mode*, the time offset will be changed when the runtime system detects that the *OS system time* has changed. The runtime system will, however, not detect this immediately when it happens. A task checking the time offset is scheduled to execute at least once a minute, so under normal operation this should be detected within a minute, but during heavy load it might take longer time.

### `erlang:time_offset(Unit) -> integer()`

Types:

**Unit = *time_unit()***

Returns the current time offset between *Erlang monotonic time* and *Erlang system time* converted into the `Unit` passed as argument.

Same as calling *`erlang:convert_time_unit(erlang:time_offset(), native, Unit)`* however optimized for commonly used `Unit`s.

**erlang:timestamp() -> Timestamp**

Types:

**Timestamp = *timestamp()***

**timestamp() =**
**{MegaSecs :: integer() >= 0,**
**Secs :: integer() >= 0,**
**MicroSecs :: integer() >= 0}**

Returns current *Erlang system time* on the format `{MegaSecs, Secs, MicroSecs}`. This format is the same as *`os:timestamp/0`* and the deprecated *`erlang:now/0`* uses. The reason for the existence of `erlang:timestamp()` is purely to simplify usage for existing code that assumes this timestamp format. Current Erlang system time can more efficiently be retrieved in the time unit of your choice using *`erlang:system_time/1`*.

The `erlang:timestamp()` BIF is equivalent to:

```
timestamp() ->
    ErlangSystemTime = erlang:system_time(micro_seconds),
    MegaSecs = ErlangSystemTime div 1000000000000,
    Secs = ErlangSystemTime div 1000000 - MegaSecs*1000000,
    MicroSecs = ErlangSystemTime rem 1000000,
    {MegaSecs, Secs, MicroSecs}.
```

It, however, uses a native implementation which does not build garbage on the heap and with slightly better performance.

> **Note:**
>
> This time is *not* a monotonically increasing time in the general case. For more information, see the documentation of *time warp modes* in the ERTS User's Guide.

**tl(List) -> term()**

Types:

**List = [term(), ...]**

Returns the tail of `List`, that is, the list minus the first element, for example:

```
> tl([geesties, guilies, beasties]).
[guilies, beasties]
```

Allowed in guard tests.

Failure: `badarg` if `List` is the empty list `[]`.

**erlang:trace(PidSpec, How, FlagList) -> integer()**

Types:

```
PidSpec = pid() | existing | new | all
How = boolean()
FlagList = [trace_flag()]
trace_flag() =
    all |
    send |
    'receive' |
    procs |
    call |
    silent |
    return_to |
    running |
    exiting |
    garbage_collection |
    timestamp |
    cpu_timestamp |
    monotonic_timestamp |
    strict_monotonic_timestamp |
    arity |
    set_on_spawn |
    set_on_first_spawn |
    set_on_link |
    set_on_first_link |
    {tracer, pid() | port()}
```

Turns on (if `How == true`) or off (if `How == false`) the trace flags in `FlagList` for the process or processes represented by `PidSpec`.

`PidSpec` is either a process identifier (pid) for a local process, or one of the following atoms:

`existing`

All currently existing processes.

`new`

All processes that are created in the future.

`all`

All currently existing processes and all processes that are created in the future.

`FlagList` can contain any number of the following flags (the "message tags" refers to the list of *trace messages*):

`all`

Sets all trace flags except `{tracer, Tracer}` and `cpu_timestamp`, which are in their nature different than the others.

`send`

Traces sending of messages.

Message tags: `send` and `send_to_non_existing_process`.

`'receive'`

Traces receiving of messages.

Message tags: `'receive'`.

`procs`

Traces process-related events.

Message tags: `spawn`, `exit`, `register`, `unregister`, `link`, `unlink`, `getting_linked`, and `getting_unlinked`.

`call`

Traces certain function calls. Specify which function calls to trace by calling *erlang:trace_pattern/3*.

Message tags: `call` and `return_from`.

`silent`

Used with the `call` trace flag. The `call`, `return_from`, and `return_to` trace messages are inhibited if this flag is set, but they are executed as normal if there are match specifications.

Silent mode is inhibited by executing `erlang:trace(_, false, [silent|_])`, or by a match specification executing the function `{silent, false}`.

The `silent` trace flag facilitates setting up a trace on many or even all processes in the system. The trace can then be activated and deactivated using the match specification function `{silent,Bool}`, giving a high degree of control of which functions with which arguments that trigger the trace.

Message tags: `call`, `return_from`, and `return_to`. Or rather, the absence of.

`return_to`

Used with the `call` trace flag. Traces the return from a traced function back to its caller. Only works for functions traced with option `local` to *erlang:trace_pattern/3*.

The semantics is that a trace message is sent when a call traced function returns, that is, when a chain of tail recursive calls ends. Only one trace message is sent per chain of tail recursive calls, so the properties of tail recursiveness for function calls are kept while tracing with this flag. Using `call` and `return_to` trace together makes it possible to know exactly in which function a process executes at any time.

To get trace messages containing return values from functions, use the `{return_trace}` match specification action instead.

Message tags: `return_to`.

`running`

Traces scheduling of processes.

Message tags: `in` and `out`.

`exiting`

Traces scheduling of exiting processes.

Message tags: `in_exiting`, `out_exiting`, and `out_exited`.

`garbage_collection`

Traces garbage collections of processes.

Message tags: `gc_start` and `gc_end`.

`timestamp`

Includes a time-stamp in all trace messages. The time-stamp (Ts) has the same form as returned by `erlang:now()`.

`cpu_timestamp`

A global trace flag for the Erlang node that makes all trace time-stamps using the `timestamp` flag to be in CPU time, not wall clock time. That is, `cpu_timestamp` will not be used if `monotonic_timestamp`, or `strict_monotonic_timestamp` is enabled. Only allowed with `PidSpec==all`. If the host machine OS does not support high-resolution CPU time measurements, `trace/3` exits with `badarg`. Notice that most OS do not synchronize this value across cores, so be prepared that time might seem to go backwards when using this option.

`monotonic_timestamp`

Includes an *Erlang monotonic time* time-stamp in all trace messages. The time-stamp (Ts) has the same format and value as produced by `erlang:monotonic_time(nano_seconds)`. This flag overrides the `cpu_timestamp` flag.

`strict_monotonic_timestamp`

Includes an timestamp consisting of *Erlang monotonic time* and a monotonically increasing integer in all trace messages. The time-stamp (Ts) has the same format and value as produced by `{erlang:monotonic_time(nano_seconds), erlang:unique_integer([monotonic])}`. This flag overrides the `cpu_timestamp` flag.

`arity`

Used with the `call` trace flag. `{M, F, Arity}` is specified instead of `{M, F, Args}` in call trace messages.

`set_on_spawn`

Makes any process created by a traced process inherit its trace flags, including flag `set_on_spawn`.

`set_on_first_spawn`

Makes the first process created by a traced process inherit its trace flags, excluding flag `set_on_first_spawn`.

`set_on_link`

Makes any process linked by a traced process inherit its trace flags, including flag `set_on_link`.

`set_on_first_link`

Makes the first process linked to by a traced process inherit its trace flags, excluding flag `set_on_first_link`.

`{tracer, Tracer}`

Specifies where to send the trace messages. `Tracer` must be the process identifier of a local process or the port identifier of a local port. If this flag is not given, trace messages are sent to the process that called `erlang:trace/3`.

The effect of combining `set_on_first_link` with `set_on_link` is the same as having `set_on_first_link` alone. Likewise for `set_on_spawn` and `set_on_first_spawn`.

The tracing process receives the *trace messages* described in the following list. `Pid` is the process identifier of the traced process in which the traced event has occurred. The third tuple element is the message tag.

If flag `timestamp`, `strict_monotonic_timestamp`, or `monotonic_timestamp` is given, the first tuple element is `trace_ts` instead, and the time-stamp is added as an extra element last in the message tuple. If multiple timestamp flags are passed, `timestamp` has precedence over `strict_monotonic_timestamp` which in turn has precedence over `monotonic_timestamp`. All timestamp flags are remembered, so if two are passed and the one with highest precedence later is disabled the other one will become active.

`{trace, Pid, 'receive', Msg}`

When `Pid` receives message `Msg`.

`{trace, Pid, send, Msg, To}`

When `Pid` sends message `Msg` to process `To`.

`{trace, Pid, send_to_non_existing_process, Msg, To}`

When `Pid` sends message `Msg` to the non-existing process `To`.

`{trace, Pid, call, {M, F, Args}}`

When `Pid` calls a traced function. The return values of calls are never supplied, only the call and its arguments.

Trace flag `arity` can be used to change the contents of this message, so that `Arity` is specified instead of `Args`.

`{trace, Pid, return_to, {M, F, Arity}}`

When `Pid` returns *to* the specified function. This trace message is sent if both the flags `call` and `return_to` are set, and the function is set to be traced on *local* function calls. The message is only sent when returning from a chain of tail recursive function calls, where at least one call generated a `call` trace message (that is, the functions match specification matched, and `{message, false}` was not an action).

`{trace, Pid, return_from, {M, F, Arity}, ReturnValue}`

When `Pid` returns *from* the specified function. This trace message is sent if flag `call` is set, and the function has a match specification with a `return_trace` or `exception_trace` action.

`{trace, Pid, exception_from, {M, F, Arity}, {Class, Value}}`

When `Pid` exits *from* the specified function because of an exception. This trace message is sent if flag `call` is set, and the function has a match specification with an `exception_trace` action.

`{trace, Pid, spawn, Pid2, {M, F, Args}}`

When `Pid` spawns a new process `Pid2` with the specified function call as entry point.

`Args` is supposed to be the argument list, but can be any term if the spawn is erroneous.

`{trace, Pid, exit, Reason}`

When `Pid` exits with reason `Reason`.

`{trace, Pid, link, Pid2}`

When `Pid` links to a process `Pid2`.

`{trace, Pid, unlink, Pid2}`

When `Pid` removes the link from a process `Pid2`.

`{trace, Pid, getting_linked, Pid2}`

When `Pid` gets linked to a process `Pid2`.

`{trace, Pid, getting_unlinked, Pid2}`

When `Pid` gets unlinked from a process `Pid2`.

`{trace, Pid, register, RegName}`

When `Pid` gets the name `RegName` registered.

`{trace, Pid, unregister, RegName}`

When `Pid` gets the name `RegName` unregistered. This is done automatically when a registered process exits.

`{trace, Pid, in, {M, F, Arity} | 0}`

When `Pid` is scheduled to run. The process runs in function `{M, F, Arity}`. On some rare occasions, the current function cannot be determined, then the last element is `0`.

`{trace, Pid, out, {M, F, Arity} | 0}`

When `Pid` is scheduled out. The process was running in function {M, F, Arity}. On some rare occasions, the current function cannot be determined, then the last element is `0`.

`{trace, Pid, gc_start, Info}`

Sent when garbage collection is about to be started. `Info` is a list of two-element tuples, where the first element is a key, and the second is the value. Do not depend on any order of the tuples. The following keys are defined:

`heap_size`
The size of the used part of the heap.

`heap_block_size`
The size of the memory block used for storing the heap and the stack.

`old_heap_size`
The size of the used part of the old heap.

`old_heap_block_size`
The size of the memory block used for storing the old heap.

`stack_size`
The size of the stack.

`recent_size`
The size of the data that survived the previous garbage collection.

`mbuf_size`
The combined size of message buffers associated with the process.

`bin_vheap_size`
The total size of unique off-heap binaries referenced from the process heap.

`bin_vheap_block_size`
The total size of binaries allowed in the virtual heap in the process before doing a garbage collection.

`bin_old_vheap_size`
The total size of unique off-heap binaries referenced from the process old heap.

`bin_old_vheap_block_size`
The total size of binaries allowed in the virtual old heap in the process before doing a garbage collection.

All sizes are in words.

`{trace, Pid, gc_end, Info}`

Sent when garbage collection is finished. `Info` contains the same kind of list as in message `gc_start`, but the sizes reflect the new sizes after garbage collection.

If the tracing process dies, the flags are silently removed.

Only one process can trace a particular process. Therefore, attempts to trace an already traced process fail.

Returns: A number indicating the number of processes that matched `PidSpec`. If `PidSpec` is a process identifier, the return value is `1`. If `PidSpec` is `all` or `existing`, the return value is the number of processes running, excluding tracer processes. If `PidSpec` is `new`, the return value is `0`.

Failure: `badarg` if the specified arguments are not supported. For example, `cpu_timestamp` is not supported on all platforms.

### `erlang:trace_delivered(Tracee) -> Ref`

Types:

```
Tracee = pid() | all
Ref = reference()
```

The delivery of trace messages is dislocated on the time-line compared to other events in the system. If you know that `Tracee` has passed some specific point in its execution, and you want to know

when at least all trace messages corresponding to events up to this point have reached the tracer, use `erlang:trace_delivered(Tracee)`. A `{trace_delivered, Tracee, Ref}` message is sent to the caller of `erlang:trace_delivered(Tracee)` when it is guaranteed that all trace messages are delivered to the tracer up to the point that `Tracee` reached at the time of the call to `erlang:trace_delivered(Tracee)`.

Notice that message `trace_delivered` does *not* imply that trace messages have been delivered. Instead it implies that all trace messages that *are to be delivered* have been delivered. It is not an error if `Tracee` is not, and has not been traced by someone, but if this is the case, *no* trace messages have been delivered when the `trace_delivered` message arrives.

Notice that that `Tracee` must refer to a process currently, or previously existing on the same node as the caller of `erlang:trace_delivered(Tracee)` resides on. The special `Tracee` atom `all` denotes all processes that currently are traced in the node.

Example: Process `A` is `Tracee`, port `B` is tracer, and process `C` is the port owner of `B`. `C` wants to close `B` when `A` exits. To ensure that the trace is not truncated, `C` can call `erlang:trace_delivered(A)`, when `A` exits, and wait for message `{trace_delivered, A, Ref}` before closing `B`.

Failure: `badarg` if `Tracee` does not refer to a process (dead or alive) on the same node as the caller of `erlang:trace_delivered(Tracee)` resides on.

**`erlang:trace_info(PidOrFunc, Item) -> Res`**

Types:

```
PidOrFunc = pid() | new | {Module, Function, Arity} | on_load
Module = module()
Function = atom()
Arity = arity()
Item =
    flags |
    tracer |
    traced |
    match_spec |
    meta |
    meta_match_spec |
    call_count |
    call_time |
    all
Res = trace_info_return()
trace_info_return() =
    undefined |
    {flags, [trace_info_flag()]} |
    {tracer, pid() | port() | []} |
    trace_info_item_result() |
    {all, [trace_info_item_result()] | false | undefined}
trace_info_item_result() =
    {traced, global | local | false | undefined} |
    {match_spec, trace_match_spec() | false | undefined} |
    {meta, pid() | port() | false | undefined | []} |
    {meta_match_spec, trace_match_spec() | false | undefined} |
    {call_count, integer() >= 0 | boolean() | undefined} |
    {call_time,
     [{pid(),
```

```
          integer() >= 0,
          integer() >= 0,
          integer() >= 0}] |
        boolean() |
        undefined}
   trace_info_flag() =
       send |
       'receive' |
       set_on_spawn |
       call |
       return_to |
       procs |
       set_on_first_spawn |
       set_on_link |
       running |
       garbage_collection |
       timestamp |
       monotonic_timestamp |
       strict_monotonic_timestamp |
       arity
   trace_match_spec() = [{[term()] | '_', [term()], [term()]}]
```

Returns trace information about a process or function.

To get information about a process, `PidOrFunc` is to be a process identifier (pid) or the atom `new`. The atom `new` means that the default trace state for processes to be created is returned.

The following `Item`s are valid:

`flags`

Returns a list of atoms indicating what kind of traces is enabled for the process. The list is empty if no traces are enabled, and one or more of the followings atoms if traces are enabled: `send`, `'receive'`, `set_on_spawn`, `call`, `return_to`, `procs`, `set_on_first_spawn`, `set_on_link`, `running`, `garbage_collection`, `timestamp`, and `arity`. The order is arbitrary.

`tracer`

Returns the identifier for process or port tracing this process. If this process is not being traced, the return value is `[]`.

To get information about a function, `PidOrFunc` is to be the three-element tuple `{Module, Function, Arity}` or the atom `on_load`. No wild cards are allowed. Returns `undefined` if the function does not exist, or `false` if the function is not traced.

The following `Item`s are valid::

`traced`

Returns `global` if this function is traced on global function calls, `local` if this function is traced on local function calls (that is, local and global function calls), and `false` if local or global function calls are not traced.

`match_spec`

Returns the match specification for this function, if it has one. If the function is locally or globally traced but has no match specification defined, the returned value is `[]`.

`meta`

Returns the meta-trace tracer process or port for this function, if it has one. If the function is not meta-traced, the returned value is `false`. If the function is meta-traced but has once detected that the tracer process is invalid, the returned value is [].

`meta_match_spec`

Returns the meta-trace match specification for this function, if it has one. If the function is meta-traced but has no match specification defined, the returned value is `[]`.

`call_count`

Returns the call count value for this function or `true` for the pseudo function `on_load` if call count tracing is active. Otherwise `false` is returned. See also *erlang:trace_pattern/3*.

`call_time`

Returns the call time values for this function or `true` for the pseudo function `on_load` if call time tracing is active. Otherwise `false` is returned. The call time values returned, `[{Pid, Count, S, Us}]`, is a list of each process that executed the function and its specific counters. See also *erlang:trace_pattern/3*.

`all`

Returns a list containing the `{Item, Value}` tuples for all other items, or returns `false` if no tracing is active for this function.

The return value is `{Item, Value}`, where `Value` is the requested information as described earlier. If a pid for a dead process was given, or the name of a non-existing function, `Value` is `undefined`.

If `PidOrFunc` is `on_load`, the information returned refers to the default value for code that will be loaded.

**`erlang:trace_pattern(MFA, MatchSpec) -> integer() >= 0`**

Types:

```
MFA = trace_pattern_mfa()
MatchSpec =
    (MatchSpecList :: trace_match_spec()) |
    boolean() |
    restart |
    pause
trace_pattern_mfa() = {atom(), atom(), arity() | '_'} | on_load
trace_match_spec() = [{[term()] | '_', [term()], [term()]}]
```

The same as *erlang:trace_pattern(MFA, MatchSpec, [])*, retained for backward compatibility.

**`erlang:trace_pattern(MFA, MatchSpec, FlagList) -> integer() >= 0`**

Types:

```
MFA = trace_pattern_mfa()
MatchSpec =
    (MatchSpecList :: trace_match_spec()) |
    boolean() |
    restart |
```

```
    pause
FlagList = [trace_pattern_flag()]
trace_pattern_mfa() = {atom(), atom(), arity() | '_'} | on_load
trace_match_spec() = [{[term()] | '_', [term()], [term()]}]
trace_pattern_flag() =
    global |
    local |
    meta |
    {meta, Pid :: pid()} |
    call_count |
    call_time
```

Enables or disables call tracing for one or more functions. Must be combined with *erlang:trace/3* to set the `call` trace flag for one or more processes.

Conceptually, call tracing works as follows. Inside the Erlang Virtual Machine, a set of processes and a set of functions are to be traced. If a traced process calls a traced function, the trace action is taken. Otherwise, nothing happens.

To add or remove one or more processes to the set of traced processes, use *erlang:trace/3*.

To add or remove functions to the set of traced functions, use `erlang:trace_pattern/3`.

The BIF `erlang:trace_pattern/3` can also add match specifications to a function. A match specification comprises a pattern that the function arguments must match, a guard expression that must evaluate to `true`, and an action to be performed. The default action is to send a trace message. If the pattern does not match or the guard fails, the action is not executed.

Argument `MFA` is to be a tuple, such as `{Module, Function, Arity}`, or the atom `on_load` (described in the following). It can be the module, function, and arity for a function (or a BIF in any module). The atom `'_'` can be used as a wild card in any of the following ways:

`{Module,Function,'_'}`

All functions of any arity named `Function` in module `Module`.

`{Module,'_','_'}`

All functions in module `Module`.

`{'_','_','_'}`

All functions in all loaded modules.

Other combinations, such as `{Module,'_',Arity}`, are not allowed. Local functions match wild cards only if option `local` is in `FlagList`.

If argument `MFA` is the atom `on_load`, the match specification and flag list are used on all modules that are newly loaded.

Argument `MatchSpec` can take the following forms:

`false`

Disables tracing for the matching functions. Any match specification is removed.

`true`

Enables tracing for the matching functions.

`MatchSpecList`

A list of match specifications. An empty list is equivalent to `true`. For a description of match specifications, see the User's Guide.

`restart`

For the `FlagList` options `call_count` and `call_time`: restarts the existing counters. The behavior is undefined for other `FlagList` options.

`pause`

For the `FlagList` options `call_count` and `call_time`: pauses the existing counters. The behavior is undefined for other `FlagList` options.

Parameter `FlagList` is a list of options. The following are the valid options:

`global`

Turns on or off call tracing for global function calls (that is, calls specifying the module explicitly). Only exported functions match and only global calls generate trace messages. *This is the default.*

`local`

Turns on or off call tracing for all types of function calls. Trace messages are sent whenever any of the specified functions are called, regardless of how they are called. If flag `return_to` is set for the process, a `return_to` message is also sent when this function returns to its caller.

`meta | {meta, Pid}`

Turns on or off meta-tracing for all types of function calls. Trace messages are sent to the tracer process or port `Pid` whenever any of the specified functions are called, regardless of how they are called. If no `Pid` is specified, `self()` is used as a default tracer process.

Meta-tracing traces all processes and does not care about the process trace flags set by `trace/3`, the trace flags are instead fixed to `[call, timestamp]`.

The match specification function `{return_trace}` works with meta-trace and sends its trace message to the same tracer process.

`call_count`

Starts (`MatchSpec == true`) or stops (`MatchSpec == false`) call count tracing for all types of function calls. For every function, a counter is incremented when the function is called, in any process. No process trace flags need to be activated.

If call count tracing is started while already running, the count is restarted from zero. To pause running counters, use `MatchSpec == pause`. Paused and running counters can be restarted from zero with `MatchSpec == restart`.

To read the counter value, use *erlang:trace_info/2*.

`call_time`

Starts (`MatchSpec == true`) or stops (`MatchSpec == false`) call time tracing for all types of function calls. For every function, a counter is incremented when the function is called. Time spent in the function is accumulated in two other counters, seconds and microseconds. The counters are stored for each call traced process.

If call time tracing is started while already running, the count and time is restarted from zero. To pause running counters, use `MatchSpec == pause`. Paused and running counters can be restarted from zero with `MatchSpec == restart`.

To read the counter value, use *erlang:trace_info/2*.

The options `global` and `local` are mutually exclusive, and `global` is the default (if no options are specified). The options `call_count` and `meta` perform a kind of local tracing, and cannot be combined with `global`. A function can be globally or locally traced. If global tracing is specified for a set of functions, then local, meta, call time, and call count tracing for the matching set of local functions is disabled, and conversely.

When disabling trace, the option must match the type of trace set on the function. That is, local tracing must be disabled with option `local` and global tracing with option `global` (or no option), and so forth.

Part of a match specification list cannot be changed directly. If a function has a match specification, it can be replaced with a new one. To change an existing match specification, use the BIF *erlang:trace_info/2* to retrieve the existing match specification.

Returns the number of functions matching argument `MFA`. This is zero if none matched.

### trunc(Number) -> integer()

Types:

**Number = number()**

Returns an integer by truncating `Number`, for example:

```
> trunc(5.5).
5
```

Allowed in guard tests.

### tuple_size(Tuple) -> integer() >= 0

Types:

**Tuple = tuple()**

Returns an integer that is the number of elements in `Tuple`, for example:

```
> tuple_size({morni, mulle, bwange}).
3
```

Allowed in guard tests.

### tuple_to_list(Tuple) -> [term()]

Types:

**Tuple = tuple()**

Returns a list corresponding to `Tuple`. `Tuple` can contain any Erlang terms.

Example:

```
> tuple_to_list({share, {'Ericsson_B', 163}}).
[share,{'Ericsson_B',163}]
```

### erlang:universaltime() -> DateTime

Types:

**DateTime = *calendar:datetime()***

Returns the current date and time according to Universal Time Coordinated (UTC) in the form `{{Year, Month, Day}, {Hour, Minute, Second}}` if supported by the underlying OS. Otherwise `erlang:universaltime()` is equivalent to `erlang:localtime()`.

Example:

```
> erlang:universaltime().
{{1996,11,6},{14,18,43}}
```

### erlang:universaltime_to_localtime(Universaltime) -> Localtime

Types:

**Localtime = Universaltime = *calendar:datetime()***

Converts Universal Time Coordinated (UTC) date and time to local date and time in the form `{{Year, Month, Day}, {Hour, Minute, Second}}` if supported by the underlying OS. Otherwise no conversion is done, and `Universaltime` is returned.

Example:

```
> erlang:universaltime_to_localtime({{1996,11,6},{14,18,43}}).
{{1996,11,7},{15,18,43}}
```

Failure: `badarg` if `Universaltime` denotes an invalid date and time.

### erlang:unique_integer() -> integer()

Generates and returns an *integer unique on current runtime system instance*. The same as calling *`erlang:unique_integer([])`*.

### erlang:unique_integer(ModifierList) -> integer()

Types:

**ModifierList = [Modifier]**

**Modifier = positive | monotonic**

Generates and returns an *integer unique on current runtime system instance*. The integer is unique in the sense that this BIF, using the same set of modifiers, will not return the same integer more than once on the current runtime system instance. Each integer value can of course be constructed by other means.

By default, when `[]` is passed as `ModifierList`, both negative and positive integers can be returned. This in order to utilize the range of integers that do not need heap memory allocation as much as possible. By default the returned integers are also only guaranteed to be unique, that is, any returned integer can be smaller or larger than previously returned integers.

Valid `Modifier`s:

positive

Return only positive integers.

Note that by passing the `positive` modifier you will get heap allocated integers (bignums) quicker.

monotonic

Return *strictly monotonically increasing* integers corresponding to creation time. That is, the integer returned will always be larger than previously returned integers on the current runtime system instance.

These values can be used to determine order between events on the runtime system instance. That is, if both `X = erlang:unique_integer([monotonic])` and `Y = erlang:unique_integer([monotonic])`

are executed by different processes (or the same process) on the same runtime system instance and `X < Y` we know that `X` was created before `Y`.

> ### Warning:
>
> Strictly monotonically increasing values are inherently quite expensive to generate and scales poorly. This is because the values need to be synchronized between cpu cores. That is, do not pass the `monotonic` modifier unless you really need strictly monotonically increasing values.

All valid `Modifier`s can be combined. Repeated (valid) `Modifier`s in the `ModifierList` are ignored.

> ### Note:
>
> Note that the set of integers returned by `unique_integer/1` using different sets of `Modifier`s *will overlap*. For example, by calling `unique_integer([monotonic])`, and `unique_integer([positive, monotonic])` repeatedly, you will eventually see some integers being returned by both calls.

Failures:

`badarg`
: if `ModifierList` is not a proper list.

`badarg`
: if `Modifier` is not a valid modifier.

**`unlink(Id) -> true`**

Types:

**`Id = pid() | port()`**

Removes the link, if there is one, between the calling process and the process or port referred to by `Id`.

Returns `true` and does not fail, even if there is no link to `Id`, or if `Id` does not exist.

Once `unlink(Id)` has returned, it is guaranteed that the link between the caller and the entity referred to by `Id` has no effect on the caller in the future (unless the link is setup again). If the caller is trapping exits, an `{'EXIT', Id, _}` message from the link can have been placed in the caller's message queue before the call.

Notice that the `{'EXIT', Id, _}` message can be the result of the link, but can also be the result of `Id` calling `exit/2`. Therefore, it *can* be appropriate to clean up the message queue when trapping exits after the call to `unlink(Id)`, as follows:

```
unlink(Id),
receive
    {'EXIT', Id, _} ->
        true
after 0 ->
        true
end
```

> ### Note:
>
> Prior to OTP release R11B (ERTS version 5.5) `unlink/1` behaved completely asynchronously, i.e., the link was active until the "unlink signal" reached the linked entity. This had an undesirable effect, as you could never know when you were guaranteed *not* to be effected by the link.
>
> The current behavior can be viewed as two combined operations: asynchronously send an "unlink signal" to the linked entity and ignore any future results of the link.

**`unregister(RegName) -> true`**

Types:

**`RegName = atom()`**

Removes the registered name `RegName` associated with a process identifier or a port identifier, for example:

```
> unregister(db).
true
```

Users are advised not to unregister system processes.

Failure: `badarg` if `RegName` is not a registered name.

**`whereis(RegName) -> pid() | port() | undefined`**

Types:

**`RegName = atom()`**

Returns the process identifier or port identifier with the registered name `RegName`. Returns `undefined` if the name is not registered.

Example:

```
> whereis(db).
<0.43.0>
```

**`erlang:yield() -> true`**

Voluntarily lets other processes (if any) get a chance to execute. Using `erlang:yield()` is similar to `receive after 1 -> ok end`, except that `yield()` is faster.

> ### Warning:
>
> There is seldom or never any need to use this BIF, especially in the SMP emulator, as other processes have a chance to run in another scheduler thread anyway. Using this BIF without a thorough grasp of how the scheduler works can cause performance degradation.

# init

Erlang module

The `init` module is pre-loaded and contains the code for the `init` system process which coordinates the start-up of the system. The first function evaluated at start-up is `boot(BootArgs)`, where `BootArgs` is a list of command line arguments supplied to the Erlang runtime system from the local operating system. See *erl(1)*.

`init` reads the boot script which contains instructions on how to initiate the system. See *script(4)* for more information about boot scripts.

`init` also contains functions to restart, reboot, and stop the system.

## Exports

**`boot(BootArgs) -> no_return()`**

Types:

**`BootArgs = [binary()]`**

Starts the Erlang runtime system. This function is called when the emulator is started and coordinates system start-up.

`BootArgs` are all command line arguments except the emulator flags, that is, flags and plain arguments. See *erl(1)*.

`init` itself interprets some of the flags, see *Command Line Flags* below. The remaining flags ("user flags") and plain arguments are passed to the `init` loop and can be retrieved by calling `get_arguments/0` and `get_plain_arguments/0`, respectively.

**`get_argument(Flag) -> {ok, Arg} | error`**

Types:

**`Flag = atom()`**

**`Arg = [Values :: [string()]]`**

Returns all values associated with the command line user flag `Flag`. If `Flag` is provided several times, each `Values` is returned in preserved order.

```
% erl -a b c -a d
...
1> init:get_argument(a).
{ok,[["b","c"],["d"]]}
```

There are also a number of flags, which are defined automatically and can be retrieved using this function:

`root`

The installation directory of Erlang/OTP, `$ROOT`.

```
2> init:get_argument(root).
{ok,[["/usr/local/otp/releases/otp_beam_solaris8_r10b_patched"]]}
```

`progname`

The name of the program which started Erlang.

```
3> init:get_argument(progname).
{ok,[["erl"]]}
```

`home`

The home directory.

```
4> init:get_argument(home).
{ok,[["/home/harry"]]}
```

Returns `error` if there is no value associated with `Flag`.

**`get_arguments() -> Flags`**

Types:

**`Flags = [{Flag :: atom(), Values :: [string()]}]`**

Returns all command line flags, as well as the system defined flags, see `get_argument/1`.

**`get_plain_arguments() -> [Arg]`**

Types:

**`Arg = string()`**

Returns any plain command line arguments as a list of strings (possibly empty).

**`get_status() -> {InternalStatus, ProvidedStatus}`**

Types:

**`InternalStatus = internal_status()`**

**`ProvidedStatus = term()`**

**`internal_status() = starting | started | stopping`**

The current status of the `init` process can be inspected. During system startup (initialization), `InternalStatus` is `starting`, and `ProvidedStatus` indicates how far the boot script has been interpreted. Each `{progress, Info}` term interpreted in the boot script affects `ProvidedStatus`, that is, `ProvidedStatus` gets the value of `Info`.

**`reboot() -> ok`**

All applications are taken down smoothly, all code is unloaded, and all ports are closed before the system terminates. If the `-heart` command line flag was given, the `heart` program will try to reboot the system. Refer to `heart(3)` for more information.

To limit the shutdown time, the time `init` is allowed to spend taking down applications, the `-shutdown_time` command line flag should be used.

**`restart() -> ok`**

The system is restarted *inside* the running Erlang node, which means that the emulator is not restarted. All applications are taken down smoothly, all code is unloaded, and all ports are closed before the system is booted again in the same way as initially started. The same `BootArgs` are used again.

To limit the shutdown time, the time `init` is allowed to spend taking down applications, the `-shutdown_time` command line flag should be used.

**`script_id() -> Id`**

Types:

**`Id = term()`**

Get the identity of the boot script used to boot the system. `Id` can be any Erlang term. In the delivered boot scripts, `Id` is `{Name, Vsn}`. `Name` and `Vsn` are strings.

**`stop() -> ok`**

All applications are taken down smoothly, all code is unloaded, and all ports are closed before the system terminates. If the `-heart` command line flag was given, the `heart` program is terminated before the Erlang node terminates. Refer to `heart(3)` for more information.

To limit the shutdown time, the time `init` is allowed to spend taking down applications, the `-shutdown_time` command line flag should be used.

**`stop(Status) -> ok`**

Types:

**`Status = integer() >= 0 | string()`**

All applications are taken down smoothly, all code is unloaded, and all ports are closed before the system terminates by calling `halt(Status)`. If the `-heart` command line flag was given, the `heart` program is terminated before the Erlang node terminates. Refer to `heart(3)` for more information.

To limit the shutdown time, the time `init` is allowed to spend taking down applications, the `-shutdown_time` command line flag should be used.

## Command Line Flags

> ### Warning:
>
> The support for loading of code from archive files is experimental. The sole purpose of releasing it before it is ready is to obtain early feedback. The file format, semantics, interfaces etc. may be changed in a future release. The `-code_path_choice` flag is also experimental.

The `init` module interprets the following command line flags:

`--`

Everything following `--` up to the next flag is considered plain arguments and can be retrieved using `get_plain_arguments/0`.

`-code_path_choice Choice`

This flag can be set to `strict` or `relaxed`. It controls whether each directory in the code path should be interpreted strictly as it appears in the `boot script` or if `init` should be more relaxed and try to find a suitable directory if it can choose from a regular ebin directory and an ebin directory in an archive file. This flag is particular useful when you want to elaborate with code loading from archives without editing the `boot script`. See *script(4)* for more information about interpretation of boot scripts. The flag does also have a similar affect on how the code server works. See *code(3)*.

`-eval Expr`

Scans, parses and evaluates an arbitrary expression `Expr` during system initialization. If any of these steps fail (syntax error, parse error or exception during evaluation), Erlang stops with an error message. Here is an example that seeds the random number generator:

```
% erl -eval '{X,Y,Z} = now(), random:seed(X,Y,Z).'
```

This example uses Erlang as a hexadecimal calculator:

```
% erl -noshell -eval 'R = 16#1F+16#A0, io:format("~.16B~n", [R])' \\
-s erlang halt
BF
```

If multiple `-eval` expressions are specified, they are evaluated sequentially in the order specified. `-eval` expressions are evaluated sequentially with `-s` and `-run` function calls (this also in the order specified). As with `-s` and `-run`, an evaluation that does not terminate, blocks the system initialization process.

`-extra`

Everything following `-extra` is considered plain arguments and can be retrieved using `get_plain_arguments/0`.

`-run Mod [Func [Arg1, Arg2, ...]]`

Evaluates the specified function call during system initialization. `Func` defaults to `start`. If no arguments are provided, the function is assumed to be of arity 0. Otherwise it is assumed to be of arity 1, taking the list `[Arg1,Arg2,...]` as argument. All arguments are passed as strings. If an exception is raised, Erlang stops with an error message.

Example:

```
% erl -run foo -run foo bar -run foo bar baz 1 2
```

This starts the Erlang runtime system and evaluates the following functions:

```
foo:start()
foo:bar()
foo:bar(["baz", "1", "2"]).
```

The functions are executed sequentially in an initialization process, which then terminates normally and passes control to the user. This means that a `-run` call which does not return will block further processing; to avoid this, use some variant of `spawn` in such cases.

`-s Mod [Func [Arg1, Arg2, ...]]`

Evaluates the specified function call during system initialization. `Func` defaults to `start`. If no arguments are provided, the function is assumed to be of arity 0. Otherwise it is assumed to be of arity 1, taking the list `[Arg1,Arg2,...]` as argument. All arguments are passed as atoms. If an exception is raised, Erlang stops with an error message.

Example:

```
% erl -s foo -s foo bar -s foo bar baz 1 2
```

This starts the Erlang runtime system and evaluates the following functions:

```
foo:start()
foo:bar()
foo:bar([baz, '1', '2']).
```

The functions are executed sequentially in an initialization process, which then terminates normally and passes control to the user. This means that a `-s` call which does not return will block further processing; to avoid this, use some variant of `spawn` in such cases.

Due to the limited length of atoms, it is recommended that `-run` be used instead.

## Example

```
% erl -- a b -children thomas claire -ages 7 3 -- x y
...

1> init:get_plain_arguments().
["a","b","x","y"]
2> init:get_argument(children).
{ok,[["thomas","claire"]]}
3> init:get_argument(ages).
{ok, [["7","3"]]}
4> init:get_argument(silly).
error
```

## SEE ALSO

*erl_prim_loader(3), heart(3)*

# zlib

Erlang module

The zlib module provides an API for the zlib library (http://www.zlib.org). It is used to compress and decompress data. The data format is described by RFCs 1950 to 1952.

A typical (compress) usage looks like:

```
Z = zlib:open(),
ok = zlib:deflateInit(Z,default),

Compress = fun(end_of_data, _Cont) -> [];
              (Data, Cont) ->
                 [zlib:deflate(Z, Data)|Cont(Read(),Cont)]
           end,
Compressed = Compress(Read(),Compress),
Last = zlib:deflate(Z, [], finish),
ok = zlib:deflateEnd(Z),
zlib:close(Z),
list_to_binary([Compressed|Last])
```

In all functions errors, `{'EXIT',{Reason,Backtrace}}`, might be thrown, where `Reason` describes the error. Typical reasons are:

`badarg`

Bad argument

`data_error`

The data contains errors

`stream_error`

Inconsistent stream state

`einval`

Bad value or wrong function called

`{need_dictionary,Adler32}`

See `inflate/2`

## Data Types

**`zstream() = port()`**

A zlib stream, see *open/0*.

**`zlevel() =`**
**`    none | default | best_compression | best_speed | 0..9`**

**`zmemlevel() = 1..9`**

**`zmethod() = deflated`**

**`zstrategy() = default | filtered | huffman_only | rle`**

**`zwindowbits() = -15..-8 | 8..47`**

Normally in the range `-15..-8 | 8..15`.

## Exports

**`open() -> zstream()`**

Open a zlib stream.

**`close(Z) -> ok`**

Types:

**`Z = zstream()`**

Closes the stream referenced by `Z`.

**`deflateInit(Z) -> ok`**

Types:

**`Z = zstream()`**

Same as `zlib:deflateInit(Z, default)`.

**`deflateInit(Z, Level) -> ok`**

Types:

**`Z = zstream()`**
**`Level = zlevel()`**

Initialize a zlib stream for compression.

`Level` decides the compression level to be used, 0 (`none`), gives no compression at all, 1 (`best_speed`) gives best speed and 9 (`best_compression`) gives best compression.

**`deflateInit(Z, Level, Method, WindowBits, MemLevel, Strategy) -> ok`**

Types:

**`Z = zstream()`**
**`Level = zlevel()`**
**`Method = zmethod()`**
**`WindowBits = zwindowbits()`**
**`MemLevel = zmemlevel()`**
**`Strategy = zstrategy()`**

Initiates a zlib stream for compression.

The `Level` parameter decides the compression level to be used, 0 (`none`), gives no compression at all, 1 (`best_speed`) gives best speed and 9 (`best_compression`) gives best compression.

The `Method` parameter decides which compression method to use, currently the only supported method is `deflated`.

The `WindowBits` parameter is the base two logarithm of the window size (the size of the history buffer). It should be in the range 8 through 15. Larger values of this parameter result in better compression at the expense of memory usage. The default value is 15 if `deflateInit/2`. A negative `WindowBits` value suppresses the zlib header (and checksum) from the stream. Note that the zlib source mentions this only as a undocumented feature.

The `MemLevel` parameter specifies how much memory should be allocated for the internal compression state. `MemLevel`=1 uses minimum memory but is slow and reduces compression ratio; `MemLevel`=9 uses maximum memory for optimal speed. The default value is 8.

The `Strategy` parameter is used to tune the compression algorithm. Use the value `default` for normal data, `filtered` for data produced by a filter (or predictor), `huffman_only` to force Huffman encoding only (no string match), or `rle` to limit match distances to one (run-length encoding). Filtered data consists mostly of small values with a somewhat random distribution. In this case, the compression algorithm is tuned to compress them better. The effect of `filtered`is to force more Huffman coding and less string matching; it is somewhat intermediate between `default` and `huffman_only`. `rle` is designed to be almost as fast as `huffman_only`, but give better compression for PNG image data. The `Strategy` parameter only affects the compression ratio but not the correctness of the compressed output even if it is not set appropriately.

### deflate(Z, Data) -> Compressed

Types:

**Z = *zstream()***
**Data = iodata()**
**Compressed = iolist()**

Same as `deflate(Z, Data, none)`.

### deflate(Z, Data, Flush) -> Compressed

Types:

**Z = *zstream()***
**Data = iodata()**
**Flush = none | sync | full | finish**
**Compressed = iolist()**

`deflate/3` compresses as much data as possible, and stops when the input buffer becomes empty. It may introduce some output latency (reading input without producing any output) except when forced to flush.

If the parameter `Flush` is set to `sync`, all pending output is flushed to the output buffer and the output is aligned on a byte boundary, so that the decompressor can get all input data available so far. Flushing may degrade compression for some compression algorithms and so it should be used only when necessary.

If `Flush` is set to `full`, all output is flushed as with `sync`, and the compression state is reset so that decompression can restart from this point if previous compressed data has been damaged or if random access is desired. Using `full` too often can seriously degrade the compression.

If the parameter `Flush` is set to `finish`, pending input is processed, pending output is flushed and `deflate/3` returns. Afterwards the only possible operations on the stream are `deflateReset/1` or `deflateEnd/1`.

`Flush` can be set to `finish` immediately after `deflateInit` if all compression is to be done in one step.

```
zlib:deflateInit(Z),
B1 = zlib:deflate(Z,Data),
B2 = zlib:deflate(Z,<< >>,finish),
zlib:deflateEnd(Z),
list_to_binary([B1,B2])
```

### deflateSetDictionary(Z, Dictionary) -> Adler32

Types:

**Z = *zstream()***
**Dictionary = iodata()**
**Adler32 = integer()**

Initializes the compression dictionary from the given byte sequence without producing any compressed output. This function must be called immediately after `deflateInit/[1|2|6]` or `deflateReset/1`, before any call of `deflate/3`. The compressor and decompressor must use exactly the same dictionary (see `inflateSetDictionary/2`). The adler checksum of the dictionary is returned.

### deflateReset(Z) -> ok

Types:

**Z = *zstream()***

This function is equivalent to `deflateEnd/1` followed by `deflateInit/[1|2|6]`, but does not free and reallocate all the internal compression state. The stream will keep the same compression level and any other attributes.

### deflateParams(Z, Level, Strategy) -> ok

Types:

**Z = *zstream()***
**Level = *zlevel()***
**Strategy = *zstrategy()***

Dynamically update the compression level and compression strategy. The interpretation of `Level` and `Strategy` is as in `deflateInit/6`. This can be used to switch between compression and straight copy of the input data, or to switch to a different kind of input data requiring a different strategy. If the compression level is changed, the input available so far is compressed with the old level (and may be flushed); the new level will take effect only at the next call of `deflate/3`.

Before the call of `deflateParams`, the stream state must be set as for a call of `deflate/3`, since the currently available input may have to be compressed and flushed.

### deflateEnd(Z) -> ok

Types:

**Z = *zstream()***

End the deflate session and cleans all data used. Note that this function will throw an `data_error` exception if the last call to `deflate/3` was not called with `Flush` set to `finish`.

### inflateInit(Z) -> ok

Types:

**Z = *zstream()***

Initialize a zlib stream for decompression.

### inflateInit(Z, WindowBits) -> ok

Types:

**Z = *zstream()***
**WindowBits = *zwindowbits()***

Initialize decompression session on zlib stream.

The `WindowBits` parameter is the base two logarithm of the maximum window size (the size of the history buffer). It should be in the range 8 through 15. The default value is 15 if `inflateInit/1` is used. If a compressed stream with a larger window size is given as input, inflate() will throw the `data_error` exception. A negative `WindowBits` value makes zlib ignore the zlib header (and checksum) from the stream. Note that the zlib source mentions this only as a undocumented feature.

### inflate(Z, Data) -> Decompressed

Types:

**Z = *zstream()***

**Data = iodata()**

**Decompressed = iolist()**

`inflate/2` decompresses as much data as possible. It may introduce some output latency (reading input without producing any output).

If a preset dictionary is needed at this point (see `inflateSetDictionary` below), `inflate/2` throws a `{need_dictionary,Adler}` exception where `Adler` is the adler32 checksum of the dictionary chosen by the compressor.

### inflateChunk(Z, Data) -> Decompressed | {more, Decompressed}

Types:

**Z = *zstream()***

**Data = iodata()**

**Decompressed = iolist()**

Like `inflate/2`, but decompress no more data than will fit in the buffer configured via `setBufSize/2`. Is is useful when decompressing a stream with a high compression ratio such that a small amount of compressed input may expand up to 1000 times. It returns `{more, Decompressed}`, when there is more output available, and `inflateChunk/1` should be used to read it. It may introduce some output latency (reading input without producing any output).

If a preset dictionary is needed at this point (see `inflateSetDictionary` below), `inflateChunk/2` throws a `{need_dictionary,Adler}` exception where `Adler` is the adler32 checksum of the dictionary chosen by the compressor.

```
walk(Compressed, Handler) ->
    Z = zlib:open(),
    zlib:inflateInit(Z),
    % Limit single uncompressed chunk size to 512kb
    zlib:setBufSize(Z, 512 * 1024),
    loop(Z, Handler, zlib:inflateChunk(Z, Compressed)),
    zlib:inflateEnd(Z),
    zlib:close(Z).

loop(Z, Handler, {more, Uncompressed}) ->
    Handler(Uncompressed),
    loop(Z, Handler, zlib:inflateChunk(Z));
loop(Z, Handler, Uncompressed) ->
    Handler(Uncompressed).
```

### inflateChunk(Z) -> Decompressed | {more, Decompressed}

Types:

**Z = *zstream()***
**Decompressed = iolist()**

Read next chunk of uncompressed data, initialized by `inflateChunk/2`.

This function should be repeatedly called, while it returns `{more, Decompressed}`.

### inflateSetDictionary(Z, Dictionary) -> ok

Types:

**Z = *zstream()***
**Dictionary = iodata()**

Initializes the decompression dictionary from the given uncompressed byte sequence. This function must be called immediately after a call of `inflate/2` if this call threw a `{need_dictionary,Adler}` exception. The dictionary chosen by the compressor can be determined from the Adler value thrown by the call to `inflate/2`. The compressor and decompressor must use exactly the same dictionary (see `deflateSetDictionary/2`).

Example:

```
unpack(Z, Compressed, Dict) ->
     case catch zlib:inflate(Z, Compressed) of
          {'EXIT',{{need_dictionary,DictID},_}} ->
                    zlib:inflateSetDictionary(Z, Dict),
                  Uncompressed = zlib:inflate(Z, []);
          Uncompressed ->
                  Uncompressed
     end.
```

### inflateReset(Z) -> ok

Types:

**Z = *zstream()***

This function is equivalent to `inflateEnd/1` followed by `inflateInit/1`, but does not free and reallocate all the internal decompression state. The stream will keep attributes that may have been set by `inflateInit/[1|2]`.

### inflateEnd(Z) -> ok

Types:

**Z = *zstream()***

End the inflate session and cleans all data used. Note that this function will throw a `data_error` exception if no end of stream was found (meaning that not all data has been uncompressed).

### setBufSize(Z, Size) -> ok

Types:

**Z = *zstream()***
**Size = integer() >= 0**

Sets the intermediate buffer size.

### getBufSize(Z) -> Size

Types:

**Z = *zstream()***
**Size = integer() >= 0**

Get the size of intermediate buffer.

### crc32(Z) -> CRC

Types:

**Z = *zstream()***
**CRC = integer()**

Get the current calculated CRC checksum.

### crc32(Z, Data) -> CRC

Types:

**Z = *zstream()***
**Data = iodata()**
**CRC = integer()**

Calculate the CRC checksum for `Data`.

### crc32(Z, PrevCRC, Data) -> CRC

Types:

**Z = *zstream()***
**PrevCRC = integer()**
**Data = iodata()**
**CRC = integer()**

Update a running CRC checksum for `Data`. If `Data` is the empty binary or the empty iolist, this function returns the required initial value for the crc.

```
Crc = lists:foldl(fun(Data,Crc0) ->
                      zlib:crc32(Z, Crc0, Data),
                  end, zlib:crc32(Z,<< >>), Datas)
```

### crc32_combine(Z, CRC1, CRC2, Size2) -> CRC

Types:

**Z = *zstream()***
**CRC = CRC1 = CRC2 = Size2 = integer()**

Combine two CRC checksums into one. For two binaries or iolists, `Data1` and `Data2` with sizes of `Size1` and `Size2`, with CRC checksums `CRC1` and `CRC2`. `crc32_combine/4` returns the `CRC` checksum of `[Data1,Data2]`, requiring only `CRC1`, `CRC2`, and `Size2`.

### adler32(Z, Data) -> CheckSum

Types:

**Z = *zstream()***
**Data = iodata()**
**CheckSum = integer()**

Calculate the Adler-32 checksum for `Data`.

**adler32(Z, PrevAdler, Data) -> CheckSum**

Types:

**Z = *zstream()***
**PrevAdler = integer()**
**Data = iodata()**
**CheckSum = integer()**

Update a running Adler-32 checksum for `Data`. If `Data` is the empty binary or the empty iolist, this function returns the required initial value for the checksum.

```
Crc = lists:foldl(fun(Data,Crc0) ->
                      zlib:adler32(Z, Crc0, Data),
                  end, zlib:adler32(Z,<< >>), Datas)
```

**adler32_combine(Z, Adler1, Adler2, Size2) -> Adler**

Types:

**Z = *zstream()***
**Adler = Adler1 = Adler2 = Size2 = integer()**

Combine two Adler-32 checksums into one. For two binaries or iolists, `Data1` and `Data2` with sizes of `Size1` and `Size2`, with Adler-32 checksums `Adler1` and `Adler2`. `adler32_combine/4` returns the `Adler` checksum of `[Data1,Data2]`, requiring only `Adler1`, `Adler2`, and `Size2`.

**compress(Data) -> Compressed**

Types:

**Data = iodata()**
**Compressed = binary()**

Compress data (with zlib headers and checksum).

**uncompress(Data) -> Decompressed**

Types:

**Data = iodata()**
**Decompressed = binary()**

Uncompress data (with zlib headers and checksum).

**zip(Data) -> Compressed**

Types:

```
Data = iodata()
Compressed = binary()
```

Compress data (without zlib headers and checksum).

**`unzip(Data) -> Decompressed`**

Types:

```
Data = iodata()
Decompressed = binary()
```

Uncompress data (without zlib headers and checksum).

**`gzip(Data) -> Compressed`**

Types:

```
Data = iodata()
Compressed = binary()
```

Compress data (with gz headers and checksum).

**`gunzip(Data) -> Decompressed`**

Types:

```
Data = iodata()
Decompressed = binary()
```

Uncompress data (with gz headers and checksum).

# epmd

Command

Erlang Port Mapper Daemon

`epmd [-d|-debug] [DbgExtra...] [-address Addresses] [-port No] [-daemon] [-relaxed_command_check]`

Starts the port mapper daemon

`epmd [-d|-debug] [-port No] [-names|-kill|-stop Name]`

Communicates with a running port mapper daemon

This daemon acts as a name server on all hosts involved in distributed Erlang computations. When an Erlang node starts, the node has a name and it obtains an address from the host OS kernel. The name and the address are sent to the `epmd` daemon running on the local host. In a TCP/IP environment, the address consists of the IP address and a port number. The name of the node is an atom on the form of `Name@Node`. The job of the `epmd` daemon is to keep track of which node name listens on which address. Hence, `epmd` maps symbolic node names to machine addresses.

The TCP/IP `epmd` daemon actually only keeps track of the `Name` (first) part of an Erlang node name. The `Host` part (whatever is after the `@`) is implicit in the node name where the `epmd` daemon was actually contacted, as is the IP address where the Erlang node can be reached. Consistent and correct TCP naming services are therefore required for an Erlang network to function correctly.

Starting the port mapper daemon

The daemon is started automatically by the `erl` command if the node is to be distributed and there is no running instance present. If automatically launched, environment variables have to be used to alter the behavior of the daemon. See the *Environment variables* section below.

If the -daemon argument is not given, `epmd` runs as a normal program with the controlling terminal of the shell in which it is started. Normally, it should run as a daemon.

Regular start-up options are described in the *Regular options* section below.

The `DbgExtra` options are described in the *DbgExtra options* section below.

Communicating with a running port mapper daemon

Communicating with the running epmd daemon by means of the `epmd` program is done primarily for debugging purposes.

The different queries are described in the *Interactive options* section below.

## Regular options

These options are available when starting the actual name server. The name server is normally started automatically by the `erl` command (if not already available), but it can also be started at i.e. system start-up.

`-address List`

Let this instance of `epmd` listen only on the comma-separated list of IP addresses and on the loopback address (which is implicitly added to the list if it has not been specified). This can also be set using the `ERL_EPMD_ADDRESS` environment variable. See the section *Environment variables* below.

`-port No`

Let this instance of epmd listen to another TCP port than default 4369. This can also be set using the `ERL_EPMD_PORT` environment variable. See the section *Environment variables* below

`-d | -debug`

Enable debug output. The more `-d` flags given, the more debug output you will get (to a certain limit). This option is most useful when the epmd daemon is not started as a daemon.

`-daemon`

Start epmd detached from the controlling terminal. Logging will end up in syslog when available and correctly configured. If the epmd daemon is started at boot, this option should definitely be used. It is also used when the `erl` command automatically starts `epmd`.

`-relaxed_command_check`

Start the epmd program with relaxed command checking (mostly for backward compatibility). This affects the following:

- With relaxed command checking, the `epmd` daemon can be killed from the localhost with i.e. `epmd -kill` even if there are active nodes registered. Normally only daemons with an empty node database can be killed with the `epmd -kill` command.
- The `epmd -stop` command (and the corresponding messages to epmd, as can be given using `erl_interface/ei`) is normally always ignored, as it opens up the possibility of a strange situation where two nodes of the same name can be alive at the same time. A node unregisters itself by just closing the connection to epmd, which is why the `stop` command was only intended for use in debugging situations.

  With relaxed command checking enabled, you can forcibly unregister live nodes.

Relaxed command checking can also be enabled by setting the environment variable `ERL_EPMD_RELAXED_COMMAND_CHECK` prior to starting `epmd`.

Only use relaxed command checking on systems with very limited interactive usage.

## DbgExtra options

These options are purely for debugging and testing epmd clients. They should not be used in normal operation.

`-packet_timeout Seconds`

Set the number of seconds a connection can be inactive before epmd times out and closes the connection (default 60).

`-delay_accept Seconds`

To simulate a busy server you can insert a delay between when epmd gets notified that a new connection is requested and when the connection gets accepted.

`-delay_write Seconds`

Also a simulation of a busy server. Inserts a delay before a reply is sent.

## Interactive options

These options make `epmd` run as an interactive command, displaying the results of sending queries to an already running instance of `epmd`. The epmd contacted is always on the local node, but the `-port` option can be used to select between instances if several are running using different ports on the host.

`-port No`

Contacts the `epmd` listening on the given TCP port number (default 4369). This can also be set using the `ERL_EPMD_PORT` environment variable. See the section *Environment variables* below.

`-names`

List names registered with the currently running epmd

`-kill`

Kill the currently running `epmd`.

Killing the running `epmd` is only allowed if `epmd -names` shows an empty database or `-relaxed_command_check` was given when the running instance of `epmd` was started. Note that `-relaxed_command_check` is given when starting the daemon that is to accept killing when it has live nodes registered. When running epmd interactively, `-relaxed_command_check` has no effect. A daemon that is started without relaxed command checking has to be killed using i.e. signals or some other OS specific method if it has active clients registered.

`-stop Name`

Forcibly unregister a live node from `epmd`'s database

This command can only be used when contacting `epmd` instances started with the `-relaxed_command_check` flag. Note that relaxed command checking has to be enabled for the `epmd` daemon contacted. When running epmd interactively, `-relaxed_command_check` has no effect.

## Environment variables

`ERL_EPMD_ADDRESS`

This environment variable may be set to a comma-separated list of IP addresses, in which case the `epmd` daemon will listen only on the specified address(es) and on the loopback address (which is implicitly added to the list if it has not been specified). The default behaviour is to listen on all available IP addresses.

`ERL_EPMD_PORT`

This environment variable can contain the port number epmd will use. The default port will work fine in most cases. A different port can be specified to allow several instances of epmd, representing independent clusters of nodes, to co-exist on the same host. All nodes in a cluster must use the same epmd port number.

`ERL_EPMD_RELAXED_COMMAND_CHECK`

If set prior to start, the `epmd` daemon will behave as if the `-relaxed_command_check` option was given at start-up. Consequently, if this option is set before starting the Erlang virtual machine, the automatically started `epmd` will accept the `-kill` and `-stop` commands without restrictions.

## Logging

On some operating systems *syslog* will be used for error reporting when epmd runs as an daemon. To enable the error logging you have to edit /etc/syslog.conf file and add an entry

```
!epmd
*.*<TABs>/var/log/epmd.log
```

where <TABs> are at least one real tab character. Spaces will silently be ignored.

## Access restrictions

The `epmd` daemon accepts messages from both localhost and remote hosts. However, only the query commands are answered (and acted upon) if the query comes from a remote host. It is always an error to try to register a nodename if the client is not a process located on the same host as the `epmd` instance is running on- such requests are considered hostile and the connection is immediately closed.

The queries accepted from remote nodes are:

- Port queries - i.e. on which port does the node with a given name listen
- Name listing - i.e. give a list of all names registered on the host

To restrict access further, firewall software has to be used.

# erl

Command

The `erl` program starts an Erlang runtime system. The exact details (for example, whether `erl` is a script or a program and which other programs it calls) are system-dependent.

Windows users probably wants to use the `werl` program instead, which runs in its own window with scrollbars and supports command-line editing. The `erl` program on Windows provides no line editing in its shell, and on Windows 95 there is no way to scroll back to text which has scrolled off the screen. The `erl` program must be used, however, in pipelines or if you want to redirect standard input or output.

> ### Note:
>
> As of ERTS version 5.9 (OTP-R15B) the runtime system will by default *not* bind schedulers to logical processors. For more information see documentation of the *+sbt* system flag.

## Exports

### `erl <arguments>`

Starts an Erlang runtime system.

The arguments can be divided into *emulator flags*, *flags* and *plain arguments*:

- Any argument starting with the character `+` is interpreted as an *emulator flag*.

  As indicated by the name, emulator flags controls the behavior of the emulator.
- Any argument starting with the character `-` (hyphen) is interpreted as a *flag* which should be passed to the Erlang part of the runtime system, more specifically to the `init` system process, see *init(3)*.

  The `init` process itself interprets some of these flags, the *init flags*. It also stores any remaining flags, the *user flags*. The latter can be retrieved by calling `init:get_argument/1`.

  It can be noted that there are a small number of "-" flags which now actually are emulator flags, see the description below.
- Plain arguments are not interpreted in any way. They are also stored by the `init` process and can be retrieved by calling `init:get_plain_arguments/0`. Plain arguments can occur before the first flag, or after a `--` flag. Additionally, the flag `-extra` causes everything that follows to become plain arguments.

Example:

```
% erl +W w -sname arnie +R 9 -s my_init -extra +bertie
(arnie@host)1> init:get_argument(sname).
{ok,[["arnie"]]}
(arnie@host)2> init:get_plain_arguments().
["+bertie"]
```

Here `+W w` and `+R 9` are emulator flags. `-s my_init` is an init flag, interpreted by `init`. `-sname arnie` is a user flag, stored by `init`. It is read by Kernel and will cause the Erlang runtime system to become distributed. Finally, everything after `-extra` (that is, `+bertie`) is considered as plain arguments.

```
% erl -myflag 1
1> init:get_argument(myflag).
{ok,[["1"]]}
2> init:get_plain_arguments().
[]
```

Here the user flag `-myflag 1` is passed to and stored by the `init` process. It is a user defined flag, presumably used by some user defined application.

## Flags

In the following list, init flags are marked (init flag). Unless otherwise specified, all other flags are user flags, for which the values can be retrieved by calling `init:get_argument/1`. Note that the list of user flags is not exhaustive, there may be additional, application specific flags which instead are documented in the corresponding application documentation.

`--`(init flag)

Everything following `--` up to the next flag (`-flag` or `+flag`) is considered plain arguments and can be retrieved using `init:get_plain_arguments/0`.

`-Application Par Val`

Sets the application configuration parameter `Par` to the value `Val` for the application `Application`, see *app(4)* and *application(3)*.

`-args_file FileName`

Command line arguments are read from the file `FileName`. The arguments read from the file replace the '`-args_file FileName`' flag on the resulting command line.

The file `FileName` should be a plain text file and may contain comments and command line arguments. A comment begins with a # character and continues until next end of line character. Backslash (\\) is used as quoting character. All command line arguments accepted by `erl` are allowed, also the `-args_file FileName` flag. Be careful not to cause circular dependencies between files containing the `-args_file` flag, though.

The `-extra` flag is treated specially. Its scope ends at the end of the file. Arguments following an `-extra` flag are moved on the command line into the `-extra` section, i.e. the end of the command line following after an `-extra` flag.

`-async_shell_start`

The initial Erlang shell does not read user input until the system boot procedure has been completed (Erlang 5.4 and later). This flag disables the start synchronization feature and lets the shell start in parallel with the rest of the system.

`-boot File`

Specifies the name of the boot file, `File.boot`, which is used to start the system. See *init(3)*. Unless `File` contains an absolute path, the system searches for `File.boot` in the current and `$ROOT/bin` directories.

Defaults to `$ROOT/bin/start.boot`.

`-boot_var Var Dir`

If the boot script contains a path variable `Var` other than `$ROOT`, this variable is expanded to `Dir`. Used when applications are installed in another directory than `$ROOT/lib`, see *systools:make_script/1,2*.

`-code_path_cache`

Enables the code path cache of the code server, see *code(3)*.

`-compile Mod1 Mod2 ...`

Compiles the specified modules and then terminates (with non-zero exit code if the compilation of some file did not succeed). Implies `-noinput`. Not recommended - use *erlc* instead.

`-config Config`

Specifies the name of a configuration file, `Config.config`, which is used to configure applications. See *app(4)* and *application(3)*.

`-connect_all false`

If this flag is present, `global` will not maintain a fully connected network of distributed Erlang nodes, and then global name registration cannot be used. See *global(3)*.

`-cookie Cookie`

Obsolete flag without any effect and common misspelling for `-setcookie`. Use `-setcookie` instead.

`-detached`

Starts the Erlang runtime system detached from the system console. Useful for running daemons and backgrounds processes. Implies `-noinput`.

`-emu_args`

Useful for debugging. Prints out the actual arguments sent to the emulator.

`-env Variable Value`

Sets the host OS environment variable `Variable` to the value `Value` for the Erlang runtime system. Example:

```
% erl -env DISPLAY gin:0
```

In this example, an Erlang runtime system is started with the `DISPLAY` environment variable set to `gin:0`.

`-eval Expr`(init flag)

Makes `init` evaluate the expression `Expr`, see *init(3)*.

`-extra`(init flag)

Everything following `-extra` is considered plain arguments and can be retrieved using `init:get_plain_arguments/0`.

`-heart`

Starts heart beat monitoring of the Erlang runtime system. See *heart(3)*.

`-hidden`

Starts the Erlang runtime system as a hidden node, if it is run as a distributed node. Hidden nodes always establish hidden connections to all other nodes except for nodes in the same global group. Hidden connections are not published on either of the connected nodes, i.e. neither of the connected nodes are part of the result from `nodes/0` on the other node. See also hidden global groups, *global_group(3)*.

`-hosts Hosts`

Specifies the IP addresses for the hosts on which Erlang boot servers are running, see *erl_boot_server(3)*. This flag is mandatory if the `-loader inet` flag is present.

The IP addresses must be given in the standard form (four decimal numbers separated by periods, for example `"150.236.20.74"`. Hosts names are not acceptable, but a broadcast address (preferably limited to the local network) is.

`-id Id`

Specifies the identity of the Erlang runtime system. If it is run as a distributed node, `Id` must be identical to the name supplied together with the `-sname` or `-name` flag.

`-init_debug`

Makes `init` write some debug information while interpreting the boot script.

`-instr`(emulator flag)

Selects an instrumented Erlang runtime system (virtual machine) to run, instead of the ordinary one. When running an instrumented runtime system, some resource usage data can be obtained and analysed using the module `instrument`. Functionally, it behaves exactly like an ordinary Erlang runtime system.

`-loader Loader`

Specifies the method used by `erl_prim_loader` to load Erlang modules into the system. See *erl_prim_loader(3)*. Two `Loader` methods are supported, `efile` and `inet`. `efile` means use the local file system, this is the default. `inet` means use a boot server on another machine, and the `-id`, `-hosts` and `-setcookie` flags must be specified as well. If `Loader` is something else, the user supplied `Loader` port program is started.

`-make`

Makes the Erlang runtime system invoke `make:all()` in the current working directory and then terminate. See *make(3)*. Implies `-noinput`.

`-man Module`

Displays the manual page for the Erlang module `Module`. Only supported on Unix.

`-mode interactive | embedded`

Indicates if the system should load code dynamically (`interactive`), or if all code should be loaded during system initialization (`embedded`), see *code(3)*. Defaults to `interactive`.

`-name Name`

Makes the Erlang runtime system into a distributed node. This flag invokes all network servers necessary for a node to become distributed. See *net_kernel(3)*. It is also ensured that `epmd` runs on the current host before Erlang is started. See *epmd(1)*.

The name of the node will be `Name@Host`, where `Host` is the fully qualified host name of the current host. For short names, use the `-sname` flag instead.

`-noinput`

Ensures that the Erlang runtime system never tries to read any input. Implies `-noshell`.

`-noshell`

Starts an Erlang runtime system with no shell. This flag makes it possible to have the Erlang runtime system as a component in a series of UNIX pipes.

`-nostick`

Disables the sticky directory facility of the Erlang code server, see *code(3)*.

`-oldshell`

Invokes the old Erlang shell from Erlang 3.3. The old shell can still be used.

`-pa Dir1 Dir2 ...`

Adds the specified directories to the beginning of the code path, similar to `code:add_pathsa/1`. See *code(3)*. As an alternative to `-pa`, if several directories are to be prepended to the code path and the directories have a

common parent directory, that parent directory could be specified in the `ERL_LIBS` environment variable. See *code(3)*.

`-pz Dir1 Dir2 ...`

Adds the specified directories to the end of the code path, similar to `code:add_pathsz/1`. See *code(3)*.

`-path Dir1 Dir2 ...`

Replaces the path specified in the boot script. See *script(4)*.

`-proto_dist Proto`

Specify a protocol for Erlang distribution.

`inet_tcp`

TCP over IPv4 (the default)

`inet_tls`

distribution over TLS/SSL

`inet6_tcp`

TCP over IPv6

For example, to start up IPv6 distributed nodes:

```
% erl -name test@ipv6node.example.com -proto_dist inet6_tcp
```

`-remsh Node`

Starts Erlang with a remote shell connected to `Node`.

`-rsh Program`

Specifies an alternative to `rsh` for starting a slave node on a remote host. See *slave(3)*.

`-run Mod [Func [Arg1, Arg2, ...]]`(init flag)

Makes `init` call the specified function. `Func` defaults to `start`. If no arguments are provided, the function is assumed to be of arity 0. Otherwise it is assumed to be of arity 1, taking the list `[Arg1,Arg2,...]` as argument. All arguments are passed as strings. See *init(3)*.

`-s Mod [Func [Arg1, Arg2, ...]]`(init flag)

Makes `init` call the specified function. `Func` defaults to `start`. If no arguments are provided, the function is assumed to be of arity 0. Otherwise it is assumed to be of arity 1, taking the list `[Arg1,Arg2,...]` as argument. All arguments are passed as atoms. See *init(3)*.

`-setcookie Cookie`

Sets the magic cookie of the node to `Cookie`, see *erlang:set_cookie/2*.

`-shutdown_time Time`

Specifies how long time (in milliseconds) the `init` process is allowed to spend shutting down the system. If `Time` ms have elapsed, all processes still existing are killed. Defaults to `infinity`.

`-sname Name`

Makes the Erlang runtime system into a distributed node, similar to `-name`, but the host name portion of the node name `Name@Host` will be the short name, not fully qualified.

This is sometimes the only way to run distributed Erlang if the DNS (Domain Name System) is not running. There can be no communication between nodes running with the `-sname` flag and those running with the `-name` flag, as node names must be unique in distributed Erlang systems.

`-smp [enable|auto|disable]`

`-smp enable` and `-smp` starts the Erlang runtime system with SMP support enabled. This may fail if no runtime system with SMP support is available. `-smp auto` starts the Erlang runtime system with SMP support enabled if it is available and more than one logical processor are detected. `-smp disable` starts a runtime system without SMP support.

*NOTE*: The runtime system with SMP support will not be available on all supported platforms. See also the *+S* flag.

`-version`(emulator flag)

Makes the emulator print out its version number. The same as `erl +V`.

## Emulator Flags

`erl` invokes the code for the Erlang emulator (virtual machine), which supports the following flags:

`+a size`

Suggested stack size, in kilowords, for threads in the async-thread pool. Valid range is 16-8192 kilowords. The default suggested stack size is 16 kilowords, i.e, 64 kilobyte on 32-bit architectures. This small default size has been chosen since the amount of async-threads might be quite large. The default size is enough for drivers delivered with Erlang/OTP, but might not be sufficiently large for other dynamically linked in drivers that use the *driver_async()* functionality. Note that the value passed is only a suggestion, and it might even be ignored on some platforms.

`+A size`

Sets the number of threads in async thread pool, valid range is 0-1024. If thread support is available, the default is 10.

`+B [c | d | i]`

The `c` option makes `Ctrl-C` interrupt the current shell instead of invoking the emulator break handler. The `d` option (same as specifying `+B` without an extra option) disables the break handler. The `i` option makes the emulator ignore any break signal.

If the `c` option is used with `oldshell` on Unix, `Ctrl-C` will restart the shell process rather than interrupt it.

Note that on Windows, this flag is only applicable for `werl`, not `erl` (`oldshell`). Note also that `Ctrl-Break` is used instead of `Ctrl-C` on Windows.

`+c true | false`

Enable or disable *time correction*:

`true`

Enable time correction. This is the default if time correction is supported on the specific platform.

`false`

Disable time correction.

For backwards compatibility, the boolean value can be omitted. This is interpreted as `+c false`.

`+C no_time_warp | single_time_warp | multi_time_warp`

Set *time warp mode*:

`no_time_warp`

*No Time Warp Mode* (the default)

`single_time_warp`

*Single Time Warp Mode*

`multi_time_warp`

*Multi Time Warp Mode*

`+d`

If the emulator detects an internal error (or runs out of memory), it will by default generate both a crash dump and a core dump. The core dump will, however, not be very useful since the content of process heaps is destroyed by the crash dump generation.

The `+d` option instructs the emulator to only produce a core dump and no crash dump if an internal error is detected.

Calling `erlang:halt/1` with a string argument will still produce a crash dump. On Unix systems, sending an emulator process a SIGUSR1 signal will also force a crash dump.

`+e Number`

Set max number of ETS tables.

`+ec`

Force the `compressed` option on all ETS tables. Only intended for test and evaluation.

`+fnl`

The VM works with file names as if they are encoded using the ISO-latin-1 encoding, disallowing Unicode characters with codepoints beyond 255.

See *STDLIB User's Guide* for more infomation about unicode file names. Note that this value also applies to command-line parameters and environment variables (see *STDLIB User's Guide*).

`+fnu[{w|i|e}]`

The VM works with file names as if they are encoded using UTF-8 (or some other system specific Unicode encoding). This is the default on operating systems that enforce Unicode encoding, i.e. Windows and MacOS X.

The `+fnu` switch can be followed by `w`, `i`, or `e` to control the way wrongly encoded file names are to be reported. `w` means that a warning is sent to the `error_logger` whenever a wrongly encoded file name is "skipped" in directory listings, `i` means that those wrongly encoded file names are silently ignored and `e` means that the API function will return an error whenever a wrongly encoded file (or directory) name is encountered. `w` is the default. Note that `file:read_link/1` will always return an error if the link points to an invalid file name.

See *STDLIB User's Guide* for more infomation about unicode file names. Note that this value also applies to command-line parameters and environment variables (see *STDLIB User's Guide*).

`+fna[{w|i|e}]`

Selection between `+fnl` and `+fnu` is done based on the current locale settings in the OS, meaning that if you have set your terminal for UTF-8 encoding, the filesystem is expected to use the same encoding for file names. This is default on all operating systems except MacOS X and Windows.

The `+fna` switch can be followed by `w`, `i`, or `e`. This will have effect if the locale settings cause the behavior of `+fnu` to be selected. See the description of `+fnu` above. If the locale settings cause the behavior of `+fnl` to be selected, then `w`, `i`, or `e` will not have any effect.

See *STDLIB User's Guide* for more infomation about unicode file names. Note that this value also applies to command-line parameters and environment variables (see *STDLIB User's Guide*).

`+hms Size`

Sets the default heap size of processes to the size `Size`.

`+hmbs Size`

Sets the default binary virtual heap size of processes to the size `Size`.

`+hpds Size`

Sets the initial process dictionary size of processes to the size `Size`.

`+K true | false`

Enables or disables the kernel poll functionality if the emulator supports it. Default is `false` (disabled). If the emulator does not support kernel poll, and the `+K` flag is passed to the emulator, a warning is issued at startup.

`+l`

Enables auto load tracing, displaying info while loading code.

`+L`

Don't load information about source file names and line numbers. This will save some memory, but exceptions will not contain information about the file names and line numbers.

`+MFlag Value`

Memory allocator specific flags, see *erts_alloc(3)* for further information.

`+n Behavior`

Control behavior of signals to ports.

As of OTP-R16 signals to ports are truly asynchronously delivered. Note that signals always have been documented as asynchronous. The underlying implementation has, however, previously delivered these signals synchronously. Correctly written Erlang programs should be able to handle this without any issues. Bugs in existing Erlang programs that make false assumptions about signals to ports may, however, be tricky to find. This switch has been introduced in order to at least make it easier to compare behaviors during a transition period. Note that *this flag is deprecated* as of its introduction, and is scheduled for removal in OTP-R17. `Behavior` should be one of the following characters:

`d`
The default. Asynchronous signals. A process that sends a signal to a port may continue execution before the signal has been delivered to the port.

`s`
Synchronous signals. A processes that sends a signal to a port will not continue execution until the signal has been delivered. Should *only* be used for testing and debugging.

`a`
Asynchronous signals. As the default, but a processes that sends a signal will even more frequently continue execution before the signal has been delivered to the port. Should *only* be used for testing and debugging.

`+pc Range`

Sets the range of characters that the system will consider printable in heuristic detection of strings. This typically affects the shell, debugger and io:format functions (when ~tp is used in the format string).

Currently two values for the `Range` are supported:

`latin1`
The default. Only characters in the ISO-latin-1 range can be considered printable, which means that a character with a code point > 255 will never be considered printable and that lists containing such characters will be displayed as lists of integers rather than text strings by tools.

`unicode`
: All printable Unicode characters are considered when determining if a list of integers is to be displayed in string syntax. This may give unexpected results if for example your font does not cover all Unicode characters.

Se also *io:printable_range/0*.

`+P Number|legacy`

Sets the maximum number of simultaneously existing processes for this system if a `Number` is passed as value. Valid range for `Number` is `[1024-134217727]`

*NOTE*: The actual maximum chosen may be much larger than the `Number` passed. Currently the runtime system often, but not always, chooses a value that is a power of 2. This might, however, be changed in the future. The actual value chosen can be checked by calling *erlang:system_info(process_limit)*.

The default value is `262144`

If `legacy` is passed as value, the legacy algorithm for allocation of process identifiers will be used. Using the legacy algorithm, identifiers will be allocated in a strictly increasing fashion until largest possible identifier has been reached. Note that this algorithm suffers from performance issues and can under certain circumstances be extremely expensive. The legacy algoritm is deprecated, and the `legacy` option is scheduled for removal in OTP-R18.

`+Q Number|legacy`

Sets the maximum number of simultaneously existing ports for this system if a Number is passed as value. Valid range for `Number` is `[1024-134217727]`

*NOTE*: The actual maximum chosen may be much larger than the actual `Number` passed. Currently the runtime system often, but not always, chooses a value that is a power of 2. This might, however, be changed in the future. The actual value chosen can be checked by calling *erlang:system_info(port_limit)*.

The default value used is normally `65536`. However, if the runtime system is able to determine maximum amount of file descriptors that it is allowed to open and this value is larger than `65536`, the chosen value will increased to a value larger or equal to the maximum amount of file descriptors that can be opened.

On Windows the default value is set to `8196` because the normal OS limitations are set higher than most machines can handle.

Previously the environment variable `ERL_MAX_PORTS` was used for setting the maximum number of simultaneously existing ports. This environment variable is deprecated, and scheduled for removal in OTP-R17, but can still be used.

If `legacy` is passed as value, the legacy algorithm for allocation of port identifiers will be used. Using the legacy algorithm, identifiers will be allocated in a strictly increasing fashion until largest possible identifier has been reached. Note that this algorithm suffers from performance issues and can under certain circumstances be extremely expensive. The legacy algoritm is deprecated, and the `legacy` option is scheduled for removal in OTP-R18.

`+R ReleaseNumber`

Sets the compatibility mode.

The distribution mechanism is not backwards compatible by default. This flags sets the emulator in compatibility mode with an earlier Erlang/OTP release `ReleaseNumber`. The release number must be in the range `<current release>-2..<current release>`. This limits the emulator, making it possible for it to communicate with Erlang nodes (as well as C- and Java nodes) running that earlier release.

Note: Make sure all nodes (Erlang-, C-, and Java nodes) of a distributed Erlang system is of the same Erlang/OTP release, or from two different Erlang/OTP releases X and Y, where *all* Y nodes have compatibility mode X.

`+r`

Force ets memory block to be moved on realloc.

`+rg ReaderGroupsLimit`

Limits the amount of reader groups used by read/write locks optimized for read operations in the Erlang runtime system. By default the reader groups limit equals 64.

When the amount of schedulers is less than or equal to the reader groups limit, each scheduler has its own reader group. When the amount of schedulers is larger than the reader groups limit, schedulers share reader groups. Shared reader groups degrades read lock and read unlock performance while a large amount of reader groups degrades write lock performance, so the limit is a tradeoff between performance for read operations and performance for write operations. Each reader group currently consumes 64 byte in each read/write lock. Also note that a runtime system using shared reader groups benefits from *binding schedulers to logical processors*, since the reader groups are distributed better between schedulers.

`+S Schedulers:SchedulerOnline`

Sets the number of scheduler threads to create and scheduler threads to set online when SMP support has been enabled. The maximum for both values is 1024. If the Erlang runtime system is able to determine the amount of logical processors configured and logical processors available, `Schedulers` will default to logical processors configured, and `SchedulersOnline` will default to logical processors available; otherwise, the default values will be 1. `Schedulers` may be omitted if `:SchedulerOnline` is not and vice versa. The number of schedulers online can be changed at run time via *erlang:system_flag(schedulers_online, SchedulersOnline)*.

If `Schedulers` or `SchedulersOnline` is specified as a negative number, the value is subtracted from the default number of logical processors configured or logical processors available, respectively.

Specifying the value 0 for `Schedulers` or `SchedulersOnline` resets the number of scheduler threads or scheduler threads online respectively to its default value.

This option is ignored if the emulator doesn't have SMP support enabled (see the *-smp* flag).

`+SP SchedulersPercentage:SchedulersOnlinePercentage`

Similar to *+S* but uses percentages to set the number of scheduler threads to create, based on logical processors configured, and scheduler threads to set online, based on logical processors available, when SMP support has been enabled. Specified values must be greater than 0. For example, `+SP 50:25` sets the number of scheduler threads to 50% of the logical processors configured and the number of scheduler threads online to 25% of the logical processors available. `SchedulersPercentage` may be omitted if `:SchedulersOnlinePercentage` is not and vice versa. The number of schedulers online can be changed at run time via *erlang:system_flag(schedulers_online, SchedulersOnline)*.

This option interacts with *+S* settings. For example, on a system with 8 logical cores configured and 8 logical cores available, the combination of the options `+S 4:4 +SP 50:25` (in either order) results in 2 scheduler threads (50% of 4) and 1 scheduler thread online (25% of 4).

This option is ignored if the emulator doesn't have SMP support enabled (see the *-smp* flag).

`+SDcpu DirtyCPUSchedulers:DirtyCPUSchedulersOnline`

Sets the number of dirty CPU scheduler threads to create and dirty CPU scheduler threads to set online when threading support has been enabled. The maximum for both values is 1024, and each value is further limited by the settings for normal schedulers: the number of dirty CPU scheduler threads created cannot exceed the number of normal scheduler threads created, and the number of dirty CPU scheduler threads online cannot exceed the number of normal scheduler threads online (see the *+S* and *+SP* flags for more details). By default, the number of dirty CPU scheduler threads created equals the number of normal scheduler threads created, and the number of dirty CPU scheduler threads online equals the number of normal scheduler threads online. `DirtyCPUSchedulers` may be omitted if `:DirtyCPUSchedulersOnline`

is not and vice versa. The number of dirty CPU schedulers online can be changed at run time via *erlang:system_flag(dirty_cpu_schedulers_online, DirtyCPUSchedulersOnline)*.

This option is ignored if the emulator doesn't have threading support enabled. Currently, *this option is experimental* and is supported only if the emulator was configured and built with support for dirty schedulers enabled (it's disabled by default).

`+SDPcpu DirtyCPUSchedulersPercentage:DirtyCPUSchedulersOnlinePercentage`

Similar to *+SDcpu* but uses percentages to set the number of dirty CPU scheduler threads to create and number of dirty CPU scheduler threads to set online when threading support has been enabled. Specified values must be greater than 0. For example, `+SDPcpu 50:25` sets the number of dirty CPU scheduler threads to 50% of the logical processors configured and the number of dirty CPU scheduler threads online to 25% of the logical processors available. `DirtyCPUSchedulersPercentage` may be omitted if `:DirtyCPUSchedulersOnlinePercentage` is not and vice versa. The number of dirty CPU schedulers online can be changed at run time via *erlang:system_flag(dirty_cpu_schedulers_online, DirtyCPUSchedulersOnline)*.

This option interacts with *+SDcpu* settings. For example, on a system with 8 logical cores configured and 8 logical cores available, the combination of the options `+SDcpu 4:4 +SDPcpu 50:25` (in either order) results in 2 dirty CPU scheduler threads (50% of 4) and 1 dirty CPU scheduler thread online (25% of 4).

This option is ignored if the emulator doesn't have threading support enabled. Currently, *this option is experimental* and is supported only if the emulator was configured and built with support for dirty schedulers enabled (it's disabled by default).

`+SDio IOSchedulers`

Sets the number of dirty I/O scheduler threads to create when threading support has been enabled. The valid range is 0-1024. By default, the number of dirty I/O scheduler threads created is 10, same as the default number of threads in the *async thread pool* .

This option is ignored if the emulator doesn't have threading support enabled. Currently, *this option is experimental* and is supported only if the emulator was configured and built with support for dirty schedulers enabled (it's disabled by default).

`+sFlag Value`

Scheduling specific flags.

`+sbt BindType`

Set scheduler bind type.

Schedulers can also be bound using the *+stbt* flag. The only difference between these two flags is how the following errors are handled:

- Binding of schedulers is not supported on the specific platform.
- No available CPU topology. That is the runtime system was not able to automatically detected the CPU topology, and no *user defined CPU topology* was set.

If any of these errors occur when `+sbt` has been passed, the runtime system will print an error message, and refuse to start. If any of these errors occur when `+stbt` has been passed, the runtime system will silently ignore the error, and start up using unbound schedulers.

Currently valid `BindType`s:

`u`

`unbound` - Schedulers will not be bound to logical processors, i.e., the operating system decides where the scheduler threads execute, and when to migrate them. This is the default.

`ns`

`no_spread` - Schedulers with close scheduler identifiers will be bound as close as possible in hardware.

`ts`

`thread_spread` - Thread refers to hardware threads (e.g. Intel's hyper-threads). Schedulers with low scheduler identifiers, will be bound to the first hardware thread of each core, then schedulers with higher scheduler identifiers will be bound to the second hardware thread of each core, etc.

`ps`

`processor_spread` - Schedulers will be spread like `thread_spread`, but also over physical processor chips.

`s`

`spread` - Schedulers will be spread as much as possible.

`nnts`

`no_node_thread_spread` - Like `thread_spread`, but if multiple NUMA (Non-Uniform Memory Access) nodes exists, schedulers will be spread over one NUMA node at a time, i.e., all logical processors of one NUMA node will be bound to schedulers in sequence.

`nnps`

`no_node_processor_spread` - Like `processor_spread`, but if multiple NUMA nodes exists, schedulers will be spread over one NUMA node at a time, i.e., all logical processors of one NUMA node will be bound to schedulers in sequence.

`tnnps`

`thread_no_node_processor_spread` - A combination of `thread_spread`, and `no_node_processor_spread`. Schedulers will be spread over hardware threads across NUMA nodes, but schedulers will only be spread over processors internally in one NUMA node at a time.

`db`

`default_bind` - Binds schedulers the default way. Currently the default is `thread_no_node_processor_spread` (which might change in the future).

Binding of schedulers is currently only supported on newer Linux, Solaris, FreeBSD, and Windows systems.

If no CPU topology is available when the `+sbt` flag is processed and `BindType` is any other type than `u`, the runtime system will fail to start. CPU topology can be defined using the *+sct* flag. Note that the `+sct` flag may have to be passed before the `+sbt` flag on the command line (in case no CPU topology has been automatically detected).

The runtime system will by default *not* bind schedulers to logical processors.

*NOTE:* If the Erlang runtime system is the only operating system process that binds threads to logical processors, this improves the performance of the runtime system. However, if other operating system processes (as for example another Erlang runtime system) also bind threads to logical processors, there might be a performance penalty instead. In some cases this performance penalty might be severe. If this is the case, you are advised to not bind the schedulers.

How schedulers are bound matters. For example, in situations when there are fewer running processes than schedulers online, the runtime system tries to migrate processes to schedulers with low scheduler identifiers. The more the schedulers are spread over the hardware, the more resources will be available to the runtime system in such situations.

*NOTE:* If a scheduler fails to bind, this will often be silently ignored. This since it isn't always possible to verify valid logical processor identifiers. If an error is reported, it will be reported to the `error_logger`. If you want to verify that the schedulers actually have bound as requested, call *erlang:system_info(scheduler_bindings)*.

`+sbwt none|very_short|short|medium|long|very_long`

Set scheduler busy wait threshold. Default is `medium`. The threshold determines how long schedulers should busy wait when running out of work before going to sleep.

*NOTE:* This flag may be removed or changed at any time without prior notice.

`+scl true|false`

Enable or disable scheduler compaction of load. By default scheduler compaction of load is enabled. When enabled, load balancing will strive for a load distribution which causes as many scheduler threads as possible to be fully loaded (i.e., not run out of work). This is accomplished by migrating load (e.g. runnable processes) into a smaller set of schedulers when schedulers frequently run out of work. When disabled, the frequency with which schedulers run out of work will not be taken into account by the load balancing logic.

`+scl false` is similar to *+sub true* with the difference that `+sub true` also will balance scheduler utilization between schedulers.

`+sct CpuTopology`

- `<Id> = integer(); when 0 =< <Id> =< 65535`
- `<IdRange> = <Id>-<Id>`
- `<IdOrIdRange> = <Id> | <IdRange>`
- `<IdList> = <IdOrIdRange>,<IdOrIdRange> | <IdOrIdRange>`
- `<LogicalIds> = L<IdList>`
- `<ThreadIds> = T<IdList> | t<IdList>`
- `<CoreIds> = C<IdList> | c<IdList>`
- `<ProcessorIds> = P<IdList> | p<IdList>`
- `<NodeIds> = N<IdList> | n<IdList>`
- `<IdDefs> = <LogicalIds><ThreadIds><CoreIds><ProcessorIds><NodeIds> | <LogicalIds><ThreadIds><CoreIds><NodeIds><ProcessorIds>`
- `CpuTopology = <IdDefs>:<IdDefs> | <IdDefs>`

Set a user defined CPU topology. The user defined CPU topology will override any automatically detected CPU topology. The CPU topology is used when *binding schedulers to logical processors*.

Upper-case letters signify real identifiers and lower-case letters signify fake identifiers only used for description of the topology. Identifiers passed as real identifiers may be used by the runtime system when trying to access specific hardware and if they are not correct the behavior is undefined. Faked logical CPU identifiers are not accepted since there is no point in defining the CPU topology without real logical CPU identifiers. Thread, core, processor, and node identifiers may be left out. If left out, thread id defaults to `t0`, core id defaults to `c0`, processor id defaults to `p0`, and node id will be left undefined. Either each logical processor must belong to one and only one NUMA node, or no logical processors must belong to any NUMA nodes.

Both increasing and decreasing `<IdRange>`s are allowed.

NUMA node identifiers are system wide. That is, each NUMA node on the system have to have a unique identifier. Processor identifiers are also system wide. Core identifiers are processor wide. Thread identifiers are core wide.

The order of the identifier types imply the hierarchy of the CPU topology. Valid orders are either `<LogicalIds><ThreadIds><CoreIds><ProcessorIds><NodeIds>`, or

<LogicalIds><ThreadIds><CoreIds><NodeIds><ProcessorIds>. That is, thread is part of a core which is part of a processor which is part of a NUMA node, or thread is part of a core which is part of a NUMA node which is part of a processor. A cpu topology can consist of both processor external, and processor internal NUMA nodes as long as each logical processor belongs to one and only one NUMA node. If <ProcessorIds> is left out, its default position will be before <NodeIds>. That is, the default is processor external NUMA nodes.

If a list of identifiers is used in an <IdDefs>:

- <LogicalIds> have to be a list of identifiers.
- At least one other identifier type apart from <LogicalIds> also have to have a list of identifiers.
- All lists of identifiers have to produce the same amount of identifiers.

A simple example. A single quad core processor may be described this way:

```
% erl +sct L0-3c0-3
1> erlang:system_info(cpu_topology).
[{processor,[{core,{logical,0}},
             {core,{logical,1}},
             {core,{logical,2}},
             {core,{logical,3}}]}]
```

A little more complicated example. Two quad core processors. Each processor in its own NUMA node. The ordering of logical processors is a little weird. This in order to give a better example of identifier lists:

```
% erl +sct L0-1,3-2c0-3p0N0:L7,4,6-5c0-3p1N1
1> erlang:system_info(cpu_topology).
[{node,[{processor,[{core,{logical,0}},
                    {core,{logical,1}},
                    {core,{logical,3}},
                    {core,{logical,2}}]}]},
 {node,[{processor,[{core,{logical,7}},
                    {core,{logical,4}},
                    {core,{logical,6}},
                    {core,{logical,5}}]}]}]
```

As long as real identifiers are correct it is okay to pass a CPU topology that is not a correct description of the CPU topology. When used with care this can actually be very useful. This in order to trick the emulator to bind its schedulers as you want. For example, if you want to run multiple Erlang runtime systems on the same machine, you want to reduce the amount of schedulers used and manipulate the CPU topology so that they bind to different logical CPUs. An example, with two Erlang runtime systems on a quad core machine:

```
% erl +sct L0-3c0-3 +sbt db +S3:2 -detached -noinput -noshell -sname one
% erl +sct L3-0c0-3 +sbt db +S3:2 -detached -noinput -noshell -sname two
```

In this example each runtime system have two schedulers each online, and all schedulers online will run on different cores. If we change to one scheduler online on one runtime system, and three schedulers online on the other, all schedulers online will still run on different cores.

Note that a faked CPU topology that does not reflect how the real CPU topology looks like is likely to decrease the performance of the runtime system.

For more information, see *erlang:system_info(cpu_topology)*.

`+secio true|false`

Enable or disable eager check I/O scheduling. The default is currently `true`. The default was changed from `false` to `true` as of erts version 7.0. The behaviour before this flag was introduced corresponds to `+secio false`.

The flag effects when schedulers will check for I/O operations possible to execute, and when such I/O operations will execute. As the name of the parameter implies, schedulers will be more eager to check for I/O when `true` is passed. This however also implies that execution of outstanding I/O operation will not be prioritized to the same extent as when `false` is passed.

*`erlang:system_info(eager_check_io)`* returns the value of this parameter used when starting the VM.

`+sfwi Interval`

Set scheduler forced wakeup interval. All run queues will be scanned each `Interval` milliseconds. While there are sleeping schedulers in the system, one scheduler will be woken for each non-empty run queue found. An `Interval` of zero disables this feature, which also is the default.

This feature has been introduced as a temporary workaround for long-executing native code, and native code that does not bump reductions properly in OTP. When these bugs have be fixed the `+sfwi` flag will be removed.

`+stbt BindType`

Try to set scheduler bind type. The same as the *+sbt* flag with the exception of how some errors are handled. For more information, see the documentation of the *+sbt* flag.

`+sub true|false`

Enable or disable *scheduler utilization* balancing of load. By default scheduler utilization balancing is disabled and instead scheduler compaction of load is enabled which will strive for a load distribution which causes as many scheduler threads as possible to be fully loaded (i.e., not run out of work). When scheduler utilization balancing is enabled the system will instead try to balance scheduler utilization between schedulers. That is, strive for equal scheduler utilization on all schedulers.

`+sub true` is only supported on systems where the runtime system detects and uses a monotonically increasing high resolution clock. On other systems, the runtime system will fail to start.

`+sub true` implies *+scl false*. The difference between `+sub true` and `+scl false` is that `+scl false` will not try to balance the scheduler utilization.

`+swct very_eager|eager|medium|lazy|very_lazy`

Set scheduler wake cleanup threshold. Default is `medium`. This flag controls how eager schedulers should be requesting wake up due to certain cleanup operations. When a lazy setting is used, more outstanding cleanup operations can be left undone while a scheduler is idling. When an eager setting is used, schedulers will more frequently be woken, potentially increasing CPU-utilization.

*NOTE:* This flag may be removed or changed at any time without prior notice.

`+sws default|legacy`

Set scheduler wakeup strategy. Default strategy changed in erts-5.10/OTP-R16A. This strategy was previously known as `proposal` in OTP-R15. The `legacy` strategy was used as default from R13 up to and including R15.

*NOTE:* This flag may be removed or changed at any time without prior notice.

`+swt very_low|low|medium|high|very_high`

Set scheduler wakeup threshold. Default is `medium`. The threshold determines when to wake up sleeping schedulers when more work than can be handled by currently awake schedulers exist. A low threshold will

cause earlier wakeups, and a high threshold will cause later wakeups. Early wakeups will distribute work over multiple schedulers faster, but work will more easily bounce between schedulers.

*NOTE:* This flag may be removed or changed at any time without prior notice.

`+spp Bool`

Set default scheduler hint for port parallelism. If set to `true`, the VM will schedule port tasks when doing so will improve parallelism in the system. If set to `false`, the VM will try to perform port tasks immediately, improving latency at the expense of parallelism. If this flag has not been passed, the default scheduler hint for port parallelism is currently `false`. The default used can be inspected in runtime by calling *erlang:system_info(port_parallelism)*. The default can be overriden on port creation by passing the *parallelism* option to *open_port/2*

.

`+sss size`

Suggested stack size, in kilowords, for scheduler threads. Valid range is 4-8192 kilowords. The default stack size is OS dependent.

`+t size`

Set the maximum number of atoms the VM can handle. Default is 1048576.

`+T Level`

Enables modified timing and sets the modified timing level. Currently valid range is 0-9. The timing of the runtime system will change. A high level usually means a greater change than a low level. Changing the timing can be very useful for finding timing related bugs.

Currently, modified timing affects the following:

Process spawning

A process calling `spawn`, `spawn_link`, `spawn_monitor`, or `spawn_opt` will be scheduled out immediately after completing the call. When higher modified timing levels are used, the caller will also sleep for a while after being scheduled out.

Context reductions

The amount of reductions a process is a allowed to use before being scheduled out is increased or reduced.

Input reductions

The amount of reductions performed before checking I/O is increased or reduced.

*NOTE:* Performance will suffer when modified timing is enabled. This flag is *only* intended for testing and debugging. Also note that `return_to` and `return_from` trace messages will be lost when tracing on the spawn BIFs. This flag may be removed or changed at any time without prior notice.

`+V`

Makes the emulator print out its version number.

`+v`

Verbose.

`+W w | i | e`

Sets the mapping of warning messages for `error_logger`. Messages sent to the error logger using one of the warning routines can be mapped either to errors (`+W e`), warnings (`+W w`), or info reports (`+W i`). The default is warnings. The current mapping can be retrieved using `error_logger:warning_map/0`. See *error_logger(3)* for further information.

`+zFlag Value`

Miscellaneous flags.

`+zdbbl size`

Set the distribution buffer busy limit (*dist_buf_busy_limit*) in kilobytes. Valid range is 1-2097151. Default is 1024.

A larger buffer limit will allow processes to buffer more outgoing messages over the distribution. When the buffer limit has been reached, sending processes will be suspended until the buffer size has shrunk. The buffer limit is per distribution channel. A higher limit will give lower latency and higher throughput at the expense of higher memory usage.

`+zdntgc time`

Set the delayed node table garbage collection time (*delayed_node_table_gc*) in seconds. Valid values are either `infinity` or an integer in the range [0-100000000]. Default is 60.

Node table entries that are not referred will linger in the table for at least the amount of time that this parameter determines. The lingering prevents repeated deletions and insertions in the tables from occurring.

## Environment variables

`ERL_CRASH_DUMP`

If the emulator needs to write a crash dump, the value of this variable will be the file name of the crash dump file. If the variable is not set, the name of the crash dump file will be `erl_crash.dump` in the current directory.

`ERL_CRASH_DUMP_NICE`

*Unix systems*: If the emulator needs to write a crash dump, it will use the value of this variable to set the nice value for the process, thus lowering its priority. The allowable range is 1 through 39 (higher values will be replaced with 39). The highest value, 39, will give the process the lowest priority.

`ERL_CRASH_DUMP_SECONDS`

*Unix systems*: This variable gives the number of seconds that the emulator will be allowed to spend writing a crash dump. When the given number of seconds have elapsed, the emulator will be terminated by a SIGALRM signal.

If the environment variable is *not* set or it is set to zero seconds, `ERL_CRASH_DUMP_SECONDS=0`, the runtime system will not even attempt to write the crash dump file. It will just terminate.

If the environment variable is set to negative valie, e.g. `ERL_CRASH_DUMP_SECONDS=-1`, the runtime system will wait indefinitely for the crash dump file to be written.

This environment variable is used in conjuction with *`heart`* if `heart` is running:

`ERL_CRASH_DUMP_SECONDS=0`

Suppresses the writing a crash dump file entirely, thus rebooting the runtime system immediately. This is the same as not setting the environment variable.

`ERL_CRASH_DUMP_SECONDS=-1`

Setting the environment variable to a negative value will cause the termination of the runtime system to wait until the crash dump file has been completly written.

`ERL_CRASH_DUMP_SECONDS=S`

Will wait for `S` seconds to complete the crash dump file and then terminate the runtime system.

`ERL_AFLAGS`

The content of this environment variable will be added to the beginning of the command line for `erl`.

The `-extra` flag is treated specially. Its scope ends at the end of the environment variable content. Arguments following an `-extra` flag are moved on the command line into the `-extra` section, i.e. the end of the command line following after an `-extra` flag.

ERL_ZFLAGS and ERL_FLAGS

The content of these environment variables will be added to the end of the command line for `erl`.

The `-extra` flag is treated specially. Its scope ends at the end of the environment variable content. Arguments following an `-extra` flag are moved on the command line into the `-extra` section, i.e. the end of the command line following after an `-extra` flag.

ERL_LIBS

This environment variable contains a list of additional library directories that the code server will search for applications and add to the code path. See *code(3)*.

ERL_EPMD_ADDRESS

This environment variable may be set to a comma-separated list of IP addresses, in which case the *epmd* daemon will listen only on the specified address(es) and on the loopback address (which is implicitly added to the list if it has not been specified).

ERL_EPMD_PORT

This environment variable can contain the port number to use when communicating with *epmd*. The default port will work fine in most cases. A different port can be specified to allow nodes of independent clusters to co-exist on the same host. All nodes in a cluster must use the same epmd port number.

## Configuration

The standard Erlang/OTP system can be re-configured to change the default behavior on start-up.

The .erlang Start-up File

When Erlang/OTP is started, the system searches for a file named .erlang in the directory where Erlang/OTP is started. If not found, the user's home directory is searched for an .erlang file.

If an .erlang file is found, it is assumed to contain valid Erlang expressions. These expressions are evaluated as if they were input to the shell.

A typical .erlang file contains a set of search paths, for example:

```
io:format("executing user profile in HOME/.erlang\n",[]).
code:add_path("/home/calvin/test/ebin").
code:add_path("/home/hobbes/bigappl-1.2/ebin").
io:format(".erlang rc finished\n",[]).
```

user_default and shell_default

Functions in the shell which are not prefixed by a module name are assumed to be functional objects (Funs), built-in functions (BIFs), or belong to the module user_default or shell_default.

To include private shell commands, define them in a module user_default and add the following argument as the first line in the .erlang file.

```
code:load_abs("..../user_default").
```

erl

If the contents of .erlang are changed and a private version of user_default is defined, it is possible to customize the Erlang/OTP environment. More powerful changes can be made by supplying command line arguments in the start-up script erl. Refer to erl(1) and *init(3)* for further information.

## SEE ALSO

*init(3)*, *erl_prim_loader(3)*, *erl_boot_server(3)*, *code(3)*, *application(3)*, *heart(3)*, *net_kernel(3)*, *auth(3)*, *make(3)*, *epmd(1)*, *erts_alloc(3)*

# erlc

Command

The `erlc` program provides a common way to run all compilers in the Erlang system. Depending on the extension of each input file, `erlc` will invoke the appropriate compiler. Regardless of which compiler is used, the same flags are used to provide parameters such as include paths and output directory.

The current working directory, `"."`, will not be included in the code path when running the compiler (to avoid loading Beam files from the current working directory that could potentially be in conflict with the compiler or Erlang/OTP system used by the compiler).

## Exports

**`erlc flags file1.ext file2.ext...`**

`Erlc` compiles one or more files. The files must include the extension, for example `.erl` for Erlang source code, or `.yrl` for Yecc source code. `Erlc` uses the extension to invoke the correct compiler.

## Generally Useful Flags

The following flags are supported:

-I *directory*

Instructs the compiler to search for include files in the specified directory. When encountering an `-include` or `-include_lib` directive, the compiler searches for header files in the following directories:

- `"."`, the current working directory of the file server;
- the base name of the compiled file;
- the directories specified using the `-I` option. The directory specified last is searched first.

-o *directory*

The directory where the compiler should place the output files. If not specified, output files will be placed in the current working directory.

-D*name*

Defines a macro.

-D*name=value*

Defines a macro with the given value. The value can be any Erlang term. Depending on the platform, the value may need to be quoted if the shell itself interprets certain characters. On Unix, terms which contain tuples and list must be quoted. Terms which contain spaces must be quoted on all platforms.

-W*error*

Makes all warnings into errors.

-W*number*

Sets warning level to *number*. Default is `1`. Use `-W0` to turn off warnings.

-W

Same as `-W1`. Default.

-v

Enables verbose output.

-b *output-type*

Specifies the type of output file. Generally, *output-type* is the same as the file extension of the output file but without the period. This option will be ignored by compilers that have a a single output format.

-smp

Compile using the SMP emulator. This is mainly useful for compiling native code, which needs to be compiled with the same run-time system that it should be run on.

-M

Produces a Makefile rule to track headers dependencies. The rule is sent to stdout. No object file is produced.

-MF *Makefile*

Like the `-M` option above, except that the Makefile is written to *Makefile*. No object file is produced.

-MD

Same as `-M -MF <File>.Pbeam`.

-MT *Target*

In conjunction with `-M` or `-MF`, change the name of the rule emitted to *Target*.

-MQ *Target*

Like the `-MT` option above, except that characters special to make(1) are quoted.

-MP

In conjunction with `-M` or `-MF`, add a phony target for each dependency.

-MG

In conjunction with `-M` or `-MF`, consider missing headers as generated files and add them to the dependencies.

--

Signals that no more options will follow. The rest of the arguments will be treated as file names, even if they start with hyphens.

+*term*

A flag starting with a plus ('+') rather than a hyphen will be converted to an Erlang term and passed unchanged to the compiler. For instance, the `export_all` option for the Erlang compiler can be specified as follows:

```
erlc +export_all file.erl
```

Depending on the platform, the value may need to be quoted if the shell itself interprets certain characters. On Unix, terms which contain tuples and list must be quoted. Terms which contain spaces must be quoted on all platforms.

## Special Flags

The flags in this section are useful in special situations such as re-building the OTP system.

-pa *directory*

Appends *directory* to the front of the code path in the invoked Erlang emulator. This can be used to invoke another compiler than the default one.

-pz *directory*

Appends *directory* to the code path in the invoked Erlang emulator.

## Supported Compilers

.erl

Erlang source code. It generates a `.beam` file.

The options -P, -E, and -S are equivalent to +'P', +'E', and +'S', except that it is not necessary to include the single quotes to protect them from the shell.

Supported options: -I, -o, -D, -v, -W, -b.

.S

Erlang assembler source code. It generates a `.beam` file.

Supported options: same as for .erl.

.core

Erlang core source code. It generates a `.beam` file.

Supported options: same as for .erl.

.yrl

Yecc source code. It generates an `.erl` file.

Use the -I option with the name of a file to use that file as a customized prologue file (the `includefile` option).

Supported options: -o, -v, -I, -W (see above).

.mib

MIB for SNMP. It generates a `.bin` file.

Supported options: -I, -o, -W.

.bin

A compiled MIB for SNMP. It generates a `.hrl` file.

Supported options: -o, -v.

.rel

Script file. It generates a boot file.

Use the -I to name directories to be searched for application files (equivalent to the `path` in the option list for `systools:make_script/2`).

Supported options: -o.

.asn1

ASN1 file.

Creates an `.erl`, `.hrl`, and `.asn1db` file from an `.asn1` file. Also compiles the `.erl` using the Erlang compiler unless the `+noobj` options is given.

Supported options: -I, -o, -b, -W.

.idl

IC file.

Runs the IDL compiler.

Supported options: -I, -o.

## Environment Variables

ERLC_EMULATOR

The command for starting the emulator. Default is *erl* in the same directory as the *erlc* program itself, or if it doesn't exist, *erl* in any of the directories given in the *PATH* environment variable.

## SEE ALSO

*erl(1), compile(3), yecc(3), snmp(3)*

# werl

Command

On Windows, the preferred way to start the Erlang system for interactive use is:

```
werl <arguments>
```

This will start Erlang in its own window, with fully functioning command-line editing and scrollbars. All flags except `-oldshell` work as they do for the *erl* command.

Ctrl-C is reserved for copying text to the clipboard (Ctrl-V to paste). To interrupt the runtime system or the shell process (depending on what has been specified with the +B system flag), you should use Ctrl-Break.

In cases where you want to redirect standard input and/or standard output or use Erlang in a pipeline, the `werl` is not suitable, and the `erl` program should be used instead.

The `werl` window is in many ways modelled after the `xterm` window present on other platforms, as the `xterm` model fits well with line oriented command based interaction. This means that selecting text is line oriented rather than rectangle oriented.

To select text in the `werl` window , simply press and hold the left mouse button and drag the mouse over the text you want to select. If the selection crosses line boundaries, the selected text will consist of complete lines where applicable (just like in a word processor). To select more text than fits in the window, start by selecting a small portion in the beginning of the text you want, then use the scrollbar to view the end of the desired selection, point to it and press the *right* mouse-button. The whole area between your first selection and the point where you right-clicked will be included in the selection.

The selected text is copied to the clipboard by either pressing `Ctrl-C`, using the menu or pressing the copy button in the toolbar.

Pasted text is always inserted at the current prompt position and will be interpreted by Erlang as usual keyboard input.

Previous command lines can be retrieved by pressing the `Up arrow` or by pressing `Ctrl-P`. There is also a drop down box in the toolbar containing the command history. Selecting a command in the drop down box will insert it at the prompt, just as if you used the keyboard to retrieve the command.

Closing the `werl` window will stop the Erlang emulator.

# escript

Command

`escript` provides support for running short Erlang programs without having to compile them first and an easy way to retrieve the command line arguments.

## Exports

**`script-name script-arg1 script-arg2...`**
**`escript escript-flags script-name script-arg1 script-arg2...`**

`escript` runs a script written in Erlang.

Here follows an example.

```
$ chmod u+x factorial
$ cat factorial
#!/usr/bin/env escript
%% -*- erlang -*-
%%! -smp enable -sname factorial -mnesia debug verbose
main([String]) ->
    try
        N = list_to_integer(String),
        F = fac(N),
        io:format("factorial ~w = ~w\n", [N,F])
    catch
        _:_ ->
            usage()
    end;
main(_) ->
    usage().

usage() ->
    io:format("usage: factorial integer\n"),
    halt(1).

fac(0) -> 1;
fac(N) -> N * fac(N-1).
$ ./factorial 5
factorial 5 = 120
$ ./factorial
usage: factorial integer
$ ./factorial five
usage: factorial integer
```

The header of the Erlang script in the example differs from a normal Erlang module. The first line is intended to be the interpreter line, which invokes `escript`. However if you invoke the `escript` like this

```
$ escript factorial 5
```

the contents of the first line does not matter, but it cannot contain Erlang code as it will be ignored.

The second line in the example, contains an optional directive to the `Emacs` editor which causes it to enter the major mode for editing Erlang source files. If the directive is present it must be located on the second line.

If there is a comment selecting the *encoding* it can be located on the second line.

> ### Note:
>
> The encoding specified by the above mentioned comment applies to the script itself. The encoding of the I/O-server, however, has to be set explicitly like this:
>
> ```
> io:setopts([{encoding, unicode}])
> ```
>
> The default encoding of the I/O-server for `standard_io` is `latin1` since the script runs in a non-interactive terminal (see *Using Unicode in Erlang*).

On the third line (or second line depending on the presence of the Emacs directive), it is possible to give arguments to the emulator, such as

```
%%! -smp enable -sname factorial -mnesia debug verbose
```

Such an argument line must start with `%%!` and the rest of the line will interpreted as arguments to the emulator.

If you know the location of the `escript` executable, the first line can directly give the path to `escript`. For instance:

```
#!/usr/local/bin/escript
```

As any other kind of scripts, Erlang scripts will not work on Unix platforms if the execution bit for the script file is not set. (Use `chmod +x script-name` to turn on the execution bit.)

The rest of the Erlang script file may either contain Erlang `source code`, an `inlined beam file` or an `inlined archive file`.

An Erlang script file must always contain the function *main/1*. When the script is run, the `main/1` function will be called with a list of strings representing the arguments given to the script (not changed or interpreted in any way).

If the `main/1` function in the script returns successfully, the exit status for the script will be 0. If an exception is generated during execution, a short message will be printed and the script terminated with exit status 127.

To return your own non-zero exit code, call `halt(ExitCode)`; for instance:

```
halt(1).
```

Call *escript:script_name()* from your to script to retrieve the pathname of the script (the pathname is usually, but not always, absolute).

If the file contains source code (as in the example above), it will be processed by the preprocessor `epp`. This means that you for example may use pre-defined macros (such as `?MODULE`) as well as include directives like the `-include_lib` directive. For instance, use

```
```

```
-include_lib("kernel/include/file.hrl").
```

to include the record definitions for the records used by the `file:read_link_info/1` function. You can also select encoding by including a encoding comment here, but if there is a valid encoding comment on the second line it takes precedence.

The script will be checked for syntactic and semantic correctness before being run. If there are warnings (such as unused variables), they will be printed and the script will still be run. If there are errors, they will be printed and the script will not be run and its exit status will be 127.

Both the module declaration and the export declaration of the `main/1` function are optional.

By default, the script will be interpreted. You can force it to be compiled by including the following line somewhere in the script file:

```
-mode(compile).
```

Execution of interpreted code is slower than compiled code. If much of the execution takes place in interpreted code it may be worthwhile to compile it, even though the compilation itself will take a little while. It is also possible to supply `native` instead of `compile`, this will compile the script using the native flag, again depending on the characteristics of the escript this could or could not be worth while.

As mentioned earlier, it is possible to have a script which contains precompiled `beam` code. In a precompiled script, the interpretation of the script header is exactly the same as in a script containing source code. That means that you can make a `beam` file executable by prepending the file with the lines starting with `#!` and `%%!` mentioned above. In a precompiled script, the function `main/1` must be exported.

As yet another option it is possible to have an entire Erlang archive in the script. In a archive script, the interpretation of the script header is exactly the same as in a script containing source code. That means that you can make an archive file executable by prepending the file with the lines starting with `#!` and `%%!` mentioned above. In an archive script, the function `main/1` must be exported. By default the `main/1` function in the module with the same name as the basename of the `escript` file will be invoked. This behavior can be overridden by setting the flag `-escript main Module` as one of the emulator flags. The `Module` must be the name of a module which has an exported `main/1` function. See *code(3)* for more information about archives and code loading.

In many cases it is very convenient to have a header in the escript, especially on Unix platforms. But the header is in fact optional. This means that you directly can "execute" an Erlang module, beam file or archive file without adding any header to them. But then you have to invoke the script like this:

```
$ escript factorial.erl 5
factorial 5 = 120
$ escript factorial.beam 5
factorial 5 = 120
$ escript factorial.zip 5
factorial 5 = 120
```

**`escript:create(FileOrBin, Sections) -> ok | {ok, binary()} | {error, term()}`**

Types:

**`FileOrBin = filename() | 'binary'`**

**`Sections = [Header] Body | Body`**

**`Header = shebang | {shebang, Shebang} | comment | {comment, Comment} | {emu_args, EmuArgs}`**

```
Shebang = string() | 'default' | 'undefined'
Comment = string() | 'default' | 'undefined'
EmuArgs = string() | 'undefined'
Body = {source, SourceCode} | {beam, BeamCode} | {archive, ZipArchive} |
{archive, ZipFiles, ZipOptions}
SourceCode = BeamCode = file:filename() | binary()
ZipArchive = zip:filename() | binary()
ZipFiles = [ZipFile]
ZipFile = file:filename() | {file:filename(), binary()} |
{file:filename(), binary(), file:file_info()}
ZipOptions = [zip:create_option()]
```

The `create/2` function creates an escript from a list of sections. The sections can be given in any order. An escript begins with an optional `Header` followed by a mandatory `Body`. If the header is present, it does always begin with a `shebang`, possibly followed by a `comment` and `emu_args`. The `shebang` defaults to `"/usr/bin/env escript"`. The comment defaults to `"This is an -*- erlang -*- file"`. The created escript can either be returned as a binary or written to file.

As an example of how the function can be used, we create an interpreted escript which uses `emu_args` to set some emulator flag. In this case it happens to disable the smp_support. We do also extract the different sections from the newly created script:

```
> Source = "%% Demo\nmain(_Args) ->\n    io:format(erlang:system_info(smp_support)).\n".
"%% Demo\nmain(_Args) ->\n    io:format(erlang:system_info(smp_support)).\n"
> io:format("~s\n", [Source]).
%% Demo
main(_Args) ->
    io:format(erlang:system_info(smp_support)).

ok
> {ok, Bin} = escript:create(binary, [shebang, comment, {emu_args, "-smp disable"},
                                      {source, list_to_binary(Source)}]).
{ok,<<"#!/usr/bin/env escript\n%% This is an -*- erlang -*- file\n%%!-smp disabl"...>>}
> file:write_file("demo.escript", Bin).
ok
> os:cmd("escript demo.escript").
"false"
> escript:extract("demo.escript", []).
{ok,[{shebang,default}, {comment,default}, {emu_args,"-smp disable"},
     {source,<<"%% Demo\nmain(_Args) ->\n    io:format(erlang:system_info(smp_su"...>>}]}
```

An escript without header can be created like this:

```
> file:write_file("demo.erl",
                  ["%% demo.erl\n-module(demo).\n-export([main/1]).\n\n", Source]).
ok
> {ok, _, BeamCode} = compile:file("demo.erl", [binary, debug_info]).
{ok,demo,
    <<70,79,82,49,0,0,2,208,66,69,65,77,65,116,111,109,0,0,0,
      79,0,0,0,9,4,100,...>>}
> escript:create("demo.beam", [{beam, BeamCode}]).
ok
> escript:extract("demo.beam", []).
{ok,[{shebang,undefined}, {comment,undefined}, {emu_args,undefined},
```

```
     {beam,<<70,79,82,49,0,0,3,68,66,69,65,77,65,116,
             111,109,0,0,0,83,0,0,0,9,...>>}]}
> os:cmd("escript demo.beam").
"true"
```

Here we create an archive script containing both Erlang code as well as beam code. Then we iterate over all files in the archive and collect their contents and some info about them.

```
> {ok, SourceCode} = file:read_file("demo.erl").
{ok,<<"%% demo.erl\n-module(demo).\n-export([main/1]).\n\n%% Demo\nmain(_Arg"...>>}
> escript:create("demo.escript",
                 [shebang,
                  {archive, [{"demo.erl", SourceCode},
                             {"demo.beam", BeamCode}], []}]).
ok
> {ok, [{shebang,default}, {comment,undefined}, {emu_args,undefined},
     {archive, ArchiveBin}]} = escript:extract("demo.escript", []).
{ok,[{shebang,default}, {comment,undefined}, {emu_args,undefined},
     {{archive,<<80,75,3,4,20,0,0,0,8,0,118,7,98,60,105,
                 152,61,93,107,0,0,0,118,0,...>>}]}
> file:write_file("demo.zip", ArchiveBin).
ok
> zip:foldl(fun(N, I, B, A) -> [{N, I(), B()} | A] end, [], "demo.zip").
{ok,[{"demo.beam",
      {file_info,748,regular,read_write,
                 {{2010,3,2},{0,59,22}},
                 {{2010,3,2},{0,59,22}},
                 {{2010,3,2},{0,59,22}},
                 54,1,0,0,0,0,0},
      <<70,79,82,49,0,0,2,228,66,69,65,77,65,116,111,109,0,0,0,
        83,0,0,...>>},
     {"demo.erl",
      {file_info,118,regular,read_write,
                 {{2010,3,2},{0,59,22}},
                 {{2010,3,2},{0,59,22}},
                 {{2010,3,2},{0,59,22}},
                 54,1,0,0,0,0,0},
      <<"%% demo.erl\n-module(demo).\n-export([main/1]).\n\n%% Demo\nmain(_Arg"...>>}]}
```

**`escript:extract(File, Options) -> {ok, Sections} | {error, term()}`**

Types:

**`File = filename()`**
**`Options = [] | [compile_source]`**
**`Sections = Headers Body`**
**`Headers = {shebang, Shebang} {comment, Comment} {emu_args, EmuArgs}`**
**`Shebang = string() | 'default' | 'undefined'`**
**`Comment = string() | 'default' | 'undefined'`**
**`EmuArgs = string() | 'undefined'`**
**`Body = {source, SourceCode} | {source, BeamCode} | {beam, BeamCode} | {archive, ZipArchive}`**
**`SourceCode = BeamCode = ZipArchive = binary()`**

The `extract/2` function parses an escript and extracts its sections. This is the reverse of `create/2`.

All sections are returned even if they do not exist in the escript. If a particular section happens to have the same value as the default value, the extracted value is set to the atom `default`. If a section is missing, the extracted value is set to the atom `undefined`.

The `compile_source` option only affects the result if the escript contains `source` code. In that case the Erlang code is automatically compiled and `{source, BeamCode}` is returned instead of `{source, SourceCode}`.

```
> escript:create("demo.escript",
                 [shebang, {archive, [{"demo.erl", SourceCode},
                                      {"demo.beam", BeamCode}], []}]).
ok
> {ok, [{shebang,default}, {comment,undefined}, {emu_args,undefined},
     {archive, ArchiveBin}]} =
               escript:extract("demo.escript", []).
{ok,[{{archive,<<80,75,3,4,20,0,0,0,8,0,118,7,98,60,105,
                 152,61,93,107,0,0,0,118,0,...>>}
     {emu_args,undefined}]}
```

**`escript:script_name() -> File`**

Types:

**`File = filename()`**

The `script_name/0` function returns the name of the escript being executed. If the function is invoked outside the context of an escript, the behavior is undefined.

## Options accepted by escript

-c
: Compile the escript regardless of the value of the mode attribute.

-d
: Debug the escript. Starts the debugger, loads the module containing the `main/1` function into the debugger, sets a breakpoint in `main/1` and invokes `main/1`. If the module is precompiled, it must be explicitly compiled with the `debug_info` option.

-i
: Interpret the escript regardless of the value of the mode attribute.

-s
: Only perform a syntactic and semantic check of the script file. Warnings and errors (if any) are written to the standard output, but the script will not be run. The exit status will be 0 if there were no errors, and 127 otherwise.

-n
: Compile the escript using the +native flag.

# erlsrv

Command

This utility is specific to Windows NT/2000/XP® (and subsequent versions of Windows) It allows Erlang emulators to run as services on the Windows system, allowing embedded systems to start without any user needing to log in. The emulator started in this way can be manipulated through the Windows® services applet in a manner similar to other services.

Note that erlsrv is not a general service utility for Windows, but designed for embedded Erlang systems.

As well as being the actual service, erlsrv also provides a command line interface for registering, changing, starting and stopping services.

To manipulate services, the logged in user should have Administrator privileges on the machine. The Erlang machine itself is (default) run as the local administrator. This can be changed with the Services applet in Windows ®.

The processes created by the service can, as opposed to normal services, be "killed" with the task manager. Killing a emulator that is started by a service will trigger the "OnFail" action specified for that service, which may be a reboot.

The following parameters may be specified for each Erlang service:

- `StopAction`: This tells `erlsrv` how to stop the Erlang emulator. Default is to kill it (Win32 TerminateProcess), but this action can specify any Erlang shell command that will be executed in the emulator to make it stop. The emulator is expected to stop within 30 seconds after the command is issued in the shell. If the emulator is not stopped, it will report a running state to the service manager.
- `OnFail`: This can be either of `reboot`, `restart`, `restart_always` or `ignore` (the default). In case of `reboot`, the NT system is rebooted whenever the emulator stops (a more simple form of watchdog), this could be useful for less critical systems, otherwise use the heart functionality to accomplish this. The restart value makes the Erlang emulator be restarted (with whatever parameters are registered for the service at the occasion) when it stops. If the emulator stops again within 10 seconds, it is not restarted to avoid an infinite loop which could completely hang the NT system. `restart_always` is similar to restart, but does not try to detect cyclic restarts, it is expected that some other mechanism is present to avoid the problem. The default (ignore) just reports the service as stopped to the service manager whenever it fails, it has to be manually restarted.

  On a system where release handling is used, this should always be set to `ignore`. Use `heart` to restart the service on failure instead.
- `Machine`: The location of the Erlang emulator. The default is the `erl.exe` located in the same directory as erlsrv.exe. Do not specify `werl.exe` as this emulator, it will not work.

  If the system uses release handling, this should be set to a program similar to `start_erl.exe`.
- `Env`: Specifies an *additional* environment for the emulator. The environment variables specified here are added to the system wide environment block that is normally present when a service starts up. Variables present in both the system wide environment and in the service environment specification will be set to the value specified in the service.
- `WorkDir`: The working directory for the Erlang emulator, has to be on a local drive (there are no network drives mounted when a service starts). Default working directory for services is `%SystemDrive%%SystemPath%`. Debug log files will be placed in this directory.
- `Priority`: The process priority of the emulator, this can be one of `realtime`, `high`, `low` or `default` (the default). Real-time priority is not recommended, the machine will possibly be inaccessible to interactive users. High priority could be used if two Erlang nodes should reside on one dedicated system and one should have precedence over the other. Low process priority may be used if interactive performance should not be affected by the emulator process.

- `SName or Name`: Specifies the short or long node-name of the Erlang emulator. The Erlang services are always distributed, default is to use the service name as (short) node-name.
- `DebugType`: Can be one of `none` (default), `new`, `reuse` or `console`. Specifies that output from the Erlang shell should be sent to a "debug log". The log file is named <servicename>`.debug` or <servicename>`.debug.`<N>, where <N> is an integer between 1 and 99. The log-file is placed in the working directory of the service (as specified in WorkDir). The `reuse` option always reuses the same log file (<servicename>`.debug`) and the `new` option uses a separate log file for every invocation of the service (<servicename>`.debug.`<N>). The `console` option opens an interactive Windows® console window for the Erlang shell of the service. The `console` option automatically disables the `StopAction` and a service started with an interactive console window will not survive logouts, `OnFail` actions do not work with debug-consoles either. If no `DebugType` is specified (`none`), the output of the Erlang shell is discarded.

  The `consoleDebugType` is *not in any way* intended for production. It is *only* a convenient way to debug Erlang services during development. The `new` and `reuse` options might seem convenient to have in a production system, but one has to take into account that the logs will grow indefinitely during the systems lifetime and there is no way, short of restarting the service, to truncate those logs. In short, the `DebugType` is intended for debugging only. Logs during production are better produced with the standard Erlang logging facilities.
- `Args`: Additional arguments passed to the emulator startup program `erl.exe` (or `start_erl.exe`). Arguments that cannot be specified here are `-noinput` (StopActions would not work), `-name` and `-sname` (they are specified in any way. The most common use is for specifying cookies and flags to be passed to init:boot() (`-s`).
- `InternalServiceName`: Specifies the Windows® internal service name (not the display name, which is the one `erlsrv` uses to identify the service).

  This internal name can not be changed, it is fixed even if the service is renamed. `Erlsrv` generates a unique internal name when a service is created, it is recommended to keep to the defaut if release-handling is to be used for the application.

  The internal service name can be seen in the Windows® service manager if viewing `Properties` for an erlang service.
- `Comment`: A textual comment describing the service. Not mandatory, but shows up as the service description in the Windows® service manager.

The naming of the service in a system that uses release handling has to follow the convention *NodeName_Release*, where *NodeName* is the first part of the Erlang nodename (up to, but not including the "@") and *Release* is the current release of the application.

## Exports

### `erlsrv {set | add} <service-name> [<service options>]`

The set and add commands adds or modifies a Erlang service respectively. The simplest form of an add command would be completely without options in which case all default values (described above) apply. The service name is mandatory.

Every option can be given without parameters, in which case the default value is applied. Values to the options are supplied *only* when the default should not be used (i.e. `erlsrv set myservice -prio -arg` sets the default priority and removes all arguments).

The following service options are currently available:

-st[opaction] [<erlang shell command>]
Defines the StopAction, the command given to the Erlang shell when the service is stopped. Default is none.
-on[fail] [{reboot | restart | restart_always}]
Specifies the action to take when the Erlang emulator stops unexpectedly. Default is to ignore.

-m[achine] [<erl-command>]
: The complete path to the Erlang emulator, never use the werl program for this. Default is the `erl.exe` in the same directory as `erlsrv.exe`. When release handling is used, this should be set to a program similar to `start_erl.exe`.

-e[nv] [<variable>[=<value>]] ...
: Edits the environment block for the service. Every environment variable specified will add to the system environment block. If a variable specified here has the same name as a system wide environment variable, the specified value overrides the system wide. Environment variables are added to this list by specifying <variable>=<value> and deleted from the list by specifying <variable> alone. The environment block is automatically sorted. Any number of `-env` options can be specified in one command. Default is to use the system environment block unmodified (except for two additions, see *below*).

-w[orkdir] [<directory>]
: The initial working directory of the Erlang emulator. Default is the system directory.

-p[riority] [{low|high|realtime}]
: The priority of the Erlang emulator. The default is the Windows® default priority.

{-sn[ame] | -n[ame]} [<node-name>]
: The node-name of the Erlang machine, distribution is mandatory. Default is `-sname <service name>`.

-d[ebugtype] [{new|reuse|console}]
: Specifies where shell output should be sent, default is that shell output is discarded. To be used only for debugging.

-ar[gs] [<limited erl arguments>]
: Additional arguments to the Erlang emulator, avoid `-noinput`, `-noshell` and `-sname`/`-name`. Default is no additional arguments. Remember that the services cookie file is not necessarily the same as the interactive users. The service runs as the local administrator. All arguments should be given together in one string, use double quotes (") to give an argument string containing spaces and use quoted quotes (\") to give an quote within the argument string if necessary.

-i[nternalservicename] [<internal name>]
: *Only* allowed for `add`. Specifies a Windows® internal service name for the service, which by default is set to something unique (prefixed with the original service name) by erlsrv when adding a new service. Specifying this is a purely cosmethic action and is *not* recommended if release handling is to be performed. The internal service name cannot be changed once the service is created. The internal name is *not* to be confused with the ordinary service name, which is the name used to identify a service to erlsrv.

-c[omment] [<short description>]
: Specifies a textual comment describing the service. This comment will show upp as the service description in the Windows® service manager.

### `erlsrv {start | start_disabled | stop | disable | enable} <service-name>`

These commands are only added for convenience, the normal way to manipulate the state of a service is through the control panels services applet. The `start` and `stop` commands communicates with the service manager for stopping and starting a service. The commands wait until the service is actually stopped or started. When disabling a service, it is not stopped, the disabled state will not take effect until the service actually is stopped. Enabling a service sets it in automatic mode, that is started at boot. This command cannot set the service to manual.

The `start_disabled` command operates on a service regardless of if it's enabled/disabled or started/stopped. It does this by first enabling it (regardless of if it's enabled or not), then starting it (if it's not already started) and then disabling it. The result will be a disabled but started service, regardless of its earlier state. This is useful for starting services temporarily during a release upgrade. The difference between using `start_disabled` and the sequence `enable`, `start` and `disable` is that all other `erlsrv` commands are locked out during the sequence of operations in `start_disable`, making the operation atomic from an `erlsrv` user's point of view.

**`erlsrv remove <service-name>`**

This command removes the service completely with all its registered options. It will be stopped before it is removed.

**`erlsrv list [<service-name>]`**

If no service name is supplied, a brief listing of all Erlang services is presented. If a service-name is supplied, all options for that service are presented.

**`erlsrv help`**

## ENVIRONMENT

The environment of an Erlang machine started as a service will contain two special variables, `ERLSRV_SERVICE_NAME`, which is the name of the service that started the machine and `ERLSRV_EXECUTABLE` which is the full path to the `erlsrv.exe` that can be used to manipulate the service. This will come in handy when defining a heart command for your service. A command file for restarting a service will simply look like this:

```
@echo off
%ERLSRV_EXECUTABLE% stop %ERLSRV_SERVICE_NAME%
%ERLSRV_EXECUTABLE% start %ERLSRV_SERVICE_NAME%
```

This command file is then set as heart command.

The environment variables can also be used to detect that we are running as a service and make port programs react correctly to the control events generated on logout (see below).

## PORT PROGRAMS

When a program runs in the service context, it has to handle the control events that is sent to every program in the system when the interactive user logs off. This is done in different ways for programs running in the console subsystem and programs running as window applications. An application which runs in the console subsystem (normal for port programs) uses the win32 function `SetConsoleCtrlHandler` to register a control handler that returns TRUE in answer to the `CTRL_LOGOFF_EVENT` and `CTRL_SHUTDOWN_EVENT` events. Other applications just forward `WM_ENDSESSION` and `WM_QUERYENDSESSION` to the default window procedure. Here is a brief example in C of how to set the console control handler:

```
#include <windows.h>
/*
** A Console control handler that ignores the log off events,
** and lets the default handler take care of other events.
*/
BOOL WINAPI service_aware_handler(DWORD ctrl){
    if(ctrl == CTRL_LOGOFF_EVENT)
        return TRUE;
    if(ctrl == CTRL_SHUTDOWN_EVENT)
        return TRUE;
    return FALSE;
}

void initialize_handler(void){
    char buffer[2];
    /*
     * We assume we are running as a service if this
     * environment variable is defined
     */
```

```
    if(GetEnvironmentVariable("ERLSRV_SERVICE_NAME",buffer,
                              (DWORD) 2)){
        /*
        ** Actually set the control handler
        */
        SetConsoleCtrlHandler(&service_aware_handler, TRUE);
    }
}
```

## NOTES

Even though the options are described in a Unix-like format, the case of the options or commands is not relevant, and the "/" character for options can be used as well as the "-" character.

Note that the program resides in the emulators `bin`-directory, not in the `bin`-directory directly under the Erlang root. The reasons for this are the subtle problem of upgrading the emulator on a running system, where a new version of the runtime system should not need to overwrite existing (and probably used) executables.

To easily manipulate the Erlang services, put the `<erlang_root>\erts-<version>\bin` directory in the path instead of `<erlang_root>\bin`. The erlsrv program can be found from inside Erlang by using the `os:find_executable/1` Erlang function.

For release handling to work, use `start_erl` as the Erlang machine. It is also worth mentioning again that the name of the service is significant (see *above*).

## SEE ALSO

start_erl(1), release_handler(3)

# start_erl

Command

This describes the `start_erl` program specific to Windows NT. Although there exists programs with the same name on other platforms, their functionality is not the same.

The `start_erl` program is distributed both in compiled form (under <Erlang root>\\erts-<version>\\bin) and in source form (under <Erlang root>\\erts-<version>\\src). The purpose of the source code is to make it possible to easily customize the program for local needs, such as cyclic restart detection etc. There is also a "make"-file, written for the `nmake` program distributed with Microsoft® Visual C++®. The program can however be compiled with any Win32 C compiler (possibly with slight modifications).

The purpose of the program is to aid release handling on Windows NT®. The program should be called by the `erlsrv` program, read up the release data file start_erl.data and start Erlang. Certain options to start_erl are added and removed by the release handler during upgrade with emulator restart (more specifically the `-data` option).

## Exports

### `start_erl [<erl options>] ++ [<start_erl options>]`

The `start_erl` program in its original form recognizes the following options:

++
: Mandatory, delimits start_erl options from normal Erlang options. Everything on the command line *before* the `++` is interpreted as options to be sent to the `erl` program. Everything *after*`++` is interpreted as options to `start_erl` itself.

-reldir <release root>
: Mandatory if the environment variable `RELDIR` is not specified and no `-rootdir` option is given. Tells start_erl where the root of the release tree is placed in the file-system (typically <Erlang root>\\releases). The `start_erl.data` file is expected to be placed in this directory (if not otherwise specified). If only the `-rootdir` option is given, the directory is assumed to be <Erlang root>\\releases.

-rootdir <Erlang root directory>
: Mandatory if `-reldir` is not given and there is no `RELDIR` in the environment. This specifies the Erlang installation root directory (under which the `lib`, `releases` and `erts-<Version>` directories are placed). If only `-reldir` (or the environment variable `RELDIR`) is given, the Erlang root is assumed to be the directory exactly one level above the release directory.

-data <data file name>
: Optional, specifies another data file than start_erl.data in the <release root>. It is specified relative to the <release root> or absolute (including drive letter etc.). This option is used by the release handler during upgrade and should not be used during normal operation. The release data file should not normally be named differently.

-bootflags <boot flags file name>
: Optional, specifies a file name relative to actual release directory (that is the subdirectory of <release root> where the `.boot` file etc. are placed). The contents of this file is appended to the command line when Erlang is started. This makes it easy to start the emulator with different options for different releases.

## NOTES

As the source code is distributed, it can easily be modified to accept other options. The program must still accept the `-data` option with the semantics described above for the release handler to work correctly.

The Erlang emulator is found by examining the registry keys for the emulator version specified in the release data file. The new emulator needs to be properly installed before the upgrade for this to work.

Although the program is located together with files specific to emulator version, it is not expected to be specific to the emulator version. The release handler does *not* change the `-machine` option to `erlsrv` during emulator restart. Place the (possibly customized) `start_erl` program so that it is not overwritten during upgrade.

The `erlsrv` program's default options are not sufficient for release handling. The machine `erlsrv` starts should be specified as the `start_erl` program and the arguments should contain the `++` followed by desired options.

## SEE ALSO

erlsrv(1), release_handler(3)

# run_erl

Command

This describes the `run_erl` program specific to Solaris/Linux. This program redirect the standard input and standard output streams so that all output can be logged. It also let the program `to_erl` connect to the Erlang console making it possible to monitor and debug an embedded system remotely.

You can read more about the use in the `Embedded System User's Guide`.

## Exports

**`run_erl [-daemon] pipe_dir/ log_dir "exec command [command_arguments]"`**

The `run_erl` program arguments are:

-daemon
: This option is highly recommended. It makes run_erl run in the background completely detached from any controlling terminal and the command returns to the caller immediately. Without this option, run_erl must be started using several tricks in the shell to detach it completely from the terminal in use when starting it. The option must be the first argument to run_erl on the command line.

pipe_dir
: This is where to put the named pipe, usually `/tmp/` on Unix or `/pipe/` on OSE. It shall be suffixed by a `/` (slash), i.e. not `/tmp/epipies`, but `/tmp/epipes/`.

log_dir
: This is where the log files are written. There will be one log file, `run_erl.log` that log progress and warnings from the `run_erl` program itself and there will be up to five log files at maximum 100KB each (both number of logs and sizes can be changed by environment variables, see below) with the content of the standard streams from and to the command. When the logs are full `run_erl` will delete and reuse the oldest log file.

"exec command [command_arguments]"
: In the third argument `command` is the to execute where everything written to stdin and stdout is logged to `log_dir`.

## Notes concerning the log files

While running, run_erl (as stated earlier) sends all output, uninterpreted, to a log file. The file is called `erlang.log.N`, where N is a number. When the log is "full", default after 100KB, run_erl starts to log in file `erlang.log.(N+1)`, until N reaches a certain number (default 5), where after N starts at 1 again and the oldest files start getting overwritten. If no output comes from the erlang shell, but the erlang machine still seems to be alive, an "ALIVE" message is written to the log, it is a timestamp and is written, by default, after 15 minutes of inactivity. Also, if output from erlang is logged but it's been more than 5 minutes (default) since last time we got anything from erlang, a timestamp is written in the log. The "ALIVE" messages look like this:

```
===== ALIVE <date-time-string>
```

while the other timestamps look like this:

```
===== <date-time-string>
```

The `date-time-string` is the date and time the message is written, default in local time (can be changed to GMT if one wants to) and is formatted with the ANSI-C function `strftime` using the format string `%a %b %e %T %Z %Y`, which produces messages on the line of `===== ALIVE Thu May 15 10:13:36 MEST 2003`, this can be changed, see below.

## Environment variables

The following environment variables are recognized by run_erl and change the logging behavior. Also see the notes above to get more info on how the log behaves.

RUN_ERL_LOG_ALIVE_MINUTES
: How long to wait for output (in minutes) before writing an "ALIVE" message to the log. Default is 15, can never be less than 1.

RUN_ERL_LOG_ACTIVITY_MINUTES
: How long erlang need to be inactive before output will be preceded with a timestamp. Default is RUN_ERL_LOG_ALIVE_MINUTES div 3, but never less than 1.

RUN_ERL_LOG_ALIVE_FORMAT
: Specifies another format string to be used in the strftime C library call. i.e specifying this to `"%e-%b-%Y, %T %Z"` will give log messages with timestamps looking like `15-May-2003, 10:23:04 MET` etc. See the documentation for the C library function strftime for more information. Default is `"%a %b %e %T %Z %Y"`.

RUN_ERL_LOG_ALIVE_IN_UTC
: If set to anything else than "0", it will make all times displayed by run_erl to be in UTC (GMT,CET,MET, without DST), rather than in local time. This does not affect data coming from erlang, only the logs output directly by run_erl. The application `sasl` can be modified accordingly by setting the erlang application variable `utc_log` to `true`.

RUN_ERL_LOG_GENERATIONS
: Controls the number of log files written before older files are being reused. Default is 5, minimum is 2, maximum is 1000.

RUN_ERL_LOG_MAXSIZE
: The size (in bytes) of a log file before switching to a new log file. Default is 100000, minimum is 1000 and maximum is approximately 2^30.

RUN_ERL_DISABLE_FLOWCNTRL
: If defined, disables input and output flow control for the pty opend by run_erl. Useful if you want to remove any risk of accidentally blocking the flow control by hit Ctrl-S (instead of Ctrl-D to detach). Which may result in blocking of the entire beam process and in the case of running heart as supervisor even the heart process will be blocked when writing log message to terminal. Leaving the heart process unable to do its work.

## SEE ALSO

start(1), start_erl(1)

# start

Command

This describes the `start` script that is an example script on how to startup the Erlang system in embedded mode on Unix.

You can read more about the use in the `Embedded System User's Guide`.

## Exports

### `start [ data_file ]`

In the example there is one argument

data_file
: Optional, specifies what `start_erl.data` file to use.

There is also an environment variable `RELDIR` that can be set prior to calling this example that set the directory where to find the release files.

## SEE ALSO

run_erl(1), start_erl(1)

# erl_driver

C Library

An Erlang driver is a library containing a set of native driver callback functions that the Erlang VM calls when certain events occur. There may be multiple instances of a driver, each instance is associated with an Erlang port.

> ## Warning:
>
> *Use this functionality with extreme care!*
>
> A driver callback is executed as a direct extension of the native code of the VM. Execution is not made in a safe environment. The VM can *not* provide the same services as provided when executing Erlang code, such as preemptive scheduling or memory protection. If the driver callback function doesn't behave well, the whole VM will misbehave.
>
> - A driver callback that crash will crash the whole VM.
> - An erroneously implemented driver callback might cause a VM internal state inconsistency which may cause a crash of the VM, or miscellaneous misbehaviors of the VM at any point after the call to the driver callback.
> - A driver callback that do *lengthy work* before returning will degrade responsiveness of the VM, and may cause miscellaneous strange behaviors. Such strange behaviors include, but are not limited to, extreme memory usage, and bad load balancing between schedulers. Strange behaviors that might occur due to lengthy work may also vary between OTP releases.

As of erts version 5.5.3 the driver interface has been extended (see *extended marker*). The extended interface introduce *version management*, the possibility to pass capability flags (see *driver flags*) to the runtime system at driver initialization, and some new driver API functions.

> ## Note:
>
> As of erts version 5.9 old drivers have to be recompiled and have to use the extended interface. They also have to be adjusted to the *64-bit capable driver interface*.

The driver calls back to the emulator, using the API functions declared in `erl_driver.h`. They are used for outputting data from the driver, using timers, etc.

Each driver instance is associated with a port. Every port has a port owner process. Communication with the port is normally done through the port owner process. Most of the functions take the `port` handle as an argument. This identifies the driver instance. Note that this port handle must be stored by the driver, it is not given when the driver is called from the emulator (see *driver_entry*).

Some of the functions take a parameter of type `ErlDrvBinary`, a driver binary. It should be both allocated and freed by the caller. Using a binary directly avoids one extra copying of data.

Many of the output functions have a "header buffer", with `hbuf` and `hlen` parameters. This buffer is sent as a list before the binary (or list, depending on port mode) that is sent. This is convenient when matching on messages received from the port. (Although in the latest versions of Erlang, there is the binary syntax, that enables you to match on the beginning of a binary.)

In the runtime system with SMP support, drivers are locked either on driver level or port level (driver instance level). By default driver level locking will be used, i.e., only one emulator thread will execute code in the driver at a time. If

port level locking is used, multiple emulator threads may execute code in the driver at the same time. There will only be one thread at a time calling driver call-backs corresponding to the same port, though. In order to enable port level locking set the `ERL_DRV_FLAG_USE_PORT_LOCKING` *driver flag* in the *driver_entry* used by the driver. When port level locking is used it is the responsibility of the driver writer to synchronize all accesses to data shared by the ports (driver instances).

Most drivers written before the runtime system with SMP support existed will be able to run in the runtime system with SMP support without being rewritten if driver level locking is used.

> ### Note:
>
> It is assumed that drivers do not access other drivers. If drivers should access each other they have to provide their own mechanism for thread safe synchronization. Such "inter driver communication" is strongly discouraged.

Previously, in the runtime system without SMP support, specific driver call-backs were always called from the same thread. This is *not* the case in the runtime system with SMP support. Regardless of locking scheme used, calls to driver call-backs may be made from different threads, e.g., two consecutive calls to exactly the same call-back for exactly the same port may be made from two different threads. This will for *most* drivers not be a problem, but it might. Drivers that depend on all call-backs being called in the same thread, *have* to be rewritten before being used in the runtime system with SMP support.

> ### Note:
>
> Regardless of locking scheme used, calls to driver call-backs may be made from different threads.

Most functions in this API are *not* thread-safe, i.e., they may *not* be called from an arbitrary thread. Functions that are not documented as thread-safe may only be called from driver call-backs or function calls descending from a driver call-back call. Note that driver call-backs may be called from different threads. This, however, is not a problem for any function in this API, since the emulator has control over these threads.

> ### Warning:
>
> Functions not explicitly documented as thread safe are *not* thread safe. Also note that some functions are *only* thread safe when used in a runtime system with SMP support.
>
> A function not explicitly documented as thread safe may at some point in time have a thread safe implementation in the runtime system. Such an implementation may however change to a thread *unsafe* implementation at any time *without any notice* at all.
>
> *Only use functions explicitly documented as thread safe from arbitrary threads.*

As mentioned in the *warning* text at the beginning of this document it is of vital importance that a driver callback does return relatively fast. It is hard to give an exact maximum amount of time that a driver callback is allowed to work, but as a rule of thumb a well behaving driver callback should return before a millisecond has passed. This can be achieved using different approaches. If you have full control over the code that are to execute in the driver callback, the best approach is to divide the work into multiple chunks of work and trigger multiple calls to the *timeout callback* using zero timeouts. The `erl_drv_consume_timeslice()` function can be useful in order to determine when to trigger such timeout callback calls. It might, however, not always be possible to implement it this way, e.g. when

calling third party libraries. In this case you typically want to dispatch the work to another thread. Information about thread primitives can be found below.

## FUNCTIONALITY

All functions that a driver needs to do with Erlang are performed through driver API functions. There are functions for the following functionality:

Timer functions
: Timer functions are used to control the timer that a driver may use. The timer will have the emulator call the *timeout* entry function after a specified time. Only one timer is available for each driver instance.

Queue handling
: Every driver instance has an associated queue. This queue is a `SysIOVec` that works as a buffer. It's mostly used for the driver to buffer data that should be written to a device, it is a byte stream. If the port owner process closes the driver, and the queue is not empty, the driver will not be closed. This enables the driver to flush its buffers before closing.

  The queue can be manipulated from arbitrary threads if a port data lock is used. See documentation of the *ErlDrvPDL* type for more information.

Output functions
: With the output functions, the driver sends data back to the emulator. They will be received as messages by the port owner process, see `open_port/2`. The vector function and the function taking a driver binary are faster, because they avoid copying the data buffer. There is also a fast way of sending terms from the driver, without going through the binary term format.

Failure
: The driver can exit and signal errors up to Erlang. This is only for severe errors, when the driver can't possibly keep open.

Asynchronous calls
: The latest Erlang versions (R7B and later) has provision for asynchronous function calls, using a thread pool provided by Erlang. There is also a select call, that can be used for asynchronous drivers.

Multi-threading
: A POSIX thread like API for multi-threading is provided. The Erlang driver thread API only provide a subset of the functionality provided by the POSIX thread API. The subset provided is more or less the basic functionality needed for multi-threaded programming:

  - *Threads*
  - *Mutexes*
  - *Condition variables*
  - *Read/Write locks*
  - *Thread specific data*

  The Erlang driver thread API can be used in conjunction with the POSIX thread API on UN-ices and with the Windows native thread API on Windows. The Erlang driver thread API has the advantage of being portable, but there might exist situations where you want to use functionality from the POSIX thread API or the Windows native thread API.

  The Erlang driver thread API only returns error codes when it is reasonable to recover from an error condition. If it isn't reasonable to recover from an error condition, the whole runtime system is terminated. For example, if a create mutex operation fails, an error code is returned, but if a lock operation on a mutex fails, the whole runtime system is terminated.

  Note that there exists no "condition variable wait with timeout" in the Erlang driver thread API. This is due to issues with `pthread_cond_timedwait()`. When the system clock suddenly is changed, it isn't always guaranteed that you will wake up from the call as expected. An Erlang runtime system has to be able to cope

with sudden changes of the system clock. Therefore, we have omitted it from the Erlang driver thread API. In the Erlang driver case, timeouts can and should be handled with the timer functionality of the Erlang driver API.

In order for the Erlang driver thread API to function, thread support has to be enabled in the runtime system. An Erlang driver can check if thread support is enabled by use of *driver_system_info()*. Note that some functions in the Erlang driver API are thread-safe only when the runtime system has SMP support, also this information can be retrieved via *driver_system_info()*. Also note that a lot of functions in the Erlang driver API are *not* thread-safe regardless of whether SMP support is enabled or not. If a function isn't documented as thread-safe it is *not* thread-safe.

*NOTE*: When executing in an emulator thread, it is *very important* that you unlock *all* locks you have locked before letting the thread out of your control; otherwise, you are *very likely* to deadlock the whole emulator. If you need to use thread specific data in an emulator thread, only have the thread specific data set while the thread is under your control, and clear the thread specific data before you let the thread out of your control.

In the future there will probably be debug functionality integrated with the Erlang driver thread API. All functions that create entities take a `name` argument. Currently the `name` argument is unused, but it will be used when the debug functionality has been implemented. If you name all entities created well, the debug functionality will be able to give you better error reports.

Adding / removing drivers

A driver can add and later remove drivers.

Monitoring processes

A driver can monitor a process that does not own a port.

Version management

Version management is enabled for drivers that have set the *extended_marker* field of their *driver_entry* to `ERL_DRV_EXTENDED_MARKER`. `erl_driver.h` defines `ERL_DRV_EXTENDED_MARKER`, `ERL_DRV_EXTENDED_MAJOR_VERSION`, and `ERL_DRV_EXTENDED_MINOR_VERSION`. `ERL_DRV_EXTENDED_MAJOR_VERSION` will be incremented when driver incompatible changes are made to the Erlang runtime system. Normally it will suffice to recompile drivers when the `ERL_DRV_EXTENDED_MAJOR_VERSION` has changed, but it could, under rare circumstances, mean that drivers have to be slightly modified. If so, this will of course be documented. `ERL_DRV_EXTENDED_MINOR_VERSION` will be incremented when new features are added. The runtime system uses the minor version of the driver to determine what features to use. The runtime system will normally refuse to load a driver if the major versions differ, or if the major versions are equal and the minor version used by the driver is greater than the one used by the runtime system. Old drivers with lower major versions will however be allowed after a bump of the major version during a transition period of two major releases. Such old drivers might however fail if deprecated features are used.

The emulator will refuse to load a driver that does not use the extended driver interface, to allow for 64-bit capable drivers, since incompatible type changes for the callbacks *output*, *control* and *call* were introduced in release R15B. A driver written with the old types would compile with warnings and when called return garbage sizes to the emulator causing it to read random memory and create huge incorrect result blobs.

Therefore it is not enough to just recompile drivers written with version management for pre-R15B types; the types have to be changed in the driver suggesting other rewrites especially regarding size variables. Investigate all warnings when recompiling!

Also, the API driver functions `driver_output*`, `driver_vec_to_buf`, `driver_alloc/realloc*` and the `driver_*` queue functions were changed to have larger length arguments and return values. This is a lesser problem since code that passes smaller types will get them auto converted in the calls and as long as the driver does not handle sizes that overflow an `int` all will work as before.

Time Measurement

Support for time measurement in drivers:

- *ErlDrvTime*
- *ErlDrvTimeUnit*
- *erl_drv_monotonic_time()*
- *erl_drv_time_offset()*
- *erl_drv_convert_time_unit()*

## REWRITES FOR 64-BIT DRIVER INTERFACE

For erts-5.9 two new integer types *ErlDrvSizeT* and *ErlDrvSSizeT* were introduced that can hold 64-bit sizes if necessary.

To not update a driver and just recompile it probably works when building for a 32-bit machine creating a false sense of security. Hopefully that will generate many important warnings. But when recompiling the same driver later on for a 64-bit machine there *will* be warnings and almost certainly crashes. So it is a BAD idea to postpone updating the driver and not fixing the warnings!

When recompiling with `gcc` use the `-Wstrict-prototypes` flag to get better warnings. Try to find a similar flag if you are using some other compiler.

Here follows a checklist for rewriting a pre erts-5.9 driver, most important first.

Return types for driver callbacks

Rewrite driver callback *`control`* to use return type `ErlDrvSSizeT` instead of `int`.

Rewrite driver callback *`call`* to use return type `ErlDrvSSizeT` instead of `int`.

> ### Note:
>
> These changes are essential to not crash the emulator or worse cause malfunction. Without them a driver may return garbage in the high 32 bits to the emulator causing it to build a huge result from random bytes either crashing on memory allocation or succeeding with a random result from the driver call.

Arguments to driver callbacks

Driver callback *`output`* now gets `ErlDrvSizeT` as 3rd argument instead of previously `int`.

Driver callback *`control`* now gets `ErlDrvSizeT` as 4th and 6th arguments instead of previously `int`.

Driver callback *`call`* now gets `ErlDrvSizeT` as 4th and 6th arguments instead of previously `int`.

Sane compiler's calling conventions probably make these changes necessary only for a driver to handle data chunks that require 64-bit size fields (mostly larger than 2 GB since that is what an `int` of 32 bits can hold). But it is possible to think of non-sane calling conventions that would make the driver callbacks mix up the arguments causing malfunction.

> ### Note:
>
> The argument type change is from signed to unsigned which may cause problems for e.g. loop termination conditions or error conditions if you just change the types all over the place.

Larger `size` field in `ErlIOVec`

The `size` field in *`ErlIOVec`* has been changed to `ErlDrvSizeT` from `int`. Check all code that use that field.

Automatic type casting probably makes these changes necessary only for a driver that encounters sizes larger than 32 bits.

> **Note:**
>
> The `size` field changed from signed to unsigned which may cause problems for e.g. loop termination conditions or error conditions if you just change the types all over the place.

Arguments and return values in the driver API

Many driver API functions have changed argument type and/or return value to `ErlDrvSizeT` from mostly `int`. Automatic type casting probably makes these changes necessary only for a driver that encounters sizes larger than 32 bits.

*driver_output*
: 3rd argument

*driver_output2*
: 3rd and 5th arguments

*driver_output_binary*
: 3rd 5th and 6th arguments

*driver_outputv*
: 3rd and 5th arguments

*driver_vec_to_buf*
: 3rd argument and return value

*driver_alloc*
: 1st argument

*driver_realloc*
: 2nd argument

*driver_alloc_binary*
: 1st argument

*driver_realloc_binary*
: 2nd argument

*driver_enq*
: 3rd argument

*driver_pushq*
: 3rd argument

*driver_deq*
: 2nd argument and return value

*driver_sizeq*
: return value

*driver_enq_bin*
: 3rd and 4th argument

*driver_pushq_bin*
: 3rd and 4th argument

*driver_enqv*
: 3rd argument

*driver_pushqv*
: 3rd argument

*driver_peekqv*
return value

> Note:
>
> This is a change from signed to unsigned which may cause problems for e.g. loop termination conditions and error conditions if you just change the types all over the place.

## DATA TYPES

ErlDrvSizeT

An unsigned integer type to be used as `size_t`

ErlDrvSSizeT

A signed integer type the size of `ErlDrvSizeT`

ErlDrvSysInfo

```
typedef struct ErlDrvSysInfo {
   int driver_major_version;
   int driver_minor_version;
   char *erts_version;
   char *otp_release;
   int thread_support;
   int smp_support;
   int async_threads;
   int scheduler_threads;
   int nif_major_version;
   int nif_minor_version;
   int dirty_scheduler_support;
} ErlDrvSysInfo;
```

The `ErlDrvSysInfo` structure is used for storage of information about the Erlang runtime system. *driver_system_info()* will write the system information when passed a reference to a `ErlDrvSysInfo` structure. A description of the fields in the structure follows:

`driver_major_version`
The value of *ERL_DRV_EXTENDED_MAJOR_VERSION* when the runtime system was compiled. This value is the same as the value of *ERL_DRV_EXTENDED_MAJOR_VERSION* used when compiling the driver; otherwise, the runtime system would have refused to load the driver.

`driver_minor_version`
The value of *ERL_DRV_EXTENDED_MINOR_VERSION* when the runtime system was compiled. This value might differ from the value of *ERL_DRV_EXTENDED_MINOR_VERSION* used when compiling the driver.

`erts_version`
A string containing the version number of the runtime system (the same as returned by *erlang:system_info(version)*).

`otp_release`
A string containing the OTP release number (the same as returned by *erlang:system_info(otp_release)*).

`thread_support`
A value `!= 0` if the runtime system has thread support; otherwise, `0`.

`smp_support`
A value `!= 0` if the runtime system has SMP support; otherwise, `0`.

`async_threads`
The number of async threads in the async thread pool used by *driver_async()* (the same as returned by *erlang:system_info(thread_pool_size)*).

`scheduler_threads`
The number of scheduler threads used by the runtime system (the same as returned by *erlang:system_info(schedulers)*).

`nif_major_version`
The value of `ERL_NIF_MAJOR_VERSION` when the runtime system was compiled.

`nif_minor_version`
The value of `ERL_NIF_MINOR_VERSION` when the runtime system was compiled.

`dirty_scheduler_support`
A value `!= 0` if the runtime system has support for dirty scheduler threads; otherwise `0`.

ErlDrvBinary

```
typedef struct ErlDrvBinary {
   ErlDrvSint orig_size;
   char orig_bytes[];
} ErlDrvBinary;
```

The `ErlDrvBinary` structure is a binary, as sent between the emulator and the driver. All binaries are reference counted; when `driver_binary_free` is called, the reference count is decremented, when it reaches zero, the binary is deallocated. The `orig_size` is the size of the binary, and `orig_bytes` is the buffer. The `ErlDrvBinary` does not have a fixed size, its size is `orig_size + 2 * sizeof(int)`.

> ### Note:
>
> The `refc` field has been removed. The reference count of an `ErlDrvBinary` is now stored elsewhere. The reference count of an `ErlDrvBinary` can be accessed via *driver_binary_get_refc()*, *driver_binary_inc_refc()*, and *driver_binary_dec_refc()*.

Some driver calls, such as `driver_enq_binary`, increment the driver reference count, and others, such as `driver_deq` decrement it.

Using a driver binary instead of a normal buffer, is often faster, since the emulator doesn't need to copy the data, only the pointer is used.

A driver binary allocated in the driver, with `driver_alloc_binary`, should be freed in the driver (unless otherwise stated), with `driver_free_binary`. (Note that this doesn't necessarily deallocate it, if the driver is still referred in the emulator, the ref-count will not go to zero.)

Driver binaries are used in the `driver_output2` and `driver_outputv` calls, and in the queue. Also the driver call-back *outputv* uses driver binaries.

If the driver for some reason or another, wants to keep a driver binary around, in a static variable for instance, the reference count should be incremented, and the binary can later be freed in the *stop* call-back, with `driver_free_binary`.

Note that since a driver binary is shared by the driver and the emulator, a binary received from the emulator or sent to the emulator, must not be changed by the driver.

Since erts version 5.5 (OTP release R11B), orig_bytes is guaranteed to be properly aligned for storage of an array of doubles (usually 8-byte aligned).

ErlDrvData

The `ErlDrvData` is a handle to driver-specific data, passed to the driver call-backs. It is a pointer, and is most often type cast to a specific pointer in the driver.

SysIOVec

This is a system I/O vector, as used by `writev` on unix and `WSASend` on Win32. It is used in `ErlIOVec`.

ErlIOVec

```
typedef struct ErlIOVec {
  int vsize;
  ErlDrvSizeT size;
  SysIOVec* iov;
  ErlDrvBinary** binv;
} ErlIOVec;
```

The I/O vector used by the emulator and drivers, is a list of binaries, with a `SysIOVec` pointing to the buffers of the binaries. It is used in `driver_outputv` and the *outputv* driver call-back. Also, the driver queue is an `ErlIOVec`.

ErlDrvMonitor

When a driver creates a monitor for a process, a `ErlDrvMonitor` is filled in. This is an opaque data-type which can be assigned to but not compared without using the supplied compare function (i.e. it behaves like a struct).

The driver writer should provide the memory for storing the monitor when calling *driver_monitor_process*. The address of the data is not stored outside of the driver, so the `ErlDrvMonitor` can be used as any other datum, it can be copied, moved in memory, forgotten etc.

ErlDrvNowData

The `ErlDrvNowData` structure holds a timestamp consisting of three values measured from some arbitrary point in the past. The three structure members are:

megasecs
: The number of whole megaseconds elapsed since the arbitrary point in time

secs
: The number of whole seconds elapsed since the arbitrary point in time

microsecs
: The number of whole microseconds elapsed since the arbitrary point in time

ErlDrvPDL

If certain port specific data have to be accessed from other threads than those calling the driver call-backs, a port data lock can be used in order to synchronize the operations on the data. Currently, the only port specific data that the emulator associates with the port data lock is the driver queue.

Normally a driver instance does not have a port data lock. If the driver instance wants to use a port data lock, it has to create the port data lock by calling *driver_pdl_create()*. *NOTE*: Once the port data lock has been created, every access to data associated with the port data lock has to be done while having the port data lock locked. The port data lock is locked, and unlocked, respectively, by use of *driver_pdl_lock()*, and *driver_pdl_unlock()*.

A port data lock is reference counted, and when the reference count reaches zero, it will be destroyed. The emulator will at least increment the reference count once when the lock is created and decrement it once when the port associated with the lock terminates. The emulator will also increment the reference count when an async job is

enqueued and decrement it after an async job has been invoked. Besides this, it is the responsibility of the driver to ensure that the reference count does not reach zero before the last use of the lock by the driver has been made. The reference count can be read, incremented, and decremented, respectively, by use of *driver_pdl_get_refc()*, *driver_pdl_inc_refc()*, and *driver_pdl_dec_refc()*.

ErlDrvTid

Thread identifier.

See also: *erl_drv_thread_create()*, *erl_drv_thread_exit()*, *erl_drv_thread_join()*, *erl_drv_thread_self()*, and *erl_drv_equal_tids()*.

ErlDrvThreadOpts

```
int suggested_stack_size;
```

Thread options structure passed to *erl_drv_thread_create()*. Currently the following fields exist:

suggested_stack_size
: A suggestion, in kilo-words, on how large a stack to use. A value less than zero means default size.

See also: *erl_drv_thread_opts_create()*, *erl_drv_thread_opts_destroy()*, and *erl_drv_thread_create()*.

ErlDrvMutex

Mutual exclusion lock. Used for synchronizing access to shared data. Only one thread at a time can lock a mutex.

See also: *erl_drv_mutex_create()*, *erl_drv_mutex_destroy()*, *erl_drv_mutex_lock()*, *erl_drv_mutex_trylock()*, and *erl_drv_mutex_unlock()*.

ErlDrvCond

Condition variable. Used when threads need to wait for a specific condition to appear before continuing execution. Condition variables need to be used with associated mutexes.

See also: *erl_drv_cond_create()*, *erl_drv_cond_destroy()*, *erl_drv_cond_signal()*, *erl_drv_cond_broadcast()*, and *erl_drv_cond_wait()*.

ErlDrvRWLock

Read/write lock. Used to allow multiple threads to read shared data while only allowing one thread to write the same data. Multiple threads can read lock an rwlock at the same time, while only one thread can read/write lock an rwlock at a time.

See also: *erl_drv_rwlock_create()*, *erl_drv_rwlock_destroy()*, *erl_drv_rwlock_rlock()*, *erl_drv_rwlock_tryrlock()*, *erl_drv_rwlock_runlock()*, *erl_drv_rwlock_rwlock()*, *erl_drv_rwlock_tryrwlock()*, and *erl_drv_rwlock_rwunlock()*.

ErlDrvTSDKey

Key which thread specific data can be associated with.

See also: *erl_drv_tsd_key_create()*, *erl_drv_tsd_key_destroy()*, *erl_drv_tsd_set()*, and *erl_drv_tsd_get()*.

ErlDrvTime

A signed 64-bit integer type for representation of time.

ErlDrvTimeUnit

An enumeration of time units supported by the driver API:

`ERL_DRV_SEC`

Seconds

`ERL_DRV_MSEC`

Milliseconds

`ERL_DRV_USEC`

Microseconds

`ERL_DRV_NSEC`

Nanoseconds

## Exports

### `void driver_system_info(ErlDrvSysInfo *sys_info_ptr, size_t size)`

This function will write information about the Erlang runtime system into the *ErlDrvSysInfo* structure referred to by the first argument. The second argument should be the size of the *ErlDrvSysInfo* structure, i.e., `sizeof(ErlDrvSysInfo)`.

See the documentation of the *ErlDrvSysInfo* structure for information about specific fields.

### `int driver_output(ErlDrvPort port, char *buf, ErlDrvSizeT len)`

The `driver_output` function is used to send data from the driver up to the emulator. The data will be received as terms or binary data, depending on how the driver port was opened.

The data is queued in the port owner process' message queue. Note that this does not yield to the emulator. (Since the driver and the emulator run in the same thread.)

The parameter `buf` points to the data to send, and `len` is the number of bytes.

The return value for all output functions is 0. (Unless the driver is used for distribution, in which case it can fail and return -1. For normal use, the output function always returns 0.)

### `int driver_output2(ErlDrvPort port, char *hbuf, ErlDrvSizeT hlen, char *buf, ErlDrvSizeT len)`

The `driver_output2` function first sends `hbuf` (length in `hlen`) data as a list, regardless of port settings. Then `buf` is sent as a binary or list. E.g. if `hlen` is 3 then the port owner process will receive `[H1, H2, H3 | T]`.

The point of sending data as a list header, is to facilitate matching on the data received.

The return value is 0 for normal use.

### `int driver_output_binary(ErlDrvPort port, char *hbuf, ErlDrvSizeT hlen, ErlDrvBinary* bin, ErlDrvSizeT offset, ErlDrvSizeT len)`

This function sends data to port owner process from a driver binary, it has a header buffer (`hbuf` and `hlen`) just like `driver_output2`. The `hbuf` parameter can be `NULL`.

The parameter `offset` is an offset into the binary and `len` is the number of bytes to send.

Driver binaries are created with `driver_alloc_binary`.

The data in the header is sent as a list and the binary as an Erlang binary in the tail of the list.

E.g. if `hlen` is 2, then the port owner process will receive `[H1, H2 | <<T>>]`.

The return value is 0 for normal use.

Note that, using the binary syntax in Erlang, the driver application can match the header directly from the binary, so the header can be put in the binary, and hlen can be set to 0.

### int driver_outputv(ErlDrvPort port, char* hbuf, ErlDrvSizeT hlen, ErlIOVec *ev, ErlDrvSizeT skip)

This function sends data from an IO vector, `ev`, to the port owner process. It has a header buffer (`hbuf` and `hlen`), just like `driver_output2`.

The `skip` parameter is a number of bytes to skip of the `ev` vector from the head.

You get vectors of `ErlIOVec` type from the driver queue (see below), and the *outputv* driver entry function. You can also make them yourself, if you want to send several `ErlDrvBinary` buffers at once. Often it is faster to use `driver_output` or `driver_output_binary`.

E.g. if `hlen` is 2 and `ev` points to an array of three binaries, the port owner process will receive `[H1, H2, <<B1>>, <<B2>> | <<B3>>]`.

The return value is 0 for normal use.

The comment for `driver_output_binary` applies for `driver_outputv` too.

### ErlDrvSizeT driver_vec_to_buf(ErlIOVec *ev, char *buf, ErlDrvSizeT len)

This function collects several segments of data, referenced by `ev`, by copying them in order to the buffer `buf`, of the size `len`.

If the data is to be sent from the driver to the port owner process, it is faster to use `driver_outputv`.

The return value is the space left in the buffer, i.e. if the `ev` contains less than `len` bytes it's the difference, and if `ev` contains `len` bytes or more, it's 0. This is faster if there is more than one header byte, since the binary syntax can construct integers directly from the binary.

### int driver_set_timer(ErlDrvPort port, unsigned long time)

This function sets a timer on the driver, which will count down and call the driver when it is timed out. The `time` parameter is the time in milliseconds before the timer expires.

When the timer reaches 0 and expires, the driver entry function *timeout* is called.

Note that there is only one timer on each driver instance; setting a new timer will replace an older one.

Return value is 0 (-1 only when the `timeout` driver function is `NULL`).

### int driver_cancel_timer(ErlDrvPort port)

This function cancels a timer set with `driver_set_timer`.

The return value is 0.

### int driver_read_timer(ErlDrvPort port, unsigned long *time_left)

This function reads the current time of a timer, and places the result in `time_left`. This is the time in milliseconds, before the timeout will occur.

The return value is 0.

### int driver_get_now(ErlDrvNowData *now)

> Warning:
>
> *This function is deprecated! Do not use it!* Use *erl_drv_monotonic_time()* (perhaps in combination with *erl_drv_time_offset()*) instead.

This function reads a timestamp into the memory pointed to by the parameter `now`. See the description of *ErlDrvNowData* for specification of its fields.

The return value is 0 unless the `now` pointer is not valid, in which case it is < 0.

### int driver_select(ErlDrvPort port, ErlDrvEvent event, int mode, int on)

This function is used by drivers to provide the emulator with events to check for. This enables the emulator to call the driver when something has happened asynchronously.

The `event` argument identifies an OS-specific event object. On Unix systems, the functions `select`/`poll` are used. The event object must be a socket or pipe (or other object that `select`/`poll` can use). On windows, the Win32 API function `WaitForMultipleObjects` is used. This places other restrictions on the event object. Refer to the Win32 SDK documentation. On Enea OSE, the receive function is used. See the  for more details.

The `on` parameter should be `1` for setting events and `0` for clearing them.

The `mode` argument is a bitwise-or combination of `ERL_DRV_READ`, `ERL_DRV_WRITE` and `ERL_DRV_USE`. The first two specify whether to wait for read events and/or write events. A fired read event will call *ready_input* while a fired write event will call *ready_output*.

> Note:
>
> Some OS (Windows and Enea OSE) do not differentiate between read and write events. The call-back for a fired event then only depends on the value of `mode`.

`ERL_DRV_USE` specifies if we are using the event object or if we want to close it. On an emulator with SMP support, it is not safe to clear all events and then close the event object after `driver_select` has returned. Another thread may still be using the event object internally. To safely close an event object call `driver_select` with `ERL_DRV_USE` and `on==0`. That will clear all events and then call *stop_select* when it is safe to close the event object. `ERL_DRV_USE` should be set together with the first event for an event object. It is harmless to set `ERL_DRV_USE` even though it already has been done. Clearing all events but keeping `ERL_DRV_USE` set will indicate that we are using the event object and probably will set events for it again.

> Note:
>
> ERL_DRV_USE was added in OTP release R13. Old drivers will still work as before. But it is recommended to update them to use `ERL_DRV_USE` and `stop_select` to make sure that event objects are closed in a safe way.

The return value is 0 (failure, -1, only if the `ready_input`/`ready_output` is `NULL`).

### void *driver_alloc(ErlDrvSizeT size)

This function allocates a memory block of the size specified in `size`, and returns it. This only fails on out of memory, in that case `NULL` is returned. (This is most often a wrapper for `malloc`).

Memory allocated must be explicitly freed with a corresponding call to `driver_free` (unless otherwise stated).

This function is thread-safe.

### void *driver_realloc(void *ptr, ErlDrvSizeT size)

This function resizes a memory block, either in place, or by allocating a new block, copying the data and freeing the old block. A pointer is returned to the reallocated memory. On failure (out of memory), `NULL` is returned. (This is most often a wrapper for `realloc`.)

This function is thread-safe.

### void driver_free(void *ptr)

This function frees the memory pointed to by `ptr`. The memory should have been allocated with `driver_alloc`. All allocated memory should be deallocated, just once. There is no garbage collection in drivers.

This function is thread-safe.

### ErlDrvBinary *driver_alloc_binary(ErlDrvSizeT size)

This function allocates a driver binary with a memory block of at least `size` bytes, and returns a pointer to it, or NULL on failure (out of memory). When a driver binary has been sent to the emulator, it must not be altered. Every allocated binary should be freed by a corresponding call to `driver_free_binary` (unless otherwise stated).

Note that a driver binary has an internal reference counter, this means that calling `driver_free_binary` it may not actually dispose of it. If it's sent to the emulator, it may be referenced there.

The driver binary has a field, `orig_bytes`, which marks the start of the data in the binary.

This function is thread-safe.

### ErlDrvBinary *driver_realloc_binary(ErlDrvBinary *bin, ErlDrvSizeT size)

This function resizes a driver binary, while keeping the data. The resized driver binary is returned. On failure (out of memory), `NULL` is returned.

This function is only thread-safe when the emulator with SMP support is used.

### void driver_free_binary(ErlDrvBinary *bin)

This function frees a driver binary `bin`, allocated previously with `driver_alloc_binary`. Since binaries in Erlang are reference counted, the binary may still be around.

This function is only thread-safe when the emulator with SMP support is used.

### long driver_binary_get_refc(ErlDrvBinary *bin)

Returns current reference count on `bin`.

This function is only thread-safe when the emulator with SMP support is used.

### long driver_binary_inc_refc(ErlDrvBinary *bin)

Increments the reference count on `bin` and returns the reference count reached after the increment.

This function is only thread-safe when the emulator with SMP support is used.

### long driver_binary_dec_refc(ErlDrvBinary *bin)

Decrements the reference count on `bin` and returns the reference count reached after the decrement.

This function is only thread-safe when the emulator with SMP support is used.

> Note:
>
> You should normally decrement the reference count of a driver binary by calling *driver_free_binary()*. `driver_binary_dec_refc()` does *not* free the binary if the reference count reaches zero. *Only* use `driver_binary_dec_refc()` when you are sure *not* to reach a reference count of zero.

### int driver_enq(ErlDrvPort port, char* buf, ErlDrvSizeT len)

This function enqueues data in the driver queue. The data in `buf` is copied (`len` bytes) and placed at the end of the driver queue. The driver queue is normally used in a FIFO way.

The driver queue is available to queue output from the emulator to the driver (data from the driver to the emulator is queued by the emulator in normal erlang message queues). This can be useful if the driver has to wait for slow devices etc, and wants to yield back to the emulator. The driver queue is implemented as an ErlIOVec.

When the queue contains data, the driver won't close, until the queue is empty.

The return value is 0.

This function can be called from an arbitrary thread if a *port data lock* associated with the `port` is locked by the calling thread during the call.

### int driver_pushq(ErlDrvPort port, char* buf, ErlDrvSizeT len)

This function puts data at the head of the driver queue. The data in `buf` is copied (`len` bytes) and placed at the beginning of the queue.

The return value is 0.

This function can be called from an arbitrary thread if a *port data lock* associated with the `port` is locked by the calling thread during the call.

### ErlDrvSizeT driver_deq(ErlDrvPort port, ErlDrvSizeT size)

This function dequeues data by moving the head pointer forward in the driver queue by `size` bytes. The data in the queue will be deallocated.

The return value is the number of bytes remaining in the queue or -1 on failure.

This function can be called from an arbitrary thread if a *port data lock* associated with the `port` is locked by the calling thread during the call.

### ErlDrvSizeT driver_sizeq(ErlDrvPort port)

This function returns the number of bytes currently in the driver queue.

This function can be called from an arbitrary thread if a *port data lock* associated with the `port` is locked by the calling thread during the call.

### int driver_enq_bin(ErlDrvPort port, ErlDrvBinary *bin, ErlDrvSizeT offset, ErlDrvSizeT len)

This function enqueues a driver binary in the driver queue. The data in `bin` at `offset` with length `len` is placed at the end of the queue. This function is most often faster than `driver_enq`, because the data doesn't have to be copied.

This function can be called from an arbitrary thread if a *port data lock* associated with the `port` is locked by the calling thread during the call.

The return value is 0.

### int driver_pushq_bin(ErlDrvPort port, ErlDrvBinary *bin, ErlDrvSizeT offset, ErlDrvSizeT len)

This function puts data in the binary `bin`, at `offset` with length `len` at the head of the driver queue. It is most often faster than `driver_pushq`, because the data doesn't have to be copied.

This function can be called from an arbitrary thread if a *port data lock* associated with the `port` is locked by the calling thread during the call.

The return value is 0.

### ErlDrvSizeT driver_peekqv(ErlDrvPort port, ErlIOVec *ev)

This function retrieves the driver queue into a supplied `ErlIOVec` `ev`. It also returns the queue size. This is one of two ways to get data out of the queue.

If `ev` is `NULL` all ones i.e. `-1` type cast to `ErlDrvSizeT` is returned.

Nothing is removed from the queue by this function, that must be done with `driver_deq`.

This function can be called from an arbitrary thread if a *port data lock* associated with the `port` is locked by the calling thread during the call.

### SysIOVec *driver_peekq(ErlDrvPort port, int *vlen)

This function retrieves the driver queue as a pointer to an array of `SysIOVec`s. It also returns the number of elements in `vlen`. This is one of two ways to get data out of the queue.

Nothing is removed from the queue by this function, that must be done with `driver_deq`.

The returned array is suitable to use with the Unix system call `writev`.

This function can be called from an arbitrary thread if a *port data lock* associated with the `port` is locked by the calling thread during the call.

### int driver_enqv(ErlDrvPort port, ErlIOVec *ev, ErlDrvSizeT skip)

This function enqueues the data in `ev`, skipping the first `skip` bytes of it, at the end of the driver queue. It is faster than `driver_enq`, because the data doesn't have to be copied.

The return value is 0.

This function can be called from an arbitrary thread if a *port data lock* associated with the `port` is locked by the calling thread during the call.

### int driver_pushqv(ErlDrvPort port, ErlIOVec *ev, ErlDrvSizeT skip)

This function puts the data in `ev`, skipping the first `skip` bytes of it, at the head of the driver queue. It is faster than `driver_pushq`, because the data doesn't have to be copied.

The return value is 0.

This function can be called from an arbitrary thread if a *port data lock* associated with the `port` is locked by the calling thread during the call.

### `ErlDrvPDL driver_pdl_create(ErlDrvPort port)`

This function creates a port data lock associated with the `port`. *NOTE*: Once a port data lock has been created, it has to be locked during all operations on the driver queue of the `port`.

On success a newly created port data lock is returned. On failure `NULL` is returned. `driver_pdl_create()` will fail if `port` is invalid or if a port data lock already has been associated with the `port`.

### `void driver_pdl_lock(ErlDrvPDL pdl)`

This function locks the port data lock passed as argument (`pdl`).

This function is thread-safe.

### `void driver_pdl_unlock(ErlDrvPDL pdl)`

This function unlocks the port data lock passed as argument (`pdl`).

This function is thread-safe.

### `long driver_pdl_get_refc(ErlDrvPDL pdl)`

This function returns the current reference count of the port data lock passed as argument (`pdl`).

This function is thread-safe.

### `long driver_pdl_inc_refc(ErlDrvPDL pdl)`

This function increments the reference count of the port data lock passed as argument (`pdl`).

The current reference count after the increment has been performed is returned.

This function is thread-safe.

### `long driver_pdl_dec_refc(ErlDrvPDL pdl)`

This function decrements the reference count of the port data lock passed as argument (`pdl`).

The current reference count after the decrement has been performed is returned.

This function is thread-safe.

### `int driver_monitor_process(ErlDrvPort port, ErlDrvTermData process, ErlDrvMonitor *monitor)`

Start monitoring a process from a driver. When a process is monitored, a process exit will result in a call to the provided *process_exit* call-back in the *ErlDrvEntry* structure. The `ErlDrvMonitor` structure is filled in, for later removal or compare.

The `process` parameter should be the return value of an earlier call to *driver_caller* or *driver_connected* call.

The function returns 0 on success, < 0 if no call-back is provided and > 0 if the process is no longer alive.

### `int driver_demonitor_process(ErlDrvPort port, const ErlDrvMonitor *monitor)`

This function cancels a monitor created earlier.

The function returns 0 if a monitor was removed and > 0 if the monitor did no longer exist.

**`ErlDrvTermData driver_get_monitored_process(ErlDrvPort port, const ErlDrvMonitor *monitor)`**

The function returns the process id associated with a living monitor. It can be used in the `process_exit` call-back to get the process identification for the exiting process.

The function returns `driver_term_nil` if the monitor no longer exists.

**`int driver_compare_monitors(const ErlDrvMonitor *monitor1, const ErlDrvMonitor *monitor2)`**

This function is used to compare two `ErlDrvMonitor`s. It can also be used to imply some artificial order on monitors, for whatever reason.

The function returns 0 if `monitor1` and `monitor2` are equal, < 0 if `monitor1` is less than `monitor2` and > 0 if `monitor1` is greater than `monitor2`.

**`void add_driver_entry(ErlDrvEntry *de)`**

This function adds a driver entry to the list of drivers known by Erlang. The *init* function of the `de` parameter is called.

> Note:
>
> To use this function for adding drivers residing in dynamically loaded code is dangerous. If the driver code for the added driver resides in the same dynamically loaded module (i.e. `.so` file) as a normal dynamically loaded driver (loaded with the `erl_ddll` interface), the caller should call *driver_lock_driver* before adding driver entries.
>
> Use of this function is generally deprecated.

**`int remove_driver_entry(ErlDrvEntry *de)`**

This function removes a driver entry `de` previously added with `add_driver_entry`.

Driver entries added by the `erl_ddll` erlang interface can not be removed by using this interface.

**`char *erl_errno_id(int error)`**

This function returns the atom name of the erlang error, given the error number in `error`. Error atoms are: `einval`, `enoent`, etc. It can be used to make error terms from the driver.

**`void erl_drv_busy_msgq_limits(ErlDrvPort port, ErlDrvSizeT *low, ErlDrvSizeT *high)`**

Sets and gets limits that will be used for controling the busy state of the port message queue.

The port message queue will be set into a busy state when the amount of command data queued on the message queue reaches the `high` limit. The port message queue will be set into a not busy state when the amount of command data queued on the message queue falls below the `low` limit. Command data is in this context data passed to the port using either `Port ! {Owner, {command, Data}}`, or `port_command/[2,3]`. Note that these limits only concerns command data that have not yet reached the port. The *busy port* feature can be used for data that has reached the port.

Valid limits are values in the range `[ERL_DRV_BUSY_MSGQ_LIM_MIN, ERL_DRV_BUSY_MSGQ_LIM_MAX]`. Limits will be automatically adjusted to be sane. That is, the system will adjust values so that the low limit used is lower than or equal to the high limit used. By default the high limit will be 8 kB and the low limit will be 4 kB.

By passing a pointer to an integer variable containing the value ERL_DRV_BUSY_MSGQ_READ_ONLY, currently used limit will be read and written back to the integer variable. A new limit can be set by passing a pointer to an integer variable containing a valid limit. The passed value will be written to the internal limit. The internal limit will then be adjusted. After this the adjusted limit will be written back to the integer variable from which the new value was read. Values are in bytes.

The busy message queue feature can be disabled either by setting the ERL_DRV_FLAG_NO_BUSY_MSGQ *driver flag* in the *driver_entry* used by the driver, or by calling this function with ERL_DRV_BUSY_MSGQ_DISABLED as a limit (either low or high). When this feature has been disabled it cannot be enabled again. When reading the limits both of them will be ERL_DRV_BUSY_MSGQ_DISABLED, if this feature has been disabled.

Processes sending command data to the port will be suspended if either the port is busy or if the port message queue is busy. Suspended processes will be resumed when neither the port is busy, nor the port message queue is busy.

For information about busy port functionality see the documentation of the *set_busy_port()* function.

### void set_busy_port(ErlDrvPort port, int on)

This function set and unset the busy state of the port. If on is non-zero, the port is set to busy, if it's zero the port is set to not busy. You typically want to combine this feature with the *busy port message queue* functionality.

Processes sending command data to the port will be suspended if either the port is busy or if the port message queue is busy. Suspended processes will be resumed when neither the port is busy, nor the port message queue is busy. Command data is in this context data passed to the port using either Port ! {Owner, {command, Data}}, or port_command/[2,3].

If the *ERL_DRV_FLAG_SOFT_BUSY* has been set in the *driver_entry*, data can be forced into the driver via *port_command(Port, Data, [force])* even though the driver has signaled that it is busy.

For information about busy port message queue functionality see the documentation of the *erl_drv_busy_msgq_limits()* function.

### void set_port_control_flags(ErlDrvPort port, int flags)

This function sets flags for how the *control* driver entry function will return data to the port owner process. (The control function is called from port_control/3 in erlang.)

Currently there are only two meaningful values for flags: 0 means that data is returned in a list, and PORT_CONTROL_FLAG_BINARY means data is returned as a binary from control.

### int driver_failure_eof(ErlDrvPort port)

This function signals to erlang that the driver has encountered an EOF and should be closed, unless the port was opened with the eof option, in that case eof is sent to the port. Otherwise, the port is closed and an 'EXIT' message is sent to the port owner process.

The return value is 0.

### int driver_failure_atom(ErlDrvPort port, char *string)
### int driver_failure_posix(ErlDrvPort port, int error)
### int driver_failure(ErlDrvPort port, int error)

These functions signal to Erlang that the driver has encountered an error and should be closed. The port is closed and the tuple {'EXIT', error, Err}, is sent to the port owner process, where error is an error atom (driver_failure_atom and driver_failure_posix), or an integer (driver_failure).

The driver should fail only when in severe error situations, when the driver cannot possibly keep open, for instance buffer allocation gets out of memory. For normal errors it is more appropriate to send error codes with `driver_output`.

The return value is 0.

### `ErlDrvTermData driver_connected(ErlDrvPort port)`

This function returns the port owner process.

Note that this function is *not* thread-safe, not even when the emulator with SMP support is used.

### `ErlDrvTermData driver_caller(ErlDrvPort port)`

This function returns the process id of the process that made the current call to the driver. The process id can be used with `driver_send_term` to send back data to the caller. `driver_caller()` only returns valid data when currently executing in one of the following driver callbacks:

*start*
: Called from `open_port/2`.

*output*
: Called from `erlang:send/2`, and `erlang:port_command/2`

*outputv*
: Called from `erlang:send/2`, and `erlang:port_command/2`

*control*
: Called from `erlang:port_control/3`

*call*
: Called from `erlang:port_call/3`

Note that this function is *not* thread-safe, not even when the emulator with SMP support is used.

### `int erl_drv_output_term(ErlDrvTermData port, ErlDrvTermData* term, int n)`

This functions sends data in the special driver term format to the port owner process. This is a fast way to deliver term data from a driver. It also needs no binary conversion, so the port owner process receives data as normal Erlang terms. The *erl_drv_send_term()* functions can be used for sending to any arbitrary process on the local node.

> **Note:**
>
> Note that the `port` parameter is *not* an ordinary port handle, but a port handle converted using `driver_mk_port()`.

The `term` parameter points to an array of `ErlDrvTermData`, with `n` elements. This array contains terms described in the driver term format. Every term consists of one to four elements in the array. The term first has a term type, and then arguments. The `port` parameter specifies the sending port.

Tuples, maps and lists (with the exception of strings, see below), are built in reverse polish notation, so that to build a tuple, the elements are given first, and then the tuple term, with a count. Likewise for lists and maps.

A tuple must be specified with the number of elements. (The elements precede the `ERL_DRV_TUPLE` term.)

A list must be specified with the number of elements, including the tail, which is the last term preceding `ERL_DRV_LIST`.

A map must be specified with the number of key-value pairs `N`. The key-value pairs must precede the `ERL_DRV_MAP` in this order: `key1,value1,key2,value2,...,keyN,valueN`. Duplicate keys are not allowed.

The special term ERL_DRV_STRING_CONS is used to "splice" in a string in a list, a string given this way is not a list per se, but the elements are elements of the surrounding list.

```
Term type            Argument(s)
========================================
ERL_DRV_NIL
ERL_DRV_ATOM         ErlDrvTermData atom (from driver_mk_atom(char *string))
ERL_DRV_INT          ErlDrvSInt integer
ERL_DRV_UINT         ErlDrvUInt integer
ERL_DRV_INT64        ErlDrvSInt64 *integer_ptr
ERL_DRV_UINT64       ErlDrvUInt64 *integer_ptr
ERL_DRV_PORT         ErlDrvTermData port (from driver_mk_port(ErlDrvPort port))
ERL_DRV_BINARY       ErlDrvBinary *bin, ErlDrvUInt len, ErlDrvUInt offset
ERL_DRV_BUF2BINARY   char *buf, ErlDrvUInt len
ERL_DRV_STRING       char *str, int len
ERL_DRV_TUPLE        int sz
ERL_DRV_LIST         int sz
ERL_DRV_PID          ErlDrvTermData pid (from driver_connected(ErlDrvPort port) or driver_caller(ErlDrvPort port
ERL_DRV_STRING_CONS  char *str, int len
ERL_DRV_FLOAT        double *dbl
ERL_DRV_EXT2TERM     char *buf, ErlDrvUInt len
ERL_DRV_MAP          int sz
```

The unsigned integer data type ErlDrvUInt and the signed integer data type ErlDrvSInt are 64 bits wide on a 64 bit runtime system and 32 bits wide on a 32 bit runtime system. They were introduced in erts version 5.6, and replaced some of the int arguments in the list above.

The unsigned integer data type ErlDrvUInt64 and the signed integer data type ErlDrvSInt64 are always 64 bits wide. They were introduced in erts version 5.7.4.

To build the tuple {tcp, Port, [100 | Binary]}, the following call could be made.

```
ErlDrvBinary* bin = ...
ErlDrvPort port = ...
ErlDrvTermData spec[] = {
    ERL_DRV_ATOM, driver_mk_atom("tcp"),
    ERL_DRV_PORT, driver_mk_port(drvport),
        ERL_DRV_INT, 100,
        ERL_DRV_BINARY, bin, 50, 0,
        ERL_DRV_LIST, 2,
    ERL_DRV_TUPLE, 3,
};
erl_drv_output_term(driver_mk_port(drvport), spec, sizeof(spec) / sizeof(spec[0]));
```

Where bin is a driver binary of length at least 50 and drvport is a port handle. Note that the ERL_DRV_LIST comes after the elements of the list, likewise the ERL_DRV_TUPLE.

The term ERL_DRV_STRING_CONS is a way to construct strings. It works differently from how ERL_DRV_STRING works. ERL_DRV_STRING_CONS builds a string list in reverse order, (as opposed to how ERL_DRV_LIST works), concatenating the strings added to a list. The tail must be given before ERL_DRV_STRING_CONS.

The ERL_DRV_STRING constructs a string, and ends it. (So it's the same as ERL_DRV_NIL followed by ERL_DRV_STRING_CONS.)

```
   /* to send [x, "abc", y] to the port: */
   ErlDrvTermData spec[] = {
       ERL_DRV_ATOM, driver_mk_atom("x"),
       ERL_DRV_STRING, (ErlDrvTermData)"abc", 3,
       ERL_DRV_ATOM, driver_mk_atom("y"),
       ERL_DRV_NIL,
       ERL_DRV_LIST, 4
   };
   erl_drv_output_term(driver_mk_port(drvport), spec, sizeof(spec) / sizeof(spec[0]));
```

```
   /* to send "abc123" to the port: */
   ErlDrvTermData spec[] = {
       ERL_DRV_NIL,        /* with STRING_CONS, the tail comes first */
       ERL_DRV_STRING_CONS, (ErlDrvTermData)"123", 3,
       ERL_DRV_STRING_CONS, (ErlDrvTermData)"abc", 3,
   };
   erl_drv_output_term(driver_mk_port(drvport), spec, sizeof(spec) / sizeof(spec[0]));
```

The `ERL_DRV_EXT2TERM` term type is used for passing a term encoded with the *external format*, i.e., a term that has been encoded by *erlang:term_to_binary*, *erl_interface*, etc. For example, if `binp` is a pointer to an `ErlDrvBinary` that contains the term `{17, 4711}` encoded with the *external format* and you want to wrap it in a two tuple with the tag `my_tag`, i.e., `{my_tag, {17, 4711}}`, you can do as follows:

```
   ErlDrvTermData spec[] = {
           ERL_DRV_ATOM, driver_mk_atom("my_tag"),
           ERL_DRV_EXT2TERM, (ErlDrvTermData) binp->orig_bytes, binp->orig_size
       ERL_DRV_TUPLE, 2,
   };
   erl_drv_output_term(driver_mk_port(drvport), spec, sizeof(spec) / sizeof(spec[0]));
```

To build the map `#{key1 => 100, key2 => {200, 300}}`, the following call could be made.

```
   ErlDrvPort port = ...
   ErlDrvTermData spec[] = {
         ERL_DRV_ATOM, driver_mk_atom("key1"),
  ERL_DRV_INT, 100,
         ERL_DRV_ATOM, driver_mk_atom("key2"),
    ERL_DRV_INT, 200,
    ERL_DRV_INT, 300,
  ERL_DRV_TUPLE, 2,
ERL_DRV_MAP, 2
   };
   erl_drv_output_term(driver_mk_port(drvport), spec, sizeof(spec) / sizeof(spec[0]));
```

If you want to pass a binary and don't already have the content of the binary in an `ErlDrvBinary`, you can benefit from using `ERL_DRV_BUF2BINARY` instead of creating an `ErlDrvBinary` via `driver_alloc_binary()` and then pass the binary via `ERL_DRV_BINARY`. The runtime system will often allocate binaries smarter if `ERL_DRV_BUF2BINARY` is used. However, if the content of the binary to pass already resides in an

ErlDrvBinary, it is normally better to pass the binary using ERL_DRV_BINARY and the ErlDrvBinary in question.

The ERL_DRV_UINT, ERL_DRV_BUF2BINARY, and ERL_DRV_EXT2TERM term types were introduced in the 5.6 version of erts.

This function is only thread-safe when the emulator with SMP support is used.

**int driver_output_term(ErlDrvPort port, ErlDrvTermData* term, int n)**

> Warning:
>
> driver_output_term() is deprecated and will be removed in the OTP-R17 release. Use *erl_drv_output_term()* instead.

The parameters term and n do the same thing as in *erl_drv_output_term()*.

Note that this function is *not* thread-safe, not even when the emulator with SMP support is used.

**ErlDrvTermData driver_mk_atom(char* string)**

This function returns an atom given a name string. The atom is created and won't change, so the return value may be saved and reused, which is faster than looking up the atom several times.

Note that this function is *not* thread-safe, not even when the emulator with SMP support is used.

**ErlDrvTermData driver_mk_port(ErlDrvPort port)**

This function converts a port handle to the erlang term format, usable in the *erl_drv_output_term()*, and *erl_drv_send_term()* functions.

Note that this function is *not* thread-safe, not even when the emulator with SMP support is used.

**int erl_drv_send_term(ErlDrvTermData port, ErlDrvTermData receiver, ErlDrvTermData* term, int n)**

This function is the only way for a driver to send data to *other* processes than the port owner process. The receiver parameter specifies the process to receive the data.

> Note:
>
> Note that the port parameter is *not* an ordinary port handle, but a port handle converted using driver_mk_port().

The parameters port, term and n do the same thing as in *erl_drv_output_term()*.

This function is only thread-safe when the emulator with SMP support is used.

**int driver_send_term(ErlDrvPort port, ErlDrvTermData receiver, ErlDrvTermData* term, int n)**

> Warning:
>
> `driver_send_term()` is deprecated and will be removed in the OTP-R17 release. Use *erl_drv_send_term()* instead.
>
> Also note that parameters of `driver_send_term()` cannot be properly checked by the runtime system when executed by arbitrary threads. This may cause the `driver_send_term()` function not to fail when it should.

The parameters `term` and `n` do the same thing as in *erl_drv_output_term()*.

This function is only thread-safe when the emulator with SMP support is used.

**long driver_async (ErlDrvPort port, unsigned int* key, void (*async_invoke)(void*), void* async_data, void (*async_free)(void*))**

This function performs an asynchronous call. The function `async_invoke` is invoked in a thread separate from the emulator thread. This enables the driver to perform time-consuming, blocking operations without blocking the emulator.

The async thread pool size can be set with the *+A* command line argument of *erl(1)*. If no async thread pool is available, the call is made synchronously in the thread calling `driver_async()`. The current number of async threads in the async thread pool can be retrieved via *driver_system_info()*.

If there is a thread pool available, a thread will be used. If the `key` argument is null, the threads from the pool are used in a round-robin way, each call to `driver_async` uses the next thread in the pool. With the `key` argument set, this behaviour is changed. The two same values of `*key` always get the same thread.

To make sure that a driver instance always uses the same thread, the following call can be used:

```
unsigned int myKey = driver_async_port_key(myPort);

r = driver_async(myPort, &myKey, myData, myFunc);
```

It is enough to initialize `myKey` once for each driver instance.

If a thread is already working, the calls will be queued up and executed in order. Using the same thread for each driver instance ensures that the calls will be made in sequence.

The `async_data` is the argument to the functions `async_invoke` and `async_free`. It's typically a pointer to a structure that contains a pipe or event that can be used to signal that the async operation completed. The data should be freed in `async_free`.

When the async operation is done, *ready_async* driver entry function is called. If `ready_async` is null in the driver entry, the `async_free` function is called instead.

The return value is -1 if the `driver_async` call fails.

> Note:
>
> As of erts version 5.5.4.3 the default stack size for threads in the async-thread pool is 16 kilowords, i.e., 64 kilobyte on 32-bit architectures. This small default size has been chosen since the amount of async-threads might be quite large. The default stack size is enough for drivers delivered with Erlang/OTP, but might not be sufficiently large for other dynamically linked in drivers that use the driver_async() functionality. A suggested stack size for threads in the async-thread pool can be configured via the *+a* command line argument of *erl(1)*.

### `unsigned int driver_async_port_key (ErlDrvPort port)`

This function calculates a key for later use in *driver_async()*. The keys are evenly distributed so that a fair mapping between port id's and async thread id's is achieved.

> Note:
>
> Before OTP-R16, the actual port id could be used as a key with proper casting, but after the rewrite of the port subsystem, this is no longer the case. With this function, you can achieve the same distribution based on port id's as before OTP-R16.

### `int driver_lock_driver(ErlDrvPort port)`

This function locks the driver used by the port `port` in memory for the rest of the emulator process' lifetime. After this call, the driver behaves as one of Erlang's statically linked in drivers.

### `ErlDrvPort driver_create_port(ErlDrvPort port, ErlDrvTermData owner_pid, char* name, ErlDrvData drv_data)`

This function creates a new port executing the same driver code as the port creating the new port. A short description of the arguments:

`port`
: The port handle of the port (driver instance) creating the new port.

`owner_pid`
: The process id of the Erlang process which will be owner of the new port. This process will be linked to the new port. You usually want to use `driver_caller(port)` as `owner_pid`.

`name`
: The port name of the new port. You usually want to use the same port name as the driver name (*driver_name* field of the *driver_entry*).

`drv_data`
: The driver defined handle that will be passed in subsequent calls to driver call-backs. Note, that the *driver start call-back* will not be called for this new driver instance. The driver defined handle is normally created in the *driver start call-back* when a port is created via *erlang:open_port/2*.

The caller of `driver_create_port()` is allowed to manipulate the newly created port when `driver_create_port()` has returned. When *port level locking* is used, the creating port is, however, only allowed to manipulate the newly created port until the current driver call-back that was called by the emulator returns.

> ### Note:
>
> When *port level locking* is used, the creating port is only allowed to manipulate the newly created port until the current driver call-back returns.

**`int erl_drv_thread_create(char *name, ErlDrvTid *tid, void * (*func)(void *), void *arg, ErlDrvThreadOpts *opts)`**

Arguments:

`name`
: A string identifying the created thread. It will be used to identify the thread in planned future debug functionality.

`tid`
: A pointer to a thread identifier variable.

`func`
: A pointer to a function to execute in the created thread.

`arg`
: A pointer to argument to the `func` function.

`opts`
: A pointer to thread options to use or `NULL`.

This function creates a new thread. On success `0` is returned; otherwise, an `errno` value is returned to indicate the error. The newly created thread will begin executing in the function pointed to by `func`, and `func` will be passed `arg` as argument. When `erl_drv_thread_create()` returns the thread identifier of the newly created thread will be available in `*tid`. `opts` can be either a `NULL` pointer, or a pointer to an *ErlDrvThreadOpts* structure. If `opts` is a `NULL` pointer, default options will be used; otherwise, the passed options will be used.

> ### Warning:
>
> You are not allowed to allocate the *ErlDrvThreadOpts* structure by yourself. It has to be allocated and initialized by *erl_drv_thread_opts_create()*.

The created thread will terminate either when `func` returns or if *erl_drv_thread_exit()* is called by the thread. The exit value of the thread is either returned from `func` or passed as argument to *erl_drv_thread_exit()*. The driver creating the thread has the responsibility of joining the thread, via *erl_drv_thread_join()*, before the driver is unloaded. It is not possible to create "detached" threads, i.e., threads that don't need to be joined.

> ### Warning:
>
> All created threads need to be joined by the driver before it is unloaded. If the driver fails to join all threads created before it is unloaded, the runtime system will most likely crash when the code of the driver is unloaded.

This function is thread-safe.

**`ErlDrvThreadOpts *erl_drv_thread_opts_create(char *name)`**

Arguments:

`name`
A string identifying the created thread options. It will be used to identify the thread options in planned future debug functionality.

This function allocates and initialize a thread option structure. On failure `NULL` is returned. A thread option structure is used for passing options to *erl_drv_thread_create()*. If the structure isn't modified before it is passed to *erl_drv_thread_create()*, the default values will be used.

> **Warning:**
> You are not allowed to allocate the *ErlDrvThreadOpts* structure by yourself. It has to be allocated and initialized by `erl_drv_thread_opts_create()`.

This function is thread-safe.

### `void erl_drv_thread_opts_destroy(ErlDrvThreadOpts *opts)`

Arguments:

`opts`
A pointer to thread options to destroy.

This function destroys thread options previously created by *erl_drv_thread_opts_create()*.

This function is thread-safe.

### `void erl_drv_thread_exit(void *exit_value)`

Arguments:

`exit_value`
A pointer to an exit value or `NULL`.

This function terminates the calling thread with the exit value passed as argument. You are only allowed to terminate threads created with *erl_drv_thread_create()*. The exit value can later be retrieved by another thread via *erl_drv_thread_join()*.

This function is thread-safe.

### `int erl_drv_thread_join(ErlDrvTid tid, void **exit_value)`

Arguments:

`tid`
The thread identifier of the thread to join.
`exit_value`
A pointer to a pointer to an exit value, or `NULL`.

This function joins the calling thread with another thread, i.e., the calling thread is blocked until the thread identified by `tid` has terminated. On success `0` is returned; otherwise, an `errno` value is returned to indicate the error. A thread can only be joined once. The behavior of joining more than once is undefined, an emulator crash is likely. If `exit_value == NULL`, the exit value of the terminated thread will be ignored; otherwise, the exit value of the terminated thread will be stored at `*exit_value`.

This function is thread-safe.

### ErlDrvTid erl_drv_thread_self(void)

This function returns the thread identifier of the calling thread.

This function is thread-safe.

### int erl_drv_equal_tids(ErlDrvTid tid1, ErlDrvTid tid2)

Arguments:

`tid1`
: A thread identifier.

`tid2`
: A thread identifier.

This function compares two thread identifiers for equality, and returns `0` it they aren't equal, and a value not equal to `0` if they are equal.

> **Note:**
>
> A Thread identifier may be reused very quickly after a thread has terminated. Therefore, if a thread corresponding to one of the involved thread identifiers has terminated since the thread identifier was saved, the result of `erl_drv_equal_tids()` might not give the expected result.

This function is thread-safe.

### ErlDrvMutex *erl_drv_mutex_create(char *name)

Arguments:

`name`
: A string identifying the created mutex. It will be used to identify the mutex in planned future debug functionality.

This function creates a mutex and returns a pointer to it. On failure `NULL` is returned. The driver creating the mutex has the responsibility of destroying it before the driver is unloaded.

This function is thread-safe.

### void erl_drv_mutex_destroy(ErlDrvMutex *mtx)

Arguments:

`mtx`
: A pointer to a mutex to destroy.

This function destroys a mutex previously created by *erl_drv_mutex_create()*. The mutex has to be in an unlocked state before being destroyed.

This function is thread-safe.

### void erl_drv_mutex_lock(ErlDrvMutex *mtx)

Arguments:

`mtx`
: A pointer to a mutex to lock.

This function locks a mutex. The calling thread will be blocked until the mutex has been locked. A thread which currently has locked the mutex may *not* lock the same mutex again.

> ### Warning:
>
> If you leave a mutex locked in an emulator thread when you let the thread out of your control, you will *very likely* deadlock the whole emulator.

This function is thread-safe.

#### `int erl_drv_mutex_trylock(ErlDrvMutex *mtx)`

Arguments:

`mtx`
: A pointer to a mutex to try to lock.

This function tries to lock a mutex. If successful `0`, is returned; otherwise, `EBUSY` is returned. A thread which currently has locked the mutex may *not* try to lock the same mutex again.

> ### Warning:
>
> If you leave a mutex locked in an emulator thread when you let the thread out of your control, you will *very likely* deadlock the whole emulator.

This function is thread-safe.

#### `void erl_drv_mutex_unlock(ErlDrvMutex *mtx)`

Arguments:

`mtx`
: A pointer to a mutex to unlock.

This function unlocks a mutex. The mutex currently has to be locked by the calling thread.

This function is thread-safe.

#### `ErlDrvCond *erl_drv_cond_create(char *name)`

Arguments:

`name`
: A string identifying the created condition variable. It will be used to identify the condition variable in planned future debug functionality.

This function creates a condition variable and returns a pointer to it. On failure `NULL` is returned. The driver creating the condition variable has the responsibility of destroying it before the driver is unloaded.

This function is thread-safe.

#### `void erl_drv_cond_destroy(ErlDrvCond *cnd)`

Arguments:

`cnd`
A pointer to a condition variable to destroy.

This function destroys a condition variable previously created by *erl_drv_cond_create()*.

This function is thread-safe.

### `void erl_drv_cond_signal(ErlDrvCond *cnd)`

Arguments:

`cnd`
A pointer to a condition variable to signal on.

This function signals on a condition variable. That is, if other threads are waiting on the condition variable being signaled, *one* of them will be woken.

This function is thread-safe.

### `void erl_drv_cond_broadcast(ErlDrvCond *cnd)`

Arguments:

`cnd`
A pointer to a condition variable to broadcast on.

This function broadcasts on a condition variable. That is, if other threads are waiting on the condition variable being broadcast on, *all* of them will be woken.

This function is thread-safe.

### `void erl_drv_cond_wait(ErlDrvCond *cnd, ErlDrvMutex *mtx)`

Arguments:

`cnd`
A pointer to a condition variable to wait on.
`mtx`
A pointer to a mutex to unlock while waiting.

This function waits on a condition variable. The calling thread is blocked until another thread wakes it by signaling or broadcasting on the condition variable. Before the calling thread is blocked it unlocks the mutex passed as argument, and when the calling thread is woken it locks the same mutex before returning. That is, the mutex currently has to be locked by the calling thread when calling this function.

> Note:
>
> `erl_drv_cond_wait()` might return even though no-one has signaled or broadcast on the condition variable. Code calling `erl_drv_cond_wait()` should always be prepared for `erl_drv_cond_wait()` returning even though the condition that the thread was waiting for hasn't occurred. That is, when returning from `erl_drv_cond_wait()` always check if the condition has occurred, and if not call `erl_drv_cond_wait()` again.

This function is thread-safe.

### `ErlDrvRWLock *erl_drv_rwlock_create(char *name)`

Arguments:

`name`
: A string identifying the created rwlock. It will be used to identify the rwlock in planned future debug functionality.

This function creates an rwlock and returns a pointer to it. On failure `NULL` is returned. The driver creating the rwlock has the responsibility of destroying it before the driver is unloaded.

This function is thread-safe.

### `void erl_drv_rwlock_destroy(ErlDrvRWLock *rwlck)`

Arguments:

`rwlck`
: A pointer to an rwlock to destroy.

This function destroys an rwlock previously created by *erl_drv_rwlock_create()*. The rwlock has to be in an unlocked state before being destroyed.

This function is thread-safe.

### `void erl_drv_rwlock_rlock(ErlDrvRWLock *rwlck)`

Arguments:

`rwlck`
: A pointer to an rwlock to read lock.

This function read locks an rwlock. The calling thread will be blocked until the rwlock has been read locked. A thread which currently has read or read/write locked the rwlock may *not* lock the same rwlock again.

> Warning:
>
> If you leave an rwlock locked in an emulator thread when you let the thread out of your control, you will *very likely* deadlock the whole emulator.

This function is thread-safe.

### `int erl_drv_rwlock_tryrlock(ErlDrvRWLock *rwlck)`

Arguments:

`rwlck`
: A pointer to an rwlock to try to read lock.

This function tries to read lock an rwlock. If successful `0`, is returned; otherwise, `EBUSY` is returned. A thread which currently has read or read/write locked the rwlock may *not* try to lock the same rwlock again.

> Warning:
>
> If you leave an rwlock locked in an emulator thread when you let the thread out of your control, you will *very likely* deadlock the whole emulator.

This function is thread-safe.

### void erl_drv_rwlock_runlock(ErlDrvRWLock *rwlck)

Arguments:

`rwlck`
A pointer to an rwlock to read unlock.

This function read unlocks an rwlock. The rwlock currently has to be read locked by the calling thread.

This function is thread-safe.

### void erl_drv_rwlock_rwlock(ErlDrvRWLock *rwlck)

Arguments:

`rwlck`
A pointer to an rwlock to read/write lock.

This function read/write locks an rwlock. The calling thread will be blocked until the rwlock has been read/write locked. A thread which currently has read or read/write locked the rwlock may *not* lock the same rwlock again.

> Warning:
>
> If you leave an rwlock locked in an emulator thread when you let the thread out of your control, you will *very likely* deadlock the whole emulator.

This function is thread-safe.

### int erl_drv_rwlock_tryrwlock(ErlDrvRWLock *rwlck)

Arguments:

`rwlck`
A pointer to an rwlock to try to read/write lock.

This function tries to read/write lock an rwlock. If successful `0`, is returned; otherwise, `EBUSY` is returned. A thread which currently has read or read/write locked the rwlock may *not* try to lock the same rwlock again.

> Warning:
>
> If you leave an rwlock locked in an emulator thread when you let the thread out of your control, you will *very likely* deadlock the whole emulator.

This function is thread-safe.

### void erl_drv_rwlock_rwunlock(ErlDrvRWLock *rwlck)

Arguments:

`rwlck`
A pointer to an rwlock to read/write unlock.

This function read/write unlocks an rwlock. The rwlock currently has to be read/write locked by the calling thread.

This function is thread-safe.

### int erl_drv_tsd_key_create(char *name, ErlDrvTSDKey *key)

Arguments:

`name`
: A string identifying the created key. It will be used to identify the key in planned future debug functionality.

`key`
: A pointer to a thread specific data key variable.

This function creates a thread specific data key. On success `0` is returned; otherwise, an `errno` value is returned to indicate the error. The driver creating the key has the responsibility of destroying it before the driver is unloaded.

This function is thread-safe.

### void erl_drv_tsd_key_destroy(ErlDrvTSDKey key)

Arguments:

`key`
: A thread specific data key to destroy.

This function destroys a thread specific data key previously created by *erl_drv_tsd_key_create()*. All thread specific data using this key in all threads have to be cleared (see *erl_drv_tsd_set()*) prior to the call to `erl_drv_tsd_key_destroy()`.

> ## Warning:
>
> A destroyed key is very likely to be reused soon. Therefore, if you fail to clear the thread specific data using this key in a thread prior to destroying the key, you will *very likely* get unexpected errors in other parts of the system.

This function is thread-safe.

### void erl_drv_tsd_set(ErlDrvTSDKey key, void *data)

Arguments:

`key`
: A thread specific data key.

`data`
: A pointer to data to associate with `key` in calling thread.

This function sets thread specific data associated with `key` for the calling thread. You are only allowed to set thread specific data for threads while they are fully under your control. For example, if you set thread specific data in a thread calling a driver call-back function, it has to be cleared, i.e. set to `NULL`, before returning from the driver call-back function.

> ## Warning:
>
> If you fail to clear thread specific data in an emulator thread before letting it out of your control, you might not ever be able to clear this data with later unexpected errors in other parts of the system as a result.

This function is thread-safe.

### void *erl_drv_tsd_get(ErlDrvTSDKey key)

Arguments:

`key`
: A thread specific data key.

This function returns the thread specific data associated with `key` for the calling thread. If no data has been associated with `key` for the calling thread, `NULL` is returned.

This function is thread-safe.

### int erl_drv_putenv(const char *key, char *value)

Arguments:

`key`
: A null terminated string containing the name of the environment variable.

`value`
: A null terminated string containing the new value of the environment variable.

This function sets the value of an environment variable. It returns `0` on success, and a value `!= 0` on failure.

> **Note:**
>
> The result of passing the empty string ("") as a value is platform dependent. On some platforms the value of the variable is set to the empty string, on others, the environment variable is removed.

> **Warning:**
>
> Do *not* use libc's `putenv` or similar C library interfaces from a driver.

This function is thread-safe.

### int erl_drv_getenv(const char *key, char *value, size_t *value_size)

Arguments:

`key`
: A null terminated string containing the name of the environment variable.

`value`
: A pointer to an output buffer.

`value_size`
: A pointer to an integer. The integer is both used for passing input and output sizes (see below).

This function retrieves the value of an environment variable. When called, `*value_size` should contain the size of the `value` buffer. On success `0` is returned, the value of the environment variable has been written to the `value` buffer, and `*value_size` contains the string length (excluding the terminating null character) of the value written to the `value` buffer. On failure, i.e., no such environment variable was found, a value less than `0` is returned. When the size of the `value` buffer is too small, a value greater than `0` is returned and `*value_size` has been set to the buffer size needed.

> Warning:
>
> Do *not* use libc's `getenv` or similar C library interfaces from a driver.

This function is thread-safe.

### `int erl_drv_consume_timeslice(ErlDrvPort port, int percent)`

Arguments:

`port`
: Port handle of the executing port.

`percent`
: Approximate consumed fraction of a full time-slice in percent.

Give the runtime system a hint about how much CPU time the current driver callback call has consumed since last hint, or since the start of the callback if no previous hint has been given. The time is given as a fraction, in percent, of a full time-slice that a port is allowed to execute before it should surrender the CPU to other runnable ports or processes. Valid range is `[1, 100]`. The scheduling time-slice is not an exact entity, but can usually be approximated to about 1 millisecond.

Note that it is up to the runtime system to determine if and how to use this information. Implementations on some platforms may use other means in order to determine the consumed fraction of the time-slice. Lengthy driver callbacks should regardless of this frequently call the `erl_drv_consume_timeslice()` function in order to determine if it is allowed to continue execution or not.

`erl_drv_consume_timeslice()` returns a non-zero value if the time-slice has been exhausted, and zero if the callback is allowed to continue execution. If a non-zero value is returned the driver callback should return as soon as possible in order for the port to be able to yield.

This function is provided to better support co-operative scheduling, improve system responsiveness, and to make it easier to prevent misbehaviors of the VM due to a port monopolizing a scheduler thread. It can be used when dividing length work into a number of repeated driver callback calls without the need to use threads. Also see the important *warning* text at the beginning of this document.

### `char *erl_drv_cond_name(ErlDrvCond *cnd)`

Arguments:

`cnd`
: A pointer to an initialized condition.

Returns a pointer to the name of the condition.

> Note:
>
> This function is intended for debugging purposes only.

### `char *erl_drv_mutex_name(ErlDrvMutex *mtx)`

Arguments:

`mtx`
: A pointer to an initialized mutex.

Returns a pointer to the name of the mutex.

> Note:
>
> This function is intended for debugging purposes only.

**`char *erl_drv_rwlock_name(ErlDrvRWLock *rwlck)`**

Arguments:

`rwlck`
: A pointer to an initialized r/w-lock.

Returns a pointer to the name of the r/w-lock.

> Note:
>
> This function is intended for debugging purposes only.

**`char *erl_drv_thread_name(ErlDrvTid tid)`**

Arguments:

`tid`
: A thread identifier.

Returns a pointer to the name of the thread.

> Note:
>
> This function is intended for debugging purposes only.

**`ErlDrvTime erl_drv_monotonic_time(ErlDrvTimeUnit time_unit)`**

Arguments:

`time_unit`
: Time unit of returned value.

Returns *Erlang monotonic time*. Note that it is not uncommon with negative values.

Returns `ERL_DRV_TIME_ERROR` if called with an invalid time unit argument, or if called from a thread that is not a scheduler thread.

See also:

- *`ErlDrvTime`*
- *`ErlDrvTimeUnit`*

**`ErlDrvTime erl_drv_time_offset(ErlDrvTimeUnit time_unit)`**

Arguments:

`time_unit`
: Time unit of returned value.

Returns the current time offset between *Erlang monotonic time* and *Erlang system time* converted into the `time_unit` passed as argument.

Returns `ERL_DRV_TIME_ERROR` if called with an invalid time unit argument, or if called from a thread that is not a scheduler thread.

See also:

- *`ErlDrvTime`*
- *`ErlDrvTimeUnit`*

**`ErlDrvTime erl_drv_convert_time_unit(ErlDrvTime val, ErlDrvTimeUnit from, ErlDrvTimeUnit to)`**

Arguments:

`val`
: Value to convert time unit for.

`from`
: Time unit of `val`.

`to`
: Time unit of returned value.

Converts the `val` value of time unit `from` to the corresponding value of time unit `to`. The result is rounded using the floor function.

Returns `ERL_DRV_TIME_ERROR` if called with an invalid time unit argument.

See also:

- *`ErlDrvTime`*
- *`ErlDrvTimeUnit`*

## SEE ALSO

*driver_entry(3)*, *erl_ddll(3)*, *erlang(3)*

An Alternative Distribution Driver (ERTS User's Guide Ch. 3)

# driver_entry

C Library

> ### Warning:
>
> *Use this functionality with extreme care!*
>
> A driver callback is executed as a direct extension of the native code of the VM. Execution is not made in a safe environment. The VM can *not* provide the same services as provided when executing Erlang code, such as preemptive scheduling or memory protection. If the driver callback function doesn't behave well, the whole VM will misbehave.
>
> - A driver callback that crash will crash the whole VM.
> - An erroneously implemented driver callback might cause a VM internal state inconsistency which may cause a crash of the VM, or miscellaneous misbehaviors of the VM at any point after the call to the driver callback.
> - A driver callback that do *lengthy work* before returning will degrade responsiveness of the VM, and may cause miscellaneous strange behaviors. Such strange behaviors include, but are not limited to, extreme memory usage, and bad load balancing between schedulers. Strange behaviors that might occur due to lengthy work may also vary between OTP releases.

As of erts version 5.9 (OTP release R15B) the driver interface has been changed with larger types for the callbacks *output*, *control* and *call*. See driver *version management* in *erl_driver*.

> ### Note:
>
> Old drivers (compiled with an `erl_driver.h` from an earlier erts version than 5.9) have to be updated and have to use the extended interface (with *version management* ).

The `driver_entry` structure is a C struct that all erlang drivers define. It contains entry points for the erlang driver that are called by the erlang emulator when erlang code accesses the driver.

The *erl_driver* driver API functions need a port handle that identifies the driver instance (and the port in the emulator). This is only passed to the `start` function, but not to the other functions. The `start` function returns a driver-defined handle that is passed to the other functions. A common practice is to have the `start` function allocate some application-defined structure and stash the `port` handle in it, to use it later with the driver API functions.

The driver call-back functions are called synchronously from the erlang emulator. If they take too long before completing, they can cause timeouts in the emulator. Use the queue or asynchronous calls if necessary, since the emulator must be responsive.

The driver structure contains the name of the driver and some 15 function pointers. These pointers are called at different times by the emulator.

The only exported function from the driver is `driver_init`. This function returns the `driver_entry` structure that points to the other functions in the driver. The `driver_init` function is declared with a macro `DRIVER_INIT(drivername)`. (This is because different OS's have different names for it.)

When writing a driver in C++, the driver entry should be of `"C"` linkage. One way to do this is to put this line somewhere before the driver entry: `extern "C" DRIVER_INIT(drivername);`.

When the driver has passed the `driver_entry` over to the emulator, the driver is *not* allowed to modify the `driver_entry`.

If compiling a driver for static inclusion via --enable-static-drivers you have to define STATIC_ERLANG_DRIVER before the DRIVER_INIT declaration.

> **Note:**
>
> Do *not* declare the `driver_entry` `const`. This since the emulator needs to modify the `handle`, and the `handle2` fields. A statically allocated, and `const` declared `driver_entry` may be located in read only memory which will cause the emulator to crash.

## DATA TYPES

*ErlDrvEntry*

```
typedef struct erl_drv_entry {
    int (*init)(void);          /* called at system start up for statically
                                   linked drivers, and after loading for
                                   dynamically loaded drivers */

#ifndef ERL_SYS_DRV
    ErlDrvData (*start)(ErlDrvPort port, char *command);
                                /* called when open_port/2 is invoked.
                                   return value -1 means failure. */
#else
    ErlDrvData (*start)(ErlDrvPort port, char *command, SysDriverOpts* opts);
                                /* special options, only for system driver */
#endif
    void (*stop)(ErlDrvData drv_data);
                                /* called when port is closed, and when the
                                   emulator is halted. */
    void (*output)(ErlDrvData drv_data, char *buf, ErlDrvSizeT len);
                                /* called when we have output from erlang to
                                   the port */
    void (*ready_input)(ErlDrvData drv_data, ErlDrvEvent event);
                                /* called when we have input from one of
                                   the driver's handles */
    void (*ready_output)(ErlDrvData drv_data, ErlDrvEvent event);
                                /* called when output is possible to one of
                                   the driver's handles */
    char *driver_name;          /* name supplied as command
                                   in open_port XXX ? */
    void (*finish)(void);       /* called before unloading the driver -
                                   DYNAMIC DRIVERS ONLY */
    void *handle;               /* Reserved -- Used by emulator internally */
    ErlDrvSSizeT (*control)(ErlDrvData drv_data, unsigned int command,
                            char *buf, ErlDrvSizeT len,
       char **rbuf, ErlDrvSizeT rlen);
                                /* "ioctl" for drivers - invoked by
                                   port_control/3 */
    void (*timeout)(ErlDrvData drv_data);        /* Handling of timeout in driver */
    void (*outputv)(ErlDrvData drv_data, ErlIOVec *ev);
                                /* called when we have output from erlang
                                   to the port */
    void (*ready_async)(ErlDrvData drv_data, ErlDrvThreadData thread_data);
    void (*flush)(ErlDrvData drv_data);
                                /* called when the port is about to be
```

```
                                closed, and there is data in the
                                driver queue that needs to be flushed
                                before 'stop' can be called */
   ErlDrvSSizeT (*call)(ErlDrvData drv_data, unsigned int command,
                        char *buf, ErlDrvSizeT len,
   char **rbuf, ErlDrvSizeT rlen, unsigned int *flags);
                             /* Works mostly like 'control', a synchronous
                                call into the driver. */
   void (*event)(ErlDrvData drv_data, ErlDrvEvent event,
                 ErlDrvEventData event_data);
                             /* Called when an event selected by
                                driver_event() has occurred */
   int extended_marker;      /* ERL_DRV_EXTENDED_MARKER */
   int major_version;        /* ERL_DRV_EXTENDED_MAJOR_VERSION */
   int minor_version;        /* ERL_DRV_EXTENDED_MINOR_VERSION */
   int driver_flags;         /* ERL_DRV_FLAGs */
   void *handle2;            /* Reserved -- Used by emulator internally */
   void (*process_exit)(ErlDrvData drv_data, ErlDrvMonitor *monitor);
                             /* Called when a process monitor fires */
   void (*stop_select)(ErlDrvEvent event, void* reserved);
                             /* Called to close an event object */
} ErlDrvEntry;
```

int (*init)(void)

This is called directly after the driver has been loaded by `erl_ddll:load_driver/2`. (Actually when the driver is added to the driver list.) The driver should return 0, or if the driver can't initialize, -1.

ErlDrvData (*start)(ErlDrvPort port, char* command)

This is called when the driver is instantiated, when `open_port/2` is called. The driver should return a number >= 0 or a pointer, or if the driver can't be started, one of three error codes should be returned:

ERL_DRV_ERROR_GENERAL - general error, no error code

ERL_DRV_ERROR_ERRNO - error with error code in `errno`

ERL_DRV_ERROR_BADARG - error, badarg

If an error code is returned, the port isn't started.

void (*stop)(ErlDrvData drv_data)

This is called when the port is closed, with `port_close/1` or `Port ! {self(), close}`. Note that terminating the port owner process also closes the port. If `drv_data` is a pointer to memory allocated in `start`, then `stop` is the place to deallocate that memory.

void (*output)(ErlDrvData drv_data, char *buf, ErlDrvSizeT len)

This is called when an erlang process has sent data to the port. The data is pointed to by `buf`, and is `len` bytes. Data is sent to the port with `Port ! {self(), {command, Data}}`, or with `port_command/2`. Depending on how the port was opened, it should be either a list of integers 0...255 or a binary. See `open_port/3` and `port_command/2`.

void (*ready_input)(ErlDrvData drv_data, ErlDrvEvent event)
void (*ready_output)(ErlDrvData drv_data, ErlDrvEvent event)

This is called when a driver event (given in the `event` parameter) is signaled. This is used to help asynchronous drivers "wake up" when something happens.

On unix the `event` is a pipe or socket handle (or something that the `select` system call understands).

On Windows the `event` is an Event or Semaphore (or something that the `WaitForMultipleObjects` API function understands). (Some trickery in the emulator allows more than the built-in limit of 64 `Events` to be used.)

On Enea OSE the `event` is one or more signals that can be retrieved using *erl_drv_ose_get_signal*.

To use this with threads and asynchronous routines, create a pipe on unix, an Event on Windows or a unique signal number on Enea OSE. When the routine completes, write to the pipe (use `SetEvent` on Windows or send a message to the emulator process on Enea OSE), this will make the emulator call `ready_input` or `ready_output`.

Spurious events may happen. That is, calls to `ready_input` or `ready_output` even though no real events are signaled. In reality it should be rare (and OS dependant), but a robust driver must nevertheless be able to handle such cases.

char *driver_name

This is the name of the driver, it must correspond to the atom used in `open_port`, and the name of the driver library file (without the extension).

void (*finish)(void)

This function is called by the `erl_ddll` driver when the driver is unloaded. (It is only called in dynamic drivers.)

The driver is only unloaded as a result of calling `unload_driver/1`, or when the emulator halts.

void *handle

This field is reserved for the emulator's internal use. The emulator will modify this field; therefore, it is important that the `driver_entry` isn't declared `const`.

ErlDrvSSizeT (*control)(ErlDrvData drv_data, unsigned int command, char *buf, ErlDrvSizeT len, char **rbuf, ErlDrvSizeT rlen)

This is a special routine invoked with the erlang function `port_control/3`. It works a little like an "ioctl" for erlang drivers. The data given to `port_control/3` arrives in `buf` and `len`. The driver may send data back, using `*rbuf` and `rlen`.

This is the fastest way of calling a driver and get a response. It won't make any context switch in the erlang emulator, and requires no message passing. It is suitable for calling C function to get faster execution, when erlang is too slow.

If the driver wants to return data, it should return it in `rbuf`. When `control` is called, `*rbuf` points to a default buffer of `rlen` bytes, which can be used to return data. Data is returned different depending on the port control flags (those that are set with *set_port_control_flags*).

If the flag is set to `PORT_CONTROL_FLAG_BINARY`, a binary will be returned. Small binaries can be returned by writing the raw data into the default buffer. A binary can also be returned by setting `*rbuf` to point to a binary allocated with *driver_alloc_binary*. This binary will be freed automatically after `control` has returned. The driver can retain the binary for *read only* access with *driver_binary_inc_refc* to be freed later with *driver_free_binary*. It is never allowed to alter the binary after `control` has returned. If `*rbuf` is set to NULL, an empty list will be returned.

If the flag is set to `0`, data is returned as a list of integers. Either use the default buffer or set `*rbuf` to point to a larger buffer allocated with *driver_alloc*. The buffer will be freed automatically after `control` has returned.

Using binaries is faster if more than a few bytes are returned.

The return value is the number of bytes returned in `*rbuf`.

void (*timeout)(ErlDrvData drv_data)

This function is called any time after the driver's timer reaches 0. The timer is activated with `driver_set_timer`. There are no priorities or ordering among drivers, so if several drivers time out at the same time, any one of them is called first.

void (*outputv)(ErlDrvData drv_data, ErlIOVec *ev)

This function is called whenever the port is written to. If it is `NULL`, the `output` function is called instead. This function is faster than `output`, because it takes an `ErlIOVec` directly, which requires no copying of the data. The port should be in binary mode, see `open_port/2`.

The `ErlIOVec` contains both a `SysIOVec`, suitable for `writev`, and one or more binaries. If these binaries should be retained, when the driver returns from `outputv`, they can be queued (using *driver_enq_bin* for instance), or if they are kept in a static or global variable, the reference counter can be incremented.

void (*ready_async)(ErlDrvData drv_data, ErlDrvThreadData thread_data)

This function is called after an asynchronous call has completed. The asynchronous call is started with *driver_async*. This function is called from the erlang emulator thread, as opposed to the asynchronous function, which is called in some thread (if multithreading is enabled).

ErlDrvSSizeT (*call)(ErlDrvData drv_data, unsigned int command, char *buf, ErlDrvSizeT len, char **rbuf, ErlDrvSizeT rlen, unsigned int *flags)

This function is called from `erlang:port_call/3`. It works a lot like the `control` call-back, but uses the external term format for input and output.

`command` is an integer, obtained from the call from erlang (the second argument to `erlang:port_call/3`).

`buf` and `len` provide the arguments to the call (the third argument to `erlang:port_call/3`). They can be decoded using `ei` functions.

`rbuf` points to a return buffer, `rlen` bytes long. The return data should be a valid erlang term in the external (binary) format. This is converted to an erlang term and returned by `erlang:port_call/3` to the caller. If more space than `rlen` bytes is needed to return data, `*rbuf` can be set to memory allocated with `driver_alloc`. This memory will be freed automatically after `call` has returned.

The return value is the number of bytes returned in `*rbuf`. If `ERL_DRV_ERROR_GENERAL` is returned (or in fact, anything < 0), `erlang:port_call/3` will throw a `BAD_ARG`.

void (*event)(ErlDrvData drv_data, ErlDrvEvent event, ErlDrvEventData event_data)

Intentionally left undocumented.

int extended_marker

This field should either be equal to `ERL_DRV_EXTENDED_MARKER` or `0`. An old driver (not aware of the extended driver interface) should set this field to `0`. If this field is equal to `0`, all the fields following this field also *have* to be `0`, or `NULL` in case it is a pointer field.

int major_version

This field should equal `ERL_DRV_EXTENDED_MAJOR_VERSION` if the `extended_marker` field equals `ERL_DRV_EXTENDED_MARKER`.

int minor_version

This field should equal `ERL_DRV_EXTENDED_MINOR_VERSION` if the `extended_marker` field equals `ERL_DRV_EXTENDED_MARKER`.

int driver_flags

This field is used to pass driver capability and other information to the runtime system. If the `extended_marker` field equals `ERL_DRV_EXTENDED_MARKER`, it should contain `0` or driver flags (`ERL_DRV_FLAG_*`) ored bitwise. Currently the following driver flags exist:

`ERL_DRV_FLAG_USE_PORT_LOCKING`
: The runtime system will use port level locking on all ports executing this driver instead of driver level locking when the driver is run in a runtime system with SMP support. For more information see the *erl_driver* documentation.

`ERL_DRV_FLAG_SOFT_BUSY`
: Marks that driver instances can handle being called in the *output* and/or *outputv* callbacks even though a driver instance has marked itself as busy (see *set_busy_port()*). Since erts version 5.7.4 this flag is required for drivers used by the Erlang distribution (the behaviour has always been required by drivers used by the distribution).

`ERL_DRV_FLAG_NO_BUSY_MSGQ`
: Disable busy port message queue functionality. For more information, see the documentation of the *erl_drv_busy_msgq_limits()* function.

void *handle2

This field is reserved for the emulator's internal use. The emulator will modify this field; therefore, it is important that the `driver_entry` isn't declared `const`.

void (*process_exit)(ErlDrvData drv_data, ErlDrvMonitor *monitor)

This callback is called when a monitored process exits. The `drv_data` is the data associated with the port for which the process is monitored (using *driver_monitor_process*) and the `monitor` corresponds to the `ErlDrvMonitor` structure filled in when creating the monitor. The driver interface function *driver_get_monitored_process* can be used to retrieve the process id of the exiting process as an `ErlDrvTermData`.

void (*stop_select)(ErlDrvEvent event, void* reserved)

This function is called on behalf of *driver_select* when it is safe to close an event object.

A typical implementation on Unix is to do `close((int)event)`.

Argument `reserved` is intended for future use and should be ignored.

In contrast to most of the other call-back functions, `stop_select` is called independent of any port. No `ErlDrvData` argument is passed to the function. No driver lock or port lock is guaranteed to be held. The port that called `driver_select` might even be closed at the time `stop_select` is called. But it could also be the case that `stop_select` is called directly by `driver_select`.

It is not allowed to call any functions in the *driver API* from `stop_select`. This strict limitation is due to the volatile context that `stop_select` may be called.

## SEE ALSO

*erl_driver(3)*, *erl_ddll(3)*, *erlang(3)*, kernel(3)

# erts_alloc

C Library

`erts_alloc` is an Erlang Run-Time System internal memory allocator library. `erts_alloc` provides the Erlang Run-Time System with a number of memory allocators.

## Allocators

Currently the following allocators are present:

`temp_alloc`
: Allocator used for temporary allocations.

`eheap_alloc`
: Allocator used for Erlang heap data, such as Erlang process heaps.

`binary_alloc`
: Allocator used for Erlang binary data.

`ets_alloc`
: Allocator used for ETS data.

`driver_alloc`
: Allocator used for driver data.

`sl_alloc`
: Allocator used for memory blocks that are expected to be short-lived.

`ll_alloc`
: Allocator used for memory blocks that are expected to be long-lived, for example Erlang code.

`fix_alloc`
: A fast allocator used for some frequently used fixed size data types.

`std_alloc`
: Allocator used for most memory blocks not allocated via any of the other allocators described above.

`sys_alloc`
: This is normally the default `malloc` implementation used on the specific OS.

`mseg_alloc`
: A memory segment allocator. `mseg_alloc` is used by other allocators for allocating memory segments and is currently only available on systems that have the `mmap` system call. Memory segments that are deallocated are kept for a while in a segment cache before they are destroyed. When segments are allocated, cached segments are used if possible instead of creating new segments. This in order to reduce the number of system calls made.

`sys_alloc` is always enabled and cannot be disabled. `mseg_alloc` is always enabled if it is available and an allocator that uses it is enabled. All other allocators can be *enabled or disabled*. By default all allocators are enabled. When an allocator is disabled, `sys_alloc` is used instead of the disabled allocator.

The main idea with the `erts_alloc` library is to separate memory blocks that are used differently into different memory areas, and by this achieving less memory fragmentation. By putting less effort in finding a good fit for memory blocks that are frequently allocated than for those less frequently allocated, a performance gain can be achieved.

## The alloc_util framework

Internally a framework called `alloc_util` is used for implementing allocators. `sys_alloc`, and `mseg_alloc` do not use this framework; hence, the following does *not* apply to them.

An allocator manages multiple areas, called carriers, in which memory blocks are placed. A carrier is either placed in a separate memory segment (allocated via `mseg_alloc`), or in the heap segment (allocated via `sys_alloc`). Multiblock carriers are used for storage of several blocks. Singleblock carriers are used for storage of one block. Blocks that are larger than the value of the singleblock carrier threshold (*sbct*) parameter are placed in singleblock carriers.

Blocks that are smaller than the value of the `sbct` parameter are placed in multiblock carriers. Normally an allocator creates a "main multiblock carrier". Main multiblock carriers are never deallocated. The size of the main multiblock carrier is determined by the value of the *mmbcs* parameter.

Sizes of multiblock carriers allocated via `mseg_alloc` are decided based on the values of the largest multiblock carrier size (*lmbcs*), the smallest multiblock carrier size (*smbcs*), and the multiblock carrier growth stages (*mbcgs*) parameters. If `nc` is the current number of multiblock carriers (the main multiblock carrier excluded) managed by an allocator, the size of the next `mseg_alloc` multiblock carrier allocated by this allocator will roughly be `smbcs +nc*(lmbcs-smbcs)/mbcgs` when `nc <= mbcgs`, and `lmbcs` when `nc > mbcgs`. If the value of the `sbct` parameter should be larger than the value of the `lmbcs` parameter, the allocator may have to create multiblock carriers that are larger than the value of the `lmbcs` parameter, though. Singleblock carriers allocated via `mseg_alloc` are sized to whole pages.

Sizes of carriers allocated via `sys_alloc` are decided based on the value of the `sys_alloc` carrier size (*ycs*) parameter. The size of a carrier is the least number of multiples of the value of the `ycs` parameter that satisfies the request.

Coalescing of free blocks are always performed immediately. Boundary tags (headers and footers) in free blocks are used which makes the time complexity for coalescing constant.

The memory allocation strategy used for multiblock carriers by an allocator is configurable via the *as* parameter. Currently the following strategies are available:

Best fit

Strategy: Find the smallest block that satisfies the requested block size.

Implementation: A balanced binary search tree is used. The time complexity is proportional to log N, where N is the number of sizes of free blocks.

Address order best fit

Strategy: Find the smallest block that satisfies the requested block size. If multiple blocks are found, choose the one with the lowest address.

Implementation: A balanced binary search tree is used. The time complexity is proportional to log N, where N is the number of free blocks.

Address order first fit

Strategy: Find the block with the lowest address that satisfies the requested block size.

Implementation: A balanced binary search tree is used. The time complexity is proportional to log N, where N is the number of free blocks.

Address order first fit carrier best fit

Strategy: Find the *carrier* with the lowest address that can satisfy the requested block size, then find a block within that carrier using the "best fit" strategy.

Implementation: Balanced binary search trees are used. The time complexity is proportional to log N, where N is the number of free blocks.

Address order first fit carrier address order best fit

Strategy: Find the *carrier* with the lowest address that can satisfy the requested block size, then find a block within that carrier using the "adress order best fit" strategy.

Implementation: Balanced binary search trees are used. The time complexity is proportional to log N, where N is the number of free blocks.

Good fit

Strategy: Try to find the best fit, but settle for the best fit found during a limited search.

Implementation: The implementation uses segregated free lists with a maximum block search depth (in each list) in order to find a good fit fast. When the maximum block search depth is small (by default 3) this implementation has a time complexity that is constant. The maximum block search depth is configurable via the *mbsd* parameter.

A fit

Strategy: Do not search for a fit, inspect only one free block to see if it satisfies the request. This strategy is only intended to be used for temporary allocations.

Implementation: Inspect the first block in a free-list. If it satisfies the request, it is used; otherwise, a new carrier is created. The implementation has a time complexity that is constant.

As of erts version 5.6.1 the emulator will refuse to use this strategy on other allocators than `temp_alloc`. This since it will only cause problems for other allocators.

Apart from the ordinary allocators described above a number of pre-allocators are used for some specific data types. These pre-allocators pre-allocate a fixed amount of memory for certain data types when the run-time system starts. As long as pre-allocated memory is available, it will be used. When no pre-allocated memory is available, memory will be allocated in ordinary allocators. These pre-allocators are typically much faster than the ordinary allocators, but can only satisfy a limited amount of requests.

## System Flags Effecting erts_alloc

### Warning:

Only use these flags if you are absolutely sure what you are doing. Unsuitable settings may cause serious performance degradation and even a system crash at any time during operation.

Memory allocator system flags have the following syntax: `+M<S><P> <V>` where `<S>` is a letter identifying a subsystem, `<P>` is a parameter, and `<V>` is the value to use. The flags can be passed to the Erlang emulator (*erl*) as command line arguments.

System flags effecting specific allocators have an upper-case letter as `<S>`. The following letters are used for the currently present allocators:

- `B: binary_alloc`
- `D: std_alloc`
- `E: ets_alloc`
- `F: fix_alloc`
- `H: eheap_alloc`
- `L: ll_alloc`
- `M: mseg_alloc`
- `R: driver_alloc`
- `S: sl_alloc`
- `T: temp_alloc`
- `Y: sys_alloc`

The following flags are available for configuration of `mseg_alloc`:

`+MMamcbf <size>`

Absolute max cache bad fit (in kilobytes). A segment in the memory segment cache is not reused if its size exceeds the requested size with more than the value of this parameter. Default value is 4096.

`+MMrmcbf <ratio>`
: Relative max cache bad fit (in percent). A segment in the memory segment cache is not reused if its size exceeds the requested size with more than relative max cache bad fit percent of the requested size. Default value is 20.

`+MMsco true|false`
: Set *super carrier* only flag. This flag defaults to `true`. When a super carrier is used and this flag is `true`, `mseg_alloc` will only create carriers in the super carrier. Note that the `alloc_util` framework may create `sys_alloc` carriers, so if you want all carriers to be created in the super carrier, you therefore want to disable use of `sys_alloc` carriers by also passing *`+Musac false`*. When the flag is `false`, `mseg_alloc` will try to create carriers outside of the super carrier when the super carrier is full.
*NOTE*: Setting this flag to `false` may not be supported on all systems. This flag will in that case be ignored.
*NOTE*: The super carrier cannot be enabled nor disabled on halfword heap systems. This flag will be ignored on halfword heap systems.

`+MMscrfsd <amount>`
: Set *super carrier* reserved free segment descriptors. This parameter defaults to `65536`. This parameter determines the amount of memory to reserve for free segment descriptors used by the super carrier. If the system runs out of reserved memory for free segment descriptors, other memory will be used. This may however cause fragmentation issues, so you want to ensure that this never happens. The maximum amount of free segment descriptors used can be retrieved from the `erts_mmap` tuple part of the result from calling *erlang:system_info({allocator, mseg_alloc})*.

`+MMscrpm true|false`
: Set *super carrier* reserve physical memory flag. This flag defaults to `true`. When this flag is `true`, physical memory will be reserved for the whole super carrier at once when it is created. The reservation will after that be left unchanged. When this flag is set to `false` only virtual address space will be reserved for the super carrier upon creation. The system will attempt to reserve physical memory upon carrier creations in the super carrier, and attempt to unreserve physical memory upon carrier destructions in the super carrier.
*NOTE*: What reservation of physical memory actually means highly depends on the operating system, and how it is configured. For example, different memory overcommit settings on Linux drastically change the behaviour. Also note, setting this flag to `false` may not be supported on all systems. This flag will in that case be ignored.
*NOTE*: The super carrier cannot be enabled nor disabled on halfword heap systems. This flag will be ignored on halfword heap systems.

`+MMscs <size in MB>`
: Set super carrier size (in MB). The super carrier size defaults to zero; i.e, the super carrier is by default disabled. The super carrier is a large continuous area in the virtual address space. `mseg_alloc` will always try to create new carriers in the super carrier if it exists. Note that the `alloc_util` framework may create `sys_alloc` carriers. For more information on this, see the documentation of the *`+MMsco`* flag.
*NOTE*: The super carrier cannot be enabled nor disabled on halfword heap systems. This flag will be ignored on halfword heap systems.

`+MMmcs <amount>`
: Max cached segments. The maximum number of memory segments stored in the memory segment cache. Valid range is 0-30. Default value is 10.

The following flags are available for configuration of `sys_alloc`:

`+MYe true`
: Enable `sys_alloc`. Note: `sys_alloc` cannot be disabled.

`+MYm libc`
: `malloc` library to use. Currently only `libc` is available. `libc` enables the standard `libc` malloc implementation. By default `libc` is used.

`+MYtt <size>`
: Trim threshold size (in kilobytes). This is the maximum amount of free memory at the top of the heap (allocated by `sbrk`) that will be kept by `malloc` (not released to the operating system). When the amount of

free memory at the top of the heap exceeds the trim threshold, `malloc` will release it (by calling `sbrk`). Trim threshold is given in kilobytes. Default trim threshold is 128. *Note:* This flag will only have any effect when the emulator has been linked with the GNU C library, and uses its `malloc` implementation.

`+MYtp <size>`

Top pad size (in kilobytes). This is the amount of extra memory that will be allocated by `malloc` when `sbrk` is called to get more memory from the operating system. Default top pad size is 0. *Note:* This flag will only have any effect when the emulator has been linked with the GNU C library, and uses its `malloc` implementation.

The following flags are available for configuration of allocators based on `alloc_util`. If `u` is used as subsystem identifier (i.e., `<S> = u`) all allocators based on `alloc_util` will be effected. If `B`, `D`, `E`, `F`, `H`, `L`, `R`, `S`, or `T` is used as subsystem identifier, only the specific allocator identified will be effected:

`+M<S>acul <utilization>|de`

Abandon carrier utilization limit. A valid `<utilization>` is an integer in the range `[0, 100]` representing utilization in percent. When a utilization value larger than zero is used, allocator instances are allowed to abandon multiblock carriers. If `de` (default enabled) is passed instead of a `<utilization>`, a recomended non zero utilization value will be used. The actual value chosen depend on allocator type and may be changed between ERTS versions. Currently the default equals `de`, but this may be changed in the future. Carriers will be abandoned when memory utilization in the allocator instance falls below the utilization value used. Once a carrier has been abandoned, no new allocations will be made in it. When an allocator instance gets an increased multiblock carrier need, it will first try to fetch an abandoned carrier from an allocator instances of the same allocator type. If no abandoned carrier could be fetched, it will create a new empty carrier. When an abandoned carrier has been fetched it will function as an ordinary carrier. This feature has special requirements on the *allocation strategy* used. Currently only the strategies `aoff`, `aoffcbf` and `aoffcaobf` support abandoned carriers. This feature also requires *multiple thread specific instances* to be enabled. When enabling this feature, multiple thread specific instances will be enabled if not already enabled, and the `aoffcbf` strategy will be enabled if current strategy does not support abandoned carriers. This feature can be enabled on all allocators based on the `alloc_util` framework with the exception of `temp_alloc` (which would be pointless).

`+M<S>as bf|aobf|aoff|aoffcbf|aoffcaobf|gf|af`

Allocation strategy. Valid strategies are `bf` (best fit), `aobf` (address order best fit), `aoff` (address order first fit), `aoffcbf` (address order first fit carrier best fit), `aoffcaobf` (address order first fit carrier address order best fit), `gf` (good fit), and `af` (a fit). See *the description of allocation strategies* in "the `alloc_util` framework" section.

`+M<S>asbcst <size>`

Absolute singleblock carrier shrink threshold (in kilobytes). When a block located in an `mseg_alloc` singleblock carrier is shrunk, the carrier will be left unchanged if the amount of unused memory is less than this threshold; otherwise, the carrier will be shrunk. See also *rsbcst*.

`+M<S>e true|false`

Enable allocator `<S>`.

`+M<S>lmbcs <size>`

Largest (`mseg_alloc`) multiblock carrier size (in kilobytes). See *the description on how sizes for mseg_alloc multiblock carriers are decided* in "the `alloc_util` framework" section. On 32-bit Unix style OS this limit can not be set higher than 128 megabyte.

`+M<S>mbcgs <ratio>`

(`mseg_alloc`) multiblock carrier growth stages. See *the description on how sizes for mseg_alloc multiblock carriers are decided* in "the `alloc_util` framework" section.

`+M<S>mbsd <depth>`

Max block search depth. This flag has effect only if the good fit strategy has been selected for allocator `<S>`. When the good fit strategy is used, free blocks are placed in segregated free-lists. Each free list contains blocks of sizes in a specific range. The max block search depth sets a limit on the maximum number of blocks to inspect in a free list during a search for suitable block satisfying the request.

`+M<S>mmbcs <size>`
Main multiblock carrier size. Sets the size of the main multiblock carrier for allocator `<S>`. The main multiblock carrier is allocated via `sys_alloc` and is never deallocated.

`+M<S>mmmbc <amount>`
Max `mseg_alloc` multiblock carriers. Maximum number of multiblock carriers allocated via `mseg_alloc` by allocator `<S>`. When this limit has been reached, new multiblock carriers will be allocated via `sys_alloc`.

`+M<S>mmsbc <amount>`
Max `mseg_alloc` singleblock carriers. Maximum number of singleblock carriers allocated via `mseg_alloc` by allocator `<S>`. When this limit has been reached, new singleblock carriers will be allocated via `sys_alloc`.

`+M<S>ramv <bool>`
Realloc always moves. When enabled, reallocate operations will more or less be translated into an allocate, copy, free sequence. This often reduce memory fragmentation, but costs performance.

`+M<S>rmbcmt <ratio>`
Relative multiblock carrier move threshold (in percent). When a block located in a multiblock carrier is shrunk, the block will be moved if the ratio of the size of the returned memory compared to the previous size is more than this threshold; otherwise, the block will be shrunk at current location.

`+M<S>rsbcmt <ratio>`
Relative singleblock carrier move threshold (in percent). When a block located in a singleblock carrier is shrunk to a size smaller than the value of the *sbct* parameter, the block will be left unchanged in the singleblock carrier if the ratio of unused memory is less than this threshold; otherwise, it will be moved into a multiblock carrier.

`+M<S>rsbcst <ratio>`
Relative singleblock carrier shrink threshold (in percent). When a block located in an `mseg_alloc` singleblock carrier is shrunk, the carrier will be left unchanged if the ratio of unused memory is less than this threshold; otherwise, the carrier will be shrunk. See also *asbcst*.

`+M<S>sbct <size>`
Singleblock carrier threshold. Blocks larger than this threshold will be placed in singleblock carriers. Blocks smaller than this threshold will be placed in multiblock carriers. On 32-bit Unix style OS this threshold can not be set higher than 8 megabytes.

`+M<S>smbcs <size>`
Smallest (`mseg_alloc`) multiblock carrier size (in kilobytes). See *the description on how sizes for mseg_alloc multiblock carriers are decided* in "the `alloc_util` framework" section.

`+M<S>t true|false`

Multiple, thread specific instances of the allocator. This option will only have any effect on the runtime system with SMP support. Default behaviour on the runtime system with SMP support is `NoSchedulers+1` instances. Each scheduler will use a lock-free instance of its own and other threads will use a common instance.

It was previously (before ERTS version 5.9) possible to configure a smaller amount of thread specific instances than schedulers. This is, however, not possible any more.

Currently the following flags are available for configuration of `alloc_util`, i.e. all allocators based on `alloc_util` will be effected:

`+Muycs <size>`
`sys_alloc` carrier size. Carriers allocated via `sys_alloc` will be allocated in sizes which are multiples of the `sys_alloc` carrier size. This is not true for main multiblock carriers and carriers allocated during a memory shortage, though.

`+Mummc <amount>`
Max `mseg_alloc` carriers. Maximum number of carriers placed in separate memory segments. When this limit has been reached, new carriers will be placed in memory retrieved from `sys_alloc`.

`+Musac <bool>`
Allow `sys_alloc` carriers. By default `true`. If set to `false`, `sys_alloc` carriers will never be created by allocators using the `alloc_util` framework.

Instrumentation flags:

`+Mim true|false`
A map over current allocations is kept by the emulator. The allocation map can be retrieved via the `instrument` module. `+Mim true` implies `+Mis true`. `+Mim true` is the same as *-instr*.

`+Mis true|false`
Status over allocated memory is kept by the emulator. The allocation status can be retrieved via the `instrument` module.

`+Mit X`
Reserved for future use. Do *not* use this flag.

> ### Note:
>
> When instrumentation of the emulator is enabled, the emulator uses more memory and runs slower.

Other flags:

`+Mea min|max|r9c|r10b|r11b|config`

`min`
Disables all allocators that can be disabled.

`max`
Enables all allocators (currently default).

`r9c|r10b|r11b`
Configures all allocators as they were configured in respective OTP release. These will eventually be removed.

`config`
Disables features that cannot be enabled while creating an allocator configuration with *erts_alloc_config(3)*. Note, this option should only be used while running `erts_alloc_config`, *not* when using the created configuration.

`+Mlpm all|no`
Lock physical memory. The default value is `no`, i.e., no physical memory will be locked. If set to `all`, all memory mappings made by the runtime system, will be locked into physical memory. If set to `all`, the runtime system will fail to start if this feature is not supported, the user has not got enough privileges, or the user is not allowed to lock enough physical memory. The runtime system will also fail with an out of memory condition if the user limit on the amount of locked memory is reached.

Only some default values have been presented here. *erlang:system_info(allocator)*, and *erlang:system_info({allocator, Alloc})* can be used in order to obtain currently used settings and current status of the allocators.

> ### Note:
>
> Most of these flags are highly implementation dependent, and they may be changed or removed without prior notice.
>
> `erts_alloc` is not obliged to strictly use the settings that have been passed to it (it may even ignore them).

*erts_alloc_config(3)* is a tool that can be used to aid creation of an `erts_alloc` configuration that is suitable for a limited number of runtime scenarios.

## SEE ALSO

*erts_alloc_config(3)*, *erl(1)*, *instrument(3)*, *erlang(3)*

# erl_nif

C Library

A NIF library contains native implementation of some functions of an Erlang module. The native implemented functions (NIFs) are called like any other functions without any difference to the caller. Each NIF must also have an implementation in Erlang that will be invoked if the function is called before the NIF library has been successfully loaded. A typical such stub implementation is to throw an exception. But it can also be used as a fallback implementation if the NIF library is not implemented for some architecture.

### Warning:

*Use this functionality with extreme care!*

A native function is executed as a direct extension of the native code of the VM. Execution is not made in a safe environment. The VM can *not* provide the same services as provided when executing Erlang code, such as preemptive scheduling or memory protection. If the native function doesn't behave well, the whole VM will misbehave.

- A native function that crash will crash the whole VM.
- An erroneously implemented native function might cause a VM internal state inconsistency which may cause a crash of the VM, or miscellaneous misbehaviors of the VM at any point after the call to the native function.
- A native function that do *lengthy work* before returning will degrade responsiveness of the VM, and may cause miscellaneous strange behaviors. Such strange behaviors include, but are not limited to, extreme memory usage, and bad load balancing between schedulers. Strange behaviors that might occur due to lengthy work may also vary between OTP releases.

A minimal example of a NIF library can look like this:

```
/* niftest.c */
#include "erl_nif.h"

static ERL_NIF_TERM hello(ErlNifEnv* env, int argc, const ERL_NIF_TERM argv[])
{
    return enif_make_string(env, "Hello world!", ERL_NIF_LATIN1);
}

static ErlNifFunc nif_funcs[] =
{
    {"hello", 0, hello}
};

ERL_NIF_INIT(niftest,nif_funcs,NULL,NULL,NULL,NULL)
```

and the Erlang module would have to look something like this:

```
-module(niftest).

-export([init/0, hello/0]).
```

```
init() ->
      erlang:load_nif("./niftest", 0).

hello() ->
      "NIF library not loaded".
```

and compile and test something like this (on Linux):

```
$> gcc -fPIC -shared -o niftest.so niftest.c -I $ERL_ROOT/usr/include/
$> erl

1> c(niftest).
{ok,niftest}
2> niftest:hello().
"NIF library not loaded"
3> niftest:init().
ok
4> niftest:hello().
"Hello world!"
```

A better solution for a real module is to take advantage of the new directive *on_load* to automatically load the NIF library when the module is loaded.

> ### Note:
>
> A NIF does not have to be exported, it can be local to the module. Note however that unused local stub functions will be optimized away by the compiler causing loading of the NIF library to fail.

A loaded NIF library is tied to the Erlang module code version that loaded it. If the module is upgraded with a new version, the new Erlang code will have to load its own NIF library (or maybe choose not to). The new code version can however choose to load the exact same NIF library as the old code if it wants to. Sharing the same dynamic library will mean that static data defined by the library will be shared as well. To avoid unintentionally shared static data, each Erlang module code can keep its own private data. This private data can be set when the NIF library is loaded and then retrieved by calling *enif_priv_data*.

There is no way to explicitly unload a NIF library. A library will be automatically unloaded when the module code that it belongs to is purged by the code server.

As mentioned in the *warning* text at the beginning of this document it is of vital importance that a native function return relatively quickly. It is hard to give an exact maximum amount of time that a native function is allowed to work, but as a rule of thumb a well-behaving native function should return to its caller before a millisecond has passed. This can be achieved using different approaches. If you have full control over the code to execute in the native function, the best approach is to divide the work into multiple chunks of work and call the native function multiple times, either directly from Erlang code or by having a native function schedule a future NIF call via the *enif_schedule_nif* function. Function *enif_consume_timeslice* can be used to help with such work division. In some cases, however, this might not be possible, e.g. when calling third-party libraries. Then you typically want to dispatch the work to another thread, return from the native function, and wait for the result. The thread can send the result back to the calling thread using message passing. Information about thread primitives can be found below. If you have built your system with *the currently experimental* support for dirty schedulers, you may want to try out this functionality by dispatching the work to a *dirty NIF*, which does not have the same duration restriction as a normal NIF.

## FUNCTIONALITY

All functions that a NIF library needs to do with Erlang are performed through the NIF API functions. There are functions for the following functionality:

Read and write Erlang terms

Any Erlang terms can be passed to a NIF as function arguments and be returned as function return values. The terms are of C-type *ERL_NIF_TERM* and can only be read or written using API functions. Most functions to read the content of a term are prefixed `enif_get_` and usually return true (or false) if the term was of the expected type (or not). The functions to write terms are all prefixed `enif_make_` and usually return the created `ERL_NIF_TERM`. There are also some functions to query terms, like `enif_is_atom`, `enif_is_identical` and `enif_compare`.

All terms of type `ERL_NIF_TERM` belong to an environment of type *ErlNifEnv*. The lifetime of a term is controlled by the lifetime of its environment object. All API functions that read or write terms has the environment, that the term belongs to, as the first function argument.

Binaries

Terms of type binary are accessed with the help of the struct type *ErlNifBinary* that contains a pointer (`data`) to the raw binary data and the length (`size`) of the data in bytes. Both `data` and `size` are read-only and should only be written using calls to API functions. Instances of `ErlNifBinary` are however always allocated by the user (usually as local variables).

The raw data pointed to by `data` is only mutable after a call to *enif_alloc_binary* or *enif_realloc_binary*. All other functions that operates on a binary will leave the data as read-only. A mutable binary must in the end either be freed with *enif_release_binary* or made read-only by transferring it to an Erlang term with *enif_make_binary*. But it does not have to happen in the same NIF call. Read-only binaries do not have to be released.

*enif_make_new_binary* can be used as a shortcut to allocate and return a binary in the same NIF call.

Binaries are sequences of whole bytes. Bitstrings with an arbitrary bit length have no support yet.

Resource objects

The use of resource objects is a safe way to return pointers to native data structures from a NIF. A resource object is just a block of memory allocated with *enif_alloc_resource*. A handle ("safe pointer") to this memory block can then be returned to Erlang by the use of *enif_make_resource*. The term returned by `enif_make_resource` is totally opaque in nature. It can be stored and passed between processes on the same node, but the only real end usage is to pass it back as an argument to a NIF. The NIF can then call *enif_get_resource* and get back a pointer to the memory block that is guaranteed to still be valid. A resource object will not be deallocated until the last handle term has been garbage collected by the VM and the resource has been released with *enif_release_resource* (not necessarily in that order).

All resource objects are created as instances of some *resource type*. This makes resources from different modules to be distinguishable. A resource type is created by calling *enif_open_resource_type* when a library is loaded. Objects of that resource type can then later be allocated and `enif_get_resource` verifies that the resource is of the expected type. A resource type can have a user supplied destructor function that is automatically called when resources of that type are released (by either the garbage collector or `enif_release_resource`). Resource types are uniquely identified by a supplied name string and the name of the implementing module.

Here is a template example of how to create and return a resource object.

```
ERL_NIF_TERM term;
MyStruct* obj = enif_alloc_resource(my_resource_type, sizeof(MyStruct));

/* initialize struct ... */
```

```
term = enif_make_resource(env, obj);

if (keep_a_reference_of_our_own) {
    /* store 'obj' in static variable, private data or other resource object */
}
else {
    enif_release_resource(obj);
    /* resource now only owned by "Erlang" */
}
return term;
```

Note that once `enif_make_resource` creates the term to return to Erlang, the code can choose to either keep its own native pointer to the allocated struct and release it later, or release it immediately and rely solely on the garbage collector to eventually deallocate the resource object when it collects the term.

Another usage of resource objects is to create binary terms with user defined memory management. *enif_make_resource_binary* will create a binary term that is connected to a resource object. The destructor of the resource will be called when the binary is garbage collected, at which time the binary data can be released. An example of this can be a binary term consisting of data from a `mmap`'ed file. The destructor can then do `munmap` to release the memory region.

Resource types support upgrade in runtime by allowing a loaded NIF library to takeover an already existing resource type and thereby "inherit" all existing objects of that type. The destructor of the new library will thereafter be called for the inherited objects and the library with the old destructor function can be safely unloaded. Existing resource objects, of a module that is upgraded, must either be deleted or taken over by the new NIF library. The unloading of a library will be postponed as long as there exist resource objects with a destructor function in the library.

Threads and concurrency

A NIF is thread-safe without any explicit synchronization as long as it acts as a pure function and only reads the supplied arguments. As soon as you write towards a shared state either through static variables or *enif_priv_data* you need to supply your own explicit synchronization. This includes terms in process independent environments that are shared between threads. Resource objects will also require synchronization if you treat them as mutable.

The library initialization callbacks `load`, `reload` and `upgrade` are all thread-safe even for shared state data.

Version Management

When a NIF library is built, information about NIF API version is compiled into the library. When a NIF library is loaded the runtime system verifies that the library is of a compatible version. `erl_nif.h` defines `ERL_NIF_MAJOR_VERSION`, and `ERL_NIF_MINOR_VERSION`. `ERL_NIF_MAJOR_VERSION` will be incremented when NIF library incompatible changes are made to the Erlang runtime system. Normally it will suffice to recompile the NIF library when the `ERL_NIF_MAJOR_VERSION` has changed, but it could, under rare circumstances, mean that NIF libraries have to be slightly modified. If so, this will of course be documented. `ERL_NIF_MINOR_VERSION` will be incremented when new features are added. The runtime system uses the minor version to determine what features to use.

The runtime system will normally refuse to load a NIF library if the major versions differ, or if the major versions are equal and the minor version used by the NIF library is greater than the one used by the runtime system. Old NIF libraries with lower major versions will however be allowed after a bump of the major version during a transition period of two major releases. Such old NIF libraries might however fail if deprecated features are used.

Time Measurement

Support for time measurement in NIF libraries:

- *`ErlNifTime`*
- *`ErlNifTimeUnit`*

- *enif_monotonic_time()*
- *enif_time_offset()*
- *enif_convert_time_unit()*

Long-running NIFs

Native functions *must normally run quickly*, as explained earlier in this document. They generally should execute for no more than a millisecond. But not all native functions can execute so quickly; for example, functions that encrypt large blocks of data or perform lengthy file system operations can often run for tens of seconds or more.

If the functionality of a long-running NIF can be split so that its work can be achieved through a series of shorter NIF calls, the application can either make that series of NIF calls from the Erlang level, or it can call a NIF that first performs a chunk of the work, then invokes the *enif_schedule_nif* function to schedule another NIF call to perform the next chunk. The final call scheduled in this manner can then return the overall result. Breaking up a long-running function in this manner enables the VM to regain control between calls to the NIFs, thereby avoiding degraded responsiveness, scheduler load balancing problems, and other strange behaviours.

A NIF that cannot be split and cannot execute in a millisecond or less is called a "dirty NIF" because it performs work that the Erlang runtime cannot handle cleanly. *Note that the dirty NIF functionality described here is experimental* and that you have to enable support for dirty schedulers when building OTP in order to try the functionality out. Applications that make use of such functions must indicate to the runtime that the functions are dirty so they can be handled specially. To schedule a dirty NIF for execution, the appropriate flags value can be set for the NIF in its *ErlNifFunc* entry, or the application can call *enif_schedule_nif*, passing to it a pointer to the dirty NIF to be executed and indicating with the `flags` argument whether it expects the operation to be CPU-bound or I/O-bound.

> **Note:**
>
> Dirty NIF support is available only when the emulator is configured with dirty schedulers enabled. This feature is currently disabled by default. To determine whether the dirty NIF API is available, native code can check to see if the C preprocessor macro `ERL_NIF_DIRTY_SCHEDULER_SUPPORT` is defined. Also, if the Erlang runtime was built without threading support, dirty schedulers are disabled. To check at runtime for the presence of dirty scheduler threads, code can use the *enif_system_info()* API function.

## INITIALIZATION

ERL_NIF_INIT(MODULE, ErlNifFunc funcs[], load, reload, upgrade, unload)

This is the magic macro to initialize a NIF library. It should be evaluated in global file scope.

`MODULE` is the name of the Erlang module as an identifier without string quotations. It will be stringified by the macro.

`funcs` is a static array of function descriptors for all the implemented NIFs in this library.

`load`, `reload`, `upgrade` and `unload` are pointers to functions. One of `load`, `reload` or `upgrade` will be called to initialize the library. `unload` is called to release the library. They are all described individually below.

If compiling a nif for static inclusion via --enable-static-nifs you have to define STATIC_ERLANG_NIF before the ERL_NIF_INIT declaration.

int (*load)(ErlNifEnv* env, void** priv_data, ERL_NIF_TERM load_info)

`load` is called when the NIF library is loaded and there is no previously loaded library for this module.

`*priv_data` can be set to point to some private data that the library needs in order to keep a state between NIF calls. `enif_priv_data` will return this pointer. `*priv_data` will be initialized to NULL when `load` is called.

`load_info` is the second argument to *erlang:load_nif/2*.

The library will fail to load if `load` returns anything other than 0. `load` can be NULL in case no initialization is needed.

int (*upgrade)(ErlNifEnv* env, void** priv_data, void** old_priv_data, ERL_NIF_TERM load_info)

`upgrade` is called when the NIF library is loaded and there is old code of this module with a loaded NIF library.

Works the same as `load`. The only difference is that `*old_priv_data` already contains the value set by the last call to `load` or `reload` for the old module code. `*priv_data` will be initialized to NULL when `upgrade` is called. It is allowed to write to both *priv_data and *old_priv_data.

The library will fail to load if `upgrade` returns anything other than 0 or if `upgrade` is NULL.

void (*unload)(ErlNifEnv* env, void* priv_data)

`unload` is called when the module code that the NIF library belongs to is purged as old. New code of the same module may or may not exist. Note that `unload` is not called for a replaced library as a consequence of `reload`.

int (*reload)(ErlNifEnv* env, void** priv_data, ERL_NIF_TERM load_info)

> ### Note:
>
> The reload mechanism is *deprecated*. It was only intended as a development feature. Do not use it as an upgrade method for live production systems. It might be removed in future releases. Be sure to pass `reload` as `NULL` to *ERL_NIF_INIT* to disable it when not used.

`reload` is called when the NIF library is loaded and there is already a previously loaded library for this module code.

Works the same as `load`. The only difference is that `*priv_data` already contains the value set by the previous call to `load` or `reload`.

The library will fail to load if `reload` returns anything other than 0 or if `reload` is NULL.

## DATA TYPES

ERL_NIF_TERM

Variables of type `ERL_NIF_TERM` can refer to any Erlang term. This is an opaque type and values of it can only by used either as arguments to API functions or as return values from NIFs. All `ERL_NIF_TERM`'s belong to an environment (*ErlNifEnv*). A term can not be destructed individually, it is valid until its environment is destructed.

ErlNifEnv

`ErlNifEnv` represents an environment that can host Erlang terms. All terms in an environment are valid as long as the environment is valid. `ErlNifEnv` is an opaque type and pointers to it can only be passed on to API functions. There are two types of environments; process bound and process independent.

A *process bound environment* is passed as the first argument to all NIFs. All function arguments passed to a NIF will belong to that environment. The return value from a NIF must also be a term belonging to the same environment. In addition a process bound environment contains transient information about the calling Erlang process. The environment is only valid in the thread where it was supplied as argument until the NIF returns. It is thus useless and dangerous to store pointers to process bound environments between NIF calls.

A *process independent environment* is created by calling *enif_alloc_env*. It can be used to store terms between NIF calls and to send terms with *enif_send*. A process independent environment with all its terms is valid until you explicitly invalidates it with *enif_free_env* or `enif_send`.

All contained terms of a list/tuple/map must belong to the same environment as the list/tuple/map itself. Terms can be copied between environments with *enif_make_copy*.

ErlNifFunc

```
typedef struct {
    const char* ;
    unsigned ;
    ERL_NIF_TERM (*)(ErlNifEnv* env, int argc, const ERL_NIF_TERM argv[]);
    unsigned flags;
} ErlNifFunc;
```

Describes a NIF by its name, arity and implementation. `fptr` is a pointer to the function that implements the NIF. The argument `argv` of a NIF will contain the function arguments passed to the NIF and `argc` is the length of the array, i.e. the function arity. `argv[N-1]` will thus denote the Nth argument to the NIF. Note that the `argc` argument allows for the same C function to implement several Erlang functions with different arity (but same name probably). For a regular NIF, `flags` is 0 (and so its value can be omitted for statically initialized `ErlNifFunc` instances), or it can be used to indicate that the NIF is a *dirty NIF* that should be executed on a dirty scheduler thread (*note that the dirty NIF functionality described here is experimental* and that you have to enable support for dirty schedulers when building OTP in order to try the functionality out). If the dirty NIF is expected to be CPU-bound, its `flags` field should be set to `ERL_NIF_DIRTY_JOB_CPU_BOUND`, or for I/O-bound jobs, `ERL_NIF_DIRTY_JOB_IO_BOUND`.

ErlNifBinary

```
typedef struct {
    unsigned ;
    unsigned char* ;
} ErlNifBinary;
```

`ErlNifBinary` contains transient information about an inspected binary term. `data` is a pointer to a buffer of `size` bytes with the raw content of the binary.

Note that `ErlNifBinary` is a semi-opaque type and you are only allowed to read fields `size` and `data`.

ErlNifPid

`ErlNifPid` is a process identifier (pid). In contrast to pid terms (instances of `ERL_NIF_TERM`), `ErlNifPid`'s are self contained and not bound to any *environment*. `ErlNifPid` is an opaque type.

ErlNifResourceType

Each instance of `ErlNifResourceType` represent a class of memory managed resource objects that can be garbage collected. Each resource type has a unique name and a destructor function that is called when objects of its type are released.

ErlNifResourceDtor

```
typedef void ErlNifResourceDtor(ErlNifEnv* env, void* obj);
```

The function prototype of a resource destructor function. A destructor function is not allowed to call any term-making functions.

ErlNifCharEncoding

```
typedef enum {
    ERL_NIF_LATIN1
}ErlNifCharEncoding;
```

The character encoding used in strings and atoms. The only supported encoding is currently `ERL_NIF_LATIN1` for iso-latin-1 (8-bit ascii).

ErlNifSysInfo

Used by *enif_system_info* to return information about the runtime system. Contains currently the exact same content as *ErlDrvSysInfo*.

ErlNifSInt64

A native signed 64-bit integer type.

ErlNifUInt64

A native unsigned 64-bit integer type.

ErlNifTime

A signed 64-bit integer type for representation of time.

ErlNifTimeUnit

An enumeration of time units supported by the NIF API:

`ERL_NIF_SEC`

Seconds

`ERL_NIF_MSEC`

Milliseconds

`ERL_NIF_USEC`

Microseconds

`ERL_NIF_NSEC`

Nanoseconds

## Exports

### `void *enif_alloc(size_t size)`

Allocate memory of `size` bytes. Return NULL if allocation failed.

### `int enif_alloc_binary(size_t size, ErlNifBinary* bin)`

Allocate a new binary of size `size` bytes. Initialize the structure pointed to by `bin` to refer to the allocated binary. The binary must either be released by *enif_release_binary* or ownership transferred to an Erlang term with *enif_make_binary*. An allocated (and owned) `ErlNifBinary` can be kept between NIF calls.

Return true on success or false if allocation failed.

### ErlNifEnv *enif_alloc_env()

Allocate a new process independent environment. The environment can be used to hold terms that is not bound to any process. Such terms can later be copied to a process environment with *enif_make_copy* or be sent to a process as a message with *enif_send*.

Return pointer to the new environment.

### void *enif_alloc_resource(ErlNifResourceType* type, unsigned size)

Allocate a memory managed resource object of type `type` and size `size` bytes.

### void enif_clear_env(ErlNifEnv* env)

Free all terms in an environment and clear it for reuse. The environment must have been allocated with *enif_alloc_env*.

### int enif_compare(ERL_NIF_TERM lhs, ERL_NIF_TERM rhs)

Return an integer less than, equal to, or greater than zero if `lhs` is found, respectively, to be less than, equal, or greater than `rhs`. Corresponds to the Erlang operators `==`, `/=`, `=<`, `<`, `>=` and `>` (but *not* `=:=` or `=/=`).

### void enif_cond_broadcast(ErlNifCond *cnd)

Same as *erl_drv_cond_broadcast*.

### ErlNifCond *enif_cond_create(char *name)

Same as *erl_drv_cond_create*.

### void enif_cond_destroy(ErlNifCond *cnd)

Same as *erl_drv_cond_destroy*.

### void enif_cond_signal(ErlNifCond *cnd)

Same as *erl_drv_cond_signal*.

### void enif_cond_wait(ErlNifCond *cnd, ErlNifMutex *mtx)

Same as *erl_drv_cond_wait*.

### int enif_consume_timeslice(ErlNifEnv *env, int percent)

Give the runtime system a hint about how much CPU time the current NIF call has consumed since last hint, or since the start of the NIF if no previous hint has been given. The time is given as a `percent` of the timeslice that a process is allowed to execute Erlang code until it may be suspended to give time for other runnable processes. The scheduling timeslice is not an exact entity, but can usually be approximated to about 1 millisecond.

Note that it is up to the runtime system to determine if and how to use this information. Implementations on some platforms may use other means in order to determine consumed CPU time. Lengthy NIFs should regardless of this frequently call `enif_consume_timeslice` in order to determine if it is allowed to continue execution or not.

Returns 1 if the timeslice is exhausted, or 0 otherwise. If 1 is returned the NIF should return as soon as possible in order for the process to yield.

Argument `percent` must be an integer between 1 and 100. This function must only be called from a NIF-calling thread and argument `env` must be the environment of the calling process.

This function is provided to better support co-operative scheduling, improve system responsiveness, and make it easier to prevent misbehaviors of the VM due to a NIF monopolizing a scheduler thread. It can be used to divide *length work* into a number of repeated NIF-calls without the need to create threads. See also the *warning* text at the beginning of this document.

### `int enif_equal_tids(ErlNifTid tid1, ErlNifTid tid2)`

Same as *erl_drv_equal_tids*.

### `void enif_free(void* ptr)`

Free memory allocated by `enif_alloc`.

### `void enif_free_env(ErlNifEnv* env)`

Free an environment allocated with *enif_alloc_env*. All terms created in the environment will be freed as well.

### `int enif_get_atom(ErlNifEnv* env, ERL_NIF_TERM term, char* buf, unsigned size, ErlNifCharEncoding encode)`

Write a null-terminated string, in the buffer pointed to by `buf` of size `size`, consisting of the string representation of the atom `term` with encoding *encode*. Return the number of bytes written (including terminating null character) or 0 if `term` is not an atom with maximum length of `size-1`.

### `int enif_get_atom_length(ErlNifEnv* env, ERL_NIF_TERM term, unsigned* len, ErlNifCharEncoding encode)`

Set `*len` to the length (number of bytes excluding terminating null character) of the atom `term` with encoding `encode`. Return true on success or false if `term` is not an atom.

### `int enif_get_double(ErlNifEnv* env, ERL_NIF_TERM term, double* dp)`

Set `*dp` to the floating point value of `term`. Return true on success or false if `term` is not a float.

### `int enif_get_int(ErlNifEnv* env, ERL_NIF_TERM term, int* ip)`

Set `*ip` to the integer value of `term`. Return true on success or false if `term` is not an integer or is outside the bounds of type `int`.

### `int enif_get_int64(ErlNifEnv* env, ERL_NIF_TERM term, ErlNifSInt64* ip)`

Set `*ip` to the integer value of `term`. Return true on success or false if `term` is not an integer or is outside the bounds of a signed 64-bit integer.

### `int enif_get_local_pid(ErlNifEnv* env, ERL_NIF_TERM term, ErlNifPid* pid)`

If `term` is the pid of a node local process, initialize the pid variable `*pid` from it and return true. Otherwise return false. No check if the process is alive is done.

### `int enif_get_list_cell(ErlNifEnv* env, ERL_NIF_TERM list, ERL_NIF_TERM* head, ERL_NIF_TERM* tail)`

Set `*head` and `*tail` from `list` and return true, or return false if `list` is not a non-empty list.

**int enif_get_list_length(ErlNifEnv* env, ERL_NIF_TERM term, unsigned* len)**

Set `*len` to the length of list `term` and return true, or return false if `term` is not a list.

**int enif_get_long(ErlNifEnv* env, ERL_NIF_TERM term, long int* ip)**

Set `*ip` to the long integer value of `term` and return true, or return false if `term` is not an integer or is outside the bounds of type `long int`.

**int enif_get_map_size(ErlNifEnv* env, ERL_NIF_TERM term, size_t *size)**

Set `*size` to the number of key-value pairs in the map `term` and return true, or return false if `term` is not a map.

**int enif_get_map_value(ErlNifEnv* env, ERL_NIF_TERM map, ERL_NIF_TERM key, ERL_NIF_TERM* value)**

Set `*value` to the value associated with `key` in the map `map` and return true. Return false if `map` is not a map or if `map` does not contain `key`.

**int enif_get_resource(ErlNifEnv* env, ERL_NIF_TERM term, ErlNifResourceType* type, void** objp)**

Set `*objp` to point to the resource object referred to by `term`.

Return true on success or false if `term` is not a handle to a resource object of type `type`.

**int enif_get_string(ErlNifEnv* env, ERL_NIF_TERM list, char* buf, unsigned size, ErlNifCharEncoding encode)**

Write a null-terminated string, in the buffer pointed to by `buf` with size `size`, consisting of the characters in the string `list`. The characters are written using encoding *encode*. Return the number of bytes written (including terminating null character), or `-size` if the string was truncated due to buffer space, or 0 if `list` is not a string that can be encoded with `encode` or if `size` was less than 1. The written string is always null-terminated unless buffer `size` is less than 1.

**int enif_get_tuple(ErlNifEnv* env, ERL_NIF_TERM term, int* arity, const ERL_NIF_TERM** array)**

If `term` is a tuple, set `*array` to point to an array containing the elements of the tuple and set `*arity` to the number of elements. Note that the array is read-only and `(*array)[N-1]` will be the Nth element of the tuple. `*array` is undefined if the arity of the tuple is zero.

Return true on success or false if `term` is not a tuple.

**int enif_get_uint(ErlNifEnv* env, ERL_NIF_TERM term, unsigned int* ip)**

Set `*ip` to the unsigned integer value of `term` and return true, or return false if `term` is not an unsigned integer or is outside the bounds of type `unsigned int`.

**int enif_get_uint64(ErlNifEnv* env, ERL_NIF_TERM term, ErlNifUInt64* ip)**

Set `*ip` to the unsigned integer value of `term` and return true, or return false if `term` is not an unsigned integer or is outside the bounds of an unsigned 64-bit integer.

**int enif_get_ulong(ErlNifEnv* env, ERL_NIF_TERM term, unsigned long* ip)**

Set `*ip` to the unsigned long integer value of `term` and return true, or return false if `term` is not an unsigned integer or is outside the bounds of type `unsigned long`.

**int enif_getenv(const char* key, char* value, size_t *value_size)**

Same as *erl_drv_getenv*.

**int enif_has_pending_exception(ErlNifEnv* env, ERL_NIF_TERM* reason)**

Return true if a pending exception is associated with the environment `env`. If `reason` is a null pointer, ignore it. Otherwise, if there's a pending exception associated with `env`, set the ERL_NIF_TERM to which `reason` points to the value of the exception's term. For example, if *enif_make_badarg* is called to set a pending `badarg` exception, a subsequent call to `enif_has_pending_exception(env, &reason)` will set `reason` to the atom `badarg`, then return true.

See also: *enif_make_badarg* and *enif_raise_exception*.

**int enif_inspect_binary(ErlNifEnv* env, ERL_NIF_TERM bin_term, ErlNifBinary* bin)**

Initialize the structure pointed to by `bin` with information about the binary term `bin_term`. Return true on success or false if `bin_term` is not a binary.

**int enif_inspect_iolist_as_binary(ErlNifEnv* env, ERL_NIF_TERM term, ErlNifBinary* bin)**

Initialize the structure pointed to by `bin` with one continuous buffer with the same byte content as `iolist`. As with inspect_binary, the data pointed to by `bin` is transient and does not need to be released. Return true on success or false if `iolist` is not an iolist.

**int enif_is_atom(ErlNifEnv* env, ERL_NIF_TERM term)**

Return true if `term` is an atom.

**int enif_is_binary(ErlNifEnv* env, ERL_NIF_TERM term)**

Return true if `term` is a binary

**int enif_is_empty_list(ErlNifEnv* env, ERL_NIF_TERM term)**

Return true if `term` is an empty list.

**int enif_is_exception(ErlNifEnv* env, ERL_NIF_TERM term)**

Return true if `term` is an exception.

**int enif_is_map(ErlNifEnv* env, ERL_NIF_TERM term)**

Return true if `term` is a map, false otherwise.

**int enif_is_number(ErlNifEnv* env, ERL_NIF_TERM term)**

Return true if `term` is a number.

**`int enif_is_fun(ErlNifEnv* env, ERL_NIF_TERM term)`**

Return true if `term` is a fun.

**`int enif_is_identical(ERL_NIF_TERM lhs, ERL_NIF_TERM rhs)`**

Return true if the two terms are identical. Corresponds to the Erlang operators `=:=` and `=/=`.

**`int enif_is_on_dirty_scheduler(ErlNifEnv* env)`**

Check to see if the current NIF is executing on a dirty scheduler thread. If the emulator is built with threading support, calling `enif_is_on_dirty_scheduler` from within a dirty NIF returns true. It returns false when the calling NIF is a regular NIF running on a normal scheduler thread, or when the emulator is built without threading support.

> Note:
>
> This function is available only when the emulator is configured with dirty schedulers enabled. This feature is currently disabled by default. To determine whether the dirty NIF API is available, native code can check to see if the C preprocessor macro `ERL_NIF_DIRTY_SCHEDULER_SUPPORT` is defined.

**`int enif_is_pid(ErlNifEnv* env, ERL_NIF_TERM term)`**

Return true if `term` is a pid.

**`int enif_is_port(ErlNifEnv* env, ERL_NIF_TERM term)`**

Return true if `term` is a port.

**`int enif_is_ref(ErlNifEnv* env, ERL_NIF_TERM term)`**

Return true if `term` is a reference.

**`int enif_is_tuple(ErlNifEnv* env, ERL_NIF_TERM term)`**

Return true if `term` is a tuple.

**`int enif_is_list(ErlNifEnv* env, ERL_NIF_TERM term)`**

Return true if `term` is a list.

**`int enif_keep_resource(void* obj)`**

Add a reference to resource object `obj` obtained from *enif_alloc_resource*. Each call to `enif_keep_resource` for an object must be balanced by a call to *enif_release_resource* before the object will be destructed.

**`ERL_NIF_TERM enif_make_atom(ErlNifEnv* env, const char* name)`**

Create an atom term from the null-terminated C-string `name` with iso-latin-1 encoding. If the length of `name` exceeds the maximum length allowed for an atom (255 characters), `enif_make_atom` invokes *enif_make_badarg*.

**ERL_NIF_TERM enif_make_atom_len(ErlNifEnv* env, const char* name, size_t len)**

Create an atom term from the string `name` with length `len`. Null-characters are treated as any other characters. If `len` is greater than the maximum length allowed for an atom (255 characters), `enif_make_atom` invokes *enif_make_badarg*.

**ERL_NIF_TERM enif_make_badarg(ErlNifEnv* env)**

Make a badarg exception to be returned from a NIF, and associate it with the environment `env`. Once a NIF or any function it calls invokes `enif_make_badarg`, the runtime ensures that a `badarg` exception is raised when the NIF returns, even if the NIF attempts to return a non-exception term instead. The return value from `enif_make_badarg` may be used only as the return value from the NIF that invoked it (directly or indirectly) or be passed to *enif_is_exception*, but not to any other NIF API function.

See also: *enif_has_pending_exception* and *enif_raise_exception*

> Note:
>
> In earlier versions (older than erts-7.0, OTP 18) the return value from `enif_make_badarg` had to be returned from the NIF. This requirement is now lifted as the return value from the NIF is ignored if `enif_make_badarg` has been invoked.

**ERL_NIF_TERM enif_make_binary(ErlNifEnv* env, ErlNifBinary* bin)**

Make a binary term from `bin`. Any ownership of the binary data will be transferred to the created term and `bin` should be considered read-only for the rest of the NIF call and then as released.

**ERL_NIF_TERM enif_make_copy(ErlNifEnv* dst_env, ERL_NIF_TERM src_term)**

Make a copy of term `src_term`. The copy will be created in environment `dst_env`. The source term may be located in any environment.

**ERL_NIF_TERM enif_make_double(ErlNifEnv* env, double d)**

Create a floating-point term from a `double`. If the `double` argument is not finite or is NaN, `enif_make_double` invokes *enif_make_badarg*.

**int enif_make_existing_atom(ErlNifEnv* env, const char* name, ERL_NIF_TERM* atom, ErlNifCharEncoding encode)**

Try to create the term of an already existing atom from the null-terminated C-string `name` with encoding *encode*. If the atom already exists store the term in `*atom` and return true, otherwise return false. If the length of `name` exceeds the maximum length allowed for an atom (255 characters), `enif_make_existing_atom` returns false.

**int enif_make_existing_atom_len(ErlNifEnv* env, const char* name, size_t len, ERL_NIF_TERM* atom, ErlNifCharEncoding encoding)**

Try to create the term of an already existing atom from the string `name` with length `len` and encoding *encode*. Null-characters are treated as any other characters. If the atom already exists store the term in `*atom` and return true, otherwise return false. If `len` is greater than the maximum length allowed for an atom (255 characters), `enif_make_existing_atom_len` returns false.

**ERL_NIF_TERM enif_make_int(ErlNifEnv* env, int i)**

Create an integer term.

**ERL_NIF_TERM enif_make_int64(ErlNifEnv* env, ErlNifSInt64 i)**

Create an integer term from a signed 64-bit integer.

**ERL_NIF_TERM enif_make_list(ErlNifEnv* env, unsigned cnt, ...)**

Create an ordinary list term of length `cnt`. Expects `cnt` number of arguments (after `cnt`) of type ERL_NIF_TERM as the elements of the list. An empty list is returned if `cnt` is 0.

**ERL_NIF_TERM enif_make_list1(ErlNifEnv* env, ERL_NIF_TERM e1)**
**ERL_NIF_TERM enif_make_list2(ErlNifEnv* env, ERL_NIF_TERM e1, ERL_NIF_TERM e2)**
**ERL_NIF_TERM enif_make_list3(ErlNifEnv* env, ERL_NIF_TERM e1, ERL_NIF_TERM e2, ERL_NIF_TERM e3)**
**ERL_NIF_TERM enif_make_list4(ErlNifEnv* env, ERL_NIF_TERM e1, ..., ERL_NIF_TERM e4)**
**ERL_NIF_TERM enif_make_list5(ErlNifEnv* env, ERL_NIF_TERM e1, ..., ERL_NIF_TERM e5)**
**ERL_NIF_TERM enif_make_list6(ErlNifEnv* env, ERL_NIF_TERM e1, ..., ERL_NIF_TERM e6)**
**ERL_NIF_TERM enif_make_list7(ErlNifEnv* env, ERL_NIF_TERM e1, ..., ERL_NIF_TERM e7)**
**ERL_NIF_TERM enif_make_list8(ErlNifEnv* env, ERL_NIF_TERM e1, ..., ERL_NIF_TERM e8)**
**ERL_NIF_TERM enif_make_list9(ErlNifEnv* env, ERL_NIF_TERM e1, ..., ERL_NIF_TERM e9)**

Create an ordinary list term with length indicated by the function name. Prefer these functions (macros) over the variadic `enif_make_list` to get a compile time error if the number of arguments does not match.

**ERL_NIF_TERM enif_make_list_cell(ErlNifEnv* env, ERL_NIF_TERM head, ERL_NIF_TERM tail)**

Create a list cell `[head | tail]`.

**ERL_NIF_TERM enif_make_list_from_array(ErlNifEnv* env, const ERL_NIF_TERM arr[], unsigned cnt)**

Create an ordinary list containing the elements of array `arr` of length `cnt`. An empty list is returned if `cnt` is 0.

**ERL_NIF_TERM enif_make_long(ErlNifEnv* env, long int i)**

Create an integer term from a `long int`.

**unsigned char *enif_make_new_binary(ErlNifEnv* env, size_t size, ERL_NIF_TERM* termp)**

Allocate a binary of size `size` bytes and create an owning term. The binary data is mutable until the calling NIF returns. This is a quick way to create a new binary without having to use *ErlNifBinary*. The drawbacks are that the binary can not be kept between NIF calls and it can not be reallocated.

Return a pointer to the raw binary data and set `*termp` to the binary term.

**ERL_NIF_TERM enif_make_new_map(ErlNifEnv* env)**

Make an empty map term.

**int enif_make_map_put(ErlNifEnv* env, ERL_NIF_TERM map_in, ERL_NIF_TERM key, ERL_NIF_TERM value, ERL_NIF_TERM* map_out)**

Make a copy of map `map_in` and insert `key` with `value`. If `key` already exists in `map_in`, the old associated value is replaced by `value`. If successful set `*map_out` to the new map and return true. Return false if `map_in` is not a map.

The `map_in` term must belong to the environment `env`.

**int enif_make_map_update(ErlNifEnv* env, ERL_NIF_TERM map_in, ERL_NIF_TERM key, ERL_NIF_TERM new_value, ERL_NIF_TERM* map_out)**

Make a copy of map `map_in` and replace the old associated value for `key` with `new_value`. If successful set `*map_out` to the new map and return true. Return false if `map_in` is not a map or if it does no contain `key`.

The `map_in` term must belong to the environment `env`.

**int enif_make_map_remove(ErlNifEnv* env, ERL_NIF_TERM map_in, ERL_NIF_TERM key, ERL_NIF_TERM* map_out)**

If map `map_in` contains `key`, make a copy of `map_in` in `*map_out` and remove `key` and associated value. If map `map_in` does not contain `key`, set `*map_out` to `map_in`. Return true for success or false if `map_in` is not a map.

The `map_in` term must belong to the environment `env`.

**ERL_NIF_TERM enif_make_pid(ErlNifEnv* env, const ErlNifPid* pid)**

Make a pid term from `*pid`.

**ERL_NIF_TERM enif_make_ref(ErlNifEnv* env)**

Create a reference like *erlang:make_ref/0*.

**ERL_NIF_TERM enif_make_resource(ErlNifEnv* env, void* obj)**

Create an opaque handle to a memory managed resource object obtained by *enif_alloc_resource*. No ownership transfer is done, as the resource object still needs to be released by *enif_release_resource*, but note that the call to `enif_release_resource` can occur immediately after obtaining the term from `enif_make_resource`, in which case the resource object will be deallocated when the term is garbage collected. See the *example of creating and returning a resource object* for more details.

Note that the only defined behaviour of using a resource term in an Erlang program is to store it and send it between processes on the same node. Other operations such as matching or `term_to_binary` will have unpredictable (but harmless) results.

**ERL_NIF_TERM enif_make_resource_binary(ErlNifEnv* env, void* obj, const void* data, size_t size)**

Create a binary term that is memory managed by a resource object `obj` obtained by *enif_alloc_resource*. The returned binary term will consist of `size` bytes pointed to by `data`. This raw binary data must be kept readable and unchanged until the destructor of the resource is called. The binary data may be stored external to the resource object in which case it is the responsibility of the destructor to release the data.

Several binary terms may be managed by the same resource object. The destructor will not be called until the last binary is garbage collected. This can be useful as a way to return different parts of a larger binary buffer.

As with *enif_make_resource*, no ownership transfer is done. The resource still needs to be released with *enif_release_resource*.

**int enif_make_reverse_list(ErlNifEnv* env, ERL_NIF_TERM list_in, ERL_NIF_TERM *list_out)**

Set `*list_out` to the reverse list of the list `list_in` and return true, or return false if `list_in` is not a list. This function should only be used on short lists as a copy will be created of the list which will not be released until after the nif returns.

The `list_in` term must belong to the environment `env`.

**ERL_NIF_TERM enif_make_string(ErlNifEnv* env, const char* string, ErlNifCharEncoding encoding)**

Create a list containing the characters of the null-terminated string `string` with encoding *encoding*.

**ERL_NIF_TERM enif_make_string_len(ErlNifEnv* env, const char* string, size_t len, ErlNifCharEncoding encoding)**

Create a list containing the characters of the string `string` with length `len` and encoding *encoding*. Null-characters are treated as any other characters.

**ERL_NIF_TERM enif_make_sub_binary(ErlNifEnv* env, ERL_NIF_TERM bin_term, size_t pos, size_t size)**

Make a subbinary of binary `bin_term`, starting at zero-based position `pos` with a length of `size` bytes. `bin_term` must be a binary or bitstring and `pos+size` must be less or equal to the number of whole bytes in `bin_term`.

**ERL_NIF_TERM enif_make_tuple(ErlNifEnv* env, unsigned cnt, ...)**

Create a tuple term of arity `cnt`. Expects `cnt` number of arguments (after `cnt`) of type ERL_NIF_TERM as the elements of the tuple.

**ERL_NIF_TERM enif_make_tuple1(ErlNifEnv* env, ERL_NIF_TERM e1)**

**ERL_NIF_TERM enif_make_tuple2(ErlNifEnv* env, ERL_NIF_TERM e1, ERL_NIF_TERM e2)**

**ERL_NIF_TERM enif_make_tuple3(ErlNifEnv* env, ERL_NIF_TERM e1, ERL_NIF_TERM e2, ERL_NIF_TERM e3)**

**ERL_NIF_TERM enif_make_tuple4(ErlNifEnv* env, ERL_NIF_TERM e1, ..., ERL_NIF_TERM e4)**

**ERL_NIF_TERM enif_make_tuple5(ErlNifEnv* env, ERL_NIF_TERM e1, ..., ERL_NIF_TERM e5)**

**ERL_NIF_TERM enif_make_tuple6(ErlNifEnv* env, ERL_NIF_TERM e1, ..., ERL_NIF_TERM e6)**

**ERL_NIF_TERM enif_make_tuple7(ErlNifEnv* env, ERL_NIF_TERM e1, ..., ERL_NIF_TERM e7)**

**ERL_NIF_TERM enif_make_tuple8(ErlNifEnv* env, ERL_NIF_TERM e1, ..., ERL_NIF_TERM e8)**

**ERL_NIF_TERM enif_make_tuple9(ErlNifEnv* env, ERL_NIF_TERM e1, ..., ERL_NIF_TERM e9)**

Create a tuple term with length indicated by the function name. Prefer these functions (macros) over the variadic `enif_make_tuple` to get a compile time error if the number of arguments does not match.

**ERL_NIF_TERM enif_make_tuple_from_array(ErlNifEnv* env, const ERL_NIF_TERM arr[], unsigned cnt)**

Create a tuple containing the elements of array `arr` of length `cnt`.

**ERL_NIF_TERM enif_make_uint(ErlNifEnv* env, unsigned int i)**

Create an integer term from an `unsigned int`.

**ERL_NIF_TERM enif_make_uint64(ErlNifEnv* env, ErlNifUInt64 i)**

Create an integer term from an unsigned 64-bit integer.

**ERL_NIF_TERM enif_make_ulong(ErlNifEnv* env, unsigned long i)**

Create an integer term from an `unsigned long int`.

**int enif_map_iterator_create(ErlNifEnv *env, ERL_NIF_TERM map, ErlNifMapIterator *iter, ErlNifMapIteratorEntry entry)**

Create an iterator for the map `map` by initializing the structure pointed to by `iter`. The `entry` argument determines the start position of the iterator: `ERL_NIF_MAP_ITERATOR_FIRST` or `ERL_NIF_MAP_ITERATOR_LAST`. Return true on success or false if `map` is not a map.

A map iterator is only useful during the lifetime of the environment `env` that the `map` belongs to. The iterator must be destroyed by calling *enif_map_iterator_destroy*.

```
ERL_NIF_TERM key, value;
ErlNifMapIterator iter;
enif_map_iterator_create(env, my_map, &iter, ERL_NIF_MAP_ITERATOR_FIRST);

while (enif_map_iterator_get_pair(env, &iter, &key, &value)) {
```

```
    do_something(key,value);
    enif_map_iterator_next(env, &iter);
}
enif_map_iterator_destroy(env, &iter);
```

> Note:
>
> The key-value pairs of a map have no defined iteration order. The only guarantee is that the iteration order of a single map instance is preserved during the lifetime of the environment that the map belongs to.

**`void enif_map_iterator_destroy(ErlNifEnv *env, ErlNifMapIterator *iter)`**

Destroy a map iterator created by *enif_map_iterator_create*.

**`int enif_map_iterator_get_pair(ErlNifEnv *env, ErlNifMapIterator *iter, ERL_NIF_TERM *key, ERL_NIF_TERM *value)`**

Get key and value terms at current map iterator position. On success set `*key` and `*value` and return true. Return false if the iterator is positioned at head (before first entry) or tail (beyond last entry).

**`int enif_map_iterator_is_head(ErlNifEnv *env, ErlNifMapIterator *iter)`**

Return true if map iterator `iter` is positioned before first entry.

**`int enif_map_iterator_is_tail(ErlNifEnv *env, ErlNifMapIterator *iter)`**

Return true if map iterator `iter` is positioned after last entry.

**`int enif_map_iterator_next(ErlNifEnv *env, ErlNifMapIterator *iter)`**

Increment map iterator to point to next key-value entry. Return true if the iterator is now positioned at a valid key-value entry, or false if the iterator is positioned at the tail (beyond the last entry).

**`int enif_map_iterator_prev(ErlNifEnv *env, ErlNifMapIterator *iter)`**

Decrement map iterator to point to previous key-value entry. Return true if the iterator is now positioned at a valid key-value entry, or false if the iterator is positioned at the head (before the first entry).

**`ErlNifMutex *enif_mutex_create(char *name)`**

Same as *erl_drv_mutex_create*.

**`void enif_mutex_destroy(ErlNifMutex *mtx)`**

Same as *erl_drv_mutex_destroy*.

**`void enif_mutex_lock(ErlNifMutex *mtx)`**

Same as *erl_drv_mutex_lock*.

**`int enif_mutex_trylock(ErlNifMutex *mtx)`**

Same as *erl_drv_mutex_trylock*.

### void enif_mutex_unlock(ErlNifMutex *mtx)

Same as *erl_drv_mutex_unlock*.

### ErlNifResourceType *enif_open_resource_type(ErlNifEnv* env, const char* module_str, const char* name, ErlNifResourceDtor* dtor, ErlNifResourceFlags flags, ErlNifResourceFlags* tried)

Create or takeover a resource type identified by the string `name` and give it the destructor function pointed to by *dtor*. Argument `flags` can have the following values:

`ERL_NIF_RT_CREATE`
: Create a new resource type that does not already exist.

`ERL_NIF_RT_TAKEOVER`
: Open an existing resource type and take over ownership of all its instances. The supplied destructor `dtor` will be called both for existing instances as well as new instances not yet created by the calling NIF library.

The two flag values can be combined with bitwise-or. The name of the resource type is local to the calling module. Argument `module_str` is not (yet) used and must be NULL. The `dtor` may be `NULL` in case no destructor is needed.

On success, return a pointer to the resource type and `*tried` will be set to either `ERL_NIF_RT_CREATE` or `ERL_NIF_RT_TAKEOVER` to indicate what was actually done. On failure, return `NULL` and set `*tried` to `flags`. It is allowed to set `tried` to `NULL`.

Note that `enif_open_resource_type` is only allowed to be called in the three callbacks *load*, *reload* and *upgrade*.

### void *enif_priv_data(ErlNifEnv* env)

Return the pointer to the private data that was set by `load`, `reload` or `upgrade`.

Was previously named `enif_get_data`.

### ERL_NIF_TERM enif_raise_exception(ErlNifEnv* env, ERL_NIF_TERM reason)

Create an error exception with the term `reason` to be returned from a NIF, and associate it with the environment `env`. Once a NIF or any function it calls invokes `enif_raise_exception`, the runtime ensures that the exception it creates is raised when the NIF returns, even if the NIF attempts to return a non-exception term instead. The return value from `enif_raise_exception` may be used only as the return value from the NIF that invoked it (directly or indirectly) or be passed to *enif_is_exception*, but not to any other NIF API function.

See also: *enif_has_pending_exception* and *enif_make_badarg*.

### int enif_realloc_binary(ErlNifBinary* bin, size_t size)

Change the size of a binary `bin`. The source binary may be read-only, in which case it will be left untouched and a mutable copy is allocated and assigned to `*bin`. Return true on success, false if memory allocation failed.

### void enif_release_binary(ErlNifBinary* bin)

Release a binary obtained from `enif_alloc_binary`.

### void enif_release_resource(void* obj)

Remove a reference to resource object `obj`obtained from *enif_alloc_resource*. The resource object will be destructed when the last reference is removed. Each call to `enif_release_resource` must correspond to a previous call to `enif_alloc_resource` or *enif_keep_resource*. References made by *enif_make_resource* can only be removed by the garbage collector.

**`ErlNifRWLock *enif_rwlock_create(char *name)`**

Same as *erl_drv_rwlock_create*.

**`void enif_rwlock_destroy(ErlNifRWLock *rwlck)`**

Same as *erl_drv_rwlock_destroy*.

**`void enif_rwlock_rlock(ErlNifRWLock *rwlck)`**

Same as *erl_drv_rwlock_rlock*.

**`void enif_rwlock_runlock(ErlNifRWLock *rwlck)`**

Same as *erl_drv_rwlock_runlock*.

**`void enif_rwlock_rwlock(ErlNifRWLock *rwlck)`**

Same as *erl_drv_rwlock_rwlock*.

**`void enif_rwlock_rwunlock(ErlNifRWLock *rwlck)`**

Same as *erl_drv_rwlock_rwunlock*.

**`int enif_rwlock_tryrlock(ErlNifRWLock *rwlck)`**

Same as *erl_drv_rwlock_tryrlock*.

**`int enif_rwlock_tryrwlock(ErlNifRWLock *rwlck)`**

Same as *erl_drv_rwlock_tryrwlock*.

**`ERL_NIF_TERM enif_schedule_nif(ErlNifEnv* env, const char* fun_name, int flags, ERL_NIF_TERM (*fp)(ErlNifEnv* env, int argc, const ERL_NIF_TERM argv[]), int argc, const ERL_NIF_TERM argv[])`**

Schedule NIF `fp` to execute. This function allows an application to break up long-running work into multiple regular NIF calls or to schedule a *dirty NIF* to execute on a dirty scheduler thread (*note that the dirty NIF functionality described here is experimental* and that you have to enable support for dirty schedulers when building OTP in order to try the functionality out).

The `fun_name` argument provides a name for the NIF being scheduled for execution. If it cannot be converted to an atom, `enif_schedule_nif` returns a `badarg` exception.

The `flags` argument must be set to 0 for a regular NIF, or if the emulator was built the experimental dirty scheduler support enabled, `flags` can be set to either `ERL_NIF_DIRTY_JOB_CPU_BOUND` if the job is expected to be primarily CPU-bound, or `ERL_NIF_DIRTY_JOB_IO_BOUND` for jobs that will be I/O-bound. If dirty scheduler threads are not available in the emulator, a try to schedule such a job will result in a `badarg` exception.

The `argc` and `argv` arguments can either be the originals passed into the calling NIF, or they can be values created by the calling NIF.

The calling NIF must use the return value of `enif_schedule_nif` as its own return value.

Be aware that `enif_schedule_nif`, as its name implies, only schedules the NIF for future execution. The calling NIF does not block waiting for the scheduled NIF to execute and return, which means that the calling NIF can't expect to receive the scheduled NIF return value and use it for further operations.

**`ErlNifPid *enif_self(ErlNifEnv* caller_env, ErlNifPid* pid)`**

Initialize the pid variable `*pid` to represent the calling process. Return `pid`.

**`int enif_send(ErlNifEnv* env, ErlNifPid* to_pid, ErlNifEnv* msg_env, ERL_NIF_TERM msg)`**

Send a message to a process.

`env`
: The environment of the calling process. Must be NULL if and only if calling from a created thread.

`*to_pid`
: The pid of the receiving process. The pid should refer to a process on the local node.

`msg_env`
: The environment of the message term. Must be a process independent environment allocated with *enif_alloc_env*.

`msg`
: The message term to send.

Return true on success, or false if `*to_pid` does not refer to an alive local process.

The message environment `msg_env` with all its terms (including `msg`) will be invalidated by a successful call to `enif_send`. The environment should either be freed with *enif_free_env* of cleared for reuse with *enif_clear_env*.

This function is only thread-safe when the emulator with SMP support is used. It can only be used in a non-SMP emulator from a NIF-calling thread.

**`unsigned enif_sizeof_resource(void* obj)`**

Get the byte size of a resource object `obj` obtained by *enif_alloc_resource*.

**`void enif_system_info(ErlNifSysInfo *sys_info_ptr, size_t size)`**

Same as *driver_system_info*.

**`int enif_thread_create(char *name,ErlNifTid *tid,void * (*func)(void *),void *args,ErlNifThreadOpts *opts)`**

Same as *erl_drv_thread_create*.

**`void enif_thread_exit(void *resp)`**

Same as *erl_drv_thread_exit*.

**`int enif_thread_join(ErlNifTid, void **respp)`**

Same as *erl_drv_thread_join* .

**`ErlNifThreadOpts *enif_thread_opts_create(char *name)`**

Same as *erl_drv_thread_opts_create*.

**`void enif_thread_opts_destroy(ErlNifThreadOpts *opts)`**

Same as *erl_drv_thread_opts_destroy*.

### ErlNifTid enif_thread_self(void)

Same as *erl_drv_thread_self*.

### int enif_tsd_key_create(char *name, ErlNifTSDKey *key)

Same as *erl_drv_tsd_key_create*.

### void enif_tsd_key_destroy(ErlNifTSDKey key)

Same as *erl_drv_tsd_key_destroy*.

### void *enif_tsd_get(ErlNifTSDKey key)

Same as *erl_drv_tsd_get*.

### void enif_tsd_set(ErlNifTSDKey key, void *data)

Same as *erl_drv_tsd_set*.

### ErlNifTime enif_monotonic_time(ErlNifTimeUnit time_unit)

Arguments:

`time_unit`
: Time unit of returned value.

Returns *Erlang monotonic time*. Note that it is not uncommon with negative values.

Returns `ERL_NIF_TIME_ERROR` if called with an invalid time unit argument, or if called from a thread that is not a scheduler thread.

See also:

- *`ErlNifTime`*
- *`ErlNifTimeUnit`*

### ErlNifTime enif_time_offset(ErlNifTimeUnit time_unit)

Arguments:

`time_unit`
: Time unit of returned value.

Returns the current time offset between *Erlang monotonic time* and *Erlang system time* converted into the `time_unit` passed as argument.

Returns `ERL_NIF_TIME_ERROR` if called with an invalid time unit argument, or if called from a thread that is not a scheduler thread.

See also:

- *`ErlNifTime`*
- *`ErlNifTimeUnit`*

### ErlNifTime enif_convert_time_unit(ErlNifTime val, ErlNifTimeUnit from, ErlNifTimeUnit to)

Arguments:

`val`
: Value to convert time unit for.

`from`
: Time unit of `val`.

`to`
: Time unit of returned value.

Converts the `val` value of time unit `from` to the corresponding value of time unit `to`. The result is rounded using the floor function.

Returns `ERL_NIF_TIME_ERROR` if called with an invalid time unit argument.

See also:

- *`ErlNifTime`*
- *`ErlNifTimeUnit`*

## SEE ALSO

*erlang:load_nif/2*