STDLIB

version 1.13
# Contents

## 1 STDLIB Reference Manual

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STDLIB Reference Manual

Short Summaries

- Erlang Module beam_lib [page 50] – An Interface To the BEAM File Format
- Erlang Module c [page 57] – Command Interface Module
- Erlang Module calendar [page 61] – Local and universal time, day-of-the-week, date and time conversions
- Erlang Module det [page 66] – A Disk Based Term Storage
- Erlang Module dict [page 82] – Key-Value Dictionary
- Erlang Module digraph [page 87] – Directed Graphs
- Erlang Module digraph_utils [page 94] – Algorithms for Directed Graphs
- Erlang Module epp [page 98] – An Erlang Code Preprocessor
- Erlang Module erl_eval [page 100] – The Erlang Meta Interpreter
- Erlang Module erl_expand_records [page 103] – Expands Records in a Module
- Erlang Module erl_id_trans [page 104] – An Identity Parse Transform
- Erlang Module erl_internal [page 105] – Internal Erlang Definitions
- Erlang Module erl_lint [page 107] – The Erlang Code Linter
- Erlang Module erl_parse [page 109] – The Erlang Parser
- Erlang Module erl_pp [page 112] – The Erlang Pretty Printer
- Erlang Module erl_scan [page 115] – The Erlang Token Scanner
- Erlang Module erl_tar [page 117] – Unix ‘tar’ utility for reading and writing tar archives
- Erlang Module ets [page 123] – Built-In Term Storage
- Erlang Module file_sorter [page 143] – File Sorter
- Erlang Module filelib [page 148] – File utilities, such as wildcard matching of filenames
- Erlang Module filename [page 151] – Filename Manipulation Functions
- Erlang Module gb_sets [page 157] – General Balanced Trees
- Erlang Module gb_trees [page 163] – General Balanced Trees
- Erlang Module gen_event [page 168] – Generic Event Handling Behaviour
- Erlang Module gen_fsm [page 178] – Generic Finite State Machine Behaviour
- Erlang Module gen_server [page 189] – Generic Server Behaviour
- Erlang Module io [page 198] – Standard IO Server Interface Functions
beam_lib

The following functions are exported:

- chunks(Beam, [ChunkRef]) -> {ok, {Module, [ChunkData]}} | {error, beam_lib, Reason} [page 52] Read selected chunks from a BEAM file or binary
- version(Beam) -> {ok, {Module, [Version]}} | {error, beam_lib, Reason} [page 52] Read the BEAM file's module version
- `info(Beam) -> [{Item, Info}] | {error, beam_lib, Reason1}`  
  [page 53] Information about a BEAM file

- `cmp(Beam1, Beam2) -> ok | {error, beam_lib, Reason}`  
  [page 53] Compare two BEAM files

- `cmp_dirs(Dir1, Dir2) -> {Only1, Only2, Different} | {error, beam_lib, Reason1}`  
  [page 53] Compare the BEAM files in two directories

- `diff_dirs(Dir1, Dir2) -> ok | {error, beam_lib, Reason1}`  
  [page 54] Compare the BEAM files in two directories

- `strip(Beam1) -> {ok, [Module, Beam2]} | {error, beam_lib, Reason1}`  
  [page 54] Removes chunks not needed by the loader from a BEAM file

- `strip_files(Files) -> {ok, [[Module, Beam2]]} | {error, beam_lib, Reason1}`  
  [page 54] Removes chunks not needed by the loader from BEAM files

- `strip_release(Dir) -> {ok, [[Module, Filename]]} | {error, beam_lib, Reason1}`  
  [page 54] Removes chunks not needed by the loader from all BEAM files of a release

- `format_error(Reason) -> Chars`  
  [page 55] Return an English description of a BEAM read error reply

- `crypto_key_fun(CryptoKeyFun) -> ok | {error, Reason}`  
  [page 55] Register a fun that provides a crypto key

- `clear_crypto_key_fun() -> {ok, Result}`  
  [page 55] Unregister the current crypto key fun

C

The following functions are exported:

- `bt(Pid) -> void()`  
  [page 57] Stack backtrace for a process

- `c(File) -> {ok, Module} | error`  
  [page 57] Compile and load code in a file

- `c(File, Options) -> {ok, Module} | error`  
  [page 57] Compile and load code in a file

- `cd(Dir) -> void()`  
  [page 57] Change working directory

- `flush() -> void()`  
  [page 58] Flush any messages sent to the shell

- `help() -> void()`  
  [page 58] Help information

- `i() -> void()`  
  [page 58] Information about the system

- `ni() -> void()`  
  [page 58] Information about the system

- `i(X, Y, Z) -> void()`  
  [page 58] Information about pid <X,Y,Z>
calendar

The following functions are exported:

- `date_to_gregorian_days(Date) -> Days`
  [page 62] Compute the number of days from year 0 up to the given date
- `date_to_gregorian_days(Year, Month, Day) -> Days`
  [page 62] Compute the number of days from year 0 up to the given date
- `datetime_to_gregorian_seconds([Date, Time]) -> Seconds`  
  [page 62] Compute the number of seconds from year 0 up to the given date and time
- `day_of_the_week(Date) -> DayNumber`  
  [page 62] Compute the day of the week
- `day_of_the_week(Year, Month, Day) -> DayNumber`  
  [page 62] Compute the day of the week
- `gregorian_days_to_date(Days) -> Date`  
  [page 62] Compute the date given the number of gregorian days
- `gregorian_seconds_to_datetime(Seconds) -> [Date, Time]`  
  [page 62] Compute the date given the number of gregorian days
- `is_leap_year(Year) -> bool()`  
  [page 62] Check if a year is a leap year
- `last_day_of_the_month(Year, Month) -> int()`  
  [page 62] Compute the number of days in a month
- `local_time() -> {Date, Time}`  
  [page 63] Compute local time
- `local_time_to_universal_time([Date1, Time1]) -> [Date2, Time2]`  
  [page 63] Convert from local time to universal time (deprecated)
- `local_time_to_universal_time_dst([Date1, Time1]) -> [Date, Time]`  
  [page 63] Convert from local time to universal time(s)
- `now_to_local_time(Now) -> {Date, Time}`  
  [page 63] Convert now to local date and time
- `now_to_universal_time(Now) -> {Date, Time}`  
  [page 64] Convert now to date and time
- `now_to_datetime(Now) -> {Date, Time}`  
  [page 64] Convert now to date and time
- `seconds_to_daystime(Seconds) -> {Days, Time}`  
  [page 64] Compute days and time from seconds
- `seconds_to_time(Seconds) -> Time`  
  [page 64] Compute time from seconds
- `time_difference(T1, T2) -> {Days, Time}`  
  [page 64] Compute the difference between two times (deprecated)
- `time_to_seconds(Time) -> Seconds`  
  [page 64] Compute the number of seconds since midnight up to the given time
- `universal_time() -> {Date, Time}`  
  [page 64] Compute universal time
- `universal_time_to_local_time([Date1, Time1]) -> [Date2, Time2]`  
  [page 65] Convert from universal time to local time
- `valid_date(Date) -> bool()`  
  [page 65] Check if a date is valid
- `valid_date(Year, Month, Day) -> bool()`  
  [page 65] Check if a date is valid
The following functions are exported:

- `all() -> [Name]`
  [page 67] Return a list of the names of all open Dets tables on this node.

- `bchunk(Name, Continuation) -> {Continuation2, Data} | '$end_of_table' | {error, Reason}`
  [page 67] Return a chunk of objects stored in a Dets table.

- `close(Name) -> ok | {error, Reason}`
  [page 68] Close a Dets table.

- `delete(Name, Key) -> ok | {error, Reason}`
  [page 68] Delete all objects with a given key from a Dets table.

- `delete_all_objects(Name) -> ok | {error, Reason}`
  [page 68] Delete all objects from a Dets table.

- `delete_object(Name, Object) -> ok | {error, Reason}`
  [page 68] Delete a given object from a Dets table.

- `first(Name) -> Key | '$end_of_table'`
  [page 68] Return the first key stored in a Dets table.

- `foldl(Function, Acc0, Name) -> Acc1 | {error, Reason}`
  [page 69] Fold a function over a Dets table.

- `foldr(Function, Acc0, Name) -> Acc1 | {error, Reason}`
  [page 69] Fold a function over a Dets table.

- `from_ets(Name, EtsTab) -> ok | {error, Reason}`
  [page 69] Replace the objects of a Dets table with the objects of an Ets table.

- `info(Name) -> InfoList | undefined`
  [page 69] Return information about a Dets table.

- `info(Name, Item) -> Value | undefined`
  [page 70] Return the information associated with a given item for a Dets table.

- `init_table(Name, InitFun [Options]) -> ok | {error, Reason}`
  [page 70] Replace all objects of a Dets table.

- `insert(Name, Objects) -> ok | {error, Reason}`
  [page 71] Insert one or more objects into a Dets table.

- `insert_new(Name, Objects) -> Bool`
  [page 71] Insert one or more objects into a Dets table.

- `is_compatible_bchunk_format(Name, BchunkFormat) -> Bool`
  [page 72] Test compatibility of a table's chunk data.

- `is_dets_file(FileName) -> Bool | {error, Reason}`
  [page 72] Test for a Dets table.

- `lookup(Name, Key) -> [Object] | {error, Reason}`
  [page 72] Return all objects with a given key stored in a Dets table.

- `match(Continuation) -> {[Match], Continuation2} | '$end_of_table' | {error, Reason}`
  [page 72] Match a chunk of objects stored in a Dets table and return a list of variable bindings.

- `match(Name, Pattern) -> [Match] | {error, Reason}`
  [page 73] Match the objects stored in a Dets table and return a list of variable bindings.
- `match(Name, Pattern, N) -> [{Match}, Continuation] | 'end_of_table' | {error, Reason}
  [page 73] Match the first chunk of objects stored in a Dets table and return a list of variable bindings.

- `match_delete(Name, Pattern) -> N | {error, Reason}
  [page 73] Delete all objects that match a given pattern from a Dets table.

- `match_object(Continuation) -> [{Object}, Continuation2] | 'end_of_table' | {error, Reason}
  [page 74] Match a chunk of objects stored in a Dets table and return a list of objects.

- `match_object(Name, Pattern) -> [Object] | {error, Reason}
  [page 74] Match the objects stored in a Dets table and return a list of objects.

- `match_object(Name, Pattern, N) -> [{Object}, Continuation] | 'end_of_table' | {error, Reason}
  [page 74] Match the first chunk of objects stored in a Dets table and return a list of objects.

- `member(Name, Key) -> Bool | {error, Reason}
  [page 75] Test for occurrence of a key in a Dets table.

- `next(Name, Key1) -> Key2 | 'end_of_table'
  [page 75] Return the next key in a Dets table.

- `open_file(Filename) -> {ok, Reference} | {error, Reason}
  [page 75] Open an existing Dets table.

- `open_file(Name, Args) -> {ok, Name} | {error, Reason}
  [page 75] Open a Dets table.

- `pid2name(Pid) -> {ok, Name} | undefined
  [page 77] Return the name of the Dets table handled by a pid.

- `repair_continuation(Continuation, MatchSpec) -> Continuation2
  [page 77] Repair a continuation from select/1 or select/3.

- `safe_fixtable(Name, Fix)
  [page 77] Fix a Dets table for safe traversal.

- `select(Continuation) -> {Selection, Continuation2} | 'end_of_table' | {error, Reason}
  [page 78] Apply a match specification to some objects stored in a Dets table.

- `select(Name, MatchSpec) -> Selection | {error, Reason}
  [page 78] Apply a match specification to all objects stored in a Dets table.

- `select(Name, MatchSpec, N) -> {Selection, Continuation} | 'end_of_table' | {error, Reason}
  [page 78] Apply a match specification to the first chunk of objects stored in a Dets table.

- `select_delete(Name, MatchSpec) -> N | {error, Reason}
  [page 79] Delete all objects that match a given pattern from a Dets table.

- `slot(Name, I) -> 'end_of_table' | [Object] | {error, Reason}
  [page 79] Return the list of objects associated with a slot of a Dets table.

- `sync(Name) -> ok | {error, Reason}
  [page 79] Ensure that all updates made to a Dets table are written to disk.

- `table(Name [, Options]) -> QueryHandle
  [page 79] Return a QLC query handle.
The following functions are exported:

- **append(Key, Value, Dict1) -> Dict2**  
  [page 82] Append a value to keys in a dictionary

- **append_list(Key, ValList, Dict1) -> Dict2**  
  [page 82] Append new values to keys in a dictionary

- **erase(Key, Dict1) -> Dict2**  
  [page 82] Erase a key from a dictionary

- **fetch(Key, Dict) -> Value**  
  [page 82] Look-up values in a dictionary

- **fetch_keys(Dict) -> Keys**  
  [page 83] Return all keys in a dictionary

- **filter(Pred, Dict1) -> Dict2**  
  [page 83] Choose elements which satisfy a predicate

- **find(Key, Dict) -> {ok, Value} | error**  
  [page 83] Search for a key in a dictionary

- **fold(Fun, Acc0, Dict) -> Acc1**  
  [page 83] Fold a function over a dictionary

- **from_list(List) -> Dict**  
  [page 83] Convert a list of pairs to a dictionary

- **is_key(Key, Dict) -> bool()**  
  [page 83] Test if a key is in a dictionary

- **map(Fun, Dict1) -> Dict2**  
  [page 84] Map a function over a dictionary

- **merge(Fun, Dict1, Dict2) -> Dict3**  
  [page 84] Merge two dictionaries

- **new() -> dictionary()**  
  [page 84] Create a dictionary

- **store(Key, Value, Dict1) -> Dict2**  
  [page 84] Store a value in a dictionary

- **to_list(Dict) -> List**  
  [page 84] Convert a dictionary to a list of pairs

- **update(Key, Fun, Dict1) -> Dict2**  
  [page 85] Update a value in a dictionary

- **update(Key, Fun, Initial, Dict1) -> Dict2**  
  [page 85] Update a value in a dictionary

- **update_counter(Key, Increment, Dict1) -> Dict2**  
  [page 85] Increment a value in a dictionary
digraph

The following functions are exported:

- `add_edge(G, E, V1, V2, Label) -> edge() | {error, Reason}`
  [page 87] Add an edge to a digraph.
- `add_edge(G, V1, V2, Label) -> edge() | {error, Reason}`
  [page 87] Add an edge to a digraph.
- `add_edge(G, V1, V2) -> edge() | {error, Reason}`
  [page 87] Add an edge to a digraph.
- `add_vertex(G, V, Label) -> vertex()`
  [page 88] Add or modify a vertex of a digraph.
- `add_vertex(G, V) -> vertex()`
  [page 88] Add or modify a vertex of a digraph.
- `add_vertex(G) -> vertex()`
  [page 88] Add or modify a vertex of a digraph.
- `del_edge(G, E) -> true`
  [page 88] Delete an edge from a digraph.
- `del_edges(G, Edges) -> true`
  [page 88] Delete edges from a digraph.
- `del_path(G, V1, V2) -> true`
  [page 88] Delete paths from a digraph.
- `del_vertex(G, V) -> true`
  [page 89] Delete a vertex from a digraph.
- `del_vertices(G, Vertices) -> true`
  [page 89] Delete vertices from a digraph.
- `delete(G) -> true`
  [page 89] Delete a digraph.
- `edge(G, E) -> {E, V1, V2, Label} | false`
  [page 89] Return the vertices and the label of an edge of a digraph.
- `edges(G) -> Edges`
  [page 89] Return all edges of a digraph.
- `edges(G, V) -> Edges`
  [page 89] Return the edges emanating from or incident on a vertex of a digraph.
- `get_cycle(G, V) -> Vertices | false`
  [page 90] Find one cycle in a digraph.
- `get_path(G, V1, V2) -> Vertices | false`
  [page 90] Find one path in a digraph.
- `get_short_cycle(G, V) -> Vertices | false`
  [page 90] Find one short cycle in a digraph.
- `get_short_path(G, V1, V2) -> Vertices | false`
  [page 90] Find one short path in a digraph.
- `in_degree(G, V) -> integer()`
  [page 91] Return the in-degree of a vertex of a digraph.
- `in_edges(G, V) -> Edges`
  [page 91] Return all edges incident on a vertex of a digraph.
- `in_neighbours(G, V) -> Vertices`  
  [page 91] Return all in-neighbours of a vertex of a digraph.

- `info(G) -> InfoList`  
  [page 91] Return information about a digraph.

- `new() -> digraph()`  
  [page 92] Return a protected empty digraph, where cycles are allowed.

- `new(Type) -> digraph() | {error, Reason}`  
  [page 92] Create a new empty digraph.

- `no_edges(G) -> integer() >= 0`  
  [page 92] Return the number of edges of the digraph.

- `no_vertices(G) -> integer() >= 0`  
  [page 92] Return the number of vertices of a digraph.

- `out_degree(G, V) -> integer()`  
  [page 92] Return the out-degree of a vertex of a digraph.

- `out_edges(G, V) -> Edges`  
  [page 92] Return all edges emanating from a vertex of a digraph.

- `out_neighbours(G, V) -> Vertices`  
  [page 92] Return all out-neighbours of a vertex of a digraph.

- `vertex(G, V) -> {V, Label} | false`  
  [page 93] Return the label of a vertex of a digraph.

- `vertices(G) -> Vertices`  
  [page 93] Return all vertices of a digraph.

**digraph_utils**

The following functions are exported:

- `components(Digraph) -> [Component]`  
  [page 95] Return the components of a digraph.

- `condensation(Digraph) -> CondensedDigraph`  
  [page 95] Return a condensed graph of a digraph.

- `cyclic_strong_components(Digraph) -> [StrongComponent]`  
  [page 95] Return the cyclic strong components of a digraph.

- `is_acyclic(Digraph) -> bool()`  
  [page 95] Check if a digraph is acyclic.

- `loop_vertices(Digraph) -> Vertices`  
  [page 95] Return the vertices of a digraph included in some loop.

- `postorder(Digraph) -> Vertices`  
  [page 96] Return the vertices of a digraph in post-order.

- `preorder(Digraph) -> Vertices`  
  [page 96] Return the vertices of a digraph in pre-order.

- `reachable(Vertices, Digraph) -> Vertices`  
  [page 96] Return the vertices reachable from some vertices of a digraph.

- `reachable_neighbours(Vertices, Digraph) -> Vertices`  
  [page 96] Return the neighbours reachable from some vertices of a digraph.

- `reaching(Vertices, Digraph) -> Vertices`  
  [page 96] Return the vertices that reach some vertices of a digraph.
- `reaching_neighbours(Vertices, Digraph) -> Vertices` [page 96] Return the neighbours that reach some vertices of a digraph.
- `strong_components(Digraph) -> [StrongComponent]` [page 97] Return the strong components of a digraph.
- `subgraph(Digraph, Vertices [, Options]) -> Subgraph | {error, Reason}` [page 97] Return a subgraph of a digraph.
- `topsort(Digraph) -> Vertices | false` [page 97] Return a topological sorting of the vertices of a digraph.

### epp

The following functions are exported:

- `open(FileName, IncludePath) -> {ok,Epp} | {error, ErrorDescriptor}` [page 98] Open a file for preprocessing
- `open(FileName, IncludePath, PredefMacros) -> {ok,Epp} | {error, ErrorDescriptor}` [page 98] Open a file for preprocessing
- `close(Epp) -> ok` [page 98] Close the preprocessing of the file associated with Epp
- `parse_erl_form(Epp) -> {ok, AbsForm} | {eof, Line} | {error, ErrorInfo}` [page 98] Return the next Erlang form from the opened Erlang source file
- `parse_file(FileName,IncludePath,PredefMacro) -> {ok,[Form]} | {error,OpenError}` [page 98] Preprocesse and parse an Erlang source file

### erl_eval

The following functions are exported:

- `exprs(Expressions, Bindings) -> {value, Value, NewBindings}` [page 100] Evaluate expressions
- `exprs(Expressions, Bindings, LocalFunctionHandler) -> {value, Value, NewBindings}` [page 100] Evaluate expressions
- `exprs(Expressions, Bindings, LocalFunctionHandler, NonlocalFunctionHandler) -> {value, Value, NewBindings}` [page 100] Evaluate expressions
- `expr(Expression, Bindings) -> {value, Value, NewBindings }` [page 100] Evaluate expression
- `expr(Expression, Bindings, LocalFunctionHandler) -> {value, Value, NewBindings }` [page 100] Evaluate expression
- `expr(Expression, Bindings, LocalFunctionHandler, NonlocalFunctionHandler) -> {value, Value, NewBindings }` [page 100] Evaluate expression
- `expr_list(ExpressionList, Bindings) -> {ValueList, NewBindings}`  
  [page 101] Evaluate a list of expressions
- `expr_list(ExpressionList, Bindings, LocalFunctionHandler) -> {ValueList, NewBindings}`  
  [page 101] Evaluate a list of expressions
- `expr_list(ExpressionList, Bindings, LocalFunctionHandler, NonlocalFunctionHandler) -> {ValueList, NewBindings}`  
  [page 101] Evaluate a list of expressions
- `new_bindings() -> BindingStruct`  
  [page 101] Return a bindings structure
- `bindings(BindingStruct) -> Bindings`  
  [page 101] Return bindings
- `binding(Name, BindingStruct) -> Binding`  
  [page 101] Return bindings
- `add_binding(Name, Value, Bindings) -> BindingStruct`  
  [page 101] Add a binding
- `del_binding(Name, Bindings) -> BindingStruct`  
  [page 101] Delete a binding

**erl_expand_records**

The following functions are exported:
- `module(AbsForms, CompileOptions) -> AbsForms`  
  [page 103] Expand all records in a module

**erl_id_trans**

The following functions are exported:
- `parse_transform(Forms, Options) -> Forms`  
  [page 104] Transform Erlang forms

**erl_internal**

The following functions are exported:
- `bif(Name, Arity) -> bool()`  
  [page 105] Test for an Erlang BIF
- `guard_bif(Name, Arity) -> bool()`  
  [page 105] Test for an Erlang BIF allowed in guards
- `type_test(Name, Arity) -> bool()`  
  [page 105] Test for a valid type test
- `arith_op(OpName, Arity) -> bool()`  
  [page 105] Test for an arithmetic operator
- `bool_op(OpName, Arity) -> bool()`  
  [page 105] Test for a Boolean operator
• comp_op(OpName, Arity) -> bool()
  [page 106] Test for a comparison operator
• list_op(OpName, Arity) -> bool()
  [page 106] Test for a list operator
• send_op(OpName, Arity) -> bool()
  [page 106] Test for a send operator
• op_type(OpName, Arity) -> Type
  [page 106] Return operator type

erl_lint

The following functions are exported:

• module(AbsForms) -> {ok,Warnings} | {error,Errors,Warnings}
  [page 107] Check a module for errors
• module(AbsForms, FileName) -> {ok,Warnings} |
  {error,Errors,Warnings}
  [page 107] Check a module for errors
• module(AbsForms, FileName, CompileOptions) -> {ok,Warnings} |
  {error,Errors,Warnings}
  [page 107] Check a module for errors
• is_guard_test(Expr) -> bool()
  [page 108] Test for a guard test
• format_error(Descriptor) -> Chars
  [page 108] Format an error descriptor

erl_parse

The following functions are exported:

• parse_form(Tokens) -> ok, AbsForm | error, ErrorInfo
  [page 109] Parse an Erlang form
• parse_exprs(Tokens) -> ok, Expr_list | error, ErrorInfo
  [page 109] Parse Erlang expressions
• parse_term(Tokens) -> ok, Term | error, ErrorInfo
  [page 109] Parse an Erlang term
• format_error(Descriptor) -> Chars
  [page 110] Format an error descriptor
• tokens(AbsTerm) -> Tokens
  [page 110] Generate a list of tokens for an expression
• tokens(AbsTerm, MoreTokens) -> Tokens
  [page 110] Generate a list of tokens for an expression
• normalise(AbsTerm) -> Data
  [page 110] Convert abstract form to an Erlang term
• abstract(Data) -> AbsTerm
  [page 110] Convert an Erlang term into an abstract form
erl_pp

The following functions are exported:

- `form(Form) -> DeepCharList`
  [page 112] Pretty print a form
- `form(Form, HookFunction) -> DeepCharList`
  [page 112] Pretty print a form
- `attribute(Attribute) -> DeepCharList`
  [page 112] Pretty print an attribute
- `attribute(Attribute, HookFunction) -> DeepCharList`
  [page 112] Pretty print an attribute
- `function(Function) -> DeepCharList`
  [page 112] Pretty print a function
- `function(Function, HookFunction) -> DeepCharList`
  [page 112] Pretty print a function
- `guard(Guard) -> DeepCharList`
  [page 112] Pretty print a guard
- `guard(Guard, HookFunction) -> DeepCharList`
  [page 112] Pretty print a guard
- `exprs(Expressions) -> DeepCharList`
  [page 113] Pretty print Expressions
- `exprs(Expressions, HookFunction) -> DeepCharList`
  [page 113] Pretty print Expressions
- `exprs(Expressions, Indent, HookFunction) -> DeepCharList`
  [page 113] Pretty print Expressions
- `expr(Expression) -> DeepCharList`
  [page 113] Pretty print one Expression
- `expr(Expression, HookFunction) -> DeepCharList`
  [page 113] Pretty print one Expression
- `expr(Expression, Indent, HookFunction) -> DeepCharList`
  [page 113] Pretty print one Expression
- `expr(Expression, Indent, Precedence, HookFunction) -> DeepCharList`
  [page 113] Pretty print one Expression

erl_scan

The following functions are exported:

- `string(CharList,StartLine) -> {ok, Tokens, EndLine} | Error`
  [page 115] Scan a string and returns the Erlang tokens
- `string(CharList) -> {ok, Tokens, EndLine} | Error`
  [page 115] Scan a string and returns the Erlang tokens
- `tokens(Continuation, CharList, StartLine) -> Return`
  [page 115] Re-entrant scanner
- `reserved_word(Atom) -> bool()`
  [page 116] Test for a reserved word
- `format_error(ErrorCode) -> string()`
  [page 116] Format an error descriptor
erl_tar

The following functions are exported:

- `add(TarDescriptor, Filename, Options) -> RetValue`
  [page 118] A dd a file to an open tar file
- `add(TarDescriptor, Filename, NameInArchive, Options) -> RetValue`
  [page 118] A dd a file to an open tar file
- `close(TarDescriptor)`
  [page 118] C lose an open tar file
- `create(Name, FileList) -> RetValue`
  [page 118] C reate a tar archive
- `create(Name, FileList, OptionList)`
  [page 119] C reate a tar archive with options
- `extract(Name) -> RetValue`
  [page 119] E xtract all files from a tar file
- `extract(Name, OptionList)`
  [page 119] E xtract files from a tar file
- `format_error(Reason) -> string()`
  [page 120] C onvert error term to a readable string
- `open(Name, OpenModeList) -> RetValue`
  [page 120] O pen a tar file.
- `table(Name) -> RetValue`
  [page 121] R etrieve the name of all files in a tar file
- `table(Name, Options)`
  [page 121] R etrieve name and information of all files in a tar file
- `t(Name)`
  [page 121] P rint the name of each file in a tar file
- `tt(Name)`
  [page 121] P rint name and information for each file in a tar file

ets

The following functions are exported:

- `all() -> [Tab]`
  [page 124] R eturn a list of all ETS tables
- `delete(Tab) -> true`
  [page 124] D elete an entire ETS table.
- `delete(Tab, Key) -> true`
  [page 124] D elete all objects with a given key from an ETS table.
- `delete_all_objects(Tab) -> true`
  [page 124] D elete all objects in an ETS table.
- `delete_object(Tab, Object) -> true`
  [page 124] D eletes a specific from an ETS table.
- `file2tab(Filename) -> {ok, Tab} | {error, Reason}`
  [page 124] R ead an ETS table from a file.
- `first(Tab)` returns the first key in an ETS table.
- `first(Tab)` returns `'$end_of_table'`.
- `foldl(Function, Acc0, Tab)` returns `Acc1`.
- `foldr(Function, Acc0, Tab)` returns `Acc1`.
- `from_dets(Tab, DetsTab)` fills an ETS table with objects from a Dets table.
- `fun2ms(LiteralFun)` transforms fun syntax to a match spec.
- `i()` displays information about all ETS tables on tty.
- `i(Tab)` browses an ETS table on tty.
- `info(Tab)` returns information about an ETS table.
- `info(Tab, Item)` returns the information associated with a given item for an ETS table.
- `init_table(Name, InitFun)` replaces all objects of an ETS table.
- `insert(Tab, ObjectOrObjects)` inserts an object into an ETS table.
- `insert_new(Tab, ObjectOrObjects)` inserts an object into an ETS table if the key is not already present.
- `is_compiled_ms(Term)` checks if an Erlang term is the result of `ets:match_spec_compile`.
- `last(Tab)` returns the last key in an ETS table of type ordered set.
- `lookup(Tab, Key)` returns all objects with a given key in an ETS table.
- `lookup_element(Tab, Key, Pos)` returns the `Pos` element of all objects with a given key in an ETS table.
- `match(Tab, Pattern)` matches the objects in an ETS table against a pattern.
- `match(Tab, Pattern, Limit)` matches the objects in an ETS table against a pattern and returns part of the answers.
- `match_delete(Tab, Pattern)` deletes all objects which match a given pattern from an ETS table.
- `match_object(Tab, Pattern)` matches the objects in an ETS table against a pattern.
Match the objects in an ETS table against a pattern and returns part of the answers.

Continues matching objects in an ETS table.

Compiles a match specification into its internal representation.

Performs matching, using a compiled match specification, on a list of tuples.

Tests for occurrence of a key in an ETS table.

Create a new ETS table.

Return the next key in an ETS table.

Return the previous key in an ETS table of type ordered set.

Rename a named ETS table.

Repair a continuation from ets:select/1 or ets:select/3 that has passed through external representation.

Fix an ETS table for safe traversal.

Match the objects in an ETS table against a match specification.

Match the objects in an ETS table against a match specification and deletes objects where the match specification returns ‘true’.

Match the objects in an ETS table against a match specification and returns the number of objects for which the match specification returned ‘true’.

Return all objects in a given slot of an ETS table.

Dump an ETS table to a file.

Return a list of all objects in an ETS table.

Return a QLC query handle.
- `test_ms(Tuple, MatchSpec) -> {ok, Result} | {error, Errors}`  
  [page 141] Test a match_spec for use in ets:select/2.
- `to_dets(Tab, DetsTab) -> Tab`  
  [page 142] Fill a Dets table with objects from an ETS table.
- `update_counter(Tab, Key, {Pos,Incr,Threshold,SetValue}) -> Result`  
  [page 142] Update a counter object in an ETS table.
- `update_counter(Tab, Key, {Pos,Incr}) -> Result`  
  [page 142] Update a counter object in an ETS table.
- `update_counter(Tab, Key, Incr) -> Result`  
  [page 142] Update a counter object in an ETS table.

### file_sorter

The following functions are exported:

- `sort(FileName) -> Reply`  
  [page 146] Sort terms on files.
- `sort(Input, Output) -> Reply`  
  [page 146] Sort terms on files.
- `sort(Input, Output, Options) -> Reply`  
  [page 146] Sort terms on files.
- `keysort(KeyPos, FileName) -> Reply`  
  [page 146] Sort terms on files by key.
- `keysort(KeyPos, Input, Output) -> Reply`  
  [page 146] Sort terms on files by key.
- `keysort(KeyPos, Input, Output, Options) -> Reply`  
  [page 146] Sort terms on files by key.
- `merge(FileNames, Output) -> Reply`  
  [page 146] Merge terms on files.
- `merge(FileNames, Output, Options) -> Reply`  
  [page 146] Merge terms on files.
- `keymerge(KeyPos, FileNames, Output) -> Reply`  
  [page 147] Merge terms on files by key.
- `keymerge(KeyPos, FileNames, Output, Options) -> Reply`  
  [page 147] Merge terms on files by key.
- `check(FileName) -> Reply`  
  [page 147] Check whether terms on files are sorted.
- `check(FileNames, Options) -> Reply`  
  [page 147] Check whether terms on files are sorted.
- `keycheck(KeyPos, FileName) -> CheckReply`  
  [page 147] Check whether terms on files are sorted by key.
- `keycheck(KeyPos, FileNames, Options) -> Reply`  
  [page 147] Check whether terms on files are sorted by key.
filelib

The following functions are exported:

- **ensure_dir(Name)** -> true
  [page 148] Ensure that all parent directories needed to create Name exist.
- **file_size(Filename)** -> integer()
- **fold_files(Dir, RegExp, Recursive, Fun, AccIn)** -> AccOut
  [page 148] Fold over all files matching a regular expression.
- **is_dir(Name)** -> true | false
  [page 148] Test whether Name refer to a directory or not.
- **is_file(Name)** -> true | false
  [page 148] Test whether Name refer to a file or directory.
- **is_regular(Name)** -> true | false
  [page 149] Test whether Name refer to a (regular) file.
- **last_modified(Name)** -> {{Year, Month, Day}, {Hour, Min, Sec}}
  [page 149] Return the local date and time when a file was last modified.
- **wildcard(Wildcard)** -> list()
- **wildcard(Wildcard, Cwd)** -> list()
  [page 150] Match filenames using Unix-style wildcards startin at a specified directory.

filename

The following functions are exported:

- **absname(Filename)** -> string()
  [page 151] Convert a filename to an absolute name, relative the working directory.
- **absname(Filename, Dir)** -> string()
  [page 152] Convert a filename to an absolute name, relative a specified directory.
- **basename(Dir, Filename)** -> string()
  [page 152] Join an absolute directory with a relative filename.
- **basename(Filename)** -> string()
  [page 152] Return the last component of a filename.
- **basename(Filename, Ext)** -> string()
  [page 152] Return the last component of a filename, stripped of the specified extension.
- **dirname(Filename)** -> string()
  [page 153] Return the directory part of a path name.
- **extension(Filename)** -> string()
  [page 153] Return the file extension.
- **flatten(Filename)** -> string()
  [page 153] Convert a filename to a flat string.
- **join(Components)** -> string()
  [page 154] Join a list of filename components with directory separators.
join(Name1, Name2) -> string()  
[page 154] Join two filename components with directory separators

nativename(Path) -> string()  
[page 154] Return the native form of a file path

pathtype(Path) -> absolute | relative | volumerelative  
[page 154] Return the type of a path

rootname(Filename) -> string()  
[page 155] Remove a filename extension

rootname(Filename, Ext) -> string()  
[page 155] Remove a filename extension

split(Filename) -> Components  
[page 155] Split a filename into its path components

find_src(Beam) -> {SourceFile, Options}  
[page 155] Find the filename and compiler options for a module

find_src(Beam, Rules) -> {SourceFile, Options}  
[page 155] Find the filename and compiler options for a module

**gb_sets**

The following functions are exported:

- add(Element, Set1) -> Set2  
  [page 158] Add a (possibly existing) element to a gb_set

- add_element(Element, Set1) -> Set2  
  [page 158] Add a (possibly existing) element to a gb_set

- balance(Set1) -> Set2  
  [page 158] Rebalance tree representation of a gb_set

- delete(Element, Set1) -> Set2  
  [page 158] Remove an element from a gb_set

- delete_any(Element, Set1) -> Set2  
  [page 158] Remove a (possibly non-existing) element from a gb_set

- del_element(Element, Set1) -> Set2  
  [page 158] Remove a (possibly non-existing) element from a gb_set

- difference(Set1, Set2) -> Set3  
  [page 158] Return the difference of two gb_sets

- subtract(Set1, Set2) -> Set3  
  [page 159] Return the difference of two gb_sets

- empty() -> Set  
  [page 159] Return an empty gb_set

- new() -> Set  
  [page 159] Return an empty gb_set

- filter(Pred, Set1) -> Set2  
  [page 159] Filter gb_set elements

- fold(Function, Acc0, Set) -> Acc1  
  [page 159] Fold over gb_set elements

- from_list(List) -> Set  
  [page 159] Convert a list into a gb_set
• `from_ordset(List) -> Set`  
  [page 159] Make a gb_set from an ordset list
• `insert(Element, Set1) -> Set2`  
  [page 159] Add a new element to a gb_set
• `intersection(Set1, Set2) -> Set3`  
  [page 160] Return the intersection of two gb_sets
• `intersection(SetList) -> Set`  
  [page 160] Return the intersection of a list of gb_sets
• `is_empty(Set) -> bool()`  
  [page 160] Test for empty gb_set
• `is_member(Element, Set) -> bool()`  
  [page 160] Test for membership of a gb_set
• `is_element(Element, Set) -> bool()`  
  [page 160] Test for membership of a gb_set
• `is_set(Set) -> bool()`  
  [page 160] Test for a gb_set
• `is_subset(Set1, Set2) -> bool()`  
  [page 160] Test for subset
• `iterator(Set) -> Iter`  
  [page 160] Return an iterator for a gb_set
• `largest(Set) -> term()`  
  [page 161] Return largest element
• `next(Iter1) -> {Element, Iter2 | none}`  
  [page 161] Traverse a gb_set with an iterator
• `singleton(Element) -> gb_set()`  
  [page 161] Return a gb_set with one element
• `size(Set) -> int()`  
  [page 161] Return the number of elements in a gb_set
• `smallest(Set) -> term()`  
  [page 161] Return smallest element
• `take_largest(Set1) -> {Element, Set2}`  
  [page 161] Extract largest element
• `take_smallest(Set1) -> {Element, Set2}`  
  [page 161] Extract smallest element
• `to_list(Set) -> List`  
  [page 162] Convert a gb_set into a list
• `union(Set1, Set2) -> Set3`  
  [page 162] Return the union of two gb_sets
• `union(SetList) -> Set`  
  [page 162] Return the union of a list of gb_sets

**gb_trees**

The following functions are exported:

• `balance(Tree1) -> Tree2`  
  [page 163] Rebalance a tree
- delete(Key, Tree1) -> Tree2
  [page 163] Remove a node from a tree
- delete_any(Key, Tree1) -> Tree2
  [page 164] Remove a (possibly non-existing) node from a tree
- empty() -> Tree
  [page 164] Return an empty tree
- enter(Key, Val, Tree1) -> Tree2
  [page 164] Insert or update key with value in a tree
- from_orddict(List) -> Tree
  [page 164] Make a tree from an orddict
- get(Key, Tree) -> Val
  [page 164] Look up a key in a tree, if present
- lookup(Key, Tree) -> {value, Val} | none
  [page 164] Look up a key in a tree
- insert(Key, Val, Tree1) -> Tree2
  [page 165] Insert a new key and value in a tree
- is_defined(Key, Tree) -> bool()
  [page 165] Test for membership of a tree
- is_empty(Tree) -> bool()
  [page 165] Test for empty tree
- iterator(Tree) -> Iter
  [page 165] Return an iterator for a tree
- keys(Tree) -> [Key]
  [page 165] Return a list of the keys in a tree
- largest(Tree) -> {Key, Val}
  [page 165] Return largest key and value
- next(Iter1) -> {Key, Val, Iter2}
  [page 165] Traverse a tree with an iterator
- size(Tree) -> int()
  [page 166] Return the number of nodes in a tree
- smallest(Tree) -> {Key, Val}
  [page 166] Return smallest key and value
- take_largest(Tree1) -> {Key, Val, Tree2}
  [page 166] Extract largest key and value
- take_smallest(Tree1) -> {Key, Val, Tree2}
  [page 166] Extract smallest key and value
- to_list(Tree) -> [[Key, Val]]
  [page 166] Convert a tree into a list
- update(Key, Val, Tree1) -> Tree2
  [page 166] Update a key to new value in a tree
- values(Tree) -> [Val]
  [page 167] Return a list of the values in a tree
gen_event

The following functions are exported:

- **start_link()** -> Result
  [page 169] Create a generic event manager process in a supervision tree.

- **start_link(EventMgrName)** -> Result
  [page 169] Create a generic event manager process in a supervision tree.

- **start()** -> Result
  [page 169] Create a stand-alone event manager process.

- **start(EventMgrName)** -> Result
  [page 169] Create a stand-alone event manager process.

- **add_handler(EventMgrRef, Handler, Args)** -> Result
  [page 169] Add an event handler to a generic event manager.

- **add_sup_handler(EventMgrRef, Handler, Args)** -> Result
  [page 170] Add a supervised event handler to a generic event manager.

- **notify(EventMgrRef, Event)** -> ok
  [page 171] Notify an event manager about an event.

- **sync_notify(EventMgrRef, Event)** -> ok
  [page 171] Notify an event manager about an event.

- **call(EventMgrRef, Handler, Request)** -> Result
  [page 171] Make a synchronous call to a generic event manager.

- **call(EventMgrRef, Handler, Request, Timeout)** -> Result
  [page 171] Make a synchronous call to a generic event manager.

- **delete_handler(EventMgrRef, Handler, Args)** -> Result
  [page 172] Delete an event handler from a generic event manager.

- **swap_handler(EventMgrRef, \{Handler1,Args1\}, \{Handler2,Args2\})** -> Result
  [page 172] Replace an event handler in a generic event manager.

- **swap_sup_handler(EventMgrRef, \{Handler1,Args1\}, \{Handler2,Args2\})** -> Result
  [page 173] Replace an event handler in a generic event manager.

- **which_handlers(EventMgrRef)** -> [Handler]
  [page 173] Return all event handlers installed in a generic event manager.

- **stop(EventMgrRef)** -> ok
  [page 174] Terminate a generic event manager.

- **Module:init(InitArgs)** -> {ok,State}
  [page 174] Initialize an event handler.

- **Module:handle_event(Event, State)** -> Result
  [page 174] Handle an event.

- **Module:handle_call(Request, State)** -> Result
  [page 175] Handle a synchronous request.

- **Module:handle_info(Info, State)** -> Result
  [page 175] Handle an incoming message.

- **Module:terminate(Arg, State)** -> term()
  [page 176] Clean up before deletion.

- **Module:code_change(OldVsn, State, Extra)** -> {ok,NewState}
  [page 176] Update the internal state during upgrade/downgrade.
The following functions are exported:

- `start_link(Module, Args, Options) -> Result` [page 179]
  Create a gen_fsm process in a supervision tree.

- `start_link(FsmName, Module, Args, Options) -> Result` [page 179]
  Create a gen_fsm process in a supervision tree.

- `start(Module, Args, Options) -> Result` [page 180]
  Create a stand-alone gen_fsm process.

- `start(FsmName, Module, Args, Options) -> Result` [page 180]
  Create a stand-alone gen_fsm process.

- `send_event(FsmRef, Event) -> ok` [page 180]
  Send an event asynchronously to a generic FSM.

- `send_all_state_event(FsmRef, Event) -> ok` [page 180]
  Send an event asynchronously to a generic FSM.

- `sync_send_event(FsmRef, Event) -> Reply` [page 181]
  Send an event synchronously to a generic FSM.

- `sync_send_event(FsmRef, Event, Timeout) -> Reply` [page 181]
  Send an event synchronously to a generic FSM.

- `sync_send_all_state_event(FsmRef, Event) -> Reply` [page 181]
  Send an event synchronously to a generic FSM.

- `sync_send_all_state_event(FsmRef, Event, Timeout) -> Reply` [page 181]
  Send an event synchronously to a generic FSM.

- `reply(Caller, Reply) -> true` [page 182]
  Send a reply to a caller.

- `send_event_after(Time, Event) -> Ref` [page 182]
  Send a delayed event internally in a generic FSM.

- `start_timer(Time, Msg) -> Ref` [page 182]
  Send a timeout event internally in a generic FSM.

- `cancel_timer(Ref) -> RemainingTime | false` [page 182]
  Cancel an internal timer in a generic FSM.

- `enter_loop(Module, Options, StateName, StateData)` [page 183]
  Enter the gen_fsm receive loop.

- `enter_loop(Module, Options, StateName, StateData, FsmName)` [page 183]
  Enter the gen_fsm receive loop.

- `enter_loop(Module, Options, StateName, StateData, Timeout)` [page 183]
  Enter the gen_fsm receive loop.

- `enter_loop(Module, Options, StateName, StateData, FsmName, Timeout)` [page 183]
  Enter the gen_fsm receive loop.

- `Module:init(Args) -> Result` [page 184]
  Initialize process and internal state name and state data.

- `Module:StateName(Event, StateData) -> Result` [page 184]
  Handle an asynchronous event.

- `Module:handle_event(Event, StateName, StateData) -> Result` [page 185]
  Handle an asynchronous event.
- Module:StateName(Event, From, StateData) -> Result
  [page 185] Handle a synchronous event.
- Module:handle_sync_event(Event, From, StateName, StateData) -> Result
  [page 186] Handle a synchronous event.
- Module:handle_info(Info, StateName, StateData) -> Result
  [page 186] Handle an incoming message.
- Module:terminate(Reason, StateName, StateData)
  [page 187] Clean up before termination.
- Module:code_change(OldVsn, StateName, StateData, Extra) -> {ok, NextStateName, NewStateData}
  [page 187] Update the internal state data during upgrade/downgrade.

**gen_server**

The following functions are exported:

- start_link(Module, Args, Options) -> Result
  [page 189] Create a gen_server process in a supervision tree.
- start_link(ServerName, Module, Args, Options) -> Result
  [page 189] Create a gen_server process in a supervision tree.
- start(Module, Args, Options) -> Result
  [page 190] Create a stand-alone gen_server process.
- start(ServerName, Module, Args, Options) -> Result
  [page 190] Create a stand-alone gen_server process.
- call(ServerRef, Request) -> Reply
  [page 191] Make a synchronous call to a generic server.
- call(ServerRef, Request, Timeout) -> Reply
  [page 191] Make a synchronous call to a generic server.
- multi_call(Name, Request) -> Result
  [page 192] Make a synchronous call to several generic servers.
- multi_call(Nodes, Name, Request) -> Result
  [page 192] Make a synchronous call to several generic servers.
- multi_call(Nodes, Name, Request, Timeout) -> Result
  [page 192] Make a synchronous call to several generic servers.
- cast(ServerRef, Request) -> ok
  [page 193] Send an asynchronous request to a generic server.
- abcast(Name, Request) -> abcast
  [page 193] Send an asynchronous request to several generic servers.
- abcast(Nodes, Name, Request) -> abcast
  [page 193] Send an asynchronous request to several generic servers.
- reply(Client, Reply) -> true
  [page 193] Send a reply to a client.
- enter_loop(Module, Options, State)
  [page 193] Enter the gen_server receive loop.
- enter_loop(Module, Options, State, ServerName)
  [page 194] Enter the gen_server receive loop.
• enter_loop(Module, Options, State, Timeout)  
  [page 194] Enter the gen_server receive loop
• enter_loop(Module, Options, State, ServerName, Timeout)  
  [page 194] Enter the gen_server receive loop
• Module:init(Args) -> Result  
  [page 194] Initialize process and internal state.
• Module:handle_call(Request, From, State) -> Result  
  [page 195] Handle a synchronous request.
• Module:handle_cast(Request, State) -> Result  
  [page 195] Handle an asynchronous request.
• Module:handle_info(Info, State) -> Result  
  [page 196] Handle an incoming message.
• Module:terminate(Reason, State)  
  [page 196] Clean up before termination.
• Module:code_change(OldVsn, State, Extra) -> {ok, NewState}  
  [page 197] Update the internal state during upgrade/downgrade.

io

The following functions are exported:

• put_chars([[IoDevice,] IoData]) -> ok  
  [page 198] Write a list of characters
• nl([IoDevice]) -> ok  
  [page 198] Write a newline
• get_chars([IoDevice,] Prompt, Count) -> string() | eof  
  [page 198] Read a specified number of characters
• get_line([IoDevice,] Prompt) -> string() | eof  
  [page 199] Read a line
• setopts([IoDevice,] Opts) -> ok | {error, Reason}  
  [page 199] Set options
• write([IoDevice,] Term) -> ok  
  [page 200] Write a term
• read([IoDevice,] Prompt) -> Result  
  [page 200] Read a term
• read(IoDevice, Prompt, StartLine) -> Result  
  [page 200] Read a term
• fwrite(Format) ->  
  [page 200] Write formatted output
• fwrite([IoDevice,] Format, Data) -> ok  
  [page 200] Write formatted output
• format(Format) ->  
  [page 200] Write formatted output
• format([IoDevice,] Format, Data) -> ok  
  [page 200] Write formatted output
• fread([IoDevice,] Prompt, Format) -> Result  
  [page 204] Read formatted input
- `scan ErlExprs(Prompt)`:
  - Read and tokenize Erlang expressions
- `scan ErlExprs([IoDevice,] Prompt, StartLine)`:
  - Read and tokenize Erlang expressions
- `scan ErlForm(Prompt)`:
  - Read and tokenize an Erlang form
- `scan ErlForm([IoDevice,] Prompt, StartLine)`:
  - Read and tokenize an Erlang form
- `parse ErlExprs(Prompt)`:
  - Read, tokenize and parse Erlang expressions
- `parse ErlExprs([IoDevice,] Prompt, StartLine)`:
  - Read, tokenize and parse Erlang expressions
- `parse ErlForm(Prompt)`:
  - Read, tokenize and parse an Erlang form
- `parse ErlForm([IoDevice,] Prompt, StartLine)`:
  - Read, tokenize and parse an Erlang form

**io_lib**

The following functions are exported:

- `nl()`:
  - Write a newline
- `write(Term)`:
  - Write a term
- `write(Term, Depth)`:
  - Write a term
- `print(Term)`:
  - Pretty print a term
- `print(Term, Column, LineLength, Depth)`:
  - Pretty print a term
- `fwrite(Format, Data)`:
  - Write formatted output
- `format(Format, Data)`:
  - Write formatted output
- `fread(Format, String)`:
  - Read formatted input
- `fread(Continuation, String, Format)`:
  - Re-entrant formatted reader
- `write_atom(Atom)`:
  - Write an atom
- `write_string(String)`:
  - Write a string
- `write_char(Integer)`:
  - Write a character
- `indentation(String, StartIndent)`:
  - Indentation after printing string
lib

The following functions are exported:

- `char_list(Term) -> bool()`  
  [page 212] Test for a list of characters
- `deep_char_list(Term) -> bool()`  
  [page 212] Test for a deep list of characters
- `printable_list(Term) -> bool()`  
  [page 212] Test for a list of printable characters

lists

The following functions are exported:

- `append(ListOfLists) -> List1`  
  [page 215] Append a list of lists
- `append(List1, List2) -> List3`  
  [page 215] Append two lists
- `concat(Things) -> string()`  
  [page 215] Concatenate a list of atoms
- `delete(Elem, List1) -> List2`  
  [page 216] Delete an element from a list
- `duplicate(N, Elem) -> List`  
  [page 216] Make N copies of element
- `flatlength(DeepList) -> int()`  
  [page 216] Length of flattened deep list
- `flatten(DeepList) -> List`  
  [page 216] Flatten a deep list
- `flatten(DeepList, Tail) -> List`  
  [page 216] Flatten a deep list
- `keydelete(Key, N, TupleList1) -> TupleList2`  
  [page 216] Delete an element from a list of tuples
- `keymember(Key, N, TupleList) -> bool()`  
  [page 217] Test for membership of a list of tuples
- keymerge(N, TupleList1, TupleList2) -> TupleList3
  [page 217] Merge two key-sorted lists of tuples
- keyreplace(Key, N, TupleList1, NewTuple) -> TupleList2
  [page 217] Replace an element in a list of tuples
- keysearch(Key, N, TupleList) -> {value, Tuple} | false
  [page 217] Search for an element in a list of tuples
- keysort(N, TupleList1) -> TupleList2
  [page 217] Sort a list of tuples
- last(List) -> Last
  [page 218] Return last element in a list
- max(List) -> Max
  [page 218] Return maximum element of list
- member(Elem, List) -> bool()
  [page 218] Test for membership of a list
- merge(ListOfLists) -> List1
  [page 218] Merge a list of sorted lists
- merge(List1, List2) -> List3
  [page 218] Merge two sorted lists
- merge(Fun, List1, List2) -> List3
  [page 218] Merge two sorted list
- merge3(List1, List2, List3) -> List4
  [page 219] Merge three sorted lists
- min(List) -> Min
  [page 219] Return minimum element of list
- nth(N, List) -> Elem
  [page 219] Return the Nth element of a list
- nthtail(N, List1) -> Tail
  [page 219] Return the Nth tail of a list
- prefix(List1, List2) -> bool()
  [page 219] Test for list prefix
- reverse(List1) -> List2
  [page 220] Reverse a list
- reverse(List1, Tail) -> List2
  [page 220] Reverse a list appending a tail
- seq(From, To) -> Seq
  [page 220] Generate a sequence of integers
- seq(From, To, Incr) -> Seq
  [page 220] Generate a sequence of integers
- sort(List1) -> List2
  [page 220] Sort a list
- sort(Fun, List1) -> List2
  [page 220] Sort a list
- split(N, List1) -> {List2, List3}
  [page 221] Split a list into two lists
- sublist(List1, Len) -> List2
  [page 221] Return a sub-list of a certain length, starting at the first position
- sublist(List1, Start, Len) -> List2
  [page 221] Return a sub-list starting at a given position and with a given number of elements
- subtract(List1, List2) -> List3
  [page 221] Subtract the element in one list from another list
- suffix(List1, List2) -> bool()
  [page 222] Test for list suffix
- sum(List) -> number()
  [page 222] Return sum of elements in a list
- ukeymerge(N, TupleList1, TupleList2) -> TupleList3
  [page 222] Merge two key-sorted lists of tuples, removing duplicates
- ukeysort(N, TupleList1) -> TupleList2
  [page 222] Sort a list of tuples, removing duplicates
- umerge(ListOfLists) -> List1
  [page 222] Merge a list of sorted lists, removing duplicates
- umerge(List1, List2) -> List3
  [page 222] Merge two sorted lists, removing duplicates
- umerge(Fun, List1, List2) -> List3
  [page 223] Merge two sorted lists, removing duplicates
- umerge3(List1, List2, List3) -> List4
  [page 223] Merge three sorted lists, removing duplicates
- unzip(List1) -> {List2, List3}
  [page 223] Unzip a list of two-tuples into two lists
- unzip3(List1) -> {List2, List3, List4}
  [page 223] Unzip a list of three-tuples into three lists
- usort(List1) -> List2
  [page 223] Sort a list, removing duplicates
- usort(Fun, List1) -> List2
  [page 224] Sort a list, removing duplicates
- zip(List1, List2) -> List3
  [page 224] Zip two lists into a list of two-tuples
- zip3(List1, List2, List3) -> List4
  [page 224] Zip three lists into a list of three-tuples
- zipwith(Combine, List1, List2) -> List3
  [page 224] Zip two lists into one list according to a fun
- zipwith3(Combine, List1, List2, List3) -> List4
  [page 225] Zip three lists into one list according to a fun
- all(Pred, List) -> bool()
  [page 225] Return true if all elements in the list satisfy Pred
- any(Pred, List) -> bool()
  [page 225] Return true if any of the elements in the list satisfies Pred
- dropwhile(Pred, List1) -> List2
  [page 226] Drop elements from a list while a predicate is true
- filter(Pred, List1) -> List2
  [page 226] Choose elements which satisfy a predicate
- flatmap(Fun, List1) -> List2
  [page 226] Map and flatten in one pass
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- `foldl(Fun, Acc0, List) -> Acc1` [page 226] Fold a function over a list
- `foldr(Fun, Acc0, List) -> Acc1` [page 227] Fold a function over a list
- `foreach(Fun, List) -> void()` [page 227] Apply a function to each element of a list
- `keymap(Fun, N, TupleList1) -> TupleList2` [page 227] Map a function over a list of tuples
- `map(Fun, List1) -> List2` [page 228] Map a function over a list
- `mapfoldl(Fun, Acc0, List1) -> {List2, Acc1}` [page 228] Map and fold in one pass
- `mapfoldr(Fun, Acc0, List1) -> {List2, Acc1}` [page 228] Map and fold in one pass
- `partition(Pred, List) -> {Satisfying, NonSatisfying}` [page 228] Partition a list into two lists based on a predicate
- `splitwith(Pred, List) -> {List1, List2}` [page 229] Split a list into two lists based on a predicate
- `takewhile(Pred, List1) -> List2` [page 229] Take elements from a list while a predicate is true

log.mf.h

The following functions are exported:

- `init(Dir, MaxBytes, MaxFiles)` [page 230] Initiate the event handler
- `init(Dir, MaxBytes, MaxFiles, Pred) -> Args` [page 230] Initiate the event handler

math

The following functions are exported:

- `pi() -> float()` [page 231] A useful number
- `sin(X)` [page 231] Diverse math functions
- `cos(X)` [page 231] Diverse math functions
- `tan(X)` [page 231] Diverse math functions
- `asin(X)` [page 231] Diverse math functions
- `acos(X)` [page 231] Diverse math functions
- `atan(X)` [page 231] Diverse math functions
- atan2(Y, X)  
  [page 231] Diverse math functions
- sinh(X)  
  [page 231] Diverse math functions
- cosh(X)  
  [page 231] Diverse math functions
- tanh(X)  
  [page 231] Diverse math functions
- asinh(X)  
  [page 231] Diverse math functions
- acosh(X)  
  [page 231] Diverse math functions
- atanh(X)  
  [page 231] Diverse math functions
- exp(X)  
  [page 231] Diverse math functions
- log(X)  
  [page 231] Diverse math functions
- log10(X)  
  [page 231] Diverse math functions
- pow(X, Y)  
  [page 231] Diverse math functions
- sqrt(X)  
  [page 231] Diverse math functions
- erf(X) -> float()  
- erfc(X) -> float()  
  [page 232] Another error function

**ms_transform**

The following functions are exported:

- parse_transform(Forms, Options) -> Forms  
  [page 242] Transforms Erlang abstract format containing calls to ets/dbg:fun2ms into literal match specifications.
- transform_from_shell(Dialect, Clauses, BoundEnvironment) -> term()  
  [page 242] Used when transforming fun's created in the shell into match specifications.
- format_error(Errcode) -> ErrMessage  
  [page 243] Error formatting function as required by the parse_transform interface.

**orddict**

No functions are exported.
ordsets

No functions are exported.

pg

The following functions are exported:

- create(PgName) -> ok | {error, Reason} [page 246] Create an empty group
- create(PgName, Node) -> ok | {error, Reason} [page 246] Create an empty group on another node
- join(PgName, Pid) -> Members [page 246] Join a pid to a process group
- send(PgName, Msg) -> void() [page 247] Send a message to all members of a process group
- esend(PgName, Msg) -> void() [page 247] Send a message to all members of a process group, except ourselves
- members(PgName) -> Members [page 247] Return a list of all members of a process group

pool

The following functions are exported:

- start(Name) -> [page 248] Start a new pool
- start(Name, Args) -> Nodes [page 248] Start a new pool
- attach(Node) -> allreadyattached | attached [page 248] Ensure that a pool master is running
- stop() -> stopped [page 249] Stop the pool and kill all the slave nodes
- getnodes() -> Nodes [page 249] Return a list of the current member nodes of the pool
- pspawn(Mod, Fun, Args) -> pid() [page 249] Spawn a process on the pool node with expected lowest future load
- pspawn_link(Mod, Fun, Args) -> pid() [page 249] Spawn and link to a process on the pool node with expected lowest future load
- getnode() -> node() [page 249] Return the node with the expected lowest future load
proc:lib

The following functions are exported:

- `spawn(Fun) -> Pid`  
  [page 250] Spawn a new process
- `spawn(Node,Fun) -> Pid`  
  [page 250] Spawn a new process
- `spawn(Module,Func,Args) -> Pid`  
  [page 250] Spawn a new process
- `spawn(Node,Module,Func,Args) -> Pid`  
  [page 250] Spawn a new process
- `spawn_link(Fun) -> Pid`  
  [page 250] Spawn a new process and set a link.
- `spawn_link(Node,Fun) -> Pid`  
  [page 250] Spawn a new process and set a link.
- `spawn_link(Module,Func,Args) -> Pid`  
  [page 250] Spawn a new process and set a link.
- `spawn_link(Node,Module,Func,Args) -> Pid`  
  [page 250] Spawn a new process and set a link.
- `spawn_opt(Fun,Opts) -> Pid`  
  [page 251] Spawn a new process with given options.
- `spawn_opt(Node,Fun,Opts) -> Pid`  
  [page 251] Spawn a new process with given options.
- `spawn_opt(Module,Func,Args,Opts) -> Pid`  
  [page 251] Spawn a new process with given options.
- `spawn_opt(Node,Module,Func,Args,Opts) -> Pid`  
  [page 251] Spawn a new process with given options.
- `start(Module,Func,Args) -> Ret`  
  [page 251] Start a new process synchronously.
- `start(Module,Func,Args,Time) -> Ret`  
  [page 251] Start a new process synchronously.
- `start(Module,Func,Args,Time,SpawnOpts) -> Ret`  
  [page 251] Start a new process synchronously.
- `start_link(Module,Func,Args) -> Ret`  
  [page 251] Start a new process synchronously.
- `start_link(Module,Func,Args,Time) -> Ret`  
  [page 251] Start a new process synchronously.
- `start_link(Module,Func,Args,Time,SpawnOpts) -> Ret`  
  [page 251] Start a new process synchronously.
- `init_ack(Parent, Ret) -> void()`  
  [page 252] Used by a process when it has started.
- `init_ack(Ret) -> void()`  
  [page 252] Used by a process when it has started.
- `format(CrashReport) -> string()`  
- `initial_call(PidOrPinfo) -> {Module,Function,Args} | Fun | false`

[page 253] Extract the initial call of a `proc_lib` spawned process.

- `translate_initial_call(PidOrPinfo) -> {Module,Function,Arity} | Fun`

[page 253] Extract and translate the initial call of a `proc_lib` spawned process.

- `hibernate(Module, Function, Arguments)`

[page 253] Hibernate the current process until a message is sent to it.

proplists

The following functions are exported:

- `append_values(Key, List) -> List`

[page 255]

- `compact(List) -> List`

[page 255]

- `delete(Key, List) -> List`

[page 255]

- `expand(Expansions, List) -> List`

[page 255]

- `get_all_values(Key, List) -> [term()]`

[page 256]

- `get_bool(Key, List) -> bool()`

[page 256]

- `get_keys(List) -> [term()]`

[page 256]

- `get_value(Key, List) -> term()`

[page 257]

- `get_value(Key, List, Default) -> term()`

[page 257]

- `is_defined(Key, List) -> bool()`

[page 257]

- `lookup(Key, List) -> none | tuple()`

[page 257]

- `lookup_all(Key, List) -> [tuple()]`

[page 257]

- `normalize(List, Stages) -> List`

[page 257]

- `property(Property) -> Property`

[page 258]

- `property(Key, Value) -> Property`

[page 258]

- `split(List, Keys) -> {Lists, Rest}`

[page 258]

- `substitute_aliases(Aliases, List) -> List`

[page 259]

- `substitute_negations(Negations, List) -> List`

[page 259]

- `unfold(List) -> List`

[page 259]
qlc

The following functions are exported:

- `append(QHL) -> QH`
  [page 266] Return a query handle.
- `append(QH1, QH2) -> QH3`
  [page 266] Return a query handle.
- `cursor(QueryHandleOrList [, Options]) -> QueryCursor`
  [page 266] Create a query cursor.
- `delete_cursor(QueryCursor) -> ok`
  [page 266] Delete a query cursor.
- `eval(QueryHandleOrList [, Options]) -> Answers | Error`
  [page 266] Return all answers to a query.
- `e(QueryHandleOrList [, Options]) -> Answers`
  [page 266] Return all answers to a query.
- `fold(Function, Acc0, QueryHandleOrList [, Options]) -> Acc1 | Error`
  [page 267] Fold a function over the answers to a query.
- `format_error(Error) -> Chars`
  [page 267] Return an English description of a an error tuple.
- `info(QueryHandleOrList [, Options]) -> Info`
  [page 267] Return code describing a query handle.
- `keysort(KeyPos, QH1 [, SortOptions]) -> QH2`
  [page 268] Return a query handle.
- `next_answers(QueryCursor [, NumberOfAnswers]) -> Answers | Error`
  [page 268] Return some or all answers to a query.
- `q(QueryListComprehension [, Options]) -> QueryHandle`
  [page 269] Return a handle for a query list comprehension.
- `sort(QH1 [, SortOptions]) -> QH2`
  [page 270] Return a query handle.
- `string_to_handle(QueryString [, Options [, Bindings]]]) -> QueryHandle | Error`
  [page 270] Return a handle for a query list comprehension.
- `table(TraverseFun, Options) -> QueryHandle`
  [page 271] Return a query handle for a table.

queue

The following functions are exported:

- `cons(Item, Q1) -> Q2`
  [page 274] Insert an item at the head of a queue
- `daeh(Q) -> Item`
  [page 274] Return the last item of a queue
- `from_list(L) -> queue()`
  [page 274] Convert a list to a queue
- `head(Q) -> Item`
  [page 274] Return the item at the head of a queue
The following functions are exported:

- `in(Item, Q1) -> Q2`  
  [page 274] Insert an item at the tail of a queue

- `in_r(Item, Q1) -> Q2`  
  [page 275] Insert an item at the head of a queue

- `init(Q1) -> Q2`  
  [page 275] Remove the last item from a queue

- `is_empty(Q) -> true | false`  
  [page 275] Test if a queue is empty

- `join(Q1, Q2) -> Q3`  
  [page 275] Join two queues

- `lait(Q1) -> Q2`  
  [page 275] Remove the last item from a queue

- `last(Q) -> Item`  
  [page 275] Return the last item of a queue

- `len(Q) -> N`  
  [page 275] Get the length of a queue

- `new() -> Q`  
  [page 276] Create a new empty FIFO queue

- `out(Q1) -> Result`  
  [page 276] Remove the head item from a queue

- `out_r(Q1) -> Result`  
  [page 276] Remove the last item from a queue

- `reverse(Q1) -> Q2`  
  [page 276] Reverse a queue

- `snoc(Q1, Item) -> Q2`  
  [page 276] Insert an item at the end of a queue

- `split(N, Q1) -> {Q2, Q3}`  
  [page 276] Split a queue in two

- `tail(Q1) -> Q2`  
  [page 276] Remove the head item from a queue

- `to_list(Q) -> list()`  
  [page 277] Convert a queue to a list

**random**

The following functions are exported:

- `seed() -> ran()`  
  [page 278] Seeds random number generation with default values

- `seed(A1, A2, A3) -> ran()`  
  [page 278] Seeds random number generator

- `seed0() -> ran()`  
  [page 278] Return default state for random number generation

- `uniform() -> float()`  
  [page 278] Return a random float

- `uniform(N) -> int()`  
  [page 278] Return a random integer
• `uniform_s(State0) -> {float(), State1}`
  [page 279] Return a random float

• `uniform_s(N, State0) -> {int(), State1}`
  [page 279] Return a random integer

**regexp**

The following functions are exported:

• `match(String, RegExp) -> MatchRes`
  [page 280] Match a regular expression

• `first_match(String, RegExp) -> MatchRes`
  [page 280] Match a regular expression

• `matches(String, RegExp) -> MatchRes`
  [page 280] Match a regular expression

• `sub(String, RegExp, New) -> SubRes`
  [page 281] Substitute the first occurrence of a regular expression

• `gsub(String, RegExp, New) -> SubRes`
  [page 281] Substitute all occurrences of a regular expression

• `split(String, RegExp) -> SplitRes`
  [page 281] Split a string into fields

• `sh_to_awk(ShRegExp) -> AwkRegExp`
  [page 282] Convert an sh regular expression into an AWK one

• `parse(RegExp) -> ParseRes`
  [page 282] Parse a regular expression

• `format_error(ErrorDescriptor) -> Chars`
  [page 282] Format an error descriptor

**sets**

The following functions are exported:

• `new() -> Set`
  [page 285] Return an empty set

• `is_set(Set) -> bool()`
  [page 285] Test for an Set

• `size(Set) -> int()`
  [page 285] Return the number of elements in a set

• `to_list(Set) -> List`
  [page 285] Convert an Set into a list

• `from_list(List) -> Set`
  [page 285] Convert a list into an Set

• `is_element(Element, Set) -> bool()`
  [page 285] Test for membership of an Set

• `add_element(Element, Set1) -> Set2`
  [page 286] Add an element to an Set

• `del_element(Element, Set1) -> Set2`
  [page 286] Remove an element from an Set
- union(Set1, Set2) -> Set3  
  [page 286] Return the union of two Sets
- union(SetList) -> Set  
  [page 286] Return the union of a list of Sets
- intersection(Set1, Set2) -> Set3  
  [page 286] Return the intersection of two Sets
- intersection(SetList) -> Set  
  [page 286] Return the intersection of a list of Sets
- subtract(Set1, Set2) -> Set3  
  [page 286] Return the difference of two Sets
- is_subset(Set1, Set2) -> bool()  
  [page 287] Test for subset
- fold(Function, Acc0, Set) -> Acc1  
  [page 287] Fold over set elements
- filter(Pred, Set1) -> Set2  
  [page 287] Filter set elements

shell

The following functions are exported:
- history(N) -> integer()  
  [page 296] Sets the number of previous commands to keep
- results(N) -> integer()  
  [page 296] Sets the number of previous commands to keep
- start_restricted(Module) -> ok  
  [page 296] Exits a normal shell and starts a restricted shell.
- stop_restricted() -> ok  
  [page 296] Exits a restricted shell and starts a normal shell.

shell_default

No functions are exported.

slave

The following functions are exported:
- start(Host) ->  
  [page 298] Start a slave node on a host
- start(Host, Name) ->  
  [page 298] Start a slave node on a host
- start(Host, Name, Args) -> {ok, Node} | {error, Reason}  
  [page 298] Start a slave node on a host
- start_link(Host) ->  
  [page 299] Start and link to a slave node on a host
• `start_link(Host, Name) ->` [page 299] Start and link to a slave node on a host.
• `start_link(Host, Name, Args) -> {ok, Node} | {error, Reason}` [page 299] Start and link to a slave node on a host.
• `stop(Node) -> ok` [page 300] Stop (kill) a node.
• `pseudo([Master | ServerList]) -> ok` [page 300] Start a number of pseudo servers.
• `pseudo(Master, ServerList) -> ok` [page 300] Start a number of pseudo servers.
• `relay(Pid)` [page 300] Run a pseudo server.

**sofs**

The following functions are exported:

• `a_function(Tuples [, Type]) -> Function` [page 305] Create a function.
• `canonical_relation(SetOfSets) -> BinRel` [page 305] Return the canonical map.
• `composite(Function1, Function2) -> Function3` [page 305] Return the composite of two functions.
• `constant_function(Set, AnySet) -> Function` [page 305] Create the function that maps each element of a set onto another set.
• `converse(BinRel1) -> BinRel2` [page 306] Return the converse of a binary relation.
• `difference(Set1, Set2) -> Set3` [page 306] Return the difference of two sets.
• `digraph_to_family(Graph [, Type]) -> Family` [page 306] Create a family from a directed graph.
• `domain(BinRel) -> Set` [page 306] Return the domain of a binary relation.
• `drestriction(BinRel1, Set) -> BinRel2` [page 306] Return a restriction of a binary relation.
• `drestriction(SetFun, Set1, Set2) -> Set3` [page 307] Return a restriction of a relation.
• `empty_set() -> Set` [page 307] Return the untyped empty set.
• `extension(BinRel1, Set, AnySet) -> BinRel2` [page 307] Extend the domain of a binary relation.
• `family(Tuples [, Type]) -> Family` [page 308] Create a family of subsets.
• `family_difference(Family1, Family2) -> Family3` [page 308] Return the difference of two families.
• `family_domain(Family1) -> Family2` [page 308] Return a family of domains.
- `family_field(Family1) -> Family2`
  [page 308] Return a family of fields.
- `family_intersection(Family1) -> Family2`
  [page 309] Return the intersection of a family of sets of sets.
- `family_intersection(Family1, Family2) -> Family3`
  [page 309] Return the intersection of two families.
- `family_projection(SetFun, Family1) -> Family2`
  [page 309] Return a family of modified subsets.
- `family_range(Family1) -> Family2`
  [page 309] Return a family of ranges.
- `family_specification(Fun, Family1) -> Family2`
  [page 310] Select a subset of a family using a predicate.
- `family_to_digraph(Family [, GraphType]) -> Graph`
  [page 310] Create a directed graph from a family.
- `family_to_relation(Family) -> BinRel`
  [page 310] Create a binary relation from a family.
- `family_union(Family1) -> Family2`
  [page 311] Return the union of a family of sets of sets.
- `family_union(Family1, Family2) -> Family3`
  [page 311] Return the union of two families.
- `field(BinRel) -> Set`
  [page 311] Return the field of a binary relation.
- `from_external(ExternalSet, Type) -> AnySet`
  [page 311] Create a set.
- `from_sets(ListOfSets) -> Set`
  [page 311] Create a set out of a list of sets.
- `from_sets(TupleOfSets) -> Ordset`
  [page 311] Create an ordered set out of a tuple of sets.
- `from_term(Term [, Type]) -> AnySet`
  [page 312] Create a set.
- `image(BinRel, Set1) -> Set2`
  [page 313] Return the image of a set under a binary relation.
- `intersection(SetOfSets) -> Set`
  [page 313] Return the intersection of a set of sets.
- `intersection(Set1, Set2) -> Set3`
  [page 313] Return the intersection of two sets.
- `intersection_of_family(Family) -> Set`
  [page 313] Return the intersection of a family.
- `inverse(Function1) -> Function2`
  [page 313] Return the inverse of a function.
- `inverse_image(BinRel, Set1) -> Set2`
  [page 314] Return the inverse image of a set under a binary relation.
- `is_a_function(BinRel) -> Bool`
  [page 314] Test for a function.
- `is_disjoint(Set1, Set2) -> Bool`
  [page 314] Test for disjoint sets.
- `isEmpty(AnySet)` -> `Bool` (page 314) Test for an empty set.
- `isEqual(AnySet1, AnySet2)` -> `Bool` (page 314) Test two sets for equality.
- `isSet(AnySet)` -> `Bool` (page 314) Test for an unordered set.
- `isSofsSet(Term)` -> `Bool` (page 315) Test for an unordered set.
- `isSubset(Set1, Set2)` -> `Bool` (page 315) Test two sets for subset.
- `isType(Term)` -> `Bool` (page 315) Test for a type.
- `join(Relation1, I, Relation2, J)` -> `Relation3` (page 315) Return the join of two relations.
- `multipleRelativeProduct(TupleOfBinRels, BinRel1)` -> `BinRel2` (page 315) Return the multiple relative product of a tuple of binary relations and a relation.
- `noElements(ASet)` -> `NoElements` (page 316) Return the number of elements of a set.
- `partition(SetOfSets)` -> `Partition` (page 316) Return the coarsest partition given a set of sets.
- `partition(SetFun, Set)` -> `Partition` (page 316) Return a partition of a set.
- `partition(SetFun, Set1, Set2)` -> `{Set3, Set4}` (page 316) Return a partition of a set.
- `partitionFamily(SetFun, Set)` -> `Family` (page 317) Return a family indexing a partition.
- `product(TupleOfSets)` -> `Relation` (page 317) Return the Cartesian product of a tuple of sets.
- `product(Set1, Set2)` -> `BinRel` (page 317) Return the Cartesian product of two sets.
- `projection(SetFun, Set1)` -> `Set2` (page 318) Return a set of substituted elements.
- `range(BinRel)` -> `Set` (page 318) Return the range of a binary relation.
- `relation(Tuples [, Type])` -> `Relation` (page 318) Create a relation.
- `relationToFamily(BinRel)` -> `Family` (page 318) Create a family from a binary relation.
- `relativeProduct(TupleOfBinRels [, BinRel1])` -> `BinRel2` (page 319) Return the relative product of a tuple of binary relations and a binary relation.
- `relativeProduct(BinRel1, BinRel2)` -> `BinRel3` (page 319) Return the relative product of two binary relations.
- `relativeProduct1(BinRel1, BinRel2)` -> `BinRel3` (page 319) Return the relative product of two binary relations.
- `restriction(BinRel1, Set) -> BinRel2`
  [page 319] Return a restriction of a binary relation.

- `restriction(SetFun, Set1, Set2) -> Set3`
  [page 320] Return a restriction of a set.

- `set(Terms [, Type]) -> Set`
  [page 320] Create a set of atoms or any type of sets.

- `specification(Fun, Set1) -> Set2`
  [page 320] Select a subset using a predicate.

- `strict_relation(BinRel1) -> BinRel2`
  [page 320] Return the strict relation corresponding to a given relation.

- `substitution(SetFun, Set1) -> Set2`
  [page 321] Return a function with a given set as domain.

- `symdiff(Set1, Set2) -> Set3`
  [page 321] Return the symmetric difference of two sets.

- `symmetric_partition(Set1, Set2) -> [{Set3, Set4, Set5}]`
  [page 322] Return a partition of two sets.

- `to_external(AnySet) -> ExternalSet`
  [page 322] Return the elements of a set.

- `to_sets(ASet) -> Sets`
  [page 322] Return a list or a tuple of the elements of set.

- `type(AnySet) -> Type`
  [page 322] Return the type of a set.

- `union(SetOfSets) -> Set`
  [page 322] Return the union of a set of sets.

- `union(Set1, Set2) -> Set3`
  [page 322] Return the union of two sets.

- `union_of_family(Family) -> Set`
  [page 323] Return the union of a family.

- `weak_relation(BinRel1) -> BinRel2`
  [page 323] Return the weak relation corresponding to a given relation.

---

**string**

The following functions are exported:

- `len(String) -> Length`
  [page 324] Return the length of a string

- `equal(String1, String2) -> bool()`
  [page 324] Test string equality

- `concat(String1, String2) -> String3`
  [page 324] Concatenate two strings

- `chr(String, Character) -> Index`
  [page 324] Return the index of the first/last occurrence of Character in String

- `rchr(String, Character) -> Index`
  [page 324] Return the index of the first/last occurrence of Character in String

- `str(String, SubString) -> Index`
  [page 324] Find the index of a substring
- `rstr(String, SubString)`: Find the index of a substring
- `span(String, Chars)`: Span characters at start of string
- `cspan(String, Chars)`: Span characters at start of string
- `substr(String, Start)`: Return a substring of `String`
- `substr(String, Start, Length)`: Return a substring of `String`
- `tokens(String, SeparatorList)`: Split string into tokens
- `chars(Character, Number)`: Returns a string consisting of numbers of characters
- `chars(Character, Number, Tail)`: Returns a string consisting of numbers of characters
- `copies(String, Number)`: Copy a string
- `words(String)`: Count blank separated words
- `words(String, Character)`: Count blank separated words
- `sub_word(String, Number)`: Extract subword
- `sub_word(String, Number, Character)`: Extract subword
- `strip(String)`: Strip leading or trailing characters
- `strip(String, Direction)`: Strip leading or trailing characters
- `strip(String, Direction, Character)`: Strip leading or trailing characters
- `left(String, Number)`: Adjust left end of string
- `left(String, Number, Character)`: Adjust left end of string
- `right(String, Number)`: Adjust right end of string
- `right(String, Number, Character)`: Adjust right end of string
- `centre(String, Number)`: Center a string
- `centre(String, Number, Character)`: Center a string
- `sub_string(String, Start)`: Extract a substring
supervisor

The following functions are exported:

- \texttt{start\_link(Module, Args) -> Result}
  [page 332] Create a supervisor process.
- \texttt{start\_link(SupName, Module, Args) -> Result}
  [page 332] Create a supervisor process.
- \texttt{start\_child(SupRef, ChildSpec) -> Result}
  [page 333] Dynamically add a child process to a supervisor.
- \texttt{terminate\_child(SupRef, Id) -> Result}
  [page 333] Terminate a child process belonging to a supervisor.
- \texttt{delete\_child(SupRef, Id) -> Result}
  [page 334] Delete a child specification from a supervisor.
- \texttt{restart\_child(SupRef, Id) -> Result}
  [page 334] Restart a terminated child process belonging to a supervisor.
- \texttt{which\_children(SupRef) -> [{Id, Child, Type, Modules}]}
  [page 335] Return information about all children specifications and child processes belonging to a supervisor.
- \texttt{check\_childspecs([ChildSpec]) -> Result}
  [page 335] Check if child specifications are syntactically correct.
- \texttt{Module:init(Args) -> Result}
  [page 336] Return a supervisor specification.

supervisor\_bridge

The following functions are exported:

- \texttt{start\_link(Module, Args) -> Result}
  [page 337] Create a supervisor bridge process.
- \texttt{start\_link(SupBridgeName, Module, Args) -> Result}
  [page 337] Create a supervisor bridge process.
- \texttt{Module:init(Args) -> Result}
  [page 338] Initialize process and start subsystem.
- \texttt{Module:terminate(Reason, State)}
  [page 338] Clean up and stop subsystem.
sys

The following functions are exported:

- `log(Name,Flag)`
  [page 341] Log system events in memory
  [page 341] Log system events in memory

- `log(Name,Flag,Timeout) -> ok | {ok, [system_event()]}`
  [page 341] Log system events in memory

- `log_to_file(Name,Flag)`
  [page 341] Log system events to the specified file

- `log_to_file(Name,Flag,Timeout) -> ok | {error, open_file}`
  [page 341] Log system events to the specified file

- `statistics(Name,Flag)`
  [page 341] Enable or disable the collections of statistics

- `statistics(Name,Flag,Timeout) -> ok | {ok, Statistics}`
  [page 341] Enable or disable the collections of statistics

- `trace(Name,Flag)`
  [page 342] Print all system events on standard io

- `trace(Name,Flag,Timeout) -> void()`
  [page 342] Print all system events on standard io

- `no_debug(Name)`
  [page 342] Turn off debugging

- `no_debug(Name,Timeout) -> void()`
  [page 342] Turn off debugging

- `suspend(Name)`
  [page 342] Suspend the process

- `suspend(Name,Timeout) -> void()`
  [page 342] Suspend the process

- `resume(Name)`
  [page 342] Resume a suspended process

- `resume(Name,Timeout) -> void()`
  [page 342] Resume a suspended process

- `change_code(Name, Module, OldVsn, Extra)`
  [page 342] Send the code change system message to the process

- `change_code(Name, Module, OldVsn, Extra, Timeout) -> ok | {error, Reason}`
  [page 342] Send the code change system message to the process

- `get_status(Name)`
  [page 342] Get the status of the process

- `get_status(Name,Timeout) -> {status, Pid, {module, Mod}, [PDict, SysState, Parent, Dbg, Misc]}`
  [page 342] Get the status of the process

- `install(Name, {Func, FuncState})`
  [page 343] Install a debug function in the process

- `install(Name, {Func, FuncState}, Timeout)`
  [page 343] Install a debug function in the process

- `remove(Name, Func)`
  [page 343] Remove a debug function from the process
- remove(Name, Func, Timeout) -> void()
  [page 343] Remove a debug function from the process
- debug_options(Options) -> [dbg_opt()]
  [page 344] Convert a list of options to a debug structure
- get_debug(Item, Debug, Default) -> term()
  [page 344] Get the data associated with a debug option
- handle_debug([dbg_opt()], FormFunc, Extra, Event) -> [dbg_opt()]
  [page 344] Generate a system event
- handle_system_msg(Msg, From, Parent, Module, Debug, Misc)
  [page 344] Take care of system messages
- print_log(Debug) -> void()
  [page 345] Print the logged events in the debug structure
- Mod:system_continue(Parent, Debug, Misc)
  [page 345] Called when the process should continue its execution
- Mod:system.terminate(Reason, Parent, Debug, Misc)
  [page 345] Called when the process should terminate
- Mod:system.code_change(Misc, Module, OldVsn, Extra) -> {ok, NMisc}
  [page 345] Called when the process should perform a code change

**timer**

The following functions are exported:

- start() -> ok
  [page 347] Start a global timer server (named timer_server).
- apply_after(Time, Module, Function, Arguments) -> {ok, Tref} | {error, Reason}
- send_after(Time, Pid, Message) -> {ok, TRef} | {error, Reason}
  [page 347] Send Message to Pid after a specified Time.
- send_after(Time, Message) -> {ok, TRef} | {error, Reason}
  [page 347] Send Message to Pid after a specified Time.
- exit_after(Time, Pid, Reason1) -> {ok, TRef} | {error, Reason2}
  [page 348] Send an exit signal with Reason after a specified Time.
- exit_after(Time, Reason1) -> {ok, TRef} | {error, Reason2}
  [page 348] Send an exit signal with Reason after a specified Time.
- kill_after(Time, Pid) -> {ok, TRef} | {error, Reason2}
  [page 348] Send an exit signal with Reason after a specified Time.
- kill_after(Time) -> {ok, TRef} | {error, Reason2}
  [page 348] Send an exit signal with Reason after a specified Time.
- apply_interval(Time, Module, Function, Arguments) -> {ok, TRef} | {error, Reason}
- send_interval(Time, Pid, Message) -> {ok, TRef} | {error, Reason}
  [page 348] Send Message repeatedly at intervals of Time.
• `send_interval(Time, Message) -> {ok, TRef} | {error, Reason}`  
  [page 348] Send Message repeatedly at intervals of Time.

• `cancel(TRef) -> {ok, cancel} | {error, Reason}`  
  [page 348] Cancel a previously requested timeout identified by TRef.

• `sleep(Time) -> ok`  
  [page 348] Suspend the calling process for Time amount of milliseconds.

• `tc(Module, Function, Arguments) -> {Time, Value}`  
  [page 349] Measure the real time it takes to evaluate apply(Module, Function, Arguments)

• `now_diff(T2, T1) -> Tdiff`  
  [page 349] Calculate time difference between now/0 timestamps

• `seconds(Seconds) -> Milliseconds`  
  [page 349] Convert Seconds to Milliseconds.

• `minutes(Minutes) -> Milliseconds`  
  [page 349] Converts Minutes to Milliseconds.

• `hours(Hours) -> Milliseconds`  
  [page 349] Convert Hours to Milliseconds.

• `hms(Hours, Minutes, Seconds) -> Milliseconds`  
  [page 349] Convert Hours+Minutes+Seconds to Milliseconds.

---

**win32reg**

The following functions are exported:

• `change_key(RegHandle, Key) -> ReturnValue`  
  [page 352] Move to a key in the registry

• `change_key_create(RegHandle, Key) -> ReturnValue`  
  [page 352] Move to a key, create it if it is not there

• `close(RegHandle) -> ReturnValue`  
  [page 352] Close the registry.

• `current_key(RegHandle) -> ReturnValue`  
  [page 352] Return the path to the current key.

• `delete_key(RegHandle) -> ReturnValue`  
  [page 352] Delete the current key

• `delete_value(RegHandle, Name) -> ReturnValue`  
  [page 353] Delete the named value on the current key.

• `expand(String) -> ExpandedString`  
  [page 353] Expand a string with environment variables

• `format_error(ErrorId) -> ErrorString`  
  [page 353] Convert an POSIX errorcode to a string

• `open(OpenModeList) -> ReturnValue`  
  [page 353] Open the registry for reading or writing

• `set_value(RegHandle, Name, Value) -> ReturnValue`  
  [page 353] Set value at the current registry key with specified name.

• `sub_keys(RegHandle) -> ReturnValue`  
  [page 354] Get subkeys to the current key.
• `value(RegHandle, Name) -> ReturnValue`
  [page 354] Get the named value on the current key.
• `values(RegHandle) -> ReturnValue`
  [page 354] Get all values on the current key.
beam_lib provides an interface to files created by the BEAM compiler ("BEAM files"). The format used, a variant of "EA IFF 1985" Standard for Interchange Format Files, divides data into chunks.

Chunk data can be returned as binaries or as compound terms. Compound terms are returned when chunks are referenced by names (atoms) rather than identifiers (strings). The names recognized and the corresponding identifiers are:

- abstract_code ("Abst")
- attributes ("Attr")
- compile_info ("CInf")
- exports ("ExpT")
- labeled_exports ("ExpT")
- imports ("ImpT")
- indexed_imports ("ImpT")
- locals ("LocT")
- labeled_locals ("LocT")
- atoms ("Atom")

**ENCRYPTED ABSTRACT CODE**

The abstract code can be encrypted in order to keep the source code secret, but still be able to use tools such as Xref or Debugger. See [compile(3)] for how to encrypt the abstract code.

To enable tools to use the abstract code, the key must be made available for beam_lib. There are two ways to provide the key:

1) Use the function crypto_key_fun/1 [page 55] to register a fun that will be called whenever beam_lib needs to decrypt the abstract code.

2) Store the key in a text file named .erlang.crypt located in either the current directory or the home directory for the current user. beam_lib will search for and read the .erlang.crypt file if no crypto fun has been registered using crypto_key_fun/1. If the file exists and contains a key, beam_lib will implicitly create a crypto key fun and register it.

The .erlang.crypt file should contain a single list. The elements of the list should be tuples looking like this:

{debug_info, Mode, Module, Key}
Mode is the type of key; currently, the only allowed value is des3_cbc. Module is either an atom, in which case Key will only be used for the module Module, or [], in which case Key will be used for all modules. Key is a non-empty string.

The Key in the first tuple where both Mode and Module matches will be used. Here is an example of an .erlang.crypt file that returns the same key for all modules:

```
[{debug_info, des3_cbc, [], " %{7}|pc/DM6Cga*68$Mw|L#&_Gejr|G""]}.
```

And here is a slightly more complicated example of an .erlang.crypt which provides one key for the module t, and another key for all other modules:

```
[{debug_info, des3_cbc, t, "My KEY"},
 {debug_info, des3_cbc, [], " %{7}|pc/DM6Cga*68$Mw|L#&_Gejr|G""]}.
```

Note: Do not use any of the keys in these examples. Use your own keys.

DATA TYPES

beam() -> Module | Filename | binary()
  Module = atom()
  Filename = string() | atom()

Each of the functions described below accept either the module name, the filename, or a binary containing the beam module.

chunkdata() = {ChunkId, DataB} | {ChunkName, DataT}
  ChunkId = chunkid()
  DataB = binary()
  {ChunkName, DataT} =
    {abstract_code, AbstractCode}
    | {attributes, [{Attribute, [AttributeValue]}]}
    | {compile_info, [[InfoKey, [InfoValue]]]}
    | {exports, [{Function, Arity}]}
    | {labeled_exports, [{Function, Arity, Label}]}
    | {imports, [{Module, Function, Arity}]}
    | {indexed_imports, [{Index, Module, Function, Arity}]}
    | {locals, [[Function, Arity]]}
    | {labeled_locals, [{Function, Arity, Label}]}
    | {atoms, [[integer()], atom()]]}  
  AbstractCode = {AbstVersion, Forms} | no_abstract_code
    AbstVersion = atom()
    Attribute = atom()
    AttributeValue = term()
    Module = Function = atom()
    Arity = int()
    Label = int()
It is not checked that the forms conform to the abstract format indicated by AbstVersion. no_abstract_code means that the "Abst" chunk is present, but empty.

The list of attributes is sorted on Attribute, and each attribute name occurs once in the list. The attribute values occur in the same order as in the file. The lists of functions are also sorted.

chunkid() = "Abst" | "Attr" | "CInf"
  | "ExpT" | "ImpT" | "LocT"
  | "Atom"

chunkname() = abstract_code | attributes | compile_info
  | exports | labeled_exports
  | imports | indexed_imports
  | locals | labeledlocals
  | atoms

chunkref() = chunkname() | chunkid()

Exports

chucks(Beam, [ChunkRef]) -> {ok, {Module, [ChunkData]}} | {error, beam_lib, Reason}

Types:
- Beam = beam()
- ChunkRef = chunkref()
- Module = atom()
- ChunkData = chunkdata()
- Reason = {unknown_chunk, Filename, atom()}
  | {key_missing_or_invalid, Filename, abstract_code}
  | {Reason1 – see info/1
- Filename = string()

Reads chunk data for selected chunks refs. The order of the returned list of chunk data is determined by the order of the list of chunks references.

version(Beam) -> {ok, {Module, [Version]}} | {error, beam_lib, Reason}

Types:
- Beam = beam()
- Module = atom()
- Version = term()
- Reason – see chunks/2

Returns the module version(s). A version is defined by the module attribute -vsn(Vsn). If this attribute is not specified, the version defaults to the checksum of the module. Note that if the version Vsn is not a list, it is made into one, that is {ok, {Module, [Vsn]}} is returned. If there are several -vsn module attributes, the result is the concatenated list of versions. Examples:
1> beam_lib:version(a). % -vsn(1).
   {ok,[a,[1]]}
2> beam_lib:version(b). % -vsn([1]).
   {ok,[b,[1]]}
3> beam_lib:version(c). % -vsn([1]). -vsn(2).
   {ok,[c,[1,2]]}
4> beam_lib:version(d). % no -vsn attribute
   {ok,[d,[275613208176997377698094100858909383631]]}

info(Beam) -> [{Item, Info} | {error, beam_lib, Reason1}]
Types:
- Beam = beam()
- Item, Info - see below
- Reason1 = \{chunk太大, Filename, ChunkId, ChunkSize, FileSize\}
- \{invalid_beam_file, Filename, Pos\}
- \{invalid_chunk, Filename, ChunkId\}
- \{missing_chunk, Filename, ChunkId\}
- \{not_a_beam_file, Filename\}
- \{file_error, Filename, Posix\}
- Filename = string()
- ChunkId = chunkid()
- ChunkSize = FileSize = int()
- Pos = int()
- Posix = posix() - see file(3)
Returns a list containing some information about a BEAM file as tuples \{Item, Info\}:
\{file, Filename\} | \{binary, Binary\} The name (string) of the BEAM file, or the binary from which the information was extracted.
\{module, Module\} The name (atom) of the module.
\{chunks, [[ChunkId, Pos, Size]]\} For each chunk, the identifier (string) and the position and size of the chunk data, in bytes.

cmp(Beam1, Beam2) -> ok | {error, beam_lib, Reason}
Types:
- Beam1 = Beam2 = beam()
- Reason = \{modules不同, Module1, Module2\}
- \{chunks不同, ChunkId\}
- \{Reason1 - see info/1\}
- Module1 = Module2 = atom()
- ChunkId = chunkid()
Compares the contents of two BEAM files. If the module names are the same, and the chunks with the identifiers "Code", "ExpT", "ImpT", "StrT", and "Atom" have the same contents in both files, ok is returned. Otherwise an error message is returned.

cmp_dirs(Dir1, Dir2) -> \{Only1, Only2, Different\} | {error, beam_lib, Reason1}
The `cmp_dirs/2` function compares the BEAM files in two directories. Only files with extension ".beam" are compared. BEAM files that exist in directory `Dir1` (`Dir2`) only are returned in `Only1` (`Only2`). BEAM files that exist on both directories but are considered different by `cmp/2` are returned as pairs `{Filename1, Filename2}` where `Filename1` (`Filename2`) exists in directory `Dir1` (`Dir2`).

```
diff_dirs(Dir1, Dir2) -> ok | {error, beam_lib, Reason1}
```

### Types:

- `Dir1 = Dir2 = string() | atom()`
- `Different = [{Filename1, Filename2}]`
- `Only1 = Only2 = [Filename]`
- `Filename = Filename1 = Filename2 = string()`
- `Reason1` – see `info/1`

The `diff_dirs/2` function compares the BEAM files in two directories the way `cmp_dirs/2` does, but names of files that exist in only one directory or are different are presented on standard output.

```
strip(Beam1) -> ok, [{Module, Beam2}] | {error, beam_lib, Reason1}
```

### Types:

- `Beam1 = Beam2 = beam()`
- `Module = atom()`
- `Reason1` – see `info/1`

The `strip/1` function removes all chunks from a BEAM file except those needed by the loader. In particular, the abstract code is removed.

```
strip_files(Files) -> ok, [{Module, Beam2}] | {error, beam_lib, Reason1}
```

### Types:

- `Files = [Beam1]`
- `Beam1 = beam()`
- `Module = atom()`
- `Beam2 = beam()`
- `Reason1` – see `info/1`

The `strip_files/1` function removes all chunks except those needed by the loader from BEAM files. In particular, the abstract code is removed. The returned list contains one element for each given file name, in the same order as in `Files`.

```
strip_release(Dir) -> ok, [{Module, Filename}] | {error, beam_lib, Reason1}
```

### Types:

- `Dir = string() | atom()`
- `Module = atom()`
- `Filename = string()`
- `Reason1` – see `info/1`
The `strip_release/1` function removes all chunks except those needed by the loader from the BEAM files of a release. Dir should be the installation root directory. For example, the current OTP release can be stripped with the call:
```
beam_lib:strip_release(code:root_dir()).
```

### `format_error(Reason) -> Chars`

**Types:**
- Reason - see other functions
- Chars = [char() | Chars]

Given the error returned by any function in this module, the function `format_error` returns a descriptive string of the error in English. For file errors, the function `file:format_error(Posix)` should be called.

### `crypto_key_fun(CryptoKeyFun) -> ok | {error, Reason}`

**Types:**
- CryptoKeyFun = fun() - see below
- Reason = badfun | exists | term()

The `crypto_key_fun/1` function registers a unary fun that will be called if `beam_lib` needs to read an abstract code chunk that has been encrypted. The fun is held in a process that is started by the function.

If there already is a fun registered when attempting to register a fun, `{error, exists}` is returned.

The fun must handle the following arguments:

- CryptoKeyFun(init): Called when the fun is registered, in the process that holds the fun. Here the crypto key fun can do any necessary initializations. Allowed return values:
  - ok
  - {ok, NewCryptoKeyFun} - NewCryptoKeyFun will be registered instead of CryptoKeyFun.
  - {error, Term} - the registration will aborted and `crypto_key_fun/1` will return `{error, Term}`, where Term can be any term.

- CryptoKeyFun({debug_info, Mode, Module, Filename}): Called when the key is needed for module Module in the file Filename. Mode describes the method of encryption; currently the only allowed value is des3_cbc.
  The fun should return the key as list of characters, or fail if there is no key available.

- CryptoKeyFun(clear): Called just before the fun is unregistered. Do any needed cleanup here. The return value is not important, but will be passed back to the caller of `clear_crypto_key_fun/0`.

### `clear_crypto_key_fun() -> {ok, Result}`

**Types:**
- Result = undefined | term()
Unregisters the crypto key fun and terminates the process holding it, started by crypto_key_fun/1.

The clear_crypto_key_fun/1 either returns {ok, undefined} if there was no crypto key fun registered, or {ok, Term}, where Term is the return value from CryptoKeyFun(clear), see crypto_key_fun/1.
C

Erlang Module

The c module enables users to enter the short form of some commonly used commands.

**Note:**
These functions are are intended for interactive use in the Erlang shell only. The module prefix may be omitted.

**Exports**

- `bt(Pid) -> void()`
  
  Types:
  - `Pid = pid()`
  
  Stack backtrace for a process. Equivalent to `erlang:process_display(Pid, backtrace)`.

- `c(File) -> {ok, Module} | error`
- `c(File, Options) -> {ok, Module} | error`
  
  Types:
  - `File = Filename | Module`
  - `Filename = string() | atom()`
  - `Options = [Opt]` – see `compile:file/2`
  - `Module = atom()`
  
  `c/1,2` compiles and then purges and loads the code for a file. `Options` defaults to `[]`. Compilation is equivalent to:
  
  `compile:file(File, Options ++ [report_errors, report_warnings])`

  Note that purging the code means that any processes lingering in old code for the module are killed without warning. See `code/3` for more information.

- `cd(Dir) -> void()`
  
  Types:
  - `Dir = string() | atom()`
  
  Changes working directory to `Dir`, which may be a relative name, and then prints the name of the new working directory.
 flush() -> void()
    Flushing any messages sent to the shell.

 help() -> void()
    Displays help information: all valid shell internal commands, and commands in this
    module.

 i() -> void()
 ni() -> void()
    i/0 displays information about the system, listing information about all processes. ni/0
does the same, but for all nodes the network.

 i(X, Y, Z) -> void()
    Types:
    • X = Y = Z = int()
    Displays information about a process, Equivalent to \texttt{process_info(pid(X, Y, Z))}, but
    location transparent.

 l(Module) -> void()
    Types:
    • Module = atom()
    Purges and loads, or reloads, a module by calling \texttt{code:purge(Module)} followed by
    \texttt{code:load_file(Module)}.
    Note that purging the code means that any processes lingering in old code for the
    module are killed without warning. See \texttt{code/3} for more information.

 lc(Files) -> ok
    Types:
    • Files = [File]
    • File = Filename | Module
    • Filename = string() | atom()
    • Module = atom()
    Compiles a list of files by calling \texttt{compile:file(File, [report_errors, report_warnings]) for each File in Files.}

 ls() -> void()
    Lists files in the current directory.

 ls(Dir) -> void()
    Types:
- Dir = string() | atom()
  Lists files in directory Dir.

m() -> void()
Displays information about the loaded modules, including the files from which they have been loaded.

m(Module) -> void()
  Types:
  - Module = atom()
  Displays information about Module.

memory() -> [{Type, Size}]
Types:
  - Type, Size - see erlang:memory/0
  Memory allocation information. Equivalent to erlang:memory/0.

memory(Type) -> Size
memory([Type]) -> [{Type, Size}]
  Types:
  - Type, Size - see erlang:memory/0
  Memory allocation information. Equivalent to erlang:memory/1.

nc(File) -> {ok, Module} | error
nc(File, Options) -> {ok, Module} | error
  Types:
  - File = Filename | Module
  - Filename = string() | atom()
  - Options = [Opt] - see compile:file/2
  - Module = atom()
  Compiles and then loads the code for a file on all nodes. Options defaults to [].
  Compilation is equivalent to:
  compile:file(File, Opts ++ [report_errors, report_warnings])

nl(Module) -> void()
  Types:
  - Module = atom()
  Loads Module on all nodes.

pid(X, Y, Z) -> pid()
  Types:
  - X = Y = Z = int()
Converts $x$, $y$, $z$ to the pid $<x.y.z>$. This function should only be used when debugging.

pwd() -> void()

Prints the name of the working directory.

q() -> void()

This function is shorthand for `init:stop()`, that is, it causes the node to stop in a controlled fashion.

regs() -> void()
nregs() -> void()

regs/0 displays information about all registered processes. nregs/0 does the same, but for all nodes in the network.

xm(ModSpec) -> void()

Types:
- ModSpec = Module | Filename
- Module = atom()
- Filename = string()

This function finds undefined functions and unused functions in a module by calling `xref:m/1`.

See Also

erlang(3)
This module provides computation of local and universal time, day-of-the-week, and several time conversion functions.

Time is local when it is adjusted in accordance with the current time zone and daylight saving. Time is universal when it reflects the time at longitude zero, without any adjustment for daylight saving. Universal Coordinated Time (UTC) time is also called Greenwich Mean Time (GMT).

The time functions `local_time/0` and `universal_time/0` provided in this module both return date and time. The reason for this is that separate functions for date and time may result in a date/time combination which is displaced by 24 hours. This happens if one of the functions is called before midnight, and the other after midnight. This problem also applies to the Erlang BIFs `date/0` and `time/0`, and their use is strongly discouraged if a reliable date/time stamp is required.

All dates conform to the Gregorian calendar. This calendar was introduced by Pope Gregory XIII in 1582 and was used in all Catholic countries from this year. Protestant parts of Germany and the Netherlands adopted it in 1698, England followed in 1752, and Russia in 1918 (the October revolution of 1917 took place in November according to the Gregorian calendar).

The Gregorian calendar in this module is extended back to year 0. For a given date, the gregorian days is the number of days up to and including the date specified. Similarly, the gregorian seconds for a given date and time, is the the number of seconds up to and including the specified date and time.

For computing differences between epochs in time, use the functions counting gregorian days or seconds. If epochs are given as local time, they must be converted to universal time, in order to get the correct value of the elapsed time between epochs. Use of the function `time_difference/2` is discouraged.

**DATA TYPES**

date() = {Year, Month, Day}
  Year = int()
  Month = 1..12
  Day = 1..31
Year cannot be abbreviated. Example: 93 denotes year 93, not 1993.
Valid range depends on the underlying OS.
The date tuple must denote a valid date.

time() = {Hour, Minute, Second}
  Hour = 0..23
  Minute = Second = 0..59
Exports

date_to_gregorian_days(Date) -> Days
date_to_gregorian_days(Year, Month, Day) -> Days

Types:
- Date = date()
- Days = int()

This function computes the number of gregorian days starting with year 0 and ending at
the given date.

datetime_to_gregorian_seconds({Date, Time}) -> Seconds

Types:
- Date = date()
- Time = time()
- Seconds = int()

This function computes the number of gregorian seconds starting with year 0 and
ending at the given date and time.

day_of_the_week(Date) -> DayNumber
day_of_the_week(Year, Month, Day) -> DayNumber

Types:
- Date = date()
- DayNumber = 1..7

This function computes the day of the week given Year, Month and Day. The return
value denotes the day of the week as 1: Monday, 2: Tuesday, and so on.

gregorian_days_to_date(Days) -> Date

Types:
- Days = int()
- Date = date()

This function computes the date given the number of gregorian days.

gregorian_seconds_to_datetime(Seconds) -> {Date, Time}

Types:
- Seconds = int()
- Date = date()
- Time = time()

This function computes the date and time from the given number of gregorian seconds.

is_leap_year(Year) -> bool()

This function checks if a year is a leap year.

last_day_of_the_month(Year, Month) -> int()
This function computes the number of days in a month.

`local_time() -> {Date, Time}`

Types:
- `Date = date()`
- `Time = time()`

This function returns the local time reported by the underlying operating system.

`local_time_to_universal_time([Date1, Time1]) -> {Date2, Time2}`

This function converts from local time to Universal Coordinated Time (UTC). `Date1` must refer to a local date after Jan 1, 1970.

**Warning:** This function is deprecated. Use `local_time_to_universal_time_dst/1` instead, as it gives a more correct and complete result. Especially for the period that does not exist since it gets skipped during the switch to daylight saving time, this function still returns a result.

`local_time_to_universal_time_dst([Date1, Time1]) -> [{Date, Time}]`

Types:
- `Date1 = Date = date()`
- `Time1 = Time = time()`

This function converts from local time to Universal Coordinated Time (UTC). `Date1` must refer to a local date after Jan 1, 1970.

The return value is a list of 0, 1 or 2 possible UTC times:
- `[]` For a local `{Date1, Time1}` during the period that is skipped when switching to daylight saving time, there is no corresponding UTC since the local time is illegal - it has never happened.
- `[DstDateTimeUTC, DateTimeUTC]` For a local `{Date1, Time1}` during the period that is repeated when switching from daylight saving time, there are two corresponding UTCs. One for the first instance of the period when daylight saving time is still active, and one for the second instance.
- `[DateTimeUTC]` For all other local times there is only one corresponding UTC.

`now_to_local_time(Now) -> {Date, Time}`

Types:
- `Now = see erlang:now/0`
- `Date = date()`
- `Time = time()`

This function returns local date and time converted from the return value from `erlang:now/0`. 
now_to_universal_time(Now) -> {Date, Time}

Types:
- Now - see erlang:now/0
- Date = date()
- Time = time()

This function returns Universal Coordinated Time (UTC) converted from the return value from erlang:now().

seconds_to_daytime(Seconds) -> {Days, Time}

Types:
- Seconds = Days = int()
- Time = time()

This function transforms a given number of seconds into days, hours, minutes, and seconds. The Time part is always non-negative, but Days is negative if the argument Seconds is.

seconds_to_time(Seconds) -> Time

Types:
- Seconds = int() < 86400
- Time = time()

This function computes the time from the given number of seconds. Seconds must be less than the number of seconds per day (86400).

time_difference(T1, T2) -> {Days, Time}

This function returns the difference between two {Date, Time} tuples. T2 should refer to an epoch later than T1.

Warning:
This function is obsolete. Use the conversion functions for gregorian days and seconds instead.

time_to_seconds(Time) -> Seconds

Types:
- Time = time()
- Seconds = int()

This function computes the number of seconds since midnight up to the specified time.

universal_time() -> {Date, Time}

Types:
- Date = date()
- Time = time()
This function returns the Universal Coordinated Time (UTC) reported by the underlying operating system. Local time is returned if universal time is not available.

universal_time_to_local_time([Date1, Time1]) -> [Date2, Time2]

Types:
- Date1 = Date2 = date()
- Time1 = Time2 = time()

This function converts from Universal Coordinated Time (UTC) to local time. Date1 must refer to a date after Jan 1, 1970.

valid_date(Date) -> bool()
valid_date(Year, Month, Day) -> bool()

Types:
- Date = date()

This function checks if a date is a valid.

Leap Years

The notion that every fourth year is a leap year is not completely true. By the Gregorian rule, a year Y is a leap year if either of the following rules is valid:

- Y is divisible by 4, but not by 100; or
- Y is divisible by 400.

Accordingly, 1996 is a leap year, 1900 is not, but 2000 is.

Date and Time Source

Local time is obtained from the Erlang BIF localtime/0. Universal time is computed from the BIF universaltime/0.

The following facts apply:

- there are 86400 seconds in a day
- there are 365 days in an ordinary year
- there are 366 days in a leap year
- there are 1461 days in a 4 year period
- there are 36524 days in a 100 year period
- there are 146097 days in a 400 year period
- there are 719528 days between Jan 1, 0 and Jan 1, 1970.
The module `dets` provides a term storage on file. The stored terms, in this module called objects, are tuples such that one element is defined to be the key. A Dets table is a collection of objects with the key at the same position stored on a file.

Dets is used by the Mnesia application, and is provided as is for users who are interested in an efficient storage of Erlang terms on disk only. Many applications just need to store some terms in a file. Mnesia adds transactions, queries, and distribution. The size of Dets files cannot exceed 2 GB. If larger tables are needed, Mnesia’s table fragmentation can be used.

There are three types of Dets tables: set, bag and duplicate_bag. A table of type set has at most one object with a given key. If an object with a key already present in the table is inserted, the existing object is overwritten by the new object. A table of type bag has zero or more different objects with a given key. A table of type duplicate_bag has zero or more possibly equal objects with a given key.

Dets tables must be opened before they can be updated or read, and when finished they must be properly closed. If a table has not been properly closed, Dets will automatically repair the table. This can take a substantial time if the table is large. A Dets table is closed when the process which opened the table terminates. If several Erlang processes (users) open the same Dets table, they will share the table. The table is properly closed when all users have either terminated or closed the table. Dets tables are not properly closed if the Erlang runtime system is terminated abnormally.

**Note:**
A `^C` command abnormally terminates an Erlang runtime system in a Unix environment with a break-handler.

Since all operations performed by Dets are disk operations, it is important to realize that a single look-up operation involves a series of disk seek and read operations. For this reason, the Dets functions are much slower than the corresponding Ets functions, although Dets exports a similar interface.

Dets organizes data as a linear hash list and the hash list grows gracefully as more data is inserted into the table. Space management on the file is performed by what is called a buddy system. The current implementation keeps the entire buddy system in RAM, which implies that if the table gets heavily fragmented, quite some memory can be used up. The only way to defragment a table is to close it and then open it again with the repair option set to force.

It is worth noting that the ordered set type present in Ets is not yet implemented by Dets, neither is the limited support for concurrent updates which makes a sequence of `first` and `next` calls safe to use on fixed Ets tables. Both these features will be implemented by Dets in a future release of Erlang/OTP. Until then, the Mnesia
application (or some user implemented method for locking) has to be used to implement safe concurrency. Currently, no library of Erlang/OTP has support for ordered disk based term storage.

Two versions of the format used for storing objects on file are supported by Dets. The first version, 8, is the format always used for tables created by OTP R7 and earlier. The second version, 9, is the default version of tables created by OTP R8 (and later OTP releases). OTP R8 can create version 8 tables, and convert version 8 tables to version 9, and vice versa, upon request.

All Dets functions return {error, Reason} if an error occurs (first/1 and next/2 are exceptions, they exit the process with the error tuple). If given badly formed arguments, all functions exit the process with a badarg message.

Types

access() = read | read_write
auto_save() = infinity | int()
bindings_cont() = tuple()
bool() = true | false
file() = string()
int() = integer() >= 0
keypos() = integer() >= 1
name() = atom() | ref()
no_slots() = integer() >= 0 | default
object() = tuple()
object_cont() = tuple()
select_cont() = tuple()
type() = bag | duplicate_bag | set
version() = 8 | 9 | default

Exports

all() -> [Name]

Types:

- Name = name()

Returns a list of the names of all open tables on this node.

bchunk(Name, Continuation) -> {Continuation2, Data} | '$end_of_table' | {error, Reason}

Types:

- Name = name()
- Continuation = start | cont()
- Continuation2 = cont()
- Data = binary() | tuple()
Returns a list of objects stored in a table. The exact representation of the returned objects is not public. The lists of data can be used for initializing a table by giving the value `bchunk` to the `format` option of the `init_table/3` function. The Mnesia application uses this function for copying open tables.

Unless the table is protected using `safe_fixtable/2`, calls to `bchunk/2` may not work as expected if concurrent updates are made to the table.

The first time `bchunk/2` is called, an initial continuation, the atom `start`, must be provided.

The `bchunk/2` function returns a tuple \( \langle \text{Continuation2}, \text{Data} \rangle \), where \( \text{Data} \) is a list of objects. \( \text{Continuation2} \) is another continuation which is to be passed on to a subsequent call to `bchunk/2`. With a series of calls to `bchunk/2` it is possible to extract all objects of the table.

`bchunk/2` returns '\$end_of_table' when all objects have been returned, or \{error, Reason\} if an error occurs.

```
close(Name) -> ok | {error, Reason}
```

Types:
- `Name` = `name()`

Closes a table. Only processes that have opened a table are allowed to close it. All open tables must be closed before the system is stopped. If an attempt is made to open a table which has not been properly closed, Dets automatically tries to repair the table.

```
delete(Name, Key) -> ok | {error, Reason}
```

Types:
- `Name` = `name()`

Deletes all objects with the key `Key` from the table `Name`.

```
delete_all_objects(Name) -> ok | {error, Reason}
```

Types:
- `Name` = `name()`

Deletes all objects from a table in almost constant time. However, if the table if fixed, `delete_all_objects(T)` is equivalent to `match_delete(T, '_')`.

```
delete_object(Name, Object) -> ok | {error, Reason}
```

Types:
- `Name` = `name()`
- `Object` = `object()`

Deletes all instances of a given object from a table. If a table is of type `bag` or `duplicate_bag`, the `delete/2` function cannot be used to delete only some of the objects with a given key. This function makes this possible.

```
first(Name) -> Key | '\$end_of_table'
```

Types:
Key = term()
Name = name()

Returns the first key stored in the table Name according to the table's internal order, or
'\$end_of_table' if the table is empty.

Unless the table is protected using safe_fixtable/2, subsequent calls to next/2 may
not work as expected if concurrent updates are made to the table.

Should an error occur, the process is exited with an error tuple \{error, Reason\}. The
reason for not returning the error tuple is that it cannot be distinguished from a key.

There are two reasons why first/1 and next/2 should not be used: they are not very
efficient, and they prevent the use of the key '\$end_of_table' since this atom is used
to indicate the end of the table. If possible, the match, match_object, and select
functions should be used for traversing tables.

```
foldl(Function, Acc0, Name) -> Acc1 | {error, Reason}

Types:
  Function = fun(Object, AccIn) -> AccOut
  Acc0 = Acc1 = AccIn = AccOut = term()
  Name = name()
  Object = object()

Calls Function on successive elements of the table Name together with an extra
argument AccIn. The order in which the elements of the table are traversed is
unspecified. Function must return a new accumulator which is passed to the next call.
Acc0 is returned if the table is empty.
```

```
foldr(Function, Acc0, Name) -> Acc1 | {error, Reason}

Types:
  Function = fun(Object, AccIn) -> AccOut
  Acc0 = Acc1 = AccIn = AccOut = term()
  Name = name()
  Object = object()

Calls Function on successive elements of the table Name together with an extra
argument AccIn. The order in which the elements of the table are traversed is
unspecified. Function must return a new accumulator which is passed to the next call.
Acc0 is returned if the table is empty.
```

```
from_ets(Name, EtsTab) -> ok | {error, Reason}

Types:
  Name = name()
  EtsTab = -see ets(3)-

Deletes all objects of the table Name and then inserts all the objects of the Ets table
EtsTab. The order in which the objects are inserted is not specified. Since
ets:safe_fixtable/2 is called the Ets table must be public or owned by the calling
process.
```

```
info(Name) -> InfoList | undefined
```

Types:
- Name = name()
- InfoList = [{Item, Value}]

Returns information about the table Name as a list of {Item, Value} tuples:
- {file_size, int()}, the size of the file in bytes.
- {filename, file()}, the name of the file where objects are stored.
- {keypos, keypos()}, the position of the key.
- {size, int()}, the number of objects stored in the table.
- {type, type()}, the type of the table.

info(Name, Item) -> Value | undefined

Types:
- Name = name()

Returns the information associated with Item for the table Name. In addition to the {Item, Value} pairs defined for info/1, the following items are allowed:
- {access, access()}, the access mode.
- {auto_save, auto_save()}, the auto save interval.
- {bchunk_format, binary()}, an opaque binary describing the format of the objects returned by bchunk/2. The binary can be used as argument to is CompatibleChunkFormat/2. Only available for version 9 tables.
- {hash, Hash}. Describes which BIF is used to calculate the hash values of the objects stored in the Dets table. Possible values of Hash are hash, which implies that the erlang:hash/2 BIF is used, phash, which implies that the erlang:phash/2 BIF is used, and phash2, which implies that the erlang:phash2/1 BIF is used.
- {memory, int()}, the size of the file in bytes. The same value is associated with the item file_size.
- {no_keys, int()}, the number of different keys stored in the table. Only available for version 9 tables.
- {no_objects, int()}, the number of objects stored in the table.
- {no_slots, {Min, Used, Max}}, the number of slots of the table. Min is the minimum number of slots, Used is the number of currently used slots, and Max is the maximum number of slots. Only available for version 9 tables.
- {owner, pid()}, the pid of the process that handles requests to the Dets table.
- {ram_file, bool()}, whether the table is kept in RAM.
- {safe_fixed, SafeFixed}. If the table is fixed, SafeFixed is a tuple [FixedAtTime, [{Pid, RefCount}]]. FixedAtTime is the time when the table was first fixed, and Pid is the pid of the process that fixes the table RefCount times. There may be any number of processes in the list. If the table is not fixed, SafeFixed is the atom false.
- {version, int()}, the version of the format of the table.

init_table(Name, InitFun [, Options]) -> ok | {error, Reason}
Types:
- Name = atom()
- InitFun = fun(Arg) -> Res
- Arg = read | close
- Res = end_of_input | [object()] | term()
- Data = binary() | tuple()

Replaces the existing objects of the table Name with objects created by calling the input function InitFun, see below. The reason for using this function rather than calling insert/2 is that of efficiency. It should be noted that the input functions are called by the process that handles requests to the Dets table, not by the calling process.

When called with the argument read the function InitFun is assumed to return end_of_input when there is no more input, or {Objects, Fun}, where Objects is a list of objects and Fun is a new input function. Any other value Value is returned as an error {error, init_fun, Value}. Each input function will be called exactly once, and should an error occur, the last function is called with the argument close, the reply of which is ignored.

If the type of the table is set and there is more than one object with a given key, one of the objects is chosen. This is not necessarily the last object with the given key in the sequence of objects returned by the input functions. Extra objects should be avoided, or the file will be unnecessarily fragmented. This holds also for duplicated objects stored in tables of type duplicate_bag.

It is important that the table has a sufficient number of slots for the objects. If not, the hash list will start to grow when init_table/2 returns which will significantly slow down access to the table for a period of time. The minimum number of slots is set by the open_file/2 option min_no_slots and returned by the info/2 item no_slots. See also the min_no_slots option below.

The Options argument is a list of {Key, Val} tuples where the following values are allowed:

- {min_no_slots, no_slots()}. Specifies the estimated number of different keys that will be stored in the table. The open_file option with the same name is ignored unless the table is created, and in that case performance can be enhanced by supplying an estimate when initializing the table.
- {format, Format}. Specifies the format of the objects returned by the function InitFun. If Format is term (the default), InitFun is assumed to return a list of tuples. If Format is bchunk, InitFun is assumed to return Data as returned by bchunk/2. This option overrides the min_no_slots option.

\[
\text{insert(Name, Objects)} \rightarrow \text{ok} | \text{error, Reason}
\]

Types:
- Name = name()
- Objects = object() | [object()]

Inserts one or more objects into the table Name. If there already exists an object with the same key as some of the given objects and the table type is set, the old object will be replaced.

\[
\text{insert\_new(Name, Objects)} \rightarrow \text{Bool}
\]
Types:
- Name = name()
- Objects = object() | [object()]
- Bool = bool()

Inserts one or more objects into the table Name. If there already exists an object with the same key as some of the given objects the table is not updated and false is returned, otherwise the objects are inserted and true returned.

\[\text{is\_compatible\_bchunk\_format(Name, BchunkFormat)} \rightarrow \text{Bool}\]

Types:
- Name = name()
- BchunkFormat = binary()
- Bool = bool()

Returns true if it would be possible to initialize the table Name, using init_table/3 with the option \{format, bchunk\}, with objects read with bchunk/2 from some table T such that calling info(T, bchunk_format) returns BchunkFormat.

\[\text{is\_dets\_file(FileName)} \rightarrow \text{Bool} | \{\text{error, Reason}\}\]

Types:
- FileName = file()
- Bool = bool()

Returns true if the file FileName is a Dets table, false otherwise.

\[\text{lookup(Name, Key)} \rightarrow \text{[Object]} | \{\text{error, Reason}\}\]

Types:
- Key = term()
- Name = name()
- Object = object()

Returns a list of all objects with the key Key stored in the table Name. For example:

2> dets:open_file(abc, [{type, bag}]).
\{ok,abc\}
3> dets:insert(abc, \{1,2,3\}).
ok
4> dets:insert(abc, \{1,3,4\}).
ok
5> dets:lookup(abc, 1).
\{\{1,2,3\},\{1,3,4\}\}

If the table is of type set, the function returns either the empty list or a list with one object, as there cannot be more than one object with a given key. If the table is of type bag or duplicate_bag, the function returns a list of arbitrary length.

Note that the order of objects returned is unspecified. In particular, the order in which objects were inserted is not reflected.

\[\text{match(Continuation)} \rightarrow \{\{\text{Match}, \text{Continuation2}\} | \{'end\_of\_table' \mid \{\text{error, Reason}\}\}}\]

Types:
Continuation = Continuation2 = bindings_cont()
Match = [term()]

Matches some objects stored in a table and returns a list of the bindings that match a given pattern in some unspecified order. The table, the pattern, and the number of objects that are matched are all defined by Continuation, which has been returned by a prior call to match/1 or match/3.

When all objects of the table have been matched, '$end_of_table' is returned.

match(Name, Pattern) -> [Match] | {error, Reason}

Types:
- Name = name()
- Pattern = tuple()
- Match = [term()]

Returns for each object of the table Name that matches Pattern a list of bindings in some unspecified order. See ets(3) [page 123] for a description of patterns. If the keypos'th element of Pattern is unbound, all objects of the table are matched. If the keypos'th element is bound, only the objects with the right key are matched.

match(Name, Pattern, N) -> {[Match], Continuation} | '$end_of_table' | {error, Reason}

Types:
- Name = name()
- Pattern = tuple()
- N = default | int()
- Match = [term()]
- Continuation = bindings_cont()

Matches some or all objects of the table Name and returns a list of the bindings that match Pattern in some unspecified order. See ets(3) [page 123] for a description of patterns.

A tuple of the bindings and a continuation is returned, unless the table is empty, in which case '$end_of_table' is returned. The continuation is to be used when matching further objects by calling match/1.

If the keypos'th element of Pattern is bound, all objects of the table are matched. If the keypos'th element is unbound, all objects of the table are matched, N objects at a time. The default, indicated by giving N the value default, is to let the number of objects vary depending on the sizes of the objects. If Name is a version 9 table, all objects with the same key are always matched at the same time which implies that more than N objects may sometimes be matched.

The table should always be protected using safe_fixtable/2 before calling match/3, or errors may occur when calling match/1.

match_delete(Name, Pattern) -> N | {error, Reason}

Types:
- Name = name()
- N = int()
- Pattern = tuple()
Deletes all objects that match Pattern from the table Name, and returns the number of deleted objects. See ets(3) [page 123] for a description of patterns.

If the keypos'th element of Pattern is bound, only the objects with the right key are matched.

match_object(Continuation) -> [[Object], Continuation2] | '$end_of_table' | {error, Reason}

Types:
- Continuation = Continuation2 = object_cont()
- Object = object()

Returns a list of some objects stored in a table that match a given pattern in some unspecified order. The table, the pattern, and the number of objects that are matched are all defined by Continuation, which has been returned by a prior call to match_object/1 or match_object/3.

When all objects of the table have been matched, '$end_of_table' is returned.

match_object(Name, Pattern) -> [Object] | {error, Reason}

Types:
- Name = name()
- Pattern = tuple()
- Object = object()

Returns a list of all objects of the table Name that match Pattern in some unspecified order. See ets(3) [page 123] for a description of patterns.

If the keypos'th element of Pattern is unbound, all objects of the table are matched. If the keypos'th element of Pattern is bound, only the objects with the right key are matched.

Using the match_object functions for traversing all objects of a table is more efficient than calling first/1 and next/2 or slot/2.

match_object(Name, Pattern, N) -> [[Object], Continuation] | '$end_of_table' | {error, Reason}

Types:
- Name = name()
- Pattern = tuple()
- N = default | int()
- Object = object()
- Continuation = object_cont()
Matches some or all objects stored in the table Name and returns a list of the objects that match Pattern in some unspecified order. See ets(3) [page 123] for a description of patterns.

A list of objects and a continuation is returned, unless the table is empty, in which case `$end_of_table` is returned. The continuation is to be used when matching further objects by calling match\_object/1.

If the keypos'th element of Pattern is bound, all objects of the table are matched. If the keypos'th element is unbound, all objects of the table are matched, N objects at a time. The default, indicated by giving N the value default, is to let the number of objects vary depending on the sizes of the objects. If Name is a version 9 table, all matching objects with the same key are always returned in the same reply which implies that more than N objects may sometimes be returned.

The table should always be protected using safe\_fixtable/2 before calling match\_object/3, or errors may occur when calling match\_object/1.

member(Name, Key) -> Bool | {error, Reason}

Types:
- Name = name()
- Key = term()
- Bool = bool()

Works like lookup/2, but does not return the objects. The function returns true if one or more elements of the table has the key Key, false otherwise.

next(Name, Key1) -> Key2 | `$end_of_table`

Types:
- Name = name()
- Key1 = Key2 = term()

Returns the key following Key1 in the table Name according to the table's internal order, or `$end_of_table` if there is no next key. Should an error occur, the process is exited with an error tuple {error, Reason}. Use first/1 to find the first key in the table.

open\_file(Filename) -> {ok, Reference} | {error, Reason}

Types:
- FileName = file()
- Reference = ref()

Opens an existing table. If the table has not been properly closed, the error {error, need\_repair} is returned. The returned reference is to be used as the name of the table. This function is most useful for debugging purposes.

open\_file(Name, Args) -> {ok, Name} | {error, Reason}

Types:
- Name = atom()
Opens a Dets table. An empty Dets table is created if no file exists.
The atom \texttt{Name} is the name of the table. The table name must be provided in all subsequent operations on the table. The name can be used by other processes as well, and several process can share one table.

If two processes open the same table by giving the same name and arguments, then the table will have two users. If one user closes the table, it still remains open until the second user closes the table.

The \texttt{Args} argument is a list of \{\texttt{Key}, \texttt{Val}\} tuples where the following values are allowed:

- \{\texttt{access}, \texttt{access()}\}. It is possible to open existing tables in read-only mode. A table which is opened in read-only mode is not subjected to the automatic file reparation algorithm if it is later opened after a crash. The default value is \texttt{read_write}.

- \{\texttt{autosave}, \texttt{auto_save()}\}, the auto save interval. If the interval is an integer \texttt{Time}, the table is flushed to disk whenever it is not accessed for \texttt{Time} milliseconds. A table that has been flushed will require no reparation when reopened after an uncontrolled emulator halt. If the interval is the atom \texttt{infinity}, auto save is disabled. The default value is 180000 (3 minutes).

- \{\texttt{estimated_no_objects}, \texttt{int()}\}. Equivalent to the \texttt{min_no_slots} option.

- \{\texttt{file}, \texttt{file()}\}, the name of the file to be opened. The default value is the name of the table.

- \{\texttt{max_no_slots}, \texttt{no_slots()}\}, the maximum number of slots that will be used. The default value is 2 M, and the maximal value is 32 M. Note that a higher value may increase the fragmentation of the table, and conversely, that a smaller value may decrease the fragmentation, at the expense of execution time. Only available for version 9 tables.

- \{\texttt{min_no_slots}, \texttt{no_slots()}\}. A application performance can be enhanced with this flag by specifying, when the table is created, the estimated number of different keys that will be stored in the table. The default value as well as the minimum value is 256.

- \{\texttt{keypos}, \texttt{keypos()}\}, the position of the element of each object to be used as key. The default value is 1. The ability to explicitly state the key position is most convenient when we want to store Erlang records in which the first position of the record is the name of the record type.

- \{\texttt{ram_file}, \texttt{bool()}\}, whether the table is to be kept in RAM. Keeping the table in RAM may sound like an anomaly, but can enhance the performance of applications which open a table, insert a set of objects, and then close the table. When the table is closed, its contents are written to the disk file. The default value is \texttt{false}.

- \{\texttt{repair}, \texttt{Value}\}. \texttt{Value} can be either a \texttt{bool()} or the atom \texttt{force}. The flag specifies whether the Dets server should invoke the automatic file reparation algorithm. The default is \texttt{true}. If \texttt{false} is specified, there is no attempt to repair the file and \{\texttt{error}, \texttt{need_repair}\} is returned if the table needs to be repaired. The value \texttt{force} means that a reparation will take place even if the table has been properly closed. This is how to convert tables created by older versions of STDLIB. An example is tables hashed with the deprecated \texttt{erlang:hash/2} BIF. Tables created with Dets from a STDLIB version of 1.8.2 and later use the \texttt{erlang:phash/2} function or the \texttt{erlang:phash2/1} function, which is preferred. The \texttt{repair} option is ignored if the table is already open.
- \{type, type()\}, the type of the table. The default value is set.
- \{version, version()\}, the version of the format used for the table. The default value is 9. Tables on the format used before OTP R8 can be created by giving the value 8. A version 8 table can be converted to a version 9 table by giving the options \{version,9\} and \{repair,force\}.

pid2name(Pid) -> \{ok, Name\} | undefined

Types:
- Name = name()
- Pid = pid()

Returns the name of the table given the pid of a process that handles requests to a table, or undefined if there is no such table.

This function is meant to be used for debugging only.

repair_continuation(Continuation, MatchSpec) -> Continuation2

Types:
- Continuation = Continuation2 = select_cont()
- MatchSpec = match_spec()

This function can be used to restore an opaque continuation returned by select/3 or select/1 if the continuation has passed through external term format (been sent between nodes or stored on disk).

The reason for this function is that continuation terms contain compiled match specifications and therefore will be invalidated if converted to external term format. Given that the original match specification is kept intact, the continuation can be restored, meaning it can once again be used in subsequent select/1 calls even though it has been stored on disk or on another node.

See also ets(3) for further explanations and examples.

**Note:**

This function is very rarely needed in application code. It is used by Mnesia to implement distributed select/3 and select/1 sequences. A normal application would either use Mnesia or keep the continuation from being converted to external format.

The reason for not having an external representation of compiled match specifications is performance. It may be subject to change in future releases, while this interface will remain for backward compatibility.

safe_fixtable(Name, Fix)

Types:
- Name = name()
- Fix = bool()
If `Fix` is true, the table `Name` is fixed (once more) by the calling process, otherwise the table is released. The table is also released when a fixing process terminates.

If several processes fix a table, the table will remain fixed until all processes have released it or terminated. A reference counter is kept on a per process basis, and N consecutive fixes require N releases to release the table.

It is not guaranteed that calls to `first/1`, `next/2`, `select` and match functions work as expected even if the table has been fixed; the limited support for concurrency implemented in Ets has not yet been implemented in Dets. Fixing a table currently only disables resizing of the hash list of the table.

If objects have been added while the table was fixed, the hash list will start to grow when the table is released which will significantly slow down access to the table for a period of time.

**select(Continuation) -> {Selection, Continuation2} | '$end_of_table' | {error, Reason}**

Types:
- `Continuation = Continuation2 = select_cont()`
- `Selection = [term()]`

Returns the results of applying a match specification to some objects stored in a table. The table, the match specification, and the number of objects that are matched are all defined by `Continuation`, which has been returned by a prior call to `select/1` or `select/3`.

When all objects of the table have been matched, '$end_of_table' is returned.

**select(Name, MatchSpec) -> Selection | {error, Reason}**

Types:
- `Name = name()`  
- `MatchSpec = match_spec()`  
- `Selection = [term()]`

Returns the results of applying the match specification `MatchSpec` to all or some objects stored in the table `Name`. The order of the objects is not specified. See the ERTS User's Guide for a description of match specifications.

If the `keypos` element of `MatchSpec` is unbound, the match specification is applied to all objects of the table. If the `keypos` element is bound, the match specification is applied to the objects with the right key(s) only.

Using the `select` functions for traversing all objects of a table is more efficient than calling `first/1` and `next/2` or `slot/2`.

**select(Name, MatchSpec, N) -> {Selection, Continuation} | '$end_of_table' | {error, Reason}**

Types:
- `Name = name()`  
- `MatchSpec = match_spec()`  
- `N = default | int()`  
- `Selection = [term()]`
- `Continuation = select_cont()`
Returns the results of applying the match specification \texttt{MatchSpec} to some or all objects stored in the table \texttt{Name}. The order of the objects is not specified. See the ERTS User's Guide for a description of match specifications.

A tuple of the results of applying the match specification and a continuation is returned, unless the table is empty, in which case \texttt{'$end_of_table'} is returned. The continuation is to be used when matching further objects by calling \texttt{select/1}.

If the keypos'th element of \texttt{MatchSpec} is bound, the match specification is applied to all objects of the table with the right key(s). If the keypos'th element of \texttt{MatchSpec} is unbound, the match specification is applied to all objects of the table, \texttt{N} objects at a time. The default, indicated by giving \texttt{N} the value \texttt{default}, is to let the number of objects vary depending on the sizes of the objects. If \texttt{Name} is a version 9 table, all objects with the same key are always handled at the same time which implies that the match specification may be applied to more than \texttt{N} objects.

The table should always be protected using \texttt{safe_fixtable/2} before calling \texttt{select/3}, or errors may occur when calling \texttt{select/1}.

\begin{verbatim}
select_delete(Name, MatchSpec) -> N | \{error, Reason\}
\end{verbatim}

Types:
- \texttt{Name} = \texttt{name()}
- \texttt{MatchSpec} = \texttt{match_spec()}
- \texttt{N} = \texttt{int()}

Deletes each object from the table \texttt{Name} such that applying the match specification \texttt{MatchSpec} to the object returns the value \texttt{true}. See the ERTS User's Guide for a description of match specifications. Returns the number of deleted objects.

If the keypos'th element of \texttt{MatchSpec} is bound, the match specification is applied to the objects with the right key(s) only.

\begin{verbatim}
slot(Name, I) -> \{'$end_of_table' | [Object] | \{error, Reason\}\}
\end{verbatim}

Types:
- \texttt{Name} = \texttt{name()}
- \texttt{I} = \texttt{int()}
- \texttt{Object} = \texttt{object()}

The objects of a table are distributed among slots, starting with slot \texttt{0} and ending with slot \texttt{n}. This function returns the list of objects associated with slot \texttt{I}. If \texttt{I} is greater than \texttt{n} \texttt{'$end_of_table'} is returned.

\begin{verbatim}
sync(Name) -> ok | \{error, Reason\}
\end{verbatim}

Types:
- \texttt{Name} = \texttt{name()}

Ensures that all updates made to the table \texttt{Name} are written to disk. This also applies to tables which have been opened with the \texttt{ram_file} flag set to \texttt{true}. In this case, the contents of the RAM file are flushed to disk.

Note that the space management data structures kept in RAM, the buddy system, is also written to the disk. This may take some time if the table is fragmented.

\begin{verbatim}
table(Name [, Options]) -> QueryHandle
\end{verbatim}
Types:
- Name = name()
- QueryHandle = -a query handle, see qlc(3)-
- Options = [Option] | Option
  - Option = {n_objects, Limit} | {traverse, TraverseMethod}
  - Limit = default | integer() => 1
  - TraverseMethod = first_next | select | {select, MatchSpec}
- MatchSpec = match_spec()

Returns a QLC (Query List Comprehension) query handle. The module qlc implements a query language aimed mainly at Mnesia but Ets tables, Dets tables, and lists are also recognized by QLC as sources of data. Calling dets:table/1,2 is the means to make the Dets table Name usable to QLC.

When there are only simple restrictions on the key position QLC uses dets:lookup/2 to look up the keys, but when that is not possible the whole table is traversed. The option traverse determines how this is done:

- first_next. The table is traversed one key at a time by calling dets:first/1 and dets:next/2.
- select. The table is traversed by calling dets:select/3 and dets:select/1. The option n_objects determines the number of objects returned (the third argument of select/3). The match specification (the second argument of select/3) is assembled by QLC: simple filters are translated into equivalent match specifications while more complicated filters have to be applied to all objects returned by select/3 given a match specification that matches all objects.
- {select, MatchSpec}. As for select the table is traversed by calling dets:select/3 and dets:select/1. The difference is that the match specification is explicitly given. This is how to state match specifications that cannot easily be expressed within the syntax provided by QLC.

The following example uses an explicit match specification to traverse the table:

1> dets:open_file(t, []).
   dets:insert(t, [[1,a],[2,b],[3,c],[4,d]]),
   MS = ets:fun2ms(fun((X,Y) when (X > 1) or (X < 5) -> Y end),
   QH1 = dets:table(t, [{traverse, {select, MS}}]).

An example with implicit match specification:

2> QH2 = qlc:q([[Y] || {X,Y} <- dets:table(t), (X > 1) or (X < 5)]).

The latter example is in fact equivalent to the former which can be verified using the function qlc:info/1:

3> qlc:info(QH1) =:= qlc:info(QH2).
   true

qlc:info/1 returns information about a query handle, and in this case identical information is returned for the two query handles.

to_ets(Name, EtsTab) -> EtsTab | {error, Reason}

Types:
- Name = name()
- EtsTab = -see ets(3)-
  Inserts the objects of the Dets table Name into the Ets table EtsTab. The order in which
  the objects are inserted is not specified. The existing objects of the Ets table are kept
  unless overwritten.

traverse(Name, Fun) -> Return | {error, Reason}

Types:
  - Fun = fun(Object) -> FunReturn
  - FunReturn = continue | {continue, Val} | {done, Value}
  - Val = Value = term()
  - Name = name()
  - Object = object()
  - Return = [term()]

Applies Fun to each object stored in the table Name in some unspecified order. Different
actions are taken depending on the return value of Fun. The following Fun return values
are allowed:

  continue  Continue to perform the traversal. For example, the following function can
            be used to print out the contents of a table:

        fun(X) -> io:format("p\n", [X]), continue end.

  {continue, Val} Continue the traversal and accumulate Val. The following function
            is supplied in order to collect all objects of a table in a list:

        fun(X) -> {continue, X} end.

  {done, Value} Terminate the traversal and return [Value | Acc].

Any other value returned by Fun terminates the traversal and is immediately returned.

update_counter(Name, Key, Increment) -> Result

Types:
  - Name = name()
  - Key = term()
  - Increment = {Pos, Incr} | Incr
  - Pos = Incr = Result = integer()

Updates the object with key Key stored in the table Name of type set by adding Incr to
the element at the Pos:th position. The new counter value is returned. If no position is
specified, the element directly following the key is updated.

This functions provides a way of updating a counter, without having to look up an
object, update the object by incrementing an element and insert the resulting object
into the table again.

See Also

dets(3) [page 123], mnesia(3), qlc(3) [page 260]
dict

Erlang Module

Dict implements a Key - Value dictionary. The representation of a dictionary is not defined.

DATA TYPES

dictionary()
    as returned by new/0

Exports

append(Key, Value, Dict1) -> Dict2
Types:
• Key = Value = term()
• Dict1 = Dict2 = dictionary()
This function appends a new Value to the current list of values associated with Key. An exception is generated if the initial value associated with Key is not a list of values.

append_list(Key, ValList, Dict1) -> Dict2
Types:
• ValList = [Value]
• Key = Value = term()
• Dict1 = Dict2 = dictionary()
This function appends a list of values ValList to the current list of values associated with Key. An exception is generated if the initial value associated with Key is not a list of values.

erase(Key, Dict1) -> Dict2
Types:
• Key = term()
• Dict1 = Dict2 = dictionary()
This function erases all items with a given key from a dictionary.

fetch(Key, Dict) -> Value
Types:
Key = Value = term()
Dict = dictionary()

This function returns the value associated with Key in the dictionary Dict. fetch assumes that the Key is present in the dictionary and an exception is generated if Key is not in the dictionary.

fetch_keys(Dict) -> Keys

Types:
- Dict = dictionary()
- Keys = [term()]

This function returns a list of all keys in the dictionary.

filter(Pred, Dict) -> Dict2

Types:
- Pred = fun(Key, Value) -> bool()
- Key = Value = term()
- Dict1 = Dict2 = dictionary()

Dict2 is a dictionary of all keys and values in Dict1 for which Pred(Key, Value) is true.

find(Key, Dict) -> {ok, Value} | error

Types:
- Key = Value = term()
- Dict = dictionary()

This function searches for a key in a dictionary. Returns {ok, Value} where Value is the value associated with Key, or error if the key is not present in the dictionary.

fold(Fun, Acc0, Dict) -> Acc1

Types:
- Fun = fun(Key, Value, AccIn) -> AccOut
- Key = Value = term()
- Acc0 = Acc1 = AccIn = AccOut = term()
- Dict = dictionary()

Calls Fun on successive keys and values of Dict together with an extra argument Acc (short for accumulator). Fun must return a new accumulator which is passed to the next call. Acc0 is returned if the list is empty. The evaluation order is undefined.

from_list(List) -> Dict

Types:
- List = [{Key, Value}]
- Dict = dictionary()

This function converts the key/value list List to a dictionary.

is_key(Key, Dict) -> bool()
map(Fun, Dict1) -> Dict2

Types:
• Fun = fun(Key, Value1) -> Value2
• Key = Value1 = Value2 = term()
• Dict1 = Dict2 = dictionary()

map calls Func on successive keys and values of Dict to return a new value for each key. The evaluation order is undefined.

merge(Fun, Dict1, Dict2) -> Dict3

Types:
• Fun = fun(Key, Value1, Value2) -> Value
• Key = Value1 = Value2 = Value3 = term()
• Dict1 = Dict2 = Dict3 = dictionary()

merge merges two dictionaries, Dict1 and Dict2, to create a new dictionary. All the Key - Value pairs from both dictionaries are included in the new dictionary. If a key occurs in both dictionaries then Fun is called with the key and both values to return a new value. merge could be defined as:

merge(Fun, D1, D2) ->
    fold(fun (K, V1, D) ->
        update(K, fun (V2) -> Fun(K, V1, V2) end, V1, D)
    end, D2, D1).

but is faster.

new() -> dictionary()

This function creates a new dictionary.

store(Key, Value, Dict1) -> Dict2

Types:
• Key = Value = term()
• Dict1 = Dict2 = dictionary()

This function stores a Key - Value pair in a dictionary. If the Key already exists in Dict1, the associated value is replaced by Value.

to_list(Dict) -> List

Types:
• Dict = dictionary()
• List = [{Key, Value}]

This function converts the dictionary to a list representation.
update(Key, Fun, Dict1) -> Dict2

Types:
- Key = term()
- Fun = fun(Value1) -> Value2
- Value1 = Value2 = term()
- Dict1 = Dict2 = dictionary()

Update the a value in a dictionary by calling Fun on the value to get a new value. An exception is generated if Key is not present in the dictionary.

update(Key, Fun, Initial, Dict1) -> Dict2

Types:
- Key = Initial = term()
- Fun = fun(Value1) -> Value2
- Value1 = Value2 = term()
- Dict1 = Dict2 = dictionary()

Update the a value in a dictionary by calling Fun on the value to get a new value. If Key is not present in the dictionary then Initial will be stored as the first value. For example append/3 could be defined as:

append(Key, Val, D) ->
    update(Key, fun (Old) -> Old ++ [Val] end, [Val], D).

update_counter(Key, Increment, Dict1) -> Dict2

Types:
- Key = term()
- Increment = number()
- Dict1 = Dict2 = dictionary()

Add Increment to the value associated with Key and store this value. If Key is not present in the dictionary then Increment will be stored as the first value. This could be defined as:

update_counter(Key, Incr, D) ->
    update(Key, fun (Old) -> Old + Incr end, Incr, D).

but is faster.
Notes

The functions `append` and `append_list` are included so we can store keyed values in a list accumulator. For example:

```erl
> D0 = dict:new(),
   D1 = dict:store(files, [], D0),
   D2 = dict:append(files, f1, D1),
   D3 = dict:append(files, f2, D2),
   D4 = dict:append(files, f3, D3),
   dict:fetch(files, D4).
[f1,f2,f3]
```

This saves the trouble of first fetching a keyed value, appending a new value to the list of stored values, and storing the result.

The function `fetch` should be used if the key is known to be in the dictionary, otherwise `find`.

See Also

`gb_trees(3)` [page 163], `orddict(3)` [page 244]
The `digraph` module implements a version of labeled directed graphs. What makes the graphs implemented here non-proper directed graphs is that multiple edges between vertices are allowed. However, the customary definition of directed graphs will be used in the text that follows.

A directed graph (or just “digraph”) is a pair (V,E) of a finite set V of vertices and a finite set E of directed edges (or just “edges”). The set of edges E is a subset of VV (the Cartesian product of V with itself). In this module, V is allowed to be empty; the so-obtained unique digraph is called the empty digraph. Both vertices and edges are represented by unique Erlang terms.

Digraphs can be annotated with additional information. Such information may be attached to the vertices and to the edges of the digraph. A digraph which has been annotated is called a labeled digraph, and the information attached to a vertex or an edge is called a label. Labels are Erlang terms.

An edge e=(v,w) is said to emanate from vertex v and to be incident on vertex w. The out-degree of a vertex is the number of edges emanating from that vertex. The in-degree of a vertex is the number of edges incident on that vertex. If there is an edge emanating from v and incident on w, then w is said to be an out-neighbour of v, and v is said to be an in-neighbour of w. A path P from v[1] to v[k] in a digraph (V,E) is a non-empty sequence v[1],v[2],...,v[k] of vertices in V such that there is an edge (v[i],v[i+1]) in E for 1≤i<k. The length of the path P is k-1. P is simple if all vertices are distinct, except that the first and the last vertices may be the same. P is a cycle if the length of P is not zero and v[1] = v[k]. A loop is a cycle of length one. A simple cycle is a path that is both a cycle and simple. An acyclic digraph is a digraph that has no cycles.

Exports

```
add_edge(G, E, V1, V2, Label) -> edge() | {error, Reason}
add_edge(G, V1, V2, Label) -> edge() | {error, Reason}
add_edge(G, V1, V2) -> edge() | {error, Reason}
```

Types:
- G = `digraph()`
- E = `edge()`
- V1 = V2 = `vertex()`
- Label = `label()`
- Reason = `{bad_edge, Path} | `{bad_vertex, V}`
- Path = `[vertex()]`

```
add_edge/5 creates (or modifies) the edge \( E \) of the digraph \( G \), using \( \text{Label} \) as the (new) label [page 87] of the edge. The edge is emanating [page 87] from \( V1 \) and incident [page 87] on \( V2 \). Returns \( E \).

\( \text{add\_edge}(G,V1,V2,\text{Label}) \) is equivalent to \( \text{add\_edge}(G,E,V1,V2,\text{Label}) \), where \( E \) is a created edge. Tuples on the form \(['e'|N] \), where \( N \) is an integer \( \geq 1 \), are used for representing the created edges.

\( \text{add\_edge}(G,V1,V2) \) is equivalent to \( \text{add\_edge}(G,V1,V2,[]) \).

If the edge would create a cycle in an acyclic digraph [page 87], then \{\text{error},\{\text{bad\_edge},\text{Path}\}\} is returned. If either of \( V1 \) or \( V2 \) is not a vertex of the digraph \( G \), then \{\text{error},\{\text{bad\_vertex},V\}\} is returned, \( V = V1 \) or \( V = V2 \).

\( \text{add\_vertex}(G, V, \text{Label}) \) \rightarrow vertex()

\( \text{add\_vertex}(G, V) \) \rightarrow vertex()

\( \text{add\_vertex}(G) \) \rightarrow vertex()

Types:
- \( G = \text{digraph()} \)
- \( V = \text{vertex()} \)
- \( \text{Label} = \text{label()} \)

\( \text{add\_vertex}/3 \) creates (or modifies) the vertex \( V \) of the digraph \( G \), using \( \text{Label} \) as the (new) label [page 87] of the vertex. Returns \( V \).

\( \text{add\_vertex}(G,V) \) is equivalent to \( \text{add\_vertex}(G,V,[]) \).

\( \text{add\_vertex}/1 \) creates a vertex using the empty list as label, and returns the created vertex. Tuples on the form \(['v'|N] \), where \( N \) is an integer \( \geq 1 \), are used for representing the created vertices.

\( \text{del\_edge}(G, E) \) \rightarrow true

Types:
- \( G = \text{digraph()} \)
- \( E = \text{edge()} \)

Deletes the edge \( E \) from the digraph \( G \).

\( \text{del\_edges}(G, \text{Edges}) \) \rightarrow true

Types:
- \( G = \text{digraph()} \)
- \( \text{Edges} = [\text{edge()}] \)

Deletes the edges in the list \( \text{Edges} \) from the digraph \( G \).

\( \text{del\_path}(G, V1, V2) \) \rightarrow true

Types:
- \( G = \text{digraph()} \)
- \( V1 = V2 = \text{vertex()} \)
Deletes edges from the digraph \( G \) until there are no paths [page 87] from the vertex \( V_1 \) to the vertex \( V_2 \).

A sketch of the procedure employed: Find an arbitrary simple path [page 87] \( v[1], v[2], \ldots, v[k] \) from \( V_1 \) to \( V_2 \) in \( G \). Remove all edges of \( G \) emanating [page 87] from \( v[i] \) and incident [page 87] on \( v[i+1] \) for \( 1 \leq i < k \) (including multiple edges). Repeat until there is no path between \( V_1 \) and \( V_2 \).

\[ \text{del}_{\text{vertex}}(G, V) \rightarrow \text{true} \]

Types:
- \( G = \text{digraph}() \)
- \( V = \text{vertex}() \)

Deletes the vertex \( V \) from the digraph \( G \). Any edges emanating [page 87] from \( V \) or incident [page 87] on \( V \) are also deleted.

\[ \text{del}_{\text{vertices}}(G, \text{Vertices}) \rightarrow \text{true} \]

Types:
- \( G = \text{digraph}() \)
- \( \text{Vertices} = \{\text{vertex}()\} \)

Deletes the vertices in the list \( \text{Vertices} \) from the digraph \( G \).

\[ \text{delete}(G) \rightarrow \text{true} \]

Types:
- \( G = \text{digraph}() \)

Deletes the digraph \( G \). This call is important because digraphs are implemented with \( \text{Ets} \). There is no garbage collection of \( \text{Ets} \) tables. The digraph will, however, be deleted if the process that created the digraph terminates.

\[ \text{edge}(G, E) \rightarrow \{E, V_1, V_2, \text{Label}\} \mid \text{false} \]

Types:
- \( G = \text{digraph}() \)
- \( E = \text{edge}() \)
- \( V_1 = V_2 = \text{vertex}() \)
- \( \text{Label} = \text{label}() \)

Returns \( \{E, V_1, V_2, \text{Label}\} \) where \( \text{Label} \) is the label [page 87] of the edge \( E \) emanating [page 87] from \( V_1 \) and incident [page 87] on \( V_2 \) of the digraph \( G \). If there is no edge \( E \) of the digraph \( G \), then \( \text{false} \) is returned.

\[ \text{edges}(G) \rightarrow \text{Edges} \]

Types:
- \( G = \text{digraph}() \)
- \( \text{Edges} = \{\text{edge}()\} \)

Returns a list of all edges of the digraph \( G \), in some unspecified order.

\[ \text{edges}(G, V) \rightarrow \text{Edges} \]
**Types:**
- \( G = \text{digraph}() \)
- \( V = \text{vertex}() \)
- \( \text{Edges} = [\text{edge}()] \)

Returns a list of all edges emanating [page 87] from or incident [page 87] on \( V \) of the
digraph \( G \), in some unspecified order.

\[ \text{get\_cycle}(G, V) \rightarrow \text{Vertices} \mid \text{false} \]

**Types:**
- \( G = \text{digraph}() \)
- \( V1 = V2 = \text{vertex}() \)
- \( \text{Vertices} = [\text{vertex}()] \)

If there is a simple cycle [page 87] of length two or more through the vertex \( V \), then the
cycle is returned as a list \([V, \ldots, V]\) of vertices, otherwise if there is a loop [page 87]
through \( V \), then the loop is returned as a list \([V]\). If there are no cycles through \( V \), then
\text{false} is returned.

\[ \text{get\_path/3} \text{ is used for finding a simple cycle through } V. \]

\[ \text{get\_path}(G, V1, V2) \rightarrow \text{Vertices} \mid \text{false} \]

**Types:**
- \( G = \text{digraph}() \)
- \( V1 = V2 = \text{vertex}() \)
- \( \text{Vertices} = [\text{vertex}()] \)

Tries to find a simple path [page 87] from the vertex \( V1 \) to the vertex \( V2 \) of the digraph
\( G \). Returns the path as a list \([V1, \ldots, V2]\) of vertices, or \text{false} if no simple path from \( V1 \)
to \( V2 \) of length one or more exists.

The digraph \( G \) is traversed in a depth-first manner, and the first path found is returned.

\[ \text{get\_short\_cycle}(G, V) \rightarrow \text{Vertices} \mid \text{false} \]

**Types:**
- \( G = \text{digraph}() \)
- \( V1 = V2 = \text{vertex}() \)
- \( \text{Vertices} = [\text{vertex}()] \)

Tries to find an as short as possible simple cycle [page 87] through the vertex \( V \) of the
digraph \( G \). Returns the cycle as a list \([V, \ldots, V]\) of vertices, or \text{false} if no simple cycle
through \( V \) exists. Note that a loop [page 87] through \( V \) is returned as the list \([V, V]\).

\[ \text{get\_short\_path/3} \text{ is used for finding a simple cycle through } V. \]

\[ \text{get\_short\_path}(G, V1, V2) \rightarrow \text{Vertices} \mid \text{false} \]

**Types:**
- \( G = \text{digraph}() \)
- \( V1 = V2 = \text{vertex}() \)
- \( \text{Vertices} = [\text{vertex}()] \)
Tries to find an as short as possible simple path [page 87] from the vertex $V_1$ to the vertex $V_2$ of the digraph $G$. Returns the path as a list $[V_1, \ldots, V_2]$ of vertices, or false if no simple path from $V_1$ to $V_2$ of length one or more exists.

The digraph $G$ is traversed in a breadth-first manner, and the first path found is returned.

**in_degree**($G$, $V$) ➞ integer()

Types:
- $G$ = digraph()
- $V$ = vertex()

Returns the in-degree [page 87] of the vertex $V$ of the digraph $G$.

**in_edges**($G$, $V$) ➞ Edges

Types:
- $G$ = digraph()
- $V$ = vertex()
- Edges = [edge()]

Returns a list of all edges incident [page 87] on $V$ of the digraph $G$, in some unspecified order.

**in_neighbours**($G$, $V$) ➞ Vertices

Types:
- $G$ = digraph()
- $V$ = vertex()
- Vertices = [vertex()]

Returns a list of all in-neighbours [page 87] of $V$ of the digraph $G$, in some unspecified order.

**info**($G$) ➞ InfoList

Types:
- $G$ = digraph()
- InfoList = [{cyclicity, Cyclicity}, {memory, NoWords}, {protection, Protection}]
- Cyclicity = cyclic | acyclic
- Protection = public | protected | private
- NoWords = integer() $\geq$ 0

Returns a list of {Tag, Value} pairs describing the digraph $G$. The following pairs are returned:

- {cyclicity, Cyclicity}, where Cyclicity is cyclic or acyclic, according to the options given to new.
- {memory, NoWords}, where NoWords is the number of words allocated to the ets tables.
- {protection, Protection}, where Protection is public, protected or private, according to the options given to new.
new() -> digraph()

   Equivalent to new([]).

new(Type) -> digraph() | [error, Reason]

   Types:
   - Type = [cyclic | acyclic | public | private | protected]
   - Reason = [unknown_type, term()]

   Returns an empty digraph [page 87] with properties according to the options in Type:

   cyclic  Allow cycles [page 87] in the digraph (default).
   acyclic  The digraph is to be kept acyclic [page 87].
   public  The digraph may be read and modified by any process.
   protected  Other processes can only read the digraph (default).
   private  The digraph can be read and modified by the creating process only.

   If an unrecognized type option T is given, then [error, {unknown_type, T}] is returned.

no_edges(G) -> integer() >= 0

   Types:
   - G = digraph()

   Returns the number of edges of the digraph G.

no_vertices(G) -> integer() >= 0

   Types:
   - G = digraph()

   Returns the number of vertices of the digraph G.

out_degree(G, V) -> integer()

   Types:
   - G = digraph()
   - V = vertex()

   Returns the out-degree [page 87] of the vertex V of the digraph G.

out_edges(G, V) -> Edges

   Types:
   - G = digraph()
   - V = vertex()
   - Edges = [edge()]

   Returns a list of all edges emanating [page 87] from V of the digraph G, in some unspecified order.

out_neighbours(G, V) -> Vertices

   Types:
• \texttt{G = digraph()}
• \texttt{V = vertex()}
• \texttt{Vertices = [vertex()]}  

Returns a list of all out-neighbours \(^{[87]}\) of \(V\) of the digraph \(G\), in some unspecified order.

\(\text{vertex}(G, V) \rightarrow \{V, \text{Label}\} | \text{false}\)

Types:
• \(G = \text{digraph()}\)
• \(V = \text{vertex()}\)
• \(\text{Label} = \text{label()}\)

Returns \(\{V, \text{Label}\}\) where \(\text{Label}\) is the label \(^{[87]}\) of the vertex \(V\) of the digraph \(G\), or \text{false} if there is no vertex \(V\) of the digraph \(G\).

\(\text{vertices}(G) \rightarrow \text{Vertices}\)

Types:
• \(G = \text{digraph()}\)
• \(\text{Vertices} = [\text{vertex()}]\)

Returns a list of all vertices of the digraph \(G\), in some unspecified order.

\textbf{See Also}

digraph\_utils(3) \(^{[94]}\), ets(3) \(^{[123]}\)
The digraph_utils module implements some algorithms based on depth-first traversal of directed graphs. See the digraph module for basic functions on directed graphs.

A directed graph (or just “digraph”) is a pair \((V,E)\) of a finite set \(V\) of vertices and a finite set \(E\) of directed edges (or just “edges”). The set of edges \(E\) is a subset of \(VV\) (the Cartesian product of \(V\) with itself).

Digraphs can be annotated with additional information. Such information may be attached to the vertices and to the edges of the digraph. A digraph which has been annotated is called a labeled digraph, and the information attached to a vertex or an edge is called a label.

An edge \(e=(v,w)\) is said to emanate from vertex \(v\) and to be incident on vertex \(w\). If there is an edge emanating from \(v\) and incident on \(w\), then \(w\) is said to be an out-neighbour of \(v\). A path \(P\) from \(v[1]\) to \(v[k]\) in a digraph \((V,E)\) is a non-empty sequence \(v[1],v[2],...,v[k]\) of vertices in \(V\) such that there is an edge \((v[i],v[i+1])\) in \(E\) for \(1\leq i<k\). The length of the path \(P\) is \(k-1\). \(P\) is a cycle if the length of \(P\) is not zero and \(v[1] = v[k]\). A loop is a cycle of length one. A acyclic digraph is a digraph that has no cycles.

A depth-first traversal of a directed digraph can be viewed as a process that visits all vertices of the digraph. Initially, all vertices are marked as unvisited. The traversal starts with an arbitrarily chosen vertex, which is marked as visited, and follows an edge to an unmarked vertex, marking that vertex. The search then proceeds from that vertex in the same fashion, until there is no edge leading to an unvisited vertex. At that point the process backtracks, and the traversal continues as long as there are unexamined edges. If there remain unvisited vertices when all edges from the first vertex have been examined, some hitherto unvisited vertex is chosen, and the process is repeated.

A partial ordering of a set \(S\) is a transitive, antisymmetric and reflexive relation between the objects of \(S\). The problem of topological sorting is to find a total ordering of \(S\) that is a superset of the partial ordering. A digraph \(G=(V,E)\) is equivalent to a relation \(E\) on \(V\) (we neglect the fact that the version of directed graphs implemented in the digraph module allows multiple edges between vertices). If the digraph has no cycles of length two or more, then the reflexive and transitive closure of \(E\) is a partial ordering.

A subgraph \(G'\) of \(G\) is a digraph whose vertices and edges form subsets of the vertices and edges of \(G\). \(G'\) is maximal with respect to a property \(P\) if all other subgraphs that include the vertices of \(G'\) do not have the property \(P\). A strongly connected component is a maximal subgraph such that there is a path between each pair of vertices. A connected component is a maximal subgraph such that there is a path between each pair of vertices, considering all edges undirected.
Exports

`components(Digraph) -> [Component]`

Types:
- `Digraph = digraph()`
- `Component = [vertex()]`

Returns a list of connected components [page 94]. Each component is represented by its vertices. The order of the vertices and the order of the components are arbitrary. Each vertex of the digraph `Digraph` occurs in exactly one component.

`condensation(Digraph) -> CondensedDigraph`

Types:
- `Digraph = CondensedDigraph = digraph()`

Creates a digraph where the vertices are the strongly connected components [page 94] of `Digraph` as returned by `strong_components/1`. If `X` and `Y` are strongly connected components, and there exist vertices `x` and `y` in `X` and `Y` respectively such that there is an edge emanating [page 94] from `x` and incident [page 94] on `y`, then an edge emanating from `X` and incident on `Y` is created.

The created digraph has the same type as `Digraph`. All vertices and edges have the default label [page 94].

Each and every cycle [page 94] is included in some strongly connected component, which implies that there always exists a topological ordering [page 94] of the created digraph.

`cyclic_strong_components(Digraph) -> [StrongComponent]`

Types:
- `Digraph = digraph()`
- `StrongComponent = [vertex()]`

Returns a list of strongly connected components [page 94]. Each strongly component is represented by its vertices. The order of the vertices and the order of the components are arbitrary. Only vertices that are included in some cycle [page 94] in `Digraph` are returned, otherwise the returned list is equal to that returned by `strong_components/1`.

`is_acyclic(Digraph) -> bool()`

Types:
- `Digraph = digraph()`

Returns `true` if and only if the digraph `Digraph` is acyclic [page 94].

`loop_vertices(Digraph) -> Vertices`

Types:
- `Digraph = digraph()`
- `Vertices = [vertex()]`

Returns a list of all vertices of `Digraph` that are included in some loop [page 94].
postorder(Digraph) -> Vertices
Types:
  • Digraph = digraph()
  • Vertices = [vertex()]
Returns all vertices of the digraph Digraph. The order is given by a depth-first traversal [page 94] of the digraph, collecting visited vertices in postorder. More precisely, the vertices visited while searching from an arbitrarily chosen vertex are collected in postorder, and all those collected vertices are placed before the subsequently visited vertices.

preorder(Digraph) -> Vertices
Types:
  • Digraph = digraph()
  • Vertices = [vertex()]
Returns all vertices of the digraph Digraph. The order is given by a depth-first traversal [page 94] of the digraph, collecting visited vertices in pre-order.

reachable(Vertices, Digraph) -> Vertices
Types:
  • Digraph = digraph()
  • Vertices = [vertex()]
Returns an unsorted list of digraph vertices such that for each vertex in the list, there is a path [page 94] in Digraph from some vertex of Vertices to the vertex. In particular, since paths may have length zero, the vertices of Vertices are included in the returned list.

reachable_neighbours(Vertices, Digraph) -> Vertices
Types:
  • Digraph = digraph()
  • Vertices = [vertex()]
Returns an unsorted list of digraph vertices such that for each vertex in the list, there is a path [page 94] in Digraph of length one or more from some vertex of Vertices to the vertex. As a consequence, only those vertices of Vertices that are included in some cycle [page 94] are returned.

reaching(Vertices, Digraph) -> Vertices
Types:
  • Digraph = digraph()
  • Vertices = [vertex()]
Returns an unsorted list of digraph vertices such that for each vertex in the list, there is a path [page 94] from the vertex to some vertex of Vertices. In particular, since paths may have length zero, the vertices of Vertices are included in the returned list.

eaching_neighbours(Vertices, Digraph) -> Vertices
Types:
Digraph = digraph()
Vertices = [vertex()]

Returns an unsorted list of digraph vertices such that for each vertex in the list, there is a path of length one or more from the vertex to some vertex of Vertices. As a consequence, only those vertices of Vertices that are included in some cycle are returned.

strong_components(Digraph) -> [StrongComponent]
Types:
• Digraph = digraph()
• StrongComponent = [vertex()]

Returns a list of strongly connected components. Each strongly component is represented by its vertices. The order of the vertices and the order of the components are arbitrary. Each vertex of the digraph Digraph occurs in exactly one strong component.

subgraph(Digraph, Vertices [, Options]) -> Subgraph | {error, Reason}
Types:
• Digraph = Subgraph = digraph()
• Options = [{type, SubgraphType}, {keep_labels, bool()}]
• Reason = {invalid_option, term()} | {unknown_type, term()}
• SubgraphType = inherit | type()
• Vertices = [vertex()]

Creates a maximal subgraph of Digraph having as vertices those vertices of Digraph that are mentioned in Vertices. If the value of the option type is inherit, which is the default, then the type of Digraph is used for the subgraph as well. Otherwise the option value of type is used as argument to digraph:new/1.

If the value of the option keep_labels is true, which is the default, then the labels of vertices and edges of Digraph are used for the subgraph as well. If the value is false, then the default label, [], is used for the subgraph’s vertices and edges.

subgraph(Digraph, Vertices) is equivalent to subgraph(Digraph, Vertices, []).

topsort(Digraph) -> Vertices | false
Types:
• Digraph = digraph()
• Vertices = [vertex()]

Returns a topological ordering of the vertices of the digraph Digraph if such an ordering exists, false otherwise. For each vertex in the returned list, there are no out-neighbours that occur earlier in the list.

See Also
digraph(3) [page 87]
The Erlang code preprocessor includes functions which are used by compile to preprocess macros and include files before the actual parsing takes place.

Exports

open(FileName, IncludePath) -> {ok, Epp} | {error, ErrorDescriptor}
open(FileName, IncludePath, PredefMacros) -> {ok, Epp} | {error, ErrorDescriptor}

Types:
- FileName = atom() | string()
- IncludePath = [DirectoryName]
- DirectoryName = atom() | string()
- PredefMacros = [{atom(), term()}]
- Epp = pid() - handle to the epp server
- ErrorDescriptor = term()

Opens a file for preprocessing.

close(Epp) -> ok

Types:
- Epp = pid() - handle to the epp server

Closes the preprocessing of a file.

parse_erl_form(Epp) -> {ok, AbsForm} | {eof, Line} | {error, ErrorInfo}

Types:
- Epp = pid()
- AbsForm = term()
- Line = integer()
- ErrorInfo = see separate description below.

Returns the next Erlang form from the opened Erlang source file. The tuple {eof, Line} is returned at end-of-file. The first form corresponds to an implicit attribute -file(File,1), where File is the name of the file.

parse_file(FileName, IncludePath, PredefMacro) -> {ok, [Form]} | {error, OpenError}

Types:
- FileName = atom() | string()
includePath = [DirectoryName]
DirectoryName = atom() | string()
PredefMacros = [{atom()},term()]
Form = term() – same as returned by erl:term().

Preprocesses and parses an Erlang source file. Note that the tuple {eof, Line} returned at end-of-file is included as a “form”.

Error Information

The ErrorInfo mentioned above is the standard ErrorInfo structure which is returned from all IO modules. It has the following format:

{ErrorLine, Module, ErrorDescriptor}

A string which describes the error is obtained with the following call:

apply(Module, format_error, ErrorDescriptor)

See Also

erl:term(). [page 109]
erl_eval

Erlang Module

This module provides an interpreter for Erlang expressions. The expressions are in the abstract syntax as returned by `erl_parse`, the Erlang parser, or a call to `io:parse_erl_exprs/2`.

Exports

```erlang
exprs(Expressions, Bindings) -> {value, Value, NewBindings}
exprs(Expressions, Bindings, LocalFunctionHandler) -> {value, Value, NewBindings}
exprs(Expressions, Bindings, LocalFunctionHandler, NonlocalFunctionHandler) -> {value, Value, NewBindings}
```

Types:
- `Expressions` = as returned by `erl_parse` or `io:parse_erl_exprs/2`
- `Bindings` = as returned by `bindings/1`
- `LocalFunctionHandler` = `value`, `Func` | `eval`, `Func` | none
- `NonlocalFunctionHandler` = `value`, `Func` | none

Evaluates `Expressions` with the set of bindings `Bindings`, where `Expressions` is a sequence of expressions (in abstract syntax) of a type which may be returned by `io:parse_erl_exprs/2`. See below for an explanation of how and when to use the arguments `LocalFunctionHandler` and `NonlocalFunctionHandler`.

Returns `{value, Value, NewBindings}`

```erlang
expr(Expression, Bindings) -> {value, Value, NewBindings}
expr(Expression, Bindings, LocalFunctionHandler) -> {value, Value, NewBindings}
expr(Expression, Bindings, LocalFunctionHandler, NonlocalFunctionHandler) -> {value, Value, NewBindings}
```

Types:
- `Expression` = as returned by `io:parse_erl_form/2`, for example
- `Bindings` = as returned by `bindings/1`
- `LocalFunctionHandler` = `value`, `Func` | `eval`, `Func` | none
- `NonlocalFunctionHandler` = `value`, `Func` | none

Evaluates `Expression` with the set of bindings `Bindings`. `Expression` is an expression (in abstract syntax) of a type which may be returned by `io:parse_erl_form/2`. See below for an explanation of how and when to use the arguments `LocalFunctionHandler` and `NonlocalFunctionHandler`.

Returns `{value, Value, NewBindings}`.
expr_list(ExpressionList, Bindings) -> {ValueList, NewBindings}
expr_list(ExpressionList, Bindings, LocalFunctionHandler) -> {ValueList, NewBindings}
expr_list(ExpressionList, Bindings, LocalFunctionHandler, NonlocalFunctionHandler) ->
        {ValueList, NewBindings}

Evaluates a list of expressions in parallel, using the same initial bindings for each
expression. Attempts are made to merge the bindings returned from each evaluation.
This function is useful in the LocalFunctionHandler. See below.
Returns {ValueList, NewBindings}.

new_bindings() -> BindingStruct

Returns an empty binding structure.

bindings(BindingStruct) ->Bindings

Returns the list of bindings contained in the binding structure.

binding(Name, BindingStruct) -> Binding

Returns the binding of Name in BindingStruct.

add_binding(Name, Value, Bindings) -> BindingStruct

Adds the binding Name = Value to Bindings. Returns an updated binding structure.

del_binding(Name, Bindings) -> BindingStruct

Removes the binding of Name in Bindings. Returns an updated binding structure.

Local Function Handler

During evaluation of a function, no calls can be made to local functions. An undefined
function error would be generated. However, the optional argument
LocalFunctionHandler may be used to define a function which is called when there is
a call to a local function. The argument can have the following formats:

{value,Func}  This defines a local function handler which is called with:
            Func(Name, Arguments)

            Name is the name of the local function (an atom) and Arguments is a list of the
            evaluated arguments. The function handler returns the value of the local function.
            In this case, it is not possible to access the current bindings. To signal an error, the
            function handler just calls exit/1 with a suitable exit value.

{eval,Func}  This defines a local function handler which is called with:
            Func(Name, Arguments, Bindings)

            Name is the name of the local function (an atom), Arguments is a list of the
            unevaluated arguments, and Bindings are the current variable bindings. The
            function handler returns:
            {value,Value,NewBindings}
Value is the value of the local function and NewBindings are the updated variable bindings. In this case, the function handler must itself evaluate all the function arguments and manage the bindings. To signal an error, the function handler just calls exit/1 with a suitable exit value.

none There is no local function handler.

Non-local Function Handler

The optional argument NonlocalFunctionHandler may be used to define a function which is called in the following cases: a functional object (fun) is called; a built-in function is called; a function is called using the M:F syntax, where M and F are atoms or expressions. Exceptions are function calls in guard tests and calls to erlang:apply/2,3; neither of the function handlers will be called for such calls. The argument can have the following formats:

{value,Func} This defines an nonlocal function handler which is called with:

    Func(FuncSpec, Arguments)

FuncSpec is the name of the function on the form {Module,Function} or a fun, and Arguments is a list of the evaluated arguments. The function handler returns the value of the function. To signal an error, the function handler just calls exit/1 with a suitable exit value.

none There is no nonlocal function handler.

The nonlocal function handler argument is probably not used as frequently as the local function handler argument. A possible use is to call exit/1 on calls to functions that for some reason are not allowed to be called.

Bugs

The evaluator is not complete. receive cannot be handled properly. Any undocumented functions in erl_eval should not be used.
erl\_expand\_records

Erlang Module

Exports

\[
\text{module(AbsForms, CompileOptions) \rightarrow AbsForms}
\]

Types:
- \text{AbsForms} = \{\text{term()\}}
- \text{CompileOptions} = \{\text{term()\}}

Expands all records in a module. The returned module has no references to records, neither attributes nor code.

See Also

The [abstract format] documentation in ERTS User's Guide
This module performs an identity parse transformation of Erlang code. It is included as an example for users who may wish to write their own parse transformers. If the option \{parse_transform, Module\} is passed to the compiler, a user written function \texttt{parse_transform/2} is called by the compiler before the code is checked for errors.

**Exports**

\texttt{parse_transform(Forms, Options) -> Forms}

Types:
- \texttt{Forms = [erlang_form()]}  
- \texttt{Options = [compiler_options()]}  

Performs an identity transformation on Erlang forms, as an example.

**Parse Transformations**

Parse transformations are used if a programmer wants to use Erlang syntax, but with different semantics. The original Erlang code is then transformed into other Erlang code.

**Note:**
Programmers are strongly advised not to engage in parse transformations and no support is offered for problems encountered.

**See Also**

\texttt{erl_parse(3) [page 109], compile(3).}
erl_internal

Erlang Module

This module defines Erlang BIFs, guard tests and operators. This module is only of interest to programmers who manipulate Erlang code.

Exports

bif(Name, Arity) -> bool()

Types:
• Name = atom()
• Arity = integer()
Returns true if Name/Arity is an Erlang BIF which is automatically recognized by the compiler, otherwise false.

guard_bif(Name, Arity) -> bool()

Types:
• Name = atom()
• Arity = integer()
Returns true if Name/Arity is an Erlang BIF which is allowed in guards, otherwise false.

type_test(Name, Arity) -> bool()

Types:
• Name = atom()
• Arity = integer()
Returns true if Name/Arity is a valid Erlang type test, otherwise false.

arith_op(OpName, Arity) -> bool()

Types:
• OpName = atom()
• Arity = integer()
Returns true if OpName/Arity is an arithmetic operator, otherwise false.

bool_op(OpName, Arity) -> bool()

Types:
• OpName = atom()
• Arity = integer()
  Returns true if OpName/Arity is a Boolean operator, otherwise false.

comp_op(OpName, Arity) -> bool()
  Types:
  • OpName = atom()
  • Arity = integer()
  Returns true if OpName/Arity is a comparison operator, otherwise false.

list_op(OpName, Arity) -> bool()
  Types:
  • OpName = atom()
  • Arity = integer()
  Returns true if OpName/Arity is a list operator, otherwise false.

send_op(OpName, Arity) -> bool()
  Types:
  • OpName = atom()
  • Arity = integer()
  Returns true if OpName/Arity is a send operator, otherwise false.

op_type(OpName, Arity) -> Type
  Types:
  • OpName = atom()
  • Arity = integer()
  • Type = arith | bool | comp | list | send
  Returns the Type of operator that OpName/Arity belongs to, or generates a function_clause error if it is not an operator at all.
This module is used to check Erlang code for illegal syntax and other bugs. It also warns against coding practices which are not recommended.

The errors detected include:

- redefined and undefined functions
- unbound and unsafe variables
- illegal record usage.

Warnings include:

- unused functions and imports
- variables imported into matches
- variables exported from if/case/receive
- variables shadowed in lambdas and list comprehensions.

Some of the warnings are optional, and can be turned on by giving the appropriate option, described below.

The functions in this module are invoked automatically by the Erlang compiler and there is no reason to invoke these functions separately unless you have written your own Erlang compiler.

Exports

\[
\text{module(AbsForms)} \rightleftharpoons \{\text{ok,Warnings}\} \mid \{\text{error,Errors,Warnings}\}
\]

\[
\text{module(AbsForms, FileName)} \rightleftharpoons \{\text{ok,Warnings}\} \mid \{\text{error,Errors,Warnings}\}
\]

\[
\text{module(AbsForms, FileName, CompileOptions)} \rightleftharpoons \{\text{ok,Warnings}\} \mid \{\text{error,Errors,Warnings}\}
\]

Types:

- AbsForms = [term()]
- FileName = FileName2 = atom() \mid string()
- Warnings = Errors = [{Filename2,[ErrorInfo]}]
- ErrorInfo = see separate description below.
- CompileOptions = [term()]

This function checks all the forms in a module for errors. It returns:

{ok,Warnings} There were no errors in the module.
{error,Errors,Warnings} There were errors in the module.
Since this module is of interest only to the maintainers of the compiler, and to avoid
having the same description in two places to avoid the usual maintenance nightmare,
the elements of Options that control the warnings are only described in the manual
page for the compile module.

The AbsForms of a module which comes from a file that is read through epp, the Erlang
pre-processor, can come from many files. This means that any references to errors must
include the file name (see epp(3) [page 98], or parser erl_parse(3) [page 109]. The
warnings and errors returned have the following format:

```
[(FileName2, [ErrorInfo])]
```

The errors and warnings are listed in the order in which they are encountered in the
forms. This means that the errors from one file may be split into different entries in the
list of errors.

```prolog
is_guard_test(Expr) -> bool()
```

Types:

- Expr = term()

This function tests if Expr is a legal guard test. Expr is an Erlang term representing the
abstract form for the expression. erl_parse:parse_exprs(Tokens) can be used to
generate a list of Expr.

```prolog
format_error(Descriptor) -> Chars
```

Types:

- Descriptor = erordesc()
- Chars = [char() | Chars]

Takes an ErrorDescriptor and returns a string which describes the error or warning.
This function is usually called implicitly when processing an ErrorInfo structure (see
below).

## Error Information

The ErrorInfo mentioned above is the standard ErrorInfo structure which is returned
from all IO modules. It has the following format:

```
{ErrorLine, Module, ErrorDescriptor}
```

A string which describes the error is obtained with the following call:

```prolog
apply(Module, format_error, ErrorDescriptor)
```

## See Also

erl_parse(3) [page 109], epp(3) [page 98]
erl_parse
Erlang Module

This module is the basic Erlang parser which converts tokens into the abstract form of either forms (i.e., top-level constructs), expressions, or terms. The Abstract Format is described in the ERTS User’s Guide. Note that a token list must end with the dot token in order to be acceptable to the parse functions (see erl_scan).

Exports

parse_form(Tokens) -> {ok, AbsForm} | {error, ErrorInfo}

Types:
- Tokens = [Token]
- Token = {Tag,Line} | {Tag,Line,term()}
- Tag = atom()
- AbsForm = term()
- ErrorInfo = see section Error Information below.
This function parses Tokens as if it were a form. It returns:
{ok, AbsForm} The parsing was successful. AbsForm is the abstract form of the parsed form.
{error, ErrorInfo} An error occurred.

parse_exprs(Tokens) -> {ok, Expr_list} | {error, ErrorInfo}

Types:
- Tokens = [Token]
- Token = {Tag,Line} | {Tag,Line,term()}
- Tag = atom()
- Expr_list = [AbsExpr]
- AbsExpr = term()
- ErrorInfo = see section Error Information below.
This function parses Tokens as if it were a list of expressions. It returns:
{ok, Expr_list} The parsing was successful. Expr_list is a list of the abstract forms of the parsed expressions.
{error, ErrorInfo} An error occurred.

parse_term(Tokens) -> {ok, Term} | {error, ErrorInfo}
Types:
- Tokens = [Token]
- Token = {Tag,Line} | {Tag,Line,term()}
- Tag = atom()
- Term = term()
- ErrorInfo = see section Error Information below.

This function parses Tokens as if it were a term. It returns:

{ok, Term} The parsing was successful. Term is the Erlang term corresponding to the token list.
{error, ErrorInfo} An error occurred.

format_error(ErrorDescriptor) -> Chars

Types:
- ErrorDescriptor = errordesc()
- Chars = [char() | Chars]

Uses an ErrorDescriptor and returns a string which describes the error. This function is usually called implicitly when an ErrorInfo structure is processed (see below).

tokens(AbsTerm) -> Tokens

tokens(AbsTerm, MoreTokens) -> Tokens

Types:
- Tokens = MoreTokens = [Token]
- Token = {Tag,Line} | {Tag,Line,term()}
- Tag = atom()
- AbsTerm = term()
- ErrorInfo = see section Error Information below.

This function generates a list of tokens representing the abstract form AbsTerm of an expression. Optionally, it appends Moretokens.

normalise(AbsTerm) -> Data

Types:
- AbsTerm = Data = term()

Converts the abstract form AbsTerm of a term into a conventional Erlang data structure (i.e., the term itself). This is the inverse of abstract/1.

abstract(Data) -> AbsTerm

Types:
- Data = AbsTerm = term()

Converts the Erlang data structure Data into an abstract form of type AbsTerm. This is the inverse of normalise/1.
Error Information

The ErrorInfo mentioned above is the standard ErrorInfo structure which is returned from all IO modules. It has the format:

{ErrorLine, Module, ErrorDescriptor}

A string which describes the error is obtained with the following call:
apply(Module, format_error, ErrorDescriptor)

See Also

io(3) [page 198], erl_scan(3) [page 115], ERTS User's Guide
**erl_pp**

Erlang Module

The functions in this module are used to generate aesthetically attractive representations of abstract forms, which are suitable for printing. All functions return (possibly deep) lists of characters and generate an error if the form is wrong. All functions can have an optional argument which specifies a hook that is called if an attempt is made to print an unknown form.

**Exports**

\[
\text{form(} \text{Form} \text{)} \rightarrow \text{DeepCharList} \\
\text{form(} \text{Form}, \text{HookFunction} \text{)} \rightarrow \text{DeepCharList}
\]

Types:
- \(\text{Form} = \text{term}()\)
- \(\text{HookFunction} = \text{see separate description below.}\)
- \(\text{DeepCharList} = \text{[char() | DeepCharList]}\)

Pretty prints a Form which is an abstract form of a type which is returned by \text{erl_parse:parse_form}.

\[
\text{attribute(} \text{Attribute} \text{)} \rightarrow \text{DeepCharList} \\
\text{attribute(} \text{Attribute}, \text{HookFunction} \text{)} \rightarrow \text{DeepCharList}
\]

Types:
- \(\text{Attribute} = \text{term}()\)
- \(\text{HookFunction} = \text{see separate description below.}\)
- \(\text{DeepCharList} = \text{[char() | DeepCharList]}\)

The same as form, but only for the attribute \text{Attribute}.

\[
\text{function(} \text{Function} \text{)} \rightarrow \text{DeepCharList} \\
\text{function(} \text{Function}, \text{HookFunction} \text{)} \rightarrow \text{DeepCharList}
\]

Types:
- \(\text{Function} = \text{term}()\)
- \(\text{HookFunction} = \text{see separate description below.}\)
- \(\text{DeepCharList} = \text{[char() | DeepCharList]}\)

The same as form, but only for the function \text{Function}.

\[
\text{guard(} \text{Guard} \text{)} \rightarrow \text{DeepCharList} \\
\text{guard(} \text{Guard}, \text{HookFunction} \text{)} \rightarrow \text{DeepCharList}
\]
Types:
- Form = term()
- HookFunction = see separate description below.
- DeepCharList = [char()|DeepCharList]

The same as form, but only for the guard test Guard.

`exprs(Expressions) -> DeepCharList`
`exprs(Expressions, HookFunction) -> DeepCharList`
`exprs(Expressions, Indent, HookFunction) -> DeepCharList`

Types:
- Expressions = term()
- HookFunction = see separate description below.
- Indent = integer()
- DeepCharList = [char()|DeepCharList]

The same as form, but only for the sequence of expressions in Expressions.

`expr(Expression) -> DeepCharList`
`expr(Expression, HookFunction) -> DeepCharList`
`expr(Expression, Indent, HookFunction) -> DeepCharList`
`expr(Expression, Indent, Precedence, HookFunction) --> DeepCharList`

Types:
- Expression = term()
- HookFunction = see separate description below.
- Indent = integer()
- Precedence =
- DeepCharList = [char()|DeepCharList]

This function prints one expression. It is useful for implementing hooks (see below).

Unknown Expression Hooks

The optional argument HookFunction, shown in the functions described above, defines a function which is called when an unknown form occurs where there should be a valid expression. It can have the following formats:

**Function** The hook function is called by:

```erlang
Function(Expr, CurrentIndentation, CurrentPrecedence, HookFunction)
```

**none** There is no hook function

The called hook function should return a (possibly deep) list of characters. `expr/4` is useful in a hook.

If CurrentIndentation is negative, there will be no line breaks and only a space is used as a separator.
Bugs

It should be possible to have hook functions for unknown forms at places other than expressions.

See Also

io(3) [page 198], erl_parse(3) [page 109], erl_eval(3) [page 100]
erl_scan

Erlang Module

This module contains functions for tokenizing characters into Erlang tokens.

Exports

string(CharList,StartLine) -> {ok, Tokens, EndLine} | Error
string(CharList) -> {ok, Tokens, EndLine} | Error

Types:
- CharList = string()
- StartLine = EndLine = Line = integer()
- Tokens = [{atom(),Line} | {atom(),Line,term()}]
- Error = {error, ErrorInfo, EndLine}

Takes the list of characters CharList and tries to scan (tokenize) them. Returns {ok, Tokens, EndLine}, where Tokens are the Erlang tokens from CharList. EndLine is the last line where a token was found.
StartLine indicates the initial line when scanning starts. string/1 is equivalent to string(CharList, 1).
{error, ErrorInfo, EndLine} is returned if an error occurs. EndLine indicates where the error occurred.

tokens(Continuation, CharList, StartLine) -> Return

Types:
- Return = {done, Result, LeftOverChars} | {more, Continuation}
- Continuation = [] | string()
- CharList = string()
- StartLine = EndLine = integer()
- Result = {ok, Tokens, EndLine} | {eof, EndLine}
- Tokens = [{atom(),Line} | {atom(),Line,term()}]

This is the re-entrant scanner which scans characters until a dot (\.') whitespace) has been reached. It returns:

{done, Result, LeftOverChars} This return indicates that there is sufficient input data to get an input. Result is:

{ok, Tokens, EndLine} The scanning was successful. Tokens is the list of tokens including dot.
{eof, EndLine} End of file was encountered before any more tokens.
{error, ErrorInfo, EndLine} An error occurred.
{more, Continuation} More data is required for building a term. Continuation must be passed in a new call to tokens/3 when more data is available.

reserved_word(Atom) -> bool()
Returns true if Atom is an Erlang reserved word, otherwise false.

format_error(ErrorDescriptor) -> string()
Types:
- ErrorDescriptor = erordesc()
Takes an ErrorDescriptor and returns a string which describes the error or warning. This function is usually called implicitly when processing an ErrorInfo structure (see below).

Error Information

The ErrorInfo mentioned above is the standard ErrorInfo structure which is returned from all IO modules. It has the following format:

{ErrorLine, Module, ErrorDescriptor}
A string which describes the error is obtained with the following call:
apply(Module, format_error, ErrorDescriptor)

Notes

The continuation of the first call to the re-entrant input functions must be []). Refer to Armstrong, Virding and Williams, 'Concurrent Programming in Erlang', Chapter 13, for a complete description of how the re-entrant input scheme works.

See Also

io(3) [page 198], erl_parse(3) [page 109]
erl_tar

Erlang Module

The erl_tar module archives and extract files to and from a tar file. The tar file format is the POSIX extended tar file format specified in IEEE Std 1003.1 and ISO/IEC 9945-1. That is the same format as used by the tar program on Solaris, but is not the same as used by the GNU tar program.

By convention, the name of a tar file should end in "*.tar". To abide to the convention, you'll need to add "*.tar" yourself to the name.

Tar files can be created in one operation using the create/2 [page 119] or create/3 [page 119] function.

Alternatively, for more control, the open [page 121], add/3,4 [page 118], and close/1 [page 118] functions can be used.

To extract all files from a tar file, use the extract/1 [page 119] function. To extract only some files or to be able to specify some more options, use the extract/2 [page 120] function.

To return a list of the files in a tar file, use either the table/1 [page 121] or table/2 [page 121] function. To print a list of files to the Erlang shell, use either the t/1 [page 121] or tt/1 [page 122] function.

To convert an error term returned from one of the functions above to a readable message, use the format_error/1 [page 120] function.

LIMITATIONS

For maximum compatibility, it is safe to archive files with names up to 100 characters in length. Such tar files can generally be extracted by any tar program.

If filenames exceed 100 characters in length, the resulting tar file can only be correctly extracted by a POSIX-compatible tar program (such as Solaris tar), not by GNU tar.

File have longer names than 256 bytes cannot be stored at all.

The filename of the file a symbolic link points is always limited to 100 characters.
Exports

add(TarDescriptor, Filename, Options) -> RetValue

Types:
- TarDescriptor = term()
- Filename = filename()
- Options = [Option]
  - Option = dereference|verbose
- RetValue = ok | {error, {Filename, Reason}}
- Reason = term()

The add/3 function adds a file to a tar file that has been opened for writing by open/1 [page 121].

dereference  By default, symbolic links will be stored as symbolic links in the tar file.
Use the dereference option to override the default and store the file that the
symbolic link points to into the tar file.
verbose Print an informational message about the file being added.

add(TarDescriptor, Filename, NameInArchive, Options) -> RetValue

Types:
- TarDescriptor = term()
- Filename = filename()
- NameInArchive = filename()
- Options = [Option]
  - Option = dereference|verbose
- RetValue = ok | {error, {Filename, Reason}}
- Reason = term()

The add/4 function adds a file to a tar file that has been opened for writing by open/1 [page 121]. It accepts the same options as add/3 [page 118].
NameInArchive is the name under which the file will be stored in the tar file. That is
the name that the file will get when it will be extracted from the tar file.

close(TarDescriptor)

Types:
- TarDescriptor = term()

The close/1 function closes a tar file opened by open/1 [page 121].

create(Name, FileList) -> RetValue

Types:
- Name = filename()
- FileList = [filename()]
- RetValue = ok | {error, {Name, Reason}}
  
Reason = term()
The `create/2` function creates a tar file and archives the files whose names are given in `FileList` into it.

```
create(Name, FileList, OptionList)
Types:
  • Name = filename()
  • FileList = [filename()]
  • OptionList = [Option]
  • Option = compressed | cooked | dereference | verbose
  • RetValue = ok | {error, {Name, Reason}} | {V, Reason = term()}
```

The `create/3` function creates a tar file and archives the files whose names are given in `FileList` into it.

The options in `OptionList` modify the defaults as follows.

- **compressed**  The entire tar file will be compressed, as if it has been run through the `gzip` program. To abide to the convention that a compressed tar file should end in ".tar.gz" or ".tgz", you'll need to add the appropriate extension yourself.
- **cooked**  By default, the `open/2` function will open the tar file in `raw` mode, which is faster but does not allow a remote (erlang) file server to be used. Adding `cooked` to the mode list will override the default and open the tar file without the `raw` option.
- **dereference**  By default, symbolic links will be stored as symbolic links in the tar file. Use the `dereference` option to override the default and store the file that the symbolic link points to into the tar file.
- **verbose**  Print an informational message about each file being added.

```
extract(Name) -> RetValue
Types:
  • Name = filename()
  • RetValue = ok | {error, {Name, Reason}}
  • Reason = term()
```

The `extract/1` function extracts all files from a tar archive.

- If the `Name` argument is given as "{binary, Binary}", the contents of the binary is assumed to be a tar archive.
- If the `Name` argument is given as "{file, Fd}", `Fd` is assumed to be a file descriptor returned from the `file:open/2` function.
- Otherwise, `Name` should be a filename.

```
extract(Name, OptionList)
Types:
  • Name = filename() | {binary, Binary} | {file, Fd}
  • Binary = binary()
  • Fd = file_descriptor()
  • OptionList = [Option]
  • Option = {cwd, Cwd} | {files, FileList} | keep_old_files | verbose
  • Cwd = [dirname()]
```
The extract/2 function extracts files from a tar archive.

If the Name argument is given as 
```
{binary, Binary}
```
the contents of the binary is assumed to be a tar archive.

If the Name argument is given as 
```
{file, Fd}
```
Fd is assumed to be a file descriptor returned from the file:open/2 function.

Otherwise, Name should be a filename.

The following options modify the defaults for the extraction as follows:

- `{cwd, Cwd}` Files with relative filenames will by default be extracted to the current working directory. Given the `{cwd, Cwd}` option, the extract/2 function will extract into the directory `Cwd` instead of to the current working directory.

- `{files, FileList}` By default, all files will be extracted from the tar file. Given the `{files, FileList}` option, the extract/2 function will only extract the files whose names are included in FileList.

- compressed Given the compressed option, the extract/2 function will uncompress the file while extracting. If the tar file is not actually compressed, the compressed will effectively be ignored.

- cooked By default, the open/2 function will open the tar file in raw mode, which is faster but does not allow a remote (erlang) file server to be used. Adding cooked to the mode list will override the default and open the tar file without the raw option.

- keep_old_files By default, all existing files with the same name as file in the tar file will be overwritten. Given the keep_old_files option, the extract/2 function will not overwrite any existing files.

- verbose Print an informational message as each file is being extracted.

---

**format_error(Reason) -> string()**

Types:

- Reason = term()

The format_error/1 converts an error reason term to a human-readable error message string.

**open(Name, OpenModeList) -> RetValue**

Types:

- Name = filename()
- OpenModeList = [OpenMode]
  - Mode = read | write | compressed | cooked
- RetValue = {ok, TarDescriptor} | {error, {Name, Reason}} | <V> TarDescriptor = term()
- Reason = term()
The `open/2` function opens a tar file. By convention, the name of a tar file should end in "\*.tar". To abide to the convention, you'll need to add "\*.tar" yourself to the name. Note that there is currently no function for reading from an opened tar file, meaning that opening a tar file for reading is not very useful.

Except for `read` and `write` (which are mutually exclusive), the following atoms may be added to `OpenModeList`:

- `compressed` The entire tar file will be compressed, as if it has been run through the `gzip` program. To abide to the convention that a compressed tar file should end in "\*.tar.gz" or "\*.tgz", you'll need to add the appropriate extension yourself.
- `cooked` By default, the `open/2` function will open the tar file in `raw` mode, which is faster but does not allow a remote (erlang) file server to be used. Adding `cooked` to the mode list will override the default and open the tar file without the `raw` option.

Use the `add/3,4` functions to add one file at the time into an opened tar file. When you are finished adding files, use the `close` function to close the tar file.

**Warning:**
The `TarDescriptor` term is not a file descriptor. You should not rely on the specific contents of the `TarDescriptor` term, as it may change in future versions as more features are added to the `erl_tar` module.

---

### table/1

**Types:**

- `Name = filename()`
- `RetValValue = {ok,[string()]} | {error, {Name, Reason}}`
- `Reason = term()`

The `table/1` function retrieves the names of all files in the tar file `Name`.

### table/2

**Types:**

- `Name = filename()`

The `table/2` function retrieves the names of all files in the tar file `Name`.

### t/1

**Types:**

- `Name = filename()`

The `t/1` function prints the names of all files in the tar file `Name` to the Erlang shell. (Similar to "tart".)

### tt/1

**Types:**

- `Name = filename()`

The `tt/1` function prints the names of all files in the tar file `Name` to the Erlang shell. (Similar to "tart".)
Name = filename()

The `tt/1` function prints names and information about all files in the tar file `Name` to the Erlang shell. (Similar to “tartv”.)
ets

Erlang Module

This module is an interface to the Erlang built-in term storage BIFs. These provide the ability to store very large quantities of data in an Erlang runtime system, and to have constant access time to the data. (In the case of ordered_set, see below, access time is proportional to the logarithm of the number of objects stored).

Data is organized as a set of dynamic tables, which can store tuples. Each table is created by a process. When the process terminates, the table is automatically destroyed. Every table has access rights set at creation.

Tables are divided into four different types: set, ordered_set, bag and duplicate_bag. A set or ordered_set table can only have one object associated with each key. A bag or duplicate_bag can have many objects associated with each key.

The number of tables stored at one Erlang node is limited. The current default limit is approximately 1400 tables. The upper limit can be increased by setting the environment variable ERL_MAX_ETS_TABLES before starting the Erlang runtime system (i.e. with the -env option to erl/werl). The actual limit may be slightly higher than the one specified, but never lower.

Note that there is no automatic garbage collection for tables. Even if there are no references to a table from any process, it will not automatically be destroyed unless the owner process terminates. It can be destroyed explicitly by using delete/1.

Some implementation details:

- In the current implementation, every object insert and look-up operation results in one copy of the object.
- This module provides very limited support for concurrent updates. No locking is available, but the safe_fixtable/2 function can be used to guarantee that a sequence of first/1 and next/2 calls will traverse the table without errors even if another process (or the same process) simultaneously deletes or inserts objects in the table.
- '$end_of_table' should not be used as a key since this atom is used to mark the end of the table when using first/next.

In general, the functions below will exit with reason badarg if any argument is of the wrong format, or if the table identifier is invalid.

Match Specifications

Some of the functions uses a match specification, match_spec. A brief explanation is given in select/2 [page 137]. For a detailed description, see the chapter “Match specifications in Erlang” in ERTS User's Guide.
DATA TYPES

match_spec()
   a match specification, see above

tid()
   a table identifier, as returned by new/2

Exports

all() -> [Tab]
   Types:
      • Tab = tid() | atom()
   Returns a list of all tables at the node. Named tables are given by their names, unnamed tables are given by their table identifiers.

delete(Tab) -> true
   Types:
      • Tab = tid() | atom()
   Deletes the entire table Tab.

delete(Tab, Key) -> true
   Types:
      • Tab = tid() | atom()
      • Key = term()
   Deletes all objects with the key Key from the table Tab.

delete_all_objects(Tab) -> true
   Types:
      • Tab = tid() | atom()
   Delete all objects in the ETS table Tab. The deletion is atomic.

delete_object(Tab, Object) -> true
   Types:
      • Tab = tid() | atom()
      • Object = tuple()
   Delete the exact object Object from the ETS table, leaving objects with the same key but other differences (useful for type bag).

file2tab(Filename) -> {ok, Tab} | {error, Reason}
   Types:
      • Filename = string() | atom()
• Tab = tid() | atom()
• Reason = term()

Reads a file produced by `tab2file/2` and creates the corresponding table Tab.

```erlang
first(Tab) -> Key | '$end_of_table'
```

Types:
• Tab = tid() | atom()
• Key = term()

Returns the first key Key in the table Tab. If the table is of the ordered_set type, the first key in Erlang term order will be returned. If the table is of any other type, the first key according to the table's internal order will be returned. If the table is empty, `$end_of_table` will be returned. Use `next/2` to find subsequent keys in the table.

```erlang
fixtable(Tab, true|false) -> true | false
```

Types:
• Tab = tid() | atom()

**Warning:**
The function is retained for backwards compatibility only. Use `safe_fixtable/2` instead.

Fixes a table for safe traversal. The function is primarily used by the Mnesia DBMS to implement functions which allow write operations in a table, although the table is in the process of being copied to disk or to another node. It does not keep track of when and how tables are fixed.

```erlang
foldl(Function, Acc0, Tab) -> Acc1
```

Types:
• Function = fun(A, AccIn) -> AccOut
• Tab = tid() | atom()
• Acc0 = Acc1 = AccIn = AccOut = term()

Acc0 is returned if the table is empty. This function is similar to `lists:foldl/3`. The order in which the elements of the table are traversed is unspecified, except for tables of type ordered_set, for which they are traversed first to last.

```erlang
foldr(Function, Acc0, Tab) -> Acc1
```

Types:
• Function = fun(A, AccIn) -> AccOut
• Tab = tid() | atom()
• Acc0 = Acc1 = AccIn = AccOut = term()
Acc0 is returned if the table is empty. This function is similar to `lists:foldr/3`. The order in which the elements of the table are traversed is unspecified, except for tables of type `ordered_set`, for which they are traversed last to first.

```prolog
from_dets(Tab, DetsTab) -> Tab
Types:
- Tab = tid() | atom()
- DetsTab = atom()
```

Fills an already created ETS table with the objects in the already opened Dets table named `DetsTab`. The ETS table is emptied before the objects are inserted.

```prolog
fun2ms(LiteralFun) -> MatchSpec
Types:
- LiteralFun - see below
- MatchSpec = match_spec()
```

Pseudo function that by means of a `parse_transform` translates `LiteralFun` typed as parameter in the function call to a `match_spec` [page 123]. With “literal” is meant that the fun needs to textually be written as the parameter of the function, it cannot be held in a variable which in turn is passed to the function).

The `parse_transform` is implemented in the module `ms_transform` and the source must include the file `ms_transform.hrl` in `stdlib` for this pseudo function to work. Failing to include the hrl file in the source will result in a runtime error, not a compile time ditto. The include file is easiest included by adding the line
```
#include("stdlib/include/ms_transform.hrl")
```
to the source file.

The fun is very restricted, it can take only a single parameter (the object to match): a sole variable or a tuple. It needs to use the `is_XXX` guard tests. Language constructs that have no representation in a `match_spec` (like `if`, `case`, `receive` etc) are not allowed.

The return value is the resulting `match_spec`.

Example:

1> ets:fun2ms(fun([M,N]) when N > 3 -> M end).
[[{"$1'"","$2'""},[{">@","$2'""],[{"$1'" }]}}]

Variables from the environment can be imported, so that this works:

2> X=3.
3
3> ets:fun2ms(fun([M,N]) when N > X -> M end).
[[{"$1'"","$2'""},[{">@","$2'"",["const","3"]],[{"$1'" }]}}]

The imported variables will be replaced by `match_spec const` expressions, which is consistent with the static scoping for Erlang funs. Local or global function calls can not be in the guard or body of the fun however. Calls to builtin `match_spec` functions of course is allowed:
As can be seen by the example, the function can be called from the shell too. The fun needs to be literally in the call when used from the shell as well. Other means than the parse_transform are used in the shell case, but more or less the same restrictions apply (the exception being records, as they are not handled by the shell).

**Warning:**
If the parse_transform is not applied to a module which calls this pseudo function, the call will fail in runtime (with a badarg). The module ets actually exports a function with this name, but it should never really be called except for when using the function in the shell. If the parse_transform is properly applied by including the ms_transform.hrl header file, compiled code will never call the function, but the function call is replaced by a literal match_spec.

For more information, see ms_transform(3) [page 233].

### i()

- **Returns:** void()
- **Description:** Displays information about all ETS tables on tty.

### i(Tab)

- **Returns:** void()
- **Types:**
  - Tab = tid() | atom()
- **Description:** Browses the table Tab on tty.

### info(Tab)

- **Returns:** tuple() | undefined
- **Types:**
  - Tab = tid() | atom()
- **Description:** Returns information about the table Tab as a tuple with {Item, Value} elements as specified below.

**Warning:**
In Erlang/OTP R11B, this function will be corrected to return a list of tuples instead.

- **Item=memory, Value=int()**
  - The number of words allocated to the table.
- **Item=owner, Value=pid()**
  - The pid of the owner of the table.
- **Item**: name, Value=atom()
  - The name of the table.

- **Item**: size, Value=int()
  - The number of objects inserted in the table.

- **Item**: node, Value=atom()
  - The node where the table is stored. This field is no longer meaningful as tables cannot be accessed from other nodes.

- **Item**: named_table, Value=true|false
  - Indicates if the table is named or not.

- **Item**: type, Value=set|ordered_set|bag|duplicate_bag
  - The table type.

- **Item**: keypos, Value=int()
  - The key position.

- **Item**: protection, Value=public|protected|private
  - The table access rights.

\[
\text{info}(	ext{Tab}, \text{Item}) \rightarrow \text{Value} \mid \text{undefined}
\]

**Types:**
- Tab = tid() | atom()
- Item, Value - see below

Returns the information associated with \text{Item} for the table \text{Tab}. In addition to the \{Item,Value\} pairs defined for \text{info/1}, the following items are allowed:

- **Item**: fixed, Value=true|false
  - Indicates if the table is fixed by any process or not.

- **Item**: safe_fixed, Value=\{FirstFixed,Info\}\mid false
  - If the table has been fixed using \text{safe_fixtable/2}, the call returns a tuple where \text{FirstFixed} is the time when the table was first fixed by a process, which may or may not be one of the processes it is fixed by right now. \text{Info} is a possibly empty lists of tuples \{Pid,RefCount\}, one tuple for every process the table is fixed by right now. \text{RefCount} is the value of the reference counter, keeping track of how many times the table has been fixed by the process. If the table never has been fixed, the call returns false.

\[
\text{init_table}(\text{Name}, \text{InitFun}) \rightarrow \text{true}
\]

**Types:**
- Name = atom()
- InitFun = fun(\text{Arg}) \rightarrow \text{Res}
- Arg = read \mid close
- Res = end_of_input \mid \{[\text{object()}], \text{InitFun}\} \mid \text{term()}

Replaces the existing objects of the table Tab with objects created by calling the input function InitFun, see below. This function is provided for compatibility with the ets module, it is not more efficient than filling a table by using ets:insert/2.

When called with the argument read the function InitFun is assumed to return end_of_input when there is no more input, or {Objects, Fun}, where Objects is a list of objects and Fun is a new input function. Any other value Value is returned as an error {error, {init_fun, Value}}. Each input function will be called exactly once, and should an error occur, the last function is called with the argument close, the reply of which is ignored.

If the type of the table is set and there is more than one object with a given key, one of the objects is chosen. This is not necessarily the last object with the given key in the sequence of objects returned by the input functions. This holds also for duplicated objects stored in tables of type duplicate_bag.

**insert(Tab, ObjectOrObjects) -> true**

Types:
- Tab = tid() | atom()
- ObjectOrObjects = tuple() | [tuple()]

Inserts the object or all of the objects in the list ObjectOrObjects into the table Tab. If there already exists an object with the same key as one of the objects, and the table is a set or ordered_set table, the old object will be replaced. If the list contains more than one object with the same key and the table is a set/ordered_set, one will be inserted, which one is not defined.

**insert_new(Tab, ObjectOrObjects) -> bool()**

Types:
- Tab = tid() | atom()
- ObjectOrObjects = tuple() | [tuple()]

This function works exactly like insert/2, with the exception that instead of overwriting objects with the same key (in the case of set or ordered_set) or adding more objects with keys already existing in the table (in the case of bag and duplicate_bag), it simply returns false. If ObjectOrObjects is a list, the function checks every key prior to inserting anything. Nothing will be inserted if not all keys present in the list are absent from the table.

**is_compiled_ms(Term) -> bool()**

Types:
- Term = term()

This function is used to check if a term is a valid compiled match_spec [page 123]. The compiled match_spec is an opaque datatype which can not be sent between Erlang nodes nor be stored on disk. Any attempt to create an external representation of a compiled match_spec will result in an empty binary (<<>>). As an example, the following expression:

```
ets:is_compiled_ms(ets:match_spec_compile([{'_',[],[true]}]))
```

will yield true, while the following expressions:

```
```
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MS = ets:match_spec_compile([{'_',[[],[true]]}],
Broken = binary_to_term(term_to_binary(MS)),
ets:is_compiled_ms(Broken).

will yield false, as the variable Broken will contain a compiled match_spec that has
passed through external representation.

**Note:**
The fact that compiled match_specs has no external representation is for
performance reasons. It may be subject to change in future releases, while this
interface will still remain for backward compatibility reasons.

last(Tab) -> Key | '$end_of_table'

Types:
- Tab = tid() | atom()
- Key = term()

Returns the last key Key according to Erlang term order in the table Tab of the
ordered_set type. If the table is of any other type, the function is synonymous to
first/2. If the table is empty, '$end_of_table' is returned.

Use prev/2 to find preceding keys in the table.

lookup(Tab, Key) -> [Object]

Types:
- Tab = tid() | atom()
- Key = term()
- Object = tuple()

Returns a list of all objects with the key Key in the table Tab.

If the table is of type set or ordered_set, the function returns either the empty list or a
list with one element, as there cannot be more than one object with the same key. If the
table is of type bag or duplicate_bag, the function returns a list of arbitrary length.

Note that the time order of object insertions is preserved; The first object inserted with
the given key will be first in the resulting list, and so on.

Insert and look-up times in tables of type set, bag and duplicate_bag are constant,
regardless of the size of the table. For the ordered_set data-type, time is proportional
to the (binary) logarithm of the number of objects.

lookup_element(Tab, Key, Pos) -> Elem

Types:
- Tab = tid() | atom()
- Key = term()
- Pos = int()
- Elem = term() | [term()]

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If the table `Tab` is of type `set` or `ordered_set`, the function returns the `Pos`th element of the object with the key `Key`.

If the table is of type `bag` or `duplicate_bag`, the function returns a list with the `Pos`th element of every object with the key `Key`.

If no object with the key `Key` exists, the function will exit with reason `badarg`.

```
match(Tab, Pattern) -> [Match]

Types:

- Tab = tid() | atom()
- Pattern = tuple()
- Match = [term()]

Matches the objects in the table `Tab` against the pattern `Pattern`.

A pattern is a term that may contain:

- bound parts (Erlang terms),
- `_` which matches any Erlang term, and
- pattern variables: `$_N` where `N=0, 1,...`

The function returns a list with one element for each matching object, where each element is an ordered list of pattern variable bindings. An example:

```
6> ets:match(T, '$_1').   % Matches every object in the table
[[[rufsen,dog,7]],[[brunte,horse,5]],[[ludde,dog,5]]]
7> ets:match(T, {'_',dog,'$_1'}).  
[[7],[5]]
8> ets:match(T, {'_',cow,'$_1'}).  
[]
```

If the key is specified in the pattern, the match is very efficient. If the key is not specified, i.e. if it is a variable or an underscore, the entire table must be searched. The search time can be substantial if the table is very large.

On tables of the `ordered_set` type, the result is in the same order as in a `first/next` traversal.

```
match(Tab, Pattern, Limit) -> [[Match],Continuation] | '$end_of_table'

Types:

- Tab = tid() | atom()
- Pattern = tuple()
- Match = [term()]
- Continuation = term()

Works like `ets:match/2` but only returns a limited (Limit) number of matching objects. The `Continuation` term can then be used in subsequent calls to `ets:match/1` to get the next chunk of matching objects. This is a space efficient way to work on objects in a table which is still faster than traversing the table object by object using `ets:first/1` and `ets:next/1`.

'$end_of_table' is returned if the table is empty.
```
match(Continuation) -> [{Match},Continuation] | 'end_of_table'

Types:
- Match = [term()]
- Continuation = term()

Continues a match started with ets:match/3. The next chunk of the size given in the initial ets:match/3 call is returned together with a new Continuation that can be used in subsequent calls to this function.

'end_of_table' is returned when there are no more objects in the table.

match_delete(Tab, Pattern) -> true

Types:
- Tab = tid() | atom()
- Pattern = tuple()

Deletes all objects which match the pattern Pattern from the table Tab. See match/2 for a description of patterns.

match_object(Tab, Pattern) -> [Object]

Types:
- Tab = tid() | atom()
- Pattern = Object = tuple()

Matches the objects in the table Tab against the pattern Pattern. See match/2 for a description of patterns. The function returns a list of all objects which match the pattern.

If the key is specified in the pattern, the match is very efficient. If the key is not specified, i.e. if it is a variable or an underscore, the entire table must be searched. The search time can be substantial if the table is very large.

On tables of the ordered_set type, the result is in the same order as in a first/next traversal.

match_object(Tab, Pattern, Limit) -> [{Match},Continuation] | 'end_of_table'

Types:
- Tab = tid() | atom()
- Pattern = tuple()
- Match = [term()]
- Continuation = term()

Works like ets:match_object/2 but only returns a limited (Limit) number of matching objects. The Continuation term can then be used in subsequent calls to ets:match_object/1 to get the next chunk of matching objects. This is a space efficient way to work on objects in a table which is still faster than traversing the table object by object using ets:first/1 and ets:next/1.

'end_of_table' is returned if the table is empty.

match_object(Continuation) -> [{Match},Continuation] | 'end_of_table'

Types:
- Match = [term()]
- Continuation = term()

Continues a match started with ets:match_object/3. The next chunk of the size given in the initial ets:match_object/3 call is returned together with a new Continuation that can be used in subsequent calls to this function.

'\$end_of_table' is returned when there are no more objects in the table.

match_spec_compile(MatchSpec) -> CompiledMatchSpec

Types:
- MatchSpec = match_spec()
- CompiledMatchSpec = comp_match_spec()

This function transforms a match_spec [page 123] into an internal representation that can be used in subsequent calls to ets:match_spec_run/2. The internal representation is opaque and can not be converted to external term format and then back again without losing its properties (meaning it can not be sent to a process on another node and still remain a valid compiled match_spec, nor can it be stored on disk). The validity of a compiled match_spec can be checked using ets:is_compiled_ms/1.

If the term MatchSpec can not be compiled (does not represent a valid match_spec), a badarg fault is thrown.

Note:
This function has limited use in normal code, it is used by Dets to perform the dets:select operations.

match_spec_run(List,CompiledMatchSpec) -> list()

Types:
- List = [ tuple() ]
- CompiledMatchSpec = comp_match_spec()

This function executes the matching specified in a compiled match_spec [page 123] on a list of tuples. The CompiledMatchSpec term should be the result of a call to ets:match_spec_compile/1 and is hence the internal representation of the match_spec one wants to use.

The matching will be executed on each element in List and the function returns a list containing all results. If an element in List does not match, nothing is returned for that element. The length of the result list is therefore equal or less than the the length of the parameter List. The two calls in the following example will give the same result (but certainly not the same execution time..):

Table = ets:new...
MatchSpec = ....
% The following call...
ets:match_spec_run(ets:tab2list(Table),
ets:match_spec_compile(MatchSpec)),
% ...will give the same result as the more common (and more efficient)
ets:select(Table,MatchSpec),

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Note:
This function has limited use in normal code, it is used by Dets to perform the
dets:select operations and by Mnesia during transactions.

member(Tab, Key) -> true | false

Types:
- Tab = tid() | atom()
- Key = term()

Works like lookup/2, but does not return the objects. The function returns true if one
or more elements in the table has the key Key, false otherwise.

new(Name, Options) -> tid()

Types:
- Name = atom()
- Options = [Option]
  - Option = Type | Access | named_table | {keypos,Pos}
  - Type = set | ordered_set | bag | duplicate_bag
  - Access = public | protected | private
  - Pos = int()

Creates a new table and returns a table identifier which can be used in subsequent
operations. The table identifier can be sent to other processes so that a table can be
shared between different processes within a node.

The parameter Options is a list of atoms which specifies table type, access rights, key
position and if the table is named or not. If one or more options are left out, the default
values are used. This means that not specifying any options ([]) is the same as
specifying [set,protected, {keypos,1}].

- set The table is a set table - one key, one object, no order among objects. This is
  the default table type.
- ordered_set The table is a ordered_set table - one key, one object, ordered in
  Erlang term order, which is the order implied by the < and > operators. Tables of
  this type have a somewhat different behavior in some situations than tables of the
  other types.
- bag The table is a bag table which can have many objects, but only one instance of
  each object, per key.
- duplicate_bag The table is a duplicate_bag table which can have many objects,
  including multiple copies of the same object, per key.
- public Any process may read or write to the table.
- protected The owner process can read and write to the table. Other processes can
  only read the table. This is the default setting for the access rights.
- private Only the owner process can read or write to the table.
- named_table If this option is present, the name Name is associated with the table
  identifier. The name can then be used instead of the table identifier in subsequent
  operations.
• \{keypos, Pos\} Specifies which element in the stored tuples should be used as key. By default, it is the first element, i.e. \(\text{Pos}=1\). However, this is not always appropriate. In particular, we do not want the first element to be the key if we want to store Erlang records in a table. Note that any tuple stored in the table must have at least \(\text{Pos}\) number of elements.

next(Tab, Key1) \rightarrow Key2 \mid '$end_of_table'

Types:
• Tab = tid() \| atom()
• Key1 = Key2 = term()

Returns the next key Key2, following the key Key1 in the table Tab. If the table is of the ordered_set type, the next key in Erlang term order is returned. If the table is of any other type, the next key according to the table's internal order is returned. If there is no next key, '$end_of_table' is returned.

Use first/1 to find the first key in the table.

Unless a table of type set, bag or duplicate_bag is protected using safe_fixtable/2, see below, a traversal may fail if concurrent updates are made to the table. If the table is of type ordered_set, the function returns the next key in order, even if the object does no longer exist.

prev(Tab, Key1) \rightarrow Key2 \mid '$end_of_table'

Types:
• Tab = tid() \| atom()
• Key1 = Key2 = term()

Returns the previous key Key2, preceding the key Key1 according the Erlang term order in the table Tab of the ordered_set type. If the table is of any other type, the function is synonymous to next/2. If there is no previous key, '$end_of_table' is returned.

Use last/1 to find the last key in the table.

rename(Tab, Name) \rightarrow Name

Types:
• Tab = Name = atom()

Renames the named table Tab to the new name Name. Afterwards, the old name can not be used to access the table. Renaming an unnamed table has no effect.

repair_continuation(Continuation, MatchSpec) \rightarrow Continuation

Types:
• Continuation = term()
• MatchSpec = match_spec()
This function can be used to restore an opaque continuation returned by ets:select/3 or ets:select/1 if the continuation has passed through external term format (been sent between nodes or stored on disk).

The reason for this function is that continuation terms contain compiled match specs and therefore will be invalidated if converted to external term format. Given that the original match spec is kept intact, the continuation can be restored, meaning it can once again be used in subsequent ets:select/1 calls even though it has been stored on disk or on another node.

As an example, the following sequence of calls will fail:

\[
\begin{align*}
T &= \text{ets:new}(x,[\]), \\
\ldots & \quad \{\_, C\} = \text{ets:select}(T, \text{ets:fun2ms(fun({N,\_}=A) \\
\ldots \quad \text{when } (N \text{ rem } 10) =:= 0 \rightarrow \A \\
\ldots \quad \text{end)},10), \\
\ldots & \quad \text{Broken} = \text{binary_to_term}(\text{term_to_binary}(C)), \\
\ldots & \quad \text{ets:select}(	ext{Broken}).
\end{align*}
\]

...while the following sequence will work:

\[
\begin{align*}
T &= \text{ets:new}(x,[\]), \\
\ldots & \quad \text{MS} = \text{ets:fun2ms(fun({N,\_}=A) \\
\ldots \quad \text{when } (N \text{ rem } 10) =:= 0 \rightarrow \A \\
\ldots \quad \text{end)}, \\
\ldots & \quad \{\_, C\} = \text{ets:select}(T, \text{MS},10), \\
\ldots & \quad \text{Broken} = \text{binary_to_term}(\text{term_to_binary}(C)), \\
\ldots & \quad \text{ets:select}((\text{ets:repair_continuation}(\text{Broken}, \text{MS})).
\end{align*}
\]

...as the call to ets:repair_continuation/2 will reestablish the (deliberately) invalidated continuation Broken.

**Note:**
This function is very rarely needed in application code. It is used by Mnesia to implement distributed select/3 and select/1 sequences. A normal application would either use Mnesia or keep the continuation from being converted to external format.

The reason for not having an external representation of a compiled match spec is performance. It may be subject to change in future releases, while this interface will remain for backward compatibility.

\[
\text{safe_fixtable}(\text{Tab}, \text{true|false}) \rightarrow \text{true}
\]

Types:
- \(\text{Tab} = \text{tid()} | \text{atom()}\)
Fixes a table of the set, bag or duplicate_bag table type for safe traversal.

A process fixes a table by calling safe_fixtable(Tab, true). The table remains fixed until the process releases it by calling safe_fixtable(Tab, false), or until the process terminates.

If several processes fix a table, the table will remain fixed until all processes have released it (or terminated). A reference counter is kept on a per process basis, and N consecutive fixes requires N releases to actually release the table.

When a table is fixed, a sequence of first/1 and next/2 calls are guaranteed to succeed even if objects are removed during the traversal. An example:

```
clean_all_with_value(Tab, X) ->
    safe_fixtable(Tab, true),
    clean_all_with_value(Tab, X, ets:first(Tab)),
    safe_fixtable(Tab, false).

clean_all_with_value(Tab, X, '$end_of_table') ->
    true;
clean_all_with_value(Tab, X, Key) ->
    case ets:lookup(Tab, Key) of
        [{Key, X}] ->
            ets:delete(Tab, Key);
        _ ->
            true
    end,
    clean_all_with_value(Tab, X, ets:next(Tab, Key)).
```

Note that no deleted objects are actually removed from a fixed table until it has been released. If a process fixes a table but never releases it, the memory used by the deleted objects will never be freed. The performance of operations on the table will also degrade significantly.

Use info/2 to retrieve information about which processes have fixed which tables. A system with a lot of processes fixing tables may need a monitor which sends alarms when tables have been fixed for too long.

Note that for tables of the ordered_set type, safe_fixtable/2 is not necessary as calls to first/1 and next/2 will always succeed.

```
select(Tab, MatchSpec) -> [Object]
```

Types:

- Tab = tid() | atom()
- Object = tuple()
- MatchSpec = match_spec()

Matches the objects in the table Tab using a match_spec [page 123]. This is a more general call than the ets:match/2 and ets:match_object/2 calls. In its simplest forms the match_specs look like this:

- MatchSpec = [MatchFunction]
- MatchFunction = {MatchHead, [Guard], [Result]}
- MatchHead = “Pattern as in ets:match”
- Guard = {“Guardtest name”,...}
Result = “Term construct”

This means that the match_spec is always a list of one or more tuples (of arity 3). The tuples first element should be a pattern as described in the documentation of ets:match/2. The second element of the tuple should be a list of 0 or more guard tests (described below). The third element of the tuple should be a list containing a description of the value to actually return. In almost all normal cases the list contains exactly one term which fully describes the value to return for each object.

The return value is constructed using the “match variables” bound in the MatchHead or using the special match variables ‘$_’ (the whole matching object) and ‘$$’ (all match variables in a list), so that the following ets:match/2 expression:

```erlang
ets:match(Tab, [\{'$1', '$2', '$3'\}])
```

is exactly equivalent to:

```erlang
ets:select(Tab, [\[\{'$1', '$2', '$3'\}, [], ['$$']\}])
```

- and the following ets:match_object/2 call:

```erlang
ets:match_object(Tab, [\{'$1', '$2', '$1'\}])
```

is exactly equivalent to

```erlang
ets:select(Tab, [\[\{'$1', '$2', '$1'\}, [], ['$_']\}])
```

Composite terms can be constructed in the Result part either by simply writing a list, so that this code:

```erlang
ets:select(Tab, [\[\{'$1', '$2', '$3'\}, [], ['$$']\}])
```

gives the same output as:

```erlang
ets:select(Tab, [\[\{'$1', '$2', '$3'\}, [], [\{'$1', '$2', '$3'\}]\}])
```

i.e. all the bound variables in the match head as a list. If tuples are to be constructed, one has to write a tuple of arity 1 with the single element in the tuple being the tuple one wants to construct (as an ordinary tuple could be mistaken for a guard). Therefore the following call:

```erlang
ets:select(Tab, [\[\{'$1', '$2', '$1'\}, [], ['$_']\}])
```

gives the same output as:

```erlang
ets:select(Tab, [\[\{'$1', '$2', '$1'\}, [], [\{'$1', '$2', '$3'\}]\}])
```

- this syntax is equivalent to the syntax used in the trace patterns (see [dbg(3)]).

The Guards are constructed as tuples where the first element is the name of the test and the rest of the elements are the parameters of the test. To check for a specific type (say a list) of the element bound to the match variable ‘$_’, one would write the test as \{is_list, ‘$_’\}. If the test fails, the object in the table will not match and the next MatchFunction (if any) will be tried. Most guard tests present in Erlang can be used, but only the new versions prefixed is_ are allowed (like is_float, is_atom etc).

The Guard section can also contain logic and arithmetic operations, which are written with the same syntax as the guard tests (prefix notation), so that a guard test written in Erlang looking like this:

```erlang
is_integer(X), is_integer(Y), X + Y < 4711
```

is expressed like this (X replaced with ‘$_’ and Y with ‘$2’):

```erlang
[{is_integer, ‘$_’}, {is_integer, ‘$2’}, {'<', {'+', ‘$_’, ‘$2’}, 4711}]
```
select(Tab, MatchSpec, Limit) -> [{Match],Continuation} | '$end_of_table'

Types:
- Tab = tid() | atom()
- Object = tuple()
- MatchSpec = match_spec()
- Continuation = term()

Works like ets:select/2 but only returns a limited (Limit) number of matching objects. The Continuation term can then be used in subsequent calls to ets:select/1 to get the next chunk of matching objects. This is a space efficient way to work on objects in a table which is still faster than traversing the table object by object using ets:first/1 and ets:next/1.

'$end_of_table' is returned if the table is empty.

select(Continuation) -> [{Match],Continuation} | '$end_of_table'

Types:
- Match = [term()]
- Continuation = term()

Continues a match started with ets:select/3. The next chunk of the size given in the initial ets:select/3 call is returned together with a new Continuation that can be used in subsequent calls to this function.

'$end_of_table' is returned when there are no more objects in the table.

select_delete(Tab, MatchSpec) -> NumDeleted

Types:
- Tab = tid() | atom()
- Object = tuple()
- MatchSpec = match_spec()
- NumDeleted = integer()

Matches the objects in the table Tab using a match_spec [page 123]. If the match_spec returns true for an object, that object is removed from the table. For any other result from the match_spec the object is retained. This is a more general call than the ets:match_delete/2 call.

The function returns the number of objects actually deleted from the table.

select_count(Tab, MatchSpec) -> NumMatched

Types:
- Tab = tid() | atom()
- Object = tuple()
- MatchSpec = match_spec()
- NumMatched = integer()
Matches the objects in the table `Tab` using a `match_spec` [page 123]. If the `match_spec` returns `true` for an object, that object considered a match and is counted. For any other result from the `match_spec` the object is not considered a match and is therefore not counted.

The function could be described as a `match_delete/2` that does not actually delete any elements, but only counts them.

The function returns the number of objects matched.

```
slot(Tab, I) -> [Object] | '$end_of_table'
```

Types:

- `Tab = tid() | atom()`
- `I = int()`
- `Object = tuple()`

This function is mostly for debugging purposes. Normally one should use `first/next` or `last/prev` instead.

Returns all objects in the `I`th slot of the table `Tab`. A table can be traversed by repeatedly calling the function, starting with the first slot `I=0` and ending when `$end_of_table` is returned. The function will fail with reason `badarg` if the `I` argument is out of range.

Unless a table of type `set`, `bag` or `duplicate_bag` is protected using `safe_fixtable/2`, see above, a traversal may fail if concurrent updates are made to the table. If the table is of type `ordered_set`, the function returns a list containing the `I`th object in Erlang term order.

```
tab2file(Tab, Filename) -> ok | {error,Reason}
```

Types:

- `Tab = tid() | atom()`
- `Filename = string() | atom()`
- `Reason = term()`

Dumps the table `Tab` to the file `Filename`. The implementation of this function is not efficient.

```
tab2list(Tab) -> [Object]
```

Types:

- `Tab = tid() | atom()`
- `Object = tuple()`

Returns a list of all objects in the table `Tab`.

```
table(Tab [, Options]) -> QueryHandle
```

Types:

- `Tab = tid() | atom()`
- `QueryHandle = -a query handle, see qlc(3)-`
- `Options = [Option] | Option`
- `Option = {n_objects, NObs} | {traverse, TraverseMethod}`
- `NObs = default | integer() > 0`
TraverseMethod = first, next, last, prev, select

MatchSpec = match_spec()

Returns a QLC (Query List Comprehension) query handle. The module qlc implements a query language aimed mainly at Mnesia but ETS tables, Dets tables, and lists are also recognized by QLC as sources of data. Calling ets:table/1,2 is the means to make the ETS table Tab usable to QLC.

When there are only simple restrictions on the key position QLC uses ets:lookup/2 to look up the keys, but when that is not possible the whole table is traversed. The option traverse determines how this is done:

- first, next. The table is traversed one key at a time by calling ets:first/1 and ets:next/2.
- last, prev. The table is traversed one key at a time by calling ets:last/1 and ets:prev/2.
- select. The table is traversed by calling ets:select/3 and ets:select/1. The option n_objects determines the number of objects returned (the third argument of select/3); the default is to return 100 objects at a time. The match_spec [page 123] (the second argument of select/3) is assembled by QLC: simple filters are translated into equivalent match specs while more complicated filters have to be applied to all objects returned by select/3 given a match_spec that matches all objects.
- {select, MatchSpec}. As for select the table is traversed by calling ets:select/3 and ets:select/1. The difference is that the match_spec is explicitly given. This is how to state match specs that cannot easily be expressed within the syntax provided by QLC.

The following example uses an explicit match_spec to traverse the table:

```elisp
(ets:insert(Tab = ets:new(t, []), [[1,a],[2,b],[3,c],[4,d]]),
 MS = ets:fun2ms(fun(X,Y) when (X > 1) or (X < 5) -> Y end),
 QH1 = ets:table(Tab, [{traverse, {select, MS}}]).
```

An example with implicit match_spec:

```elisp
QH2 = qlc:q([[Y] || [X,Y] <- ets:table(Tab), (X > 1) or (X < 5)].
```

The latter example is in fact equivalent to the former which can be verified using the function qlc:info/1:

```elisp
qlc:info(QH1) =:= qlc:info(QH2).
true
```

qlc:info/1 returns information about a query handle, and in this case identical information is returned for the two query handles.

```elisp
test_ms(Tuple, MatchSpec) -> {ok, Result} | {error, Errors}
```

Types:
- Tuple = tuple()
- MatchSpec = match_spec()
- Result = term()
This function is a utility to test a match spec [page 123] used in calls to ets:select/2. The function both tests MatchSpec for "syntactic" correctness and runs the match spec against the object Tuple. If the match spec contains errors, the tuple [error, Errors] is returned where Errors is a list of natural language descriptions of what was wrong with the match spec. If the match spec is syntactically OK, the function returns {ok,Term} where Term is what would have been the result in a real ets:select/2 call or false if the match spec does not match the object Tuple.

This is a useful debugging and test tool, especially when writing complicated ets:select/2 calls.

to_dets(Tab, DetsTab) -> Tab
Types:
  • Tab = tid() | atom()
  • DetsTab = atom()
Fills an already created/opened Dets table with the objects in the already opened ETS table named Tab. The Dets table is emptied before the objects are inserted.

update_counter(Tab, Key, {Pos,Incr,Threshold,SetValue}) -> Result
update_counter(Tab, Key, {Pos,Incr}) -> Result
update_counter(Tab, Key, Incr) -> Result
Types:
  • Tab = tid() | atom()
  • Key = term()
  • Pos = Incr = Threshold = SetValue = Result = int()
This function provides an efficient way to update a counter, without the hassle of having to look up an object, update the object by incrementing an element and insert the resulting object into the table again. (The update is done atomically; i.e. no process can access the ets table in the middle of the operation.)

It will destructively update the object with key Key in the table Tab by adding Incr to the element at the Pos:th position. The new counter value is returned. If no position is specified, the element directly following the key (<keypos>+1) is updated.

If a Threshold is specified, the counter will be reset to the value SetValue if the following conditions occur:
  • The Incr is not negative (>= 0) and the result would be greater than (> Threshold
  • The Incr is negative (< 0) and the result would be less than (<) Threshold

The function will fail with reason badarg if:
  • the table is not of type set or ordered_set,
  • no object with the right key exists,
  • the object has the wrong arity,
  • the element to update is not an integer, or,
  • any of Pos, Incr, Threshold or SetValue is not an integer
The functions of this module sort terms on files, merge already sorted files, and check files for sortedness. Chunks containing binary terms are read from a sequence of files, sorted internally in memory and written on temporary files, which are merged producing one sorted file as output. Merging is provided as an optimization; it is faster when the files are already sorted, but it always works to sort instead of merge.

On a file, a term is represented by a header and a binary. Two options define the format of terms on files:

- \{header, HeaderLength\}. HeaderLength determines the number of bytes preceding each binary and containing the length of the binary in bytes. Default is 4. The order of the header bytes is defined as follows: if B is a binary containing a header only, the size Size of the binary is calculated as \langle\langle\text{Size:HeaderLength}/\text{unit:8}\rangle\rangle = B.

- \{format, Format\}. The format determines the function that is applied to binaries in order to create the terms that will be sorted. The default value is binary_term, which is equivalent to fun binary_to_term/1. The value binary is equivalent to fun(X) -> X end, which means that the binaries will be sorted as they are. This is the fastest format. If Format is term, io:read/2 is called to read terms. In that case only the default value of the header option is allowed. The format option also determines what is written to the sorted output file: if Format is term then io:format/3 is called to write each term, otherwise the binary prefixed by a header is written. Note that the binary written is the same binary that was read; the results of applying the Format function are thrown away as soon as the terms have been sorted. Reading and writing terms using the io module is very much slower than reading and writing binaries.

Other options are:

- \{order, Order\}. The default is to sort terms in ascending order, but that can be changed by the value descending or by giving an ordering function Fun. Fun(A, B) should return true if A comes before B in the ordering, false otherwise. Using an ordering function will slow down the sort considerably. The keysort, keymerge and keycheck functions do not accept ordering functions.

- \{unique, bool()\}. When sorting or merging files, only the first of a sequence of terms that compare equal is output if this option is set to true. The default value is false which implies that all terms that compare equal are output. When checking files for sortedness, a check that no pair of consecutive terms compares equal is done if this option is set to true.
The directory where temporary files are put can be chosen explicitly. The default, implied by the value "", is to put temporary files on the same directory as the sorted output file. If output is a function (see below), the directory returned by \texttt{file:get_cwd()} is used instead. The names of temporary files are derived from the Erlang nodename (\texttt{node()}), the process identifier of the current Erlang emulator (\texttt{os:getpid()}) and a timestamp (\texttt{erlang:now()}); a typical name would be \texttt{fs_mynode@myhost_1763_1043_337000_266005.17}, where 17 is a sequence number. Existing files will be overwritten. Temporary files are deleted unless some uncaught \texttt{EXIT} signal occurs.

Temporary files and the output file may be compressed. The default value \texttt{false} implies that written files are not compressed. Regardless of the value of the \texttt{compressed} option, compressed files can always be read. Note that reading and writing compressed files is significantly slower than reading and writing uncompressed files.

By default approximately 512*1024 bytes read from files are sorted internally. This option should rarely be needed.

By default 16 files are merged at a time. This option should rarely be needed.

To summarize, here is the syntax of the options:

\begin{itemize}
\item \texttt{Options} = [\texttt{Option}] | \texttt{Option}
\item \texttt{Option} = \{\texttt{header}, \texttt{HeaderLength}\} | \{\texttt{format}, \texttt{Format}\} | \{\texttt{order}, \texttt{Order}\} | \{\texttt{unique}, \texttt{bool()}\} | \{\texttt{tmpdir}, \texttt{TempDirectory}\} | \{\texttt{compressed}, \texttt{bool()}\} | \{\texttt{size}, \texttt{Size}\} | \{\texttt{no_files}, \texttt{NoFiles}\}
\item \texttt{HeaderLength} = \texttt{int()} > 0
\item \texttt{Format} = \texttt{binary_term} | \texttt{term} | \texttt{binary} | \texttt{FormatFun}
\item \texttt{FormatFun} = \texttt{fun(Binary) - Term}
\item \texttt{Order} = \texttt{ascending} | \texttt{descending} | \texttt{OrderFun}
\item \texttt{OrderFun} = \texttt{fun(Term, Term) - bool()}
\item \texttt{TempDirectory} = "" | \texttt{filename()}
\item \texttt{Size} = \texttt{int()} > 0
\item \texttt{NoFiles} = \texttt{int()} > 1
\end{itemize}

As an alternative to sorting files, a function of one argument can be given as input. When called with the argument \texttt{read} the function is assumed to return \texttt{end_of_input} or \{\texttt{end_of_input}, \texttt{Value}\} when there is no more input (\texttt{Value} is explained below), or \{\texttt{Objects}, \texttt{Fun}\}, where \texttt{Objects} is a list of binaries or terms depending on the format and \texttt{Fun} is a new input function. Any other value is immediately returned as value of the current call to \texttt{sort} or \texttt{keysort}. Each input function will be called exactly once, and should an error occur, the last function is called with the argument \texttt{close}, the reply of which is ignored.

A function of one argument can be given as output. The results of sorting or merging the input is collected in a non-empty sequence of variable length lists of binaries or terms depending on the format. The output function is called with one list at a time, and is assumed to return a new output function. Any other return value is immediately returned as value of the current call to the \texttt{sort} or \texttt{merge} function. Each output function is called exactly once. When some output function has been applied to all of the results or an error occurs, the last function is called with the argument \texttt{close}, and the reply is...
returned as value of the current call to the sort or merge function. If a function is given as input and the last input function returns \{end_of_input, Value\}, the function given as output will be called with the argument \{value, Value\}. This makes it easy to initiate the sequence of output functions with a value calculated by the input functions.

As an example, consider sorting the terms on a disk log file. A function that reads chunks from the disk log and returns a list of binaries is used as input. The results are collected in a list of terms.

```
sort(Log) ->
  {ok, _} = disk_log:open([[name,Log], [mode,read_only]]),
  Input = input(Log, start),
  Output = output([],)
  Reply = file_sorter:sort(Input, Output, [format,term]),
  ok = disk_log:close(Log),
  Reply.

input(Log, Cont) ->
  fun(close) ->
    ok;
  (read) ->
    case disk_log:chunk(Log, Cont) of
      {error, Reason} ->
        {error, Reason};
      {Cont2, Terms} ->
        {Terms, input(Log, Cont2)};
      {Cont2, Terms, _Badbytes} ->
        {Terms, input(Log, Cont2)};
      eof ->
        end_of_input
    end
  end.

output(L) ->
  fun(close) ->
    lists:append(lists:reverse(L));
  (Terms) ->
    output([Terms | L])
  end.
```

Further examples of functions as input and output can be found at the end of the file_sorter module; the term format is implemented with functions.

The possible values of Reason returned when an error occurs are:

- \{bad_object, \{bad_object, FileName\}\}. Applying the format function failed for some binary, or the key(s) could not be extracted from some term.
- \{bad_term, FileName\}. io:read/2 failed to read some term.
- \{file_error, FileName, Reason2\}. See file(3) for an explanation of Reason2.
- \{premature_eof, FileName\}. End-of-file was encountered inside some binary term.
- \{not_a_directory, FileName\}. The file supplied with the tmpdir option is not a directory.
Types

Binary = binary()
FileName = file_name()
FileNames = [FileName]
ICommand = read | close
IReply = end_of_input | {end_of_input, Value} | {{Object}, Infun} | InputReply
Infun = fun(ICommand) -> IReply
Input = FileNames | Infun
InputReply = Term
KeyPos = int() > 0 | [int() > 0]
OCommand = {value, Value} | [Object] | close
OReply = Outfun | OutputReply
Object = Term | Binary
Outfun = fun(OCommand) -> OReply
Output = FileName | Outfun
OutputReply = Term
Term = term()
Value = Term

Exports

sort(FileName) -> Reply
sort(Input, Output) -> Reply
sort(Input, Output, Options) -> Reply

Types:

• Reply = ok | {error, Reason} | InputReply | OutputReply
Sorting terms on files
sort(FileName) is equivalent to sort([FileName], FileName).
sort(Input, Output) is equivalent to sort(Input, Output, []).

keysort(KeyPos, FileName) -> Reply
keysort(KeyPos, Input, Output) -> Reply
keysort(KeyPos, Input, Output, Options) -> Reply

Types:

• Reply = ok | {error, Reason} | InputReply | OutputReply
Sorting tuples on files. The sort is performed on the element(s) mentioned in KeyPos. If two tuples compare equal on one element, next element according to KeyPos is compared. The sort is stable.
keysort(N, FileName) is equivalent to keysort(N, [FileName], FileName).
keysort(N, Input, Output) is equivalent to keysort(N, Input, Output, []).

merge(FileNames, Output) -> Reply
merge(FileNames, Output, Options) -> Reply

Types:
Merges terms on files. Each input file is assumed to be sorted.
merge(FileNames, Output) is equivalent to merge(FileNames, Output, []).

keymerge(KeyPos, FileNames, Output) -> Reply
keymerge(KeyPos, FileNames, Output, Options) -> Reply
Types:
  - Reply = ok | {error, Reason} | OutputReply
Merges tuples on files. Each input file is assumed to be sorted on key(s).
keymerge(KeyPos, FileNames, Output) is equivalent to keymerge(KeyPos, FileNames, Output, []).

check(FileName) -> Reply
check(FileNames, Options) -> Reply
Types:
  - Reply = ok | {error, Reason} | OutputReply
  - Result = {FileName, TermPosition, Term}
  - TermPosition = int() > 1
Checks files for sortedness. If a file is not sorted, the first out-of-order element is returned. The first term on a file has position 1.
check(FileName) is equivalent to check([[FileName], []]).

keycheck(KeyPos, FileName) -> CheckReply
keycheck(KeyPos, FileNames, Options) -> Reply
Types:
  - Reply = ok | {error, Reason} | OutputReply
  - Result = {FileName, TermPosition, Term}
  - TermPosition = int() > 1
Checks files for sortedness. If a file is not sorted, the first out-of-order element is returned. The first term on a file has position 1.
keycheck(KeyPos, FileName) is equivalent to keycheck(KeyPos, [FileName], []).
This module contains utilities on a higher level than the `file` module.

**Exports**

```erlang
ensure_dir(Name) -> true
Types:
- Name = filename() | dirname()
The `ensure_dir/1` function checks that all parent directories for the given file or directory name exist, creating them if not.

filesize(Filename) -> integer()
The `filesize` function returns the size of the given file.

fold_files(Dir, RegExp, Recursive, Fun, AccIn) -> AccOut
Types:
- Dir = dirname()
- RegExp = regexp()
- Recursive = true | false
- Fun = fun(F, AccIn) -> AccOut
- AccIn = AccOut = term()
The `fold_files/5` function folds the function `Fun` over all (regular) files `F` in the directory `Dir` that match the regular expression `RegExp`. If `Recursive` is true all sub-directories to `Dir` are processed. The match is tried on just the filename without the directory part.

is_dir(Name) -> true | false
Types:
- Name = filename() | dirname()
The `is_dir/1` function returns `true` if `Name` refers to a directory, and `false` otherwise.

is_file(Name) -> true | false
Types:
- Name = filename() | dirname()
```
The is_file/1 function returns true if Name refers to a file or a directory, and false otherwise.

\[
is_{\text{regular}}(\text{Name}) \rightarrow \text{true} \mid \text{false}
\]

Types:
- Name = filename()

The is_regular/1 function returns true if Name refers to a file (regular file), and false otherwise.

last_modified(Name) \rightarrow \{\{\text{Year},\text{Month},\text{Day}\},\{\text{Hour},\text{Min},\text{Sec}\}\}

Types:
- Name = filename() \mid dirname()

The last_modified/1 function returns the date and time the given file or directory was last modified.

wildcard(Wildcard) \rightarrow \text{list()}

Types:
- Wildcard = filename() \mid dirname()

The wildcard/1 function returns a list of all files that match Unix-style wildcard-string Wildcard.

The wildcard string looks like an ordinary filename, except that certain “wildcard characters” are interpreted in a special way. The following characters are special:

? Matches one character.
* Matches any number of characters up to the end of the filename, the next dot, or the next slash.
\{Item,...\} Alternation. Matches one of the alternatives.

Other characters represent themselves. Only filenames that have exactly the same character in the same position will match. (Matching is case-sensitive; i.e. “a” will not match “A”).

Note that multiple “*” characters are allowed (as in Unix wildcards, but opposed to Windows/DOS wildcards).

Examples:
The following examples assume that the current directory is the top of an Erlang/OTP installation.

To find all .beam files in all applications, the following line can be used:

\[
\text{filelib: wildcard("lib/*/ebin/*.beam")}
\]

To find either .erl or .hrl in all applications src directories, the following

\[
\text{filelib: wildcard("lib/*/src/*/?.rl")}
\]
or the following line

\[
\text{filelib: wildcard("lib/*/src/*.{erl,hrl}"")}
\]
can be used.
To find all \texttt{.hrl} files in either \texttt{src} or \texttt{include} directories use:
\begin{verbatim}
    filelib:wildcard("lib/*/\{src,include}\/{*.hrl}).
\end{verbatim}
To find all \texttt{.erl} or \texttt{.hrl} files in either \texttt{src} or \texttt{include} directories, use:
\begin{verbatim}
    filelib:wildcard("lib/*/\{src,include}\/{*.erl,hrl}").
\end{verbatim}
\begin{verbatim}
wildcard(Wildcard, Cwd) -> list()
Types:
\begin{itemize}
    \item Wildcard = filename() \mid dirname()
    \item Cwd = dirname()
\end{itemize}
The \texttt{wildcard/2} function works like \texttt{wildcard/1}, except that instead of the actual working directory, \texttt{Cwd} will be used.
The module `filename` provides a number of useful functions for analyzing and manipulating file names. These functions are designed so that the Erlang code can work on many different platforms with different formats for file names. With file name is meant all strings that can be used to denote a file. They can be short relative names like `foo.erl`, very long absolute name which include a drive designator and directory names like `D:\usr\local\bin\erl\lib\tools\foo.erl`, or any variations in between.

In Windows, all functions return file names with forward slashes only, even if the arguments contain back slashes. Use `join/1` to normalize a file name by removing redundant directory separators.

**DATA TYPES**

```
name() = string() | atom() | DeepList
  DeepList = [char() | atom() | DeepList]
```

**Exports**

```
absname(Filename) -> string()
```

Types:

- `Filename = name()`

Converts a relative `Filename` and returns an absolute name. No attempt is made to create the shortest absolute name, because this can give incorrect results on file systems which allow links.

Unix examples:

1> `pwd()`.  
   
   
   
   
   
   "/usr/local"
   2> `filename:absname("foo")`.  
   
   
   
   
   
   
   
   3> `filename:absname("../x")`.  
   
   
   
   
   
   4> `filename:absname("/"`.  
   
   
   
   
   
   
   "/"

Windows examples:
1> pwd().
"D:/usr/local"
2> filename:absname("foo").
"D:/usr/local/foo"
3> filename:absname("../x").
"D:/usr/local/../x"
4> filename:absname("/").
"D:"

absname(Filename, Dir) -> string()
Types:
  • Filename = name()
  • Dir = string()
This function works like absname/1, except that the directory to which the file name
should be made relative is given explicitly in the Dir argument.

absname_join(Dir, Filename) -> string()
Types:
  • Dir = string()
  • Filename = name()
Joins an absolute directory with a relative filename. Similar to join/2, but on platforms
with tight restrictions on raw filename length and no support for symbolic links (read:
VxWorks), leading parent directory components in Filename are matched against
trailing directory components in Dir so they can be removed from the result -
minimizing its length.

basename(Filename) -> string()
Types:
  • Filename = name()
Returns the last component of Filename, or Filename itself if it does not contain any
directory separators.
5> filename:basename("foo").
"foo"
6> filename:basename("/usr/foo").
"foo"
7> filename:basename("/").
[]

basename(Filename, Ext) -> string()
Types:
  • Filename = Ext = name()
Returns the last component of Filename with the extension Ext stripped. This function should be used to remove a specific extension which might, or might not, be there. Use rootname(basename(Filename)) to remove an extension that exists, but you are not sure which one it is.

```
8> filename:basename("/src/kalle.erl", ".erl").
  "kalle"
9> filename:basename("/src/kalle.beam", ".erl").
  "kalle.beam"
10> filename:basename("/src/kalle.old.erl", ".erl").
    "kalle.old"
11> filename:rootname(filename:basename("/src/kalle.erl")).
    "kalle"
12> filename:rootname(filename:basename("/src/kalle.beam")).
    "kalle"
```

dirname(Filename) -> string()

Types:

- Filename = name()

Returns the directory part of Filename.

```
13> filename:dirname("/usr/src/kalle.erl").
   "/usr/src"
14> filename:dirname("kalle.erl").
   "."
```

extension(Filename) -> string()

Types:

- Filename = name()

Returns the file extension of Filename, including the period. Returns an empty string if there is no extension.

```
15> filename:extension("foo.erl").
   ".erl"
16> filename:extension("beam.src/kalle").
   []
```

flatten(Filename) -> string()

Types:

- Filename = name()

Converts a possibly deep list filename consisting of characters and atoms into the corresponding flat string filename.
join(Components) -> string()

Types:
- Components = [string()]

Joins a list of file name Components with directory separators. If one of the elements of Components includes an absolute path, for example "/xxx", the preceding elements, if any, are removed from the result.

The result is "normalized":
- Redundant directory separators are removed.
- In Windows, all directory separators are forward slashes and the drive letter is in lower case.

```
17> filename:join(["/usr", "local", "bin"]).
"/usr/local/bin"
18> filename:join(["a/b///c/"]).
"a/b/c"
6> filename:join(["B:a\b///c/"]). % Windows
"b:a/b/c"
```

join(Name1, Name2) -> string()

Types:
- Name1 = Name2 = string()

Joins two file name components with directory separators. Equivalent to join([Name1, Name2]).

nativename(Path) -> string()

Types:
- Path = string()

Converts Path to a form accepted by the command shell and native applications on the current platform. On Windows, forward slashes is converted to backward slashes. On all platforms, the name is normalized as done by join/1.

```
19> filename:nativename("/usr/local/bin"). % Unix
"/usr/local/bin"
7> filename:nativename("/usr/local/bin"). % Windows
"\\usr\\local\\bin"
```

pathtype(Path) -> absolute | relative | volumerelative

Returns the type of path, one of absolute, relative, or volumerelative.

absolute The path name refers to a specific file on a specific volume.
- Unix example: /usr/local/bin
- Windows example: D:/usr/local/bin
The path name is relative to the current working directory on the current volume.
Example: foo/bar, ../src

The path name is relative to the current working directory on a specified volume, or it is a specific file on the current working volume.
Windows example: D:bar.erl, /bar/foo.erl

```
rootname(Filename) -> string()
rootname(Filename, Ext) -> string()

Types:
  • Filename = Ext = name()
Remove a filename extension. rootname/2 works as rootname/1, except that the extension is removed only if it is Ext.

20> filename:rootname("/beam.src/kalle").
    /beam.src/kalle"
21> filename:rootname("/beam.src/foo.erl").
    "/beam.src/foo"
22> filename:rootname("/beam.src/foo.erl", ".erl").
    "/beam.src/foo"
23> filename:rootname("/beam.src/foo.beam", ".erl").
    "/beam.src/foo.beam"
```

```
split(Filename) -> Components

Types:
  • Filename = name()
  • Components = [string()]
Returns a list whose elements are the path components of Filename.

24> filename:split("/usr/local/bin").
    ["/","usr","local","bin"]
25> filename:split("foo/bar").
    ["foo","bar"]
26> filename:split("a:\msdev\include").
    ["a:/","msdev","include"]
```

```
find_src(Beam) -> {SourceFile, Options}
find_src(Beam, Rules) -> {SourceFile, Options}

Types:
  • Beam = Module | Filename
  • Module = atom()
  • Filename = string() | atom()
  • SourceFile = string()
  • Options = [Opt]
  • Opt = [i, string()] | [outdir, string()] | [d, atom()]
```
Finds the source filename and compiler options for a module. The result can be fed to compile:file/2 in order to compile the file again.

The Beam argument, which can be a string or an atom, specifies either the module name or the path to the source code, with or without the ".erl" extension. In either case, the module must be known by the code server, i.e. code:which(Module) must succeed.

Rules describes how the source directory can be found, when the object code directory is known. It is a list of tuples [BinSuffix, SourceSuffix] and is interpreted as follows: If the end of the directory name where the object is located matches BinSuffix, then the source code directory has the same name, but with BinSuffix replaced by SourceSuffix. Rules defaults to:

`[{"", ","}, {"ebin", "src"}, {"ebin", "esrc"}]`

If the source file is found in the resulting directory, then the function returns that location together with Options. Otherwise, the next rule is tried, and so on.

The function returns {SourceFile, Options}. SourceFile is the absolute path to the source file without the ".erl" extension. Options include the options which are necessary to recompile the file with compile:file/2, but excludes options such as report or verbose which do not change the way code is generated. The paths in the {outdir, Path} and {i, Path} options are guaranteed to be absolute.
gb_sets

Erlang Module

An implementation of ordered sets using Prof. Arne Andersson’s General Balanced Trees. This can be much more efficient than using ordered lists, for larger sets, but depends on the application.

Complexity note

The complexity on set operations is bounded by either \( O(|S|) \) or \( O(|T| \times \log|S|) \), where \( S \) is the largest given set, depending on which is fastest for any particular function call. For operating on sets of almost equal size, this implementation is about 3 times slower than using ordered-list sets directly. For sets of very different sizes, however, this solution can be arbitrarily much faster; in practical cases, often between 10 and 100 times. This implementation is particularly suited for accumulating elements a few at a time, building up a large set (more than 100-200 elements), and repeatedly testing for membership in the current set.

As with normal tree structures, lookup (membership testing), insertion and deletion have logarithmic complexity.

Compatibility

All of the following functions in this module also exist and do the same thing in the sets and ordsets modules. That is, by only changing the module name for each call, you can try out different set representations.

- `add_element/2`
- `del_element/2`
- `filter/2`
- `fold/3`
- `from_list/1`
- `intersection/1`
- `intersection/2`
- `is_element/2`
- `is_set/1`
- `is_subset/2`
- `new/0`
- `size/1`
- `subtract/2`
• to_list/1
• union/1
• union/2

DATA TYPES

gb_set() = a GB set

Exports

add(Element, Set1) -> Set2
add_element(Element, Set1) -> Set2

Types:
• Element = term()
• Set1 = Set2 = gb_set()

Returns a new gb_set formed from Set1 with Element inserted. If Element is already an element in Set1, nothing is changed.

balance(Set1) -> Set2

Types:
• Set1 = Set2 = gb_set()

Rebalances the tree representation of Set1. Note that this is rarely necessary, but may be motivated when a large number of elements have been deleted from the tree without further insertions. Rebalancing could then be forced in order to minimise lookup times, since deletion only does not rebalance the tree.

delete(Element, Set1) -> Set2

del_element(Element, Set1) -> Set2

Types:
• Element = term()
• Set1 = Set2 = gb_set()

Returns a new gb_set formed from Set1 with Element removed. Assumes that Element is present in Set1.

delete_any(Element, Set1) -> Set2

del_element(Element, Set1) -> Set2

Types:
• Element = term()
• Set1 = Set2 = gb_set()

Returns a new gb_set formed from Set1 with Element removed. If Element is not an element in Set1, nothing is changed.

difference(Set1, Set2) -> Set3
subtract(Set1, Set2) -> Set3

Types:
- Set1 = Set2 = Set3 = gb_set()

Returns only the elements of Set1 which are not also elements of Set2.

empty() -> Set

new() -> Set

Types:
- Set = gb_set()

Returns a new empty gb_set.

filter(Pred, Set1) -> Set2

Types:
- Pred = fun (E) -> bool()
- E = term()
- Set1 = Set2 = gb_set()

Filters elements in Set1 using predicate function Pred.

fold(Function, Acc0, Set) -> Acc1

Types:
- Function = fun (E, AccIn) -> AccOut
- Acc0 = Acc1 = AccIn = AccOut = term()
- E = term()
- Set = gb_set()

Folds Function over every element in Set returning the final value of the accumulator.

from_list(List) -> Set

Types:
- List = [term()]
- Set = gb_set()

Returns a gb_set of the elements in List, where List may be unordered and contain duplicates.

from_ordset(List) -> Set

Types:
- List = [term()]
- Set = gb_set()

Turns an ordered-set list List into a gb_set. The list must not contain duplicates.

insert(Element, Set1) -> Set2

Types:
- Element = term()
• Set1 = Set2 = gb_set()
  Returns a new gb_set formed from Set1 with Element inserted. Assumes that Element
  is not present in Set1.

intersection(Set1, Set2) -> Set3
  Types:
  • Set1 = Set2 = Set3 = gb_set()
  Returns the intersection of Set1 and Set2.

intersection(SetList) -> Set
  Types:
  • SetList = [gb_set()]
  • Set = gb_set()
  Returns the intersection of the non-empty list of gb_sets.

is_empty(Set) -> bool()
  Types:
  • Set = gb_set()
  Returns true if Set is an empty set, and false otherwise.

is_member(Element, Set) -> bool()

is_element(Element, Set) -> bool()
  Types:
  • Element = term()
  • Set = gb_set()
  Returns true if Element is an element of Set, otherwise false.

is_set(Set) -> bool()
  Types:
  • Set = gb_set()
  Returns true if Set appears to be a gb_set, otherwise false.

is_subset(Set1, Set2) -> bool()
  Types:
  • Set1 = Set2 = gb_set()
  Returns true when every element of Set1 is also a member of Set2, otherwise false.

iterator(Set) -> Iter
  Types:
  • Set = gb_set()
  • Iter = term()
Returns an iterator that can be used for traversing the entries of Set; see next/1. The
implementation of this is very efficient; traversing the whole set using next/1 is only
slightly slower than getting the list of all elements using to_list/1 and traversing that.
The main advantage of the iterator approach is that it does not require the complete list
of all elements to be built in memory at one time.

largest(Set) -> term()

Types:
• Set = gb_set()
Returns the largest element in Set. Assumes that Set is nonempty.

next(Iter1) -> [Element, Iter2 | none]

Types:
• Iter1 = Iter2 = Element = term()
Returns [Element, Iter2] where Element is the smallest element referred to by the
iterator Iter1, and Iter2 is the new iterator to be used for traversing the remaining
elements, or the atom none if no elements remain.

singleton(Element) -> gb_set()

Types:
• Element = term()
Returns a gb_set containing only the element Element.

size(Set) -> int()

Types:
• Set = gb_set()
Returns the number of elements in Set.

smallest(Set) -> term()

Types:
• Set = gb_set()
Returns the smallest element in Set. Assumes that Set is nonempty.

take_largest(Set1) -> [Element, Set2]

Types:
• Set1 = Set2 = gb_set()
• Element = term()
Returns [Element, Set2], where Element is the largest element in Set1, and Set2 is
this set with Element deleted. Assumes that Set1 is nonempty.

take_smallest(Set1) -> [Element, Set2]

Types:
• Set1 = Set2 = gb_set()
• Element = term()
Returns \{Element, Set2\}, where Element is the smallest element in Set1, and Set2 is this set with Element deleted. Assumes that Set1 is nonempty.

to_list(Set) -> List
Types:
• Set = gb_set()
• List = [term()]
Returns the elements of Set as a list.

union(Set1, Set2) -> Set3
Types:
• Set1 = Set2 = Set3 = gb_set()
Returns the merged (union) gb_set of Set1 and Set2.

union(SetList) -> Set
Types:
• SetList = [gb_set()]
• Set = gb_set()
Returns the merged (union) gb_set of the list of gb_sets.

SEE ALSO

gb_trees(3) [page 163], ordsets(3) [page 245], sets(3) [page 285]
gb_trees

Erlang Module

An efficient implementation of Prof. Arne Andersson's General Balanced Trees. These have no storage overhead compared to unbalanced binary trees, and their performance is in general better than AVL trees.

Data structure

Data structure:
- {Size, Tree}, where 'Tree' is composed of nodes of the form:
  - {Key, Value, Smaller, Bigger}, and the "empty tree" node:
  - nil.

There is no attempt to balance trees after deletions. Since deletions do not increase the height of a tree, this should be OK.

Original balance condition $h(T) \leq \text{ceil}(c \cdot \log(|T|))$ has been changed to the similar (but not quite equivalent) condition $2^{-h(T)} \leq |T| - c$. This should also be OK.

Performance is comparable to the AVL trees in the Erlang book (and faster in general due to less overhead); the difference is that deletion works for these trees, but not for the book's trees. Behaviour is logarithmic (as it should be).

DATA TYPES

gb_tree() = a GB tree

Exports

balance(Tree1) -> Tree2

Types:
- Tree1 = Tree2 = gb_tree()

Rebalances Tree1. Note that this is rarely necessary, but may be motivated when a large number of nodes have been deleted from the tree without further insertions. Rebalancing could then be forced in order to minimise lookup times, since deletion only does not rebalance the tree.

delete(Key, Tree1) -> Tree2

Types:
gb_trees

- Key = term()
- Tree1 = Tree2 = gb_tree()
Removes the node with key Key from Tree1; returns new tree. Assumes that the key is present in the tree, crashes otherwise.

delany(Key, Tree1) -> Tree2
Types:
- Key = term()
- Tree1 = Tree2 = gb_tree()
Removes the node with key Key from Tree1 if the key is present in the tree, otherwise does nothing; returns new tree.

del(Key, Tree) -> Tree
Types:
- Key = term()
- Tree = gb_tree()
Removes the node with key Key from Tree1; returns new tree. Assumes that the key is present in the tree, crashes otherwise.

delany(Key, Tree1) -> Tree2
Types:
- Key = term()
- Tree1 = Tree2 = gb_tree()
Removes the node with key Key from Tree1 if the key is present in the tree, otherwise does nothing; returns new tree.

del(Key, Tree) -> Tree
Types:
- Key = term()
- Tree = gb_tree()
Removes the node with key Key from Tree1; returns new tree. Assumes that the key is present in the tree, crashes otherwise.

empty() -> Tree
Types:
- Tree = gb_tree()
Returns a new empty tree.

to_orddict(List) -> Tree
Types:
- List = [{Key, Val}]
- Key = Val = term()
- Tree = gb_tree()
Turns an ordered list List of key-value tuples into a tree. The list must not contain duplicate keys.

get(Key, Tree) -> Val
Types:
- Key = Val = term()
- Tree = gb_tree()
Retrieves the value stored with Key in Tree. Assumes that the key is present in the tree, crashes otherwise.

lookup(Key, Tree) -> {value, Val} | none
Types:
- Key = Val = term()
- Tree = gb_tree()
Looks up Key in Tree; returns {value, Val}, or none if Key is not present.

insert(Key, Val, Tree1) -> Tree2

Types:
- Key = Val = term()
- Tree1 = Tree2 = gb_tree()

Inserts Key with value Val into Tree1; returns the new tree. Assumes that the key is not present in the tree, crashes otherwise.

is_defined(Key, Tree) -> bool()

Types:
- Tree = gb_tree()

Returns true if Key is present in Tree, otherwise false.

is_empty(Tree) -> bool()

Types:
- Tree = gb_tree()

Returns true if Tree is an empty tree, and false otherwise.

iterator(Tree) -> Iter

Types:
- Tree = gb_tree()
- Iter = term()

Returns an iterator that can be used for traversing the entries of Tree; see next/1. The implementation of this is very efficient; traversing the whole tree using next/1 is only slightly slower than getting the list of all elements using to_list/1 and traversing that. The main advantage of the iterator approach is that it does not require the complete list of all elements to be built in memory at one time.

keys(Tree) -> [Key]

Types:
- Tree = gb_tree()
- Key = term()

Returns the keys in Tree as an ordered list.

largest(Tree) -> {Key, Val}

Types:
- Tree = gb_tree()
- Key = Val = term()

Returns {Key, Val}, where Key is the largest key in Tree, and Val is the value associated with this key. Assumes that the tree is nonempty.

next(Iter1) -> {Key, Val, Iter2}
Types:
- Iter1 = Iter2 = Key = Val = term()

Returns \{Key, Val, Iter2\} where Key is the smallest key referred to by the iterator Iter1, and Iter2 is the new iterator to be used for traversing the remaining nodes, or the atom none if no nodes remain.

\[\text{size}(\text{Tree}) \rightarrow \text{int()}\]
Types:
- Tree = gb\_tree()
Returns the number of nodes in Tree.

\[\text{smallest}(\text{Tree}) \rightarrow \{\text{Key}, \text{Val}\}\]
Types:
- Tree = gb\_tree()
- Key = Val = term()
Returns \{Key, Val\}, where Key is the smallest key in Tree, and Val is the value associated with this key. Assumes that the tree is nonempty.

\[\text{take\_largest}(\text{Tree1}) \rightarrow \{\text{Key}, \text{Val}, \text{Tree2}\}\]
Types:
- Tree1 = Tree2 = gb\_tree()
- Key = Val = term()
Returns \{Key, Val, Tree2\}, where Key is the largest key in Tree1, Val is the value associated with this key, and Tree2 is this tree with the corresponding node deleted. Assumes that the tree is nonempty.

\[\text{take\_smallest}(\text{Tree1}) \rightarrow \{\text{Key}, \text{Val}, \text{Tree2}\}\]
Types:
- Tree1 = Tree2 = gb\_tree()
- Key = Val = term()
Returns \{Key, Val, Tree2\}, where Key is the smallest key in Tree1, Val is the value associated with this key, and Tree2 is this tree with the corresponding node deleted. Assumes that the tree is nonempty.

\[\text{to\_list}(\text{Tree}) \rightarrow [[\text{Key}, \text{Val}]]\]
Types:
- Tree = gb\_tree()
- Key = Val = term()
Converts a tree into an ordered list of key-value tuples.

\[\text{update}(\text{Key}, \text{Val}, \text{Tree1}) \rightarrow \text{Tree2}\]
Types:
- Key = Val = term()
• Tree1 = Tree2 = gb_tree()  
  Updates Key to value Val in Tree1; returns the new tree. Assumes that the key is present in the tree.

values(Tree) -> [Val]

Types:
• Tree = gb_tree()
• Val = term()

Returns the values in Tree as an ordered list, sorted by their corresponding keys. Duplicates are not removed.

SEE ALSO

gb_sets(3) [page 157], dict(3) [page 82]
**gen_event**

Erlang Module

A behaviour module for implementing event handling functionality. The OTP event handling model consists of a generic event manager process with an arbitrary number of event handlers which are added and deleted dynamically.

An event manager implemented using this module will have a standard set of interface functions and include functionality for tracing and error reporting. It will also fit into an OTP supervision tree. Refer to OTP Design Principles for more information.

Each event handler is implemented as a callback module exporting a pre-defined set of functions. The relationship between the behaviour functions and the callback functions can be illustrated as follows:

```
gen_event module          Callback module
---------------------------
gen_event:start_link      ----> -      
gen_event:add_handler          ----> Module:init/1
ngen_event:add_suphandler    ----> Module:terminate/2
ngen_event:notify          ----> Module:handle_event/2
ngen_event:sync_notify      ----> Module:handle_cast/2
ngen_event:call            ----> Module:handle_info/2
ngen_event:delete_handler   ----> Module:terminate/2
ngen_event:swap_handler     ----> Module1:terminate/2
ngen_event:swap_sup_handler ----> Module2:init/1
ngen_event:which_handlers   ----> -      
gen_event:stop             ----> Module:terminate/2
ngen_event:stop             ----> Module:terminate/2
ngen_event:stop             ----> Module:code_change/3
```

Since each event handler is one callback module, an event manager will have several callback modules which are added and deleted dynamically. Therefore gen_event is more tolerant of callback module errors than the other behaviours. If a callback function for an installed event handler fails with Reason, or returns a bad value Term, the event manager will not fail. It will delete the event handler by calling the callback function...
Module: terminate/2 (see below), giving as argument \{error,\{'EXIT',Reason\}\} or \{error,Term\}, respectively. No other event handler will be affected.

The sys module can be used for debugging an event manager.

Note that an event manager does trap exit signals automatically.

Unless otherwise stated, all functions in this module fail if the specified event manager does not exist or if bad arguments are given.

Exports

**start_link()** -> Result  
**start_link(EventMgrName)** -> Result

Types:
- EventMgrName = \{local,Name\} \| \{global,Name\}
- Name = atom()
- Result = \{ok,Pid\} \| \{error,\{already started,Pid\}\}
- Pid = pid()

Creates an event manager process as part of a supervision tree. The function should be called, directly or indirectly, by the supervisor. It will, among other things, ensure that the event manager is linked to the supervisor.

If EventMgrName=\{local,Name\}, the event manager is registered locally as Name using register/2. If EventMgrName=\{global,Name\}, the event manager is registered globally as Name using global:register_name/2. If no name is provided, the event manager is not registered.

If the event manager is successfully created the function returns \{ok,Pid\}, where Pid is the pid of the event manager. If there already exists a process with the specified EventMgrName the function returns \{error,\{already started,Pid\}\}, where Pid is the pid of that process.

**start()** -> Result  
**start(EventMgrName)** -> Result

Types:
- EventMgrName = \{local,Name\} \| \{global,Name\}\| pid()
- Name = Node = atom()
- Result = \{ok,Pid\} \| \{error,\{already started,Pid\}\}
- Pid = pid()

Creates a stand-alone event manager process, i.e. an event manager which is not part of a supervision tree and thus has no supervisor.

See **start_link/0,1** for a description of arguments and return values.

**add_handler(EventMgrRef, Handler, Args)** -> Result

Types:
- EventMgr = Name \| \{Name,Node\} \| \{global,Name\} \| pid()
- Name = Node = atom()
- Handler = Module \| \{Module,Id\}
**Module = atom()**

**Id = term()**

**Args = term()**

**Result = ok | \{EXIT',Reason\} \| term()**

**Reason = term()**

Add a new event handler to the event manager EventMgrRef. The event manager will call Module:init/1 to initiate the event handler and its internal state. EventMgrRef can be:

- the pid,
- Name, if the event manager is locally registered,
- \{Name,Node\}, if the event manager is locally registered at another node, or
- \{global,Name\}, if the event manager is globally registered.

Handler is the name of the callback module Module or a tuple \{Module,Id\}, where Id is any term. The \{Module,Id\} representation makes it possible to identify a specific event handler when there are several event handlers using the same callback module.

Args is an arbitrary term which is passed as the argument to Module:init/1.

If Module:init/1 returns a correct value, the event manager adds the event handler and this function returns ok. If Module:init/1 fails with Reason or returns an unexpected value Term, the event handler is ignored and this function returns \{EXIT',Reason\} or Term, respectively.

### add_sup_handler(EventMgrRef, Handler, Args) -> Result

**Types:**

- EventMgr = Name | \{Name,Node\} | \{global,Name\} | pid()
- Name = Node = atom()
- Handler = Module | \{Module,Id\}
- Module = atom()
- Id = term()
- Args = term()
- Result = ok | \{EXIT',Reason\} \| term()
- Reason = term()

Add a new event handler in the same way as add_handler/3 but will also supervise the connection between the event handler and the calling process.

- If the calling process later terminates with Reason, the event manager will delete the event handler by calling Module:terminate/2 with \{stop,Reason\} as argument.

- If the event handler later is deleted, the event manager sends a message \{gen_event_EXIT,Handler,Reason\} to the calling process. Reason is one of the following:
  - normal, if the event handler has been removed due to a call to delete_handler/3, or remove_handler has been returned by a callback function (see below).
  - shutdown, if the event handler has been removed because the event manager is terminating.
- {swapped, NewHandler, Pid}, if the process Pid has replaced the event handler with another event handler NewHandler using a call to swap_handler/3 or swap_sup_handler/3.
- a term, if the event handler is removed due to an error. Which term depends on the error.

See add_handler/3 for a description of the arguments and return values.

notify(EventMgrRef, Event) -> ok
sync_notify(EventMgrRef, Event) -> ok

Types:
- EventMgrRef = Name | {Name, Node} | {global, Name} | pid()
- Name = Node = atom()
- Event = term()

Sends an event notification to the event manager EventMgrRef. The event manager will call Module:handle_event/2 for each installed event handler to handle the event. notify is asynchronous and will return immediately after the event notification has been sent. sync_notify is synchronous in the sense that it will return ok after the event has been handled by all event handlers.

See add_handler/3 for a description of EventMgrRef.
Event is an arbitrary term which is passed as one of the arguments to Module:handle_event/2.
notify will not fail even if the specified event manager does not exist, unless it is specified as Name.

call(EventMgrRef, Handler, Request) -> Result
call(EventMgrRef, Handler, Request, Timeout) -> Result

Types:
- EventMgrRef = Name | {Name, Node} | {global, Name} | pid()
- Name = Node = atom()
- Handler = Module | {Module, Id}
- Module = atom()
- Id = term()
- Request = term()
- Timeout = int() > 0 | infinity
- Result = Reply | {error, Error}
- Reply = term()
- Error = bad_module | {'EXIT', Reason} | term()
- Reason = term()
Makes a synchronous call to the event handler `Handler` installed in the event manager `EventMgrRef` by sending a request and waiting until a reply arrives or a timeout occurs. The event manager will call `Module:handle_call/2` to handle the request.

See `add_handler/3` for a description of `EventMgrRef` and `Handler`.

Request is an arbitrary term which is passed as one of the arguments to `Module:handle_call/2`. Timeout is an integer greater than zero which specifies how many milliseconds to wait for a reply, or the atom `infinity` to wait indefinitely. Default value is 5000. If no reply is received within the specified time, the function call fails.

The return value `Reply` is defined in the return value of `Module:handle_call/2`. If the specified event handler is not installed, the function returns `{error, bad_module}`. If the callback function fails with `Reason` or returns an unexpected value `Term`, this function returns `{error, ['EXIT', Reason]} or {error, Term}, respectively.

```
define add_handler(EventMgrRef, Handler, Args) -> Result
Types:
  * EventMgrRef = Name | {Name, Node} | {global, Name} | pid()
  * Name = Node = atom()
  * Handler = Module | {Module, Id}
  * Module = atom()
  * Id = term()
  * Args = term()
  * Result = term() | {error, module_not_found} | ['EXIT', Reason]
  * Reason = term()
```

Deletes an event handler from the event manager `EventMgrRef`. The event manager will call `Module:terminate/2` to terminate the event handler.

See `add_handler/3` for a description of `EventMgrRef` and `Handler`.

```
define delete_handler(EventMgrRef, Handler, Args) -> Result
Types:
  * EventMgrRef = Name | {Name, Node} | {global, Name} | pid()
  * Name = Node = atom()
  * Handler = Module | {Module, Id}
  * Module = atom()
  * Id = term()
  * Args = term()
  * Result = ok | {error, Error}
  * Error = ['EXIT', Reason] | term()
  * Reason = term()
```

```
define swap_handler(EventMgrRef, {Handler1, Args1}, {Handler2, Args2}) -> Result
Types:
  * EventMgrRef = Name | {Name, Node} | {global, Name} | pid()
  * Name = Node = atom()
  * Handler1 = Handler2 = Module | {Module, Id}
  * Module = atom()
  * Id = term()
  * Args1 = Args2 = term()
  * Result = ok | {error, Error}
  * Error = ['EXIT', Reason] | term()
  * Reason = term()
```
Replaces an old event handler with a new event handler in the event manager `EventMgrRef`.

See `add_handler/3` for a description of the arguments.

First the old event handler `Handler1` is deleted. The event manager calls
`Module1:terminate(Args1, ...)`, where `Module1` is the callback module of `Handler1`, and collects the return value.

Then the new event handler `Handler2` is added and initiated by calling
`Module2:init([Args2, Term])`, where `Module2` is the callback module of `Handler2` and `Term` the return value of `Module1:terminate/2`. This makes it possible to transfer information from `Handler1` to `Handler2`.

The new handler will be added even if the specified old event handler is not installed in which case `Term=error`, or if `Module1:terminate/2` fails with `Reason` in which case `Term=\('EXIT', Reason\)`. The old handler will be deleted even if `Module2:init/1` fails.

If there was a supervised connection between `Handler1` and a process `Pid`, there will be a supervised connection between `Handler2` and `Pid` instead.

If `Module2:init/1` returns a correct value, this function returns `ok`. If `Module2:init/1` fails with `Reason` or returns an unexpected value `Term`, this function returns `{error, \('EXIT', Reason\)}` or `{error, Term}`, respectively.

```
swap_sup_handler(EventMgrRef, [Handler1,Args1], [Handler2,Args2]) -> Result
```

Types:
- `EventMgrRef = Name | \{Name,Node\} | \{global,Name\} | pid()`
- `Name = Node = atom()`
- `Handler1 = Handler2 = Module | \{Module,Id\}`
- `Module = atom()`
- `Id = term()`
- `Args1 = Args2 = term()`
- `Result = ok | \{error,Error\}`
- `Error = \('EXIT', Reason\) | term()`
- `Reason = term()`

Replaces an event handler in the event manager `EventMgrRef` in the same way as `swap_handler/3` but will also supervise the connection between `Handler2` and the calling process.

See `swap_handler/3` for a description of the arguments and return values.

```
which_handlers(EventMgrRef) -> [Handler]
```

Types:
- `EventMgrRef = Name | \{Name,Node\} | \{global,Name\} | pid()`
- `Name = Node = atom()`
- `Handler = Module | \{Module,Id\}`
- `Module = atom()`
- `Id = term()`

Returns a list of all event handlers installed in the event manager `EventMgrRef`.

See `add_handler/3` for a description of `EventMgrRef` and `Handler`. 
stop(EventMgrRef) -> ok

Types:
- EventMgrRef = Name | {Name,Node} | {global,Name} | pid()
- Name = Node = atom()

Terminates the event manager EventMgrRef. Before terminating, the event manager will call Module:terminate(stop,...) for each installed event handler.
See add_handler/3 for a description of the argument.

CALLBACK FUNCTIONS

The following functions should be exported from a gen_event callback module.

Exports

Module:init(InitArgs) -> {ok,State}

Types:
- InitArgs = Args | {Args,Term}
- Args = Term = term()
- State = term()

Whenever a new event handler is added to an event manager, this function is called to initialize the event handler.

If the event handler is added due to a call to gen_event:add_handler/3 or gen_event:add_sup_handler/3, InitArgs is the Args argument of these functions.

If the event handler is replacing another event handler due to a call to gen_event:swap_handler/3 or gen_event:swap_sup_handler/3, or due to a swap return tuple from one of the other callback functions, InitArgs is a tuple {Args,Term} where Args is the argument provided in the function call/return tuple and Term is the result of terminating the old event handler, see gen_event:swap_handler/3.

The function should return {ok,State} where State is the initial internal state of the event handler.

Module:handle_event(Event, State) -> Result

Types:
- Event = term()
- State = term()
- Result = {ok,NewState}
- | {swap_handler,Args1,NewState,Handler2,Args2} | remove_handler
- NewState = term()
- Args1 = Args2 = term()
- Handler2 = Module2 | {Module2,Id}
- Module2 = atom()
- Id = term()
Whenever an event manager receives an event sent using `gen_event:notify/2` or `gen_event:sync_notify/2`, this function is called for each installed event handler to handle the event.

- **Event** is the `Event` argument of `notify/sync_notify`.
- **State** is the internal state of the event handler.

If the function returns `{ok, NewState}` the event handler will remain in the event manager with the possible updated internal state `NewState`.

If the function returns `{swap_handler, Args1, NewState, Handler2, Args2}` the event handler will be replaced by `Handler2` by first calling `Module:terminate(Args1, NewState)` and then `Module2:init(Args2, Term)` where `Term` is the return value of `Module:terminate/2`. See `gen_event:swap_handler/3` for more information.

If the function returns `remove_handler` the event handler will be deleted by calling `Module:terminate(remove_handler, State)`.

### Module:handle_call(Request, State) -> Result

**Types:**
- `Request = term()`
- `State = term()`
- `Result = {ok, Reply, NewState}`
- `{swap_handler, Reply, Args1, NewState, Handler2, Args2}`
- `{remove_handler, Reply}`
- `Reply = term()`
- `NewState = term()`
- `Args1 = Args2 = term()`
- `Handler2 = Module2 | {Module2, Id}`
- `Module2 = atom()`
- `Id = term()`

Whenever an event manager receives a request sent using `gen_event:call/3,4`, this function is called for the specified event handler to handle the request.

- **Request** is the `Request` argument of `call`.
- **State** is the internal state of the event handler.

The return values are the same as for `handle_event/2` except they also contain a term `Reply` which is the reply given back to the client as the return value of `call`.

### Module:handle_info(Info, State) -> Result

**Types:**
- `Info = term()`
- `State = term()`
- `Result = {ok, NewState}`
- `{swap_handler, Args1, NewState, Handler2, Args2} | remove_handler`
- `NewState = term()`
- `Args1 = Args2 = term()`
- `Handler2 = Module2 | {Module2, Id}`
- `Module2 = atom()`
• \texttt{Id = term()}

This function is called for each installed event handler when an event manager receives any other message than an event or a synchronous request (or a system message). \texttt{Info} is the received message.

See \texttt{Module:handle_event/2} for a description of \texttt{State} and possible return values.

\texttt{Module:terminate(Arg, State) -> term()}

Types:

- \texttt{Arg = Args | \{stop,Reason\} | \texttt{stop} | \texttt{remove_handler}}
- \texttt{Args = Reason = Term = term()}

Whenever an event handler is deleted from an event manager, this function is called. It should be the opposite of \texttt{Module:init/1} and do any necessary cleaning up.

If the event handler is deleted due to a call to \texttt{gen_event:delete_handler}, \texttt{gen_event:swap_handler/3} or \texttt{gen_event:swap_sup_handler/3}, \texttt{Arg} is the \texttt{Args} argument of this function call.

\texttt{Arg = \{stop,Reason\}} if the event handler has a supervised connection to a process which has terminated with reason \texttt{Reason}.

\texttt{Arg = \texttt{stop}} if the event handler is deleted because the event manager is terminating.

\texttt{Arg = \texttt{remove_handler}} if the event handler is deleted because another callback function has returned \texttt{remove_handler or \{remove_handler,Reply\}}.

\texttt{Arg = \{error,Term\}} if the event handler is deleted because a callback function returned an unexpected value \texttt{Term}, or \texttt{Arg = \{error,\texttt{\textquoteright EXIT',Reason\}} if a callback function failed.

\texttt{State} is the internal state of the event handler.

The function may return any term. If the event handler is deleted due to a call to \texttt{gen_event:delete_handler}, the return value of that function will be the return value of this function. If the event handler is to be replaced with another event handler due to a swap, the return value will be passed to the \texttt{init} function of the new event handler. Otherwise the return value is ignored.

\texttt{Module:code_change(OldVsn, State, Extra) -> \{ok, NewState\}}

Types:

- \texttt{OldVsn = Vsn | \{down, Vsn\}}
- \texttt{Vsn = term()}
- \texttt{State = NewState = term()}
- \texttt{Extra = term()}

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This function is called for an installed event handler which should update its internal state during a release upgrade/downgrade, i.e. when the instruction 
\{update,Module,Change,...\} where \texttt{Change=\{advanced,Extra\}} is given in the .appup file. See OTP Design Principles for more information.

In the case of an upgrade, \texttt{OldVsn} is \texttt{Vsn}, and in the case of a downgrade, \texttt{OldVsn} is \texttt{\{down,Vsn\}}. \texttt{Vsn} is defined by the \texttt{vsn} attribute(s) of the old version of the callback module \texttt{Module}. If no such attribute is defined, the version is the checksum of the BEAM file.

\texttt{State} is the internal state of the event handler.
\texttt{Extra} is passed as-is from the \{advanced,Extra\} part of the update instruction. The function should return the updated internal state.

\textbf{SEE ALSO}

supervisor(3) [page 330], sys(3) [page 340]
A behaviour module for implementing a finite state machine. A generic finite state machine process (gen_fsm) implemented using this module will have a standard set of interface functions and include functionality for tracing and error reporting. It will also fit into an OTP supervision tree. Refer to OTP Design Principles for more information.

A gen_fsm assumes all specific parts to be located in a callback module exporting a pre-defined set of functions. The relationship between the behaviour functions and the callback functions can be illustrated as follows:

```
gen_fsm module                                Callback module
-----------------------------------------------
gen_fsm:start_link                             ----> Module:init/1

gen_fsm:send_event                             ----> Module:StateName/2

ngen_fsm:send_all_state_event                  ----> Module:handle_event/3

gen_fsm:sync_send_event                        ----> Module:StateName/3

gen_fsm:sync_send_all_state_event             ----> Module:handle_sync_event/4

-                                                ----> Module:handle_info/3
-                                                ----> Module:terminate/3
-                                                ----> Module:code_change/4
```

If a callback function fails or returns a bad value, the gen_fsm will terminate. The sys module can be used for debugging a gen_fsm.

Note that a gen_fsm does not trap exit signals automatically, this must be explicitly initiated in the callback module.

Unless otherwise stated, all functions in this module fail if the specified gen_fsm does not exist or if bad arguments are given.
Exports

\[
\text{start\_link(Module, Args, Options) } \to \text{ Result} \\
\text{start\_link(FsmName, Module, Args, Options) } \to \text{ Result}
\]

Types:
- \(\text{FsmName} = \{\text{local,Name}\} \mid \{\text{global,GlobalName}\}\)
- \(\text{Name} = \text{atom}()\)
- \(\text{GlobalName} = \text{term}()\)
- \(\text{Module} = \text{atom}()\)
- \(\text{Args} = \text{term}()\)
- \(\text{Options} = [\text{Option}]\)
  - \(\text{Option} = \{\text{debug,Dbgs}\} \mid \{\text{timeout,Time}\} \mid \{\text{spawn\_opt,SOpts}\}\)
  - \(\text{Dbgs} = [\text{Dbg}]\)
  - \(\text{Dbg} = \text{trace} \mid \text{log} \mid \text{statistics}\)
  - \(\text{SOpts} = [\text{SOpt}]\)
  - \(\text{SOpt} = \text{see erlang:spawn\_opt/2,3,4,5}\)
- \(\text{Result} = \{\text{ok,Pid}\} \mid \text{ignore} \mid \{\text{error,Error}\}\)
- \(\text{Pid} = \text{pid}()\)
- \(\text{Error} = \{\text{already\_started,Pid}\} \mid \text{term}()\)

Creates a \text{gen\_fsm} process as part of a supervision tree. The function should be called, directly or indirectly, by the supervisor. It will, among other things, ensure that the \text{gen\_fsm} is linked to the supervisor.

The \text{gen\_fsm} process calls \text{Module:}\text{init/1} to initialize. To ensure a synchronized start-up procedure, \text{start\_link/3,4} does not return until \text{Module:}\text{init/1} has returned.

If \text{FsmName=local,Name}, the \text{gen\_fsm} is registered locally as \text{Name} using \text{register/2}.

If \text{FsmName=global,GlobalName}, the \text{gen\_fsm} is registered globally as \text{GlobalName} using \text{global:register\_name/2}. If no name is provided, the \text{gen\_fsm} is not registered.

\text{Module} is the name of the callback module.

\text{Args} is an arbitrary term which is passed as the argument to \text{Module:}\text{init/1}.

If the option \{timeout,Time\} is present, the \text{gen\_fsm} is allowed to spend \text{Time} milliseconds initializing or it will be terminated and the start function will return \{error,timeout\}.

If the option \{debug,Dbgs\} is present, the corresponding \text{sys} function will be called for each item in \text{Dbgs}. Refer to \text{sys(3)} for more information.

If the option \{spawn\_opt,SOpts\} is present, \text{SOpts} will be passed as option list to the \text{spawn\_opt} BIF which is used to spawn the \text{gen\_fsm} process. Refer to \text{erlang(3)} for information about the \text{spawn\_opt} options.

If the \text{gen\_fsm} is successfully created and initialized the function returns \{ok,Pid\}, where \text{Pid} is the pid of the \text{gen\_fsm}. If there already exists a process with the specified \text{FsmName}, the function returns \{error,\{already\_started,Pid\}\} where \text{Pid} is the pid of that process.

If \text{Module:}\text{init/1} fails with \text{Reason}, the function returns \{error,Reason\}. If \text{Module:}\text{init/1} returns \{stop,Reason\} or ignore, the process is terminated and the function returns \{error,Reason\} or ignore, respectively.
gen_fsm

**start(Module, Args, Options) -> Result**

**start(FsmName, Module, Args, Options) -> Result**

Types:
- FsmName = \{local, Name\} | \{global, GlobalName\}
- Name = atom()
- GlobalName = term()
- Module = atom()
- Args = term()
- Options = [Option]
- Option = \{debug, Dbs\} | \{timeout, Time\} | \{spawn_opt, SOpts\}
- Dbs = [D bg]
- D bg = trace | log | statistics
- \{log_to_file, FileName\} | \{install, \{Func, FuncState\}\}
- SOpts = [term()]
- Result = \{ok, Pid\} | ignore | \{error, Error\}
- Pid = pid()
- Error = \{already_started, Pid\} | term()

Creates a stand-alone gen_fsm process, i.e. a gen_fsm which is not part of a supervision tree and thus has no supervisor.

See `start_link/3,4` for a description of arguments and return values.

**send_event(FsmRef, Event) -> ok**

Types:
- FsmRef = Name | \{Name, Node\} | \{global, GlobalName\} | pid()
- Name = Node = atom()
- GlobalName = term()
- Event = term()

Sends an event asynchronously to the gen_fsm FsmRef and returns `ok` immediately. The gen_fsm will call `Module:StateName/2` to handle the event, where `StateName` is the name of the current state of the gen_fsm.

FsmRef can be:
- the pid,
- Name, if the gen_fsm is locally registered,
- \{Name, Node\}, if the gen_fsm is locally registered at another node, or
- \{global, GlobalName\}, if the gen fsm is globally registered.

Event is an arbitrary term which is passed as one of the arguments to `Module:StateName/2`.

**send_all_state_event(FsmRef, Event) -> ok**

Types:
- FsmRef = Name | \{Name, Node\} | \{global, GlobalName\} | pid()
- Name = Node = atom()
- GlobalName = term()
Event = term()
Sends an event asynchronously to the gen_fsm FsmRef and returns ok immediately. The gen_fsm will call Module:handle_event/3 to handle the event.
See send_event/2 for a description of the arguments.
The difference between send_event and send_all_state_event is which callback function is used to handle the event. This function is useful when sending events that are handled the same way in every state, as only one handle_event clause is needed to handle the event instead of one clause in each state name function.

sync_send_event(FsmRef, Event) -> Reply
sync_send_event(FsmRef, Event, Timeout) -> Reply

Types:
- FsmRef = Name | {Name,Node} | {global,GlobalName} | pid()
- Name = Node = atom()
- GlobalName = term()
- Event = term()
- Timeout = int() > 0 | infinity
- Reply = term()

Sends an event to the gen_fsm FsmRef and waits until a reply arrives or a timeout occurs. The gen_fsm will call Module:StateName/3 to handle the event, where StateName is the name of the current state of the gen_fsm.
See send_event/2 for a description of FsmRef and Event.
Timeout is an integer greater than zero which specifies how many milliseconds to wait for a reply, or the atom infinity to wait indefinitely. Default value is 5000. If no reply is received within the specified time, the function call fails.
The return value Reply is defined in the return value of Module:StateName/3.
In the case where the gen_fsm terminates during the handling of the event and the caller is linked to the gen_fsm and trapping exits, the exit message is removed from the caller’s receive queue before the function call fails.
This behaviour is retained for backwards compatibility only and may change in the future. Note that if the gen_fsm crashes in between calls, a linked process must take care of the exit message anyway.
Warning: Under certain circumstances (e.g. FsmRef = {Name,Node}, and Node goes down) the exit message cannot be removed.

sync_send_all_state_event(FsmRef, Event) -> Reply
sync_send_all_state_event(FsmRef, Event, Timeout) -> Reply

Types:
- FsmRef = Name | {Name,Node} | {global,GlobalName} | pid()
- Name = Node = atom()
- GlobalName = term()
- Event = term()
- Timeout = int() > 0 | infinity
- Reply = term()
Sends an event to the `gen_fsm FsmRef` and waits until a reply arrives or a timeout occurs. The `gen_fsm` will call `Module:handle_sync_event/4` to handle the event.

See `send_event/2` for a description of `FsmRef` and `Event`. See `sync_send_event/3` for a description of `Timeout` and `Reply`.

See `send_all_state_event/2` for a discussion about the difference between `sync_send_event` and `sync_send_all_state_event`.

\[
\text{reply}(\text{Caller}, \text{Reply}) \rightarrow \text{true}
\]

**Types:**
- `Caller` - see below
- `Reply` = `term()`

This function can be used by a `gen_fsm` to explicitly send a reply to a client process that called `sync_send_event` or `sync_send_all_state_event`, when the reply cannot be defined in the return value of `Module:State/3` or `Module:handle_sync_event/4`.

`Caller` must be the `From` argument provided to the callback function. `Reply` is an arbitrary term, which will be given back to the client as the return value of `sync_send_event` or `sync_send_all_state_event`.

\[
\text{send_event_after}(\text{Time}, \text{Event}) \rightarrow \text{Ref}
\]

**Types:**
- `Time` = `integer()`
- `Event` = `term()`
- `Ref` = `reference()`

Sends a delayed event internally in the `gen_fsm` that calls this function after `Time` ms. Returns immediately a reference that can be used to cancel the delayed send using `cancel_timer/1`.

The `gen_fsm` will call `Module:StateName/2` to handle the event, where `StateName` is the name of the current state of the `gen_fsm` at the time the delayed event is delivered.

`Event` is an arbitrary term which is passed as one of the arguments to `Module:StateName/2`.

\[
\text{start_timer}(\text{Time}, \text{Msg}) \rightarrow \text{Ref}
\]

**Types:**
- `Time` = `integer()`
- `Msg` = `term()`
- `Ref` = `reference()`

Sends a timeout event internally in the `gen_fsm` that calls this function after `Time` ms. Returns immediately a reference that can be used to cancel the timer using `cancel_timer/1`.

The `gen_fsm` will call `Module:StateName/2` to handle the event, where `StateName` is the name of the current state of the `gen_fsm` at the time the timeout message is delivered.

`Msg` is an arbitrary term which is passed in the timeout message, `{timeout, Ref, Msg}`, as one of the arguments to `Module:StateName/2`.

\[
\text{cancel_timer}(\text{Ref}) \rightarrow \text{RemainingTime} | \text{false}
\]
Types:
- Ref = reference()
- RemainingTime = integer()

Cancels an internal timer referred by Ref in the gen_fsm that calls this function. 
Ref is a reference returned from send_event_after/2 or start_timer/2.

If the timer has already timed out, but the event not yet been delivered, it is cancelled as if it had not timed out, so there will be no false timer event after returning from this function.

Returns the remaining time in ms until the timer would have expired if Ref referred to an active timer, false otherwise.

```
enter_loop(Module, Options, StateName, StateData)
```
```
enter_loop(Module, Options, StateName, StateData, FsmName)
```
```
enter_loop(Module, Options, StateName, StateData, Timeout)
```
```
enter_loop(Module, Options, StateName, StateData, FsmName, Timeout)
```

Types:
- Module = atom()
- Options = [Option]
- Option = (debug, Dbgs)
- Dbgs = [Dbg]
- Dbg = trace | log | statistics
-蝼 [log_to_file, FileName] | install([Func, FuncState])
- StateName = atom()
- StateData = term()
- FsmName = (local, Name) | (global, GlobalName)
- Name = atom()
- GlobalName = term()
- Timeout = int() | infinity

Makes an existing process into a gen_fsm. Does not return, instead the calling process will enter the gen_fsm receive loop and become a gen_fsm process. The process must have been started using one of the start functions in proc_lib, see proc_lib(3) [page 250]. The user is responsible for any initialization of the process, including registering a name for it.

This function is useful when a more complex initialization procedure is needed than the gen_fsm behaviour provides.

Module, Options and FsmName have the same meanings as when calling start_link/3,4 [page 179]. However, if FsmName is specified, the process must have been registered accordingly before this function is called.

StateName, StateData and Timeout have the same meanings as in the return value of Module:init/1 [page 184]. Also, the callback module Module does not need to export an init/1 function.

Failure: If the calling process was not started by a proc_lib start function, or if it is not registered according to FsmName.
CALLBACK FUNCTIONS

The following functions should be exported from a gen_fsm callback module.
In the description, the expression state name is used to denote a state of the state
machine. state data is used to denote the internal state of the Erlang process which
implements the state machine.

Exports

Module:init(Args) -> Result

Types:
- Args = term()
- Return = {ok,StateName,StateData} | ok,StateName,StateData,Timeout
- | {stop,Reason} | ignore
- StateName = atom()
- StateData = term()
- Timeout = int() > 0 | infinity
- Reason = term()

Whenever a gen_fsm is started using gen_fsm:start/3,4 or gen_fsm:start_link/3,4,
this function is called by the new process to initialize.

Args is the Args argument provided to the start function.
If initialization is successful, the function should return {ok,StateName,StateData} or
{ok,StateName,StateData,Timeout}, where StateName is the initial state name and
StateData the initial state data of the gen_fsm.
If an integer timeout value is provided, a timeout will occur unless an event or a message
is received within Timeout milliseconds. A timeout is represented by the atom timeout
and should be handled by the Module:StateName/2 callback functions. The atom
infinity can be used to wait indefinitely, this is the default value.
If something goes wrong during the initialization the function should return
{stop,Reason}, where Reason is any term, or ignore.

Module:StateName(Event, StateData) -> Result

Types:
- Event = timeout | term()
- StateData = term()
- Result = {next_state,NextStateName,NewStateData} | {next_state,NextStateName,NewStateData,Timeout}
- | {stop,Reason,NewStateData}
- NextStateName = atom()
- NewStateData = term()
- Timeout = int() > 0 | infinity
- Reason = term()
There should be one instance of this function for each possible state name. Whenever a 
gen_fsm
receives an event sent using 
gen_fsm:send_event/2, the instance of this
function with the same name as the current state name StateName is called to handle
the event. It is also called if a timeout occurs.

Event is either the atom timeout, if a timeout has occurred, or the Event argument
provided to send_event.

StateData is the state data of the 
gen_fsm.

If the function returns {next_state,NextStateName,NewStateData} or
{next_state,NextStateName,NewStateData,Timeout}, the 
gen_fsm will continue
executing with the current state name set to NextStateName and with the possibly
updated state data NewStateData. See Module:init/1 for a description of Timeout.

If the function returns {stop,Reason,NewStateData}, the 
gen_fsm will call
Module:terminate(Reason,NewStateData) and terminate.

Module:handle_event(Event, StateName, StateData) -> Result

Types:
- Event = term()
- StateName = atom()
- StateData = term()
- Result = {next_state,NextStateName,NewStateData} ||
  {next_state,NextStateName,NewStateData,Timeout} ||
  {stop,Reason,NewStateData}
- NextStateName = atom()
- NewStateData = term()
- Timeout = int() > 0 || infinity
- Reason = term()

Whenever a 
gen_fsm receives an event sent using 
gen_fsm:send_all_state_event/2,
this function is called to handle the event.

StateName is the current state name of the 
gen_fsm.

See Module:StateName/2 for a description of the other arguments and possible return
values.

Module:StateName(Event, From, StateData) -> Result

Types:
- Event = term()
- From = {pid(),Tag}
- StateData = term()
- Result = {reply,Reply,NextStateName,NewStateData} ||
  {reply,Reply,NextStateName,NewStateData,Timeout} ||
  {next_state,NextStateName,NewStateData} ||
  {next_state,NextStateName,NewStateData,Timeout} ||
  {stop,Reason,Reply,NewStateData} ||
  {stop,Reason,NewStateData} ||
  Reply = term()
- NextStateName = atom()
- NewStateData = term()
- Timeout = int() > 0 || infinity
• Reason = normal | term()

There should be one instance of this function for each possible state name. Whenever a gen_fsm receives an event sent using gen_fsm:sync_send_event/2,3, the instance of this function with the same name as the current state name StateName is called to handle the event.

Event is the Event argument provided to sync_send_event.

From is a tuple {Pid, Tag} where Pid is the pid of the process which called sync_send_event and Tag is a unique tag.

StateData is the state data of the gen_fsm.

If the function returns {reply,Reply,NextStateName,NewStateData} or {reply,Reply,NextStateName,NewStateData,Timeout}, Reply will be given back to From as the return value of sync_send_event. The gen fsm then continues executing with the current state name set to NextStateName and with the possibly updated state data NewStateData. See Module:init/1 for a description of Timeout.

If the function returns {next_state,NextStateName,NewStateData} or {next_state,NextStateName,NewStateData,Timeout}, the gen_fsm will continue executing in NextStateName with NewStateData. Any reply to From must be given explicitly using gen_fsm:reply/2.

If the function returns {stop,Reason,Reply,NewStateData}, Reply will be given back to From. If the function returns {stop,Reason,NewStateData}, any reply to From must be given explicitly using gen_fsm:reply/2. The gen_fsm will then call Module:terminate(Reason,NewStateData) and terminate.

Module:handle_sync_event(Event, From, StateName, StateData) -> Result

Types:
• Event = term()
• From = {pid(),Tag}
• StateName = atom()
• StateData = term()
• Result = {reply,Reply,NextStateName,NewStateData} | {reply,Reply,NextStateName,NewStateData,Timeout} | {next_state,NextStateName,NewStateData} | {next_state,NextStateName,NewStateData,Timeout} | {stop,Reason,Reply,NewStateData} | {stop,Reason,NewStateData}
• Reply = term()
• NextStateName = atom()
• NewStateData = term()
• Timeout = int() > 0 | infinity
• Reason = term()

Whenever a gen_fsm receives an event sent using gen_fsm:sync_send_all_state_event/2,3, this function is called to handle the event. StateName is the current state name of the gen_fsm.

See Module:StateName/3 for a description of the other arguments and possible return values.

Module:handle_info(Info, StateName, StateData) -> Result
Types:
- Info = term()
- StateName = atom()
- StateData = term()
- Result = {next_state, NextStateName, NewStateData} | {next_state, NextStateName, NewStateData, Timeout} | {stop, Reason, NewStateData}
- NextStateName = atom()
- NewStateData = term()
- Timeout = int() > 0 | infinity
- Reason = normal | term()

This function is called by a gen fsm when it receives any other message than a synchronous or asynchronous event (or a system message).

Info is the received message.

See Module:StateName/2 for a description of the other arguments and possible return values.

Module:terminate(Reason, StateName, StateData)

Types:
- Reason = normal | shutdown | term()
- StateName = atom()
- StateData = term()

This function is called by a gen fsm when it is about to terminate. It should be the opposite of Module:init/1 and do any necessary cleaning up. When it returns, the gen fsm terminates with Reason. The return value is ignored.

Reason is a term denoting the stop reason, StateName is the current state name, and StateData is the state data of the gen fsm.

Reason depends on why the gen fsm is terminating. If it is because another callback function has returned a stop tuple {stop, ...}, Reason will have the value specified in that tuple. If it is due to a failure, Reason is the error reason.

If the gen fsm is part of a supervision tree and is ordered by its supervisor to terminate, this function will be called with Reason=shutdown if the following conditions apply:

- the gen fsm has been set to trap exit signals, and
- the shutdown strategy as defined in the supervisor's child specification is an integer timeout value, not brutal kill.

Otherwise, the gen fsm will be immediately terminated.

Note that for any other reason than normal or shutdown, the gen fsm is assumed to terminate due to an error and an error report is issued using error_logger: format/2.

Module:code change(OldVsn, StateName, StateData, Extra) -> {ok, NextStateName, NewStateData}

Types:
- OldVsn = Vsn | {down, Vsn}
- Vsn = term()}
This function is called by a gen_fsm when it should update its internal state data during a release upgrade/downgrade, i.e. when the instruction \{update, Module, Change,...\} where Change=\{advanced,Extra\} is given in the appup file. See OTP Design Principles for more information.

In the case of an upgrade, OldVsn is Vsn, and in the case of a downgrade, OldVsn is \{down, Vsn\}. Vsn is defined by the vsn attribute(s) of the old version of the callback module Module. If no such attribute is defined, the version is the checksum of the BEAM file.

StateName is the current state name and StateData the internal state data of the gen_fsm.

Extra is passed as-is from the \{advanced,Extra\} part of the update instruction.

The function should return the new current state name and updated internal data.

SEE ALSO

supervisor(3) [page 330], sys(3) [page 340]
A behaviour module for implementing the server of a client-server relation. A generic server process (gen_server) implemented using this module will have a standard set of interface functions and include functionality for tracing and error reporting. It will also fit into an OTP supervision tree. Refer to OTP Design Principles for more information.

A gen_server assumes all specific parts to be located in a callback module exporting a pre-defined set of functions. The relationship between the behaviour functions and the callback functions can be illustrated as follows:

```
gen_server module       Callback module
------------------       ---------------
gen_server:start_link    Module:init/1
  gen_server:call
  gen_server:multi_call   Module:handle_call/3
  gen_server:cast
  gen_server:abcast      Module:handle_cast/2
    Module:handle_info/2
    Module:terminate/2
    Module:code_change/3
```

If a callback function fails or returns a bad value, the gen_server will terminate. The sys module can be used for debugging a gen_server.

Note that a gen_server does not trap exit signals automatically, this must be explicitly initiated in the callback module.

Unless otherwise stated, all functions in this module fail if the specified gen_server does not exist or if bad arguments are given.

Exports

```
start_link(Module, Args, Options) -> Result
start_link(ServerName, Module, Args, Options) -> Result
```

Types:
- ServerName = {local,Name} | {global,GlobalName}
- Name = atom()
- GlobalName = term()
Module = atom()
Args = term()
Options = [Option]
  Option = {debug,Dbgs} | {timeout,Time} | {spawn_opt,SOpts}
Dbgs = [Dbg]
Dbg = trace | log | statistics | {log_to_file,FileName} | {install,{Func,FuncState}}
SOpts = [term()]
Result = {ok,Pid} | ignore | {error,Error}
Pid = pid()
Error = {already_started,Pid} | term()

Creates a gen_server process as part of a supervision tree. The function should be called,
directly or indirectly, by the supervisor. It will, among other things, ensure that
the gen_server is linked to the supervisor.

The gen_server process calls Module:init/1 to initialize. To ensure a synchronized
start-up procedure, start_link/3,4 does not return until Module:init/1 has returned.
If ServerName=local,Name the gen_server is registered locally as Name using
register/2. If ServerName=global,GlobalName the gen_server is registered globally
as GlobalName using global:register_name/2. If no name is provided, the gen_server
is not registered.

Module is the name of the callback module.
Args is an arbitrary term which is passed as the argument to Module:init/1.
If the option {timeout,Time} is present, the gen_server is allowed to spend Time
milliseconds initializing or it will be terminated and the start function will return
{error,timeout}.
If the option {debug,Dbgs} is present, the corresponding sys function will be called for
each item in Dbgs. Refer to sys(3) for more information.
If the option {spawn_opt,SOpts} is present, SOpts will be passed as option list to the
spawn_opt BIF which is used to spawn the gen_server. Refer to erlang(3) for
information about the spawn_opt options.

If the gen_server is successfully created and initialized the function returns {ok,Pid},
where Pid is the pid of the gen_server. If there already exists a process with the
specified ServerName the function returns {error,{already_started,Pid}}, where
Pid is the pid of that process.
If Module:init/1 fails with Reason, the function returns {error,Reason}. If
Module:init/1 returns {stop,Reason} or ignore, the process is terminated and the
function returns {error,Reason} or ignore, respectively.

start(Module, Args, Options) -> Result
start(ServerName, Module, Args, Options) -> Result

Types:
   ServerName = {local,Name} | {global,GlobalName}
   Name = atom()
   GlobalName = term()
   Module = atom()
   Args = term()
   Options = [Option]
Option = [debug, Dbgs] | [timeout, Time] | [spawn, SOpts]
Dbgs = [Dbg]
Dbg = trace | log | statistics | [log_to_file, FileName] | [install, {Func, FuncState}]
SOpts = [term()]
Result = [ok, Pid] | ignore | [error, Error]
Pid = pid()
Error = [already_started, Pid] | term()

Creates a stand-alone gen_server process, i.e. a gen_server which is not part of a supervision tree and thus has no supervisor.
See start_link/3,4 for a description of arguments and return values.

call(ServerRef, Request) -> Reply
call(ServerRef, Request, Timeout) -> Reply

Types:
- ServerRef = Name | {Name, Node} | {global, GlobalName} | pid()
- Node = atom()
- GlobalName = term()
- Request = term()
- Timeout = int() > 0 | infinity
- Reply = term()

Makes a synchronous call to the gen_server ServerRef by sending a request and waiting until a reply arrives or a timeout occurs. The gen_server will call Module:handle_call/3 to handle the request.

ServerRef can be:
- the pid,
- Name, if the gen_server is locally registered,
- {Name, Node}, if the gen_server is locally registered at another node, or
- {global, GlobalName}, if the gen_server is globally registered.

Request is an arbitrary term which is passed as one of the arguments to Module: handle_call/3.

Timeout is an integer greater than zero which specifies how many milliseconds to wait for a reply, or the atom infinity to wait indefinitely. Default value is 5000. If no reply is received within the specified time, the function call fails.

The return value Reply is defined in the return value of Module: handle_call/3.

The call may fail for several reasons, including timeout and the called gen_server dying before or during the call.

There is a special case for backwards compatibility. If:
- the client is linked to the gen_server, and
- the client is trapping exits, and
- the gen_server terminates while handling the request
then the exit message is removed from the client's receive queue before the function call fails. This special-case behaviour may be removed in the future because it is inconsistent with the behaviour when a gen_server dies between calls and also because the exit message cannot be removed in some circumstances, for instance when ServerRef = {Name, Node} and Node goes down.

multi_call(Name, Request) -> Result
multi_call(Nodes, Name, Request) -> Result
multi_call(Nodes, Name, Request, Timeout) -> Result

Types:
- Nodes = [Node]
- Node = atom()
- Name = atom()
- Request = term()
- Timeout = int()>=0 | infinity
- Result = {Replies,BadNodes}
- Replies = [{Node,Reply}]
- Reply = term()
- BadNodes = [Node]

Makes a synchronous call to all gen_servers locally registered as Name at the specified nodes by first sending a request to every node and then waiting for the replies. The gen_servers will call Module:handle_call/3 to handle the request.

The function returns a tuple {Replies, BadNodes} where Replies is a list of {Node,Reply} and BadNodes is a list of node that either did not exist, or where the gen_server Name did not exist or did not reply.

Nodes is a list of node names to which the request should be sent. Default value is the list of all known nodes [node()]|nodes().

Name is the locally registered name of each gen_server.

Request is an arbitrary term which is passed as one of the arguments to Module:handle_call/3.

Timeout is an integer greater than zero which specifies how many milliseconds to wait for each reply, or the atom infinity to wait indefinitely. Default value is infinity. If no reply is received from a node within the specified time, the node is added to BadNodes.

When a reply Reply is received from the gen_server at a node Node, {Node,Reply} is added to Replies. Reply is defined in the return value of Module:handle_call/3.

**Warning:**
If one of the nodes is running Erlang/OTP R6B or older, and the gen_server is not started when the requests are sent, but starts within 2 seconds, this function waits the whole Timeout, which may be infinity.

This problem does not exist if all nodes are running Erlang/OTP R7B or later.

This function does not read out any exit messages like call/2,3 does.
The previously undocumented functions safe\texttt{multi\_call}/2,3,4 were removed in OTP R7B/Erlang 5.0 since this function is now safe, except in the case mentioned above.

To avoid that late answers (after the timeout) pollutes the caller's message queue, a middleman process is used to do the actual calls. Late answers will then be discarded when they arrive to a terminated process.

\begin{verbatim}

\textbf{cast} (ServerRef, Request) \rightarrow \texttt{ok}

Types:
- \texttt{ServerRef} = Name | \{ Name, Node \} | \{ global, GlobalName \} | \texttt{pid()}
- \texttt{Node} = atom()
- \texttt{GlobalName} = term()
- \texttt{Request} = term()

Sends an asynchronous request to the \texttt{gen\_server} \texttt{ServerRef} and returns \texttt{ok} immediately, ignoring if the destination node or \texttt{gen\_server} does not exist. The \texttt{gen\_server} will call \texttt{Module:\_handle\_cast/2} to handle the request.

See \texttt{call}/2,3 for a description of \texttt{ServerRef}.

Request is an arbitrary term which is passed as one of the arguments to \texttt{Module:\_handle\_cast/2}.

\textbf{abcast} (Name, Request) \rightarrow \texttt{abcast}

\textbf{abcast} (Nodes, Name, Request) \rightarrow \texttt{abcast}

Types:
- \texttt{Nodes} = \{ Node \}
- \texttt{Node} = atom()
- \texttt{Name} = atom()
- \texttt{Request} = term()

Sends an asynchronous request to the \texttt{gen\_servers} locally registered as \texttt{Name} at the specified nodes. The function returns immediately and ignores nodes that does not exist, or where the \texttt{gen\_server} \texttt{Name} does not exist. The \texttt{gen\_servers} will call \texttt{Module:\_handle\_cast/2} to handle the request.

See \texttt{multi\_call}/2,3,4 for a description of the arguments.

\textbf{reply} (Client, Reply) \rightarrow \texttt{true}

Types:
- \texttt{Client} - see below
- \texttt{Reply} = term()

This function can be used by a \texttt{gen\_server} to explicitly send a reply to a client that called \texttt{call} or \texttt{multi\_call}, when the reply cannot be defined in the return value of \texttt{Module:\_handle\_call/3}.

\texttt{Client} must be the \texttt{From} argument provided to the callback function. \texttt{Reply} is an arbitrary term, which will be given back to the client as the return value of \texttt{call} or \texttt{multi\_call}.

\textbf{enter\_loop} (Module, Options, State)
\end{verbatim}
enter_loop(Module, Options, State, ServerName)
enter_loop(Module, Options, State, Timeout)
enter_loop(Module, Options, State, ServerName, Timeout)

Types:
- Module = atom()
- Options = {Option}
- Option = {debug,D bg}
- D bg = [Dbg]
- Dbg = trace | log | statistics
- | {log_to_file,FileName} | {install, {Func,FuncState}}
- State = term()
- ServerName = {local,Name} | {global,GlobalName}
- Name = atom()
- GlobalName = term()
- Timeout = int() | infinity

Makes an existing process into a gen_server. Does not return, instead the calling process will enter the gen_server receive loop and become a gen_server process. The process must have been started using one of the start functions in proc_lib, see proc_lib(3) [page 250]. The user is responsible for any initialization of the process, including registering a name for it.

This function is useful when a more complex initialization procedure is needed than the gen_server behaviour provides.

Module, Options and ServerName have the same meanings as when calling gen_server:start[link]/3,4 [page 189]. However, if ServerName is specified, the process must have been registered accordingly before this function is called.

State and Timeout have the same meanings as in the return value of Module:init/1 [page 195]. Also, the callback module Module does not need to export an init/1 function.

Failure: If the calling process was not started by a proc_lib start function, or if it is not registered according to ServerName.

CALLBACK FUNCTIONS

The following functions should be exported from a gen_server callback module.

Exports

Module:init(Arg) -> Result

Types:
- Args = term()
- Result = {ok, State} | {ok, State, Timeout}
- | {stop, Reason} | ignore
- State = term()
- Timeout = int() > 0 | infinity
• Reason = term()

Whenever a gen_server is started using gen_server:start/3,4 or
gen_server:start_link/3,4, this function is called by the new process to initialize.

Args is the Args argument provided to the start function.

If the initialization is successful, the function should return \{ok,State\} or
\{ok,State,Timeout\}, where State is the internal state of the gen_server.

If an integer timeout value is provided, a timeout will occur unless a request or a message
is received within Timeout milliseconds. A timeout is represented by the atom timeout
which should be handled by the handle_info/2 callback function. The atom
infinity can be used to wait indefinitely, this is the default value.

If something goes wrong during the initialization the function should return
\{stop,Reason\} where Reason is any term, or ignore.

Module:handle_call(Request, From, State) -> Result

Types:
• Request = term()
• From = \{pid(),Tag\}
• State = term()
• Result = \{reply,Reply,NewState\} | \{reply,Reply,NewState,Timeout\}
• | \{noreply,NewState\} | \{noreply,NewState,Timeout\}
• | \{stop,Reason,Reply,NewState\} | \{stop,Reason,NewState\}
• Reply = term()
• NewState = term()
• Timeout = int() \(\geq 0\) | infinity
• Reason = term()

Whenever a gen_server receives a request sent using gen_server:call/2,3 or
gen_server:multi_call/2,3,4, this function is called to handle the request.

Request is the Request argument provided to call or multi_call.

From is a tuple \{Pid,Tag\} where Pid is the pid of the client and Tag is a unique tag.

State is the internal state of the gen_server.

If the function returns \{reply,Reply,NewState\} or
\{reply,Reply,NewState,Timeout\}, Reply will be given back to From as the return
value of call or included in the return value of multi_call. The gen_server then
continues executing with the possibly updated internal state NewState. See
Module:init/1 for a description of Timeout.

If the functions returns \{noreply,NewState\} or \{noreply,NewState,Timeout\}, the
gen_server will continue executing with NewState. Any reply to From must be given
explicitly using gen_server:reply/2.

If the function returns \{stop,Reason,Reply,NewState\}, Reply will be given back to
From. If the function returns \{stop,Reason,NewState\}, any reply to From must be
given explicitly using gen_server:reply/2. The gen_server will then call
Module:terminate(Reason,NewState) and terminate.

Module:handle_cast(Request, State) -> Result

Types:
Whenever a gen_server receives a request sent using `gen_server:cast/2` or `gen_server:abcast/2,3`, this function is called to handle the request.

See `Module:handle_call/3` for a description of the arguments and possible return values.

```
Module:handle_info(Info, State) -> Result
```

Types:
- Info = `timeout` | `term()`
- State = `term()`
- Result = `{noreply,N ewState} ` | `{noreply,N ewState,Timeout}
- | `{stop,Reason,N ewState}
- NewState = `term()`
- Timeout = `int() >=0 ` | `infinity`
- Reason = `term()`

This function is called by a `gen_server` when a timeout occurs or when it receives any other message than a synchronous or asynchronous request (or a system message). Info is either the atom `timeout`, if a timeout has occurred, or the received message. See `Module:handle_call/3` for a description of the other arguments and possible return values.

```
Module:terminate(Reason, State)
```

Types:
- Reason = `normal` | `shutdown` | `term()`
- State = `term()`

This function is called by a `gen_server` when it is about to terminate. It should be the opposite of `Module:init/1` and do any necessary cleaning up. When it returns, the `gen_server` terminates with Reason. The return value is ignored.

Reason is a term denoting the stop reason and State is the internal state of the `gen_server`. Reason depends on why the `gen_server` is terminating. If it is because another callback function has returned a stop tuple `{stop,..}`, Reason will have the value specified in that tuple. If it is due to a failure, Reason is the error reason.

If the `gen_server` is part of a supervision tree and is ordered by its supervisor to terminate, this function will be called with Reason=shutdown if the following conditions apply:

- the `gen_server` has been set to trap exit signals, and
- the shutdown strategy as defined in the supervisor's child specification is an integer timeout value, not `brutal_kill`. 
Otherwise, the gen_server will be immediately terminated.

Note that for any other reason than normal or shutdown, the gen_server is assumed to terminate due to an error and an error report is issued using error_logger:format/2.

```
Module:code_change(OldVsn, State, Extra) -> {ok, NewState}
```

**Types:**
- `OldVsn = Vsn | {down, Vsn}`
- `Vsn = term()`
- `State = NewState = term()`
- `Extra = term()`

This function is called by a gen_server when it should update its internal state during a release upgrade/downgrade, i.e. when the instruction `{update, Module, Change, ...}` where `Change = {advanced, Extra}` is given in the appup file. See OTP Design Principles for more information.

In the case of an upgrade, `OldVsn` is `Vsn`, and in the case of a downgrade, `OldVsn` is `{down, Vsn}. Vsn` is defined by the `vsn` attribute(s) of the old version of the callback module `Module`. If no such attribute is defined, the version is the checksum of the BEAM file.

`State` is the internal state of the gen_server.

`Extra` is passed as-is from the `{advanced, Extra}` part of the update instruction.

The function should return the updated internal state.

**SEE ALSO**

supervisor(3) [page 330], sys(3) [page 340]
This module provides an interface to standard Erlang IO servers. The output functions all return `ok` if they are successful, or `exit` if they are not.

In the following description, all functions have an optional parameter `IoDevice`. If included, it must be the pid of a process which handles the IO protocols. Normally, it is the `IoDevice` returned by `[file:open/2]`.

For a description of the IO protocols refer to Armstrong, Virding and Williams, ‘Concurrent Programming in Erlang’, Chapter 13, unfortunately now very outdated, but the general principles still apply.

**DATA TYPES**

- `io_device()` as returned by `file:open/2`, a process handling IO protocols

**Exports**

- `put_chars([IoDevice,] IoData) -> ok`
  - Types:
    - `IoDevice = io_device()`
    - `IoData = IoList | binary()`
    - `IoList = [char() | binary() | IoList]`
  - Writes the characters of `IoData` to the standard output (`IoDevice`).

- `nl([IoDevice]) -> ok`
  - Types:
    - `IoDevice = io_device()`
  - Writes new line to the standard output (`IoDevice`).

- `get_chars([IoDevice,] Prompt, Count) -> string() | eof`
  - Types:
    - `IoDevice = io_device()`
    - `Prompt = atom() | string()`
    - `Count = int()`
Reads Count characters from standard input (IoDevice), prompting it with Prompt. It returns:

String The input characters.
eof End of file was encountered.

get_line([IoDevice,] Prompt) -> string() | eof

Types:
- IoDevice = io_device()
- Prompt = atom() | string()

Reads a line from the standard input (IoDevice), prompting it with Prompt. It returns:

String The characters in the line terminated by a LF (or end of file).
eof End of file was encountered.

setopts([IoDevice,] Opts) -> ok | {error, Reason}

Types:
- IoDevice = io_device()
- Opts = [Opt]
- Opt = binary | list
- Reason = term()

Set options for standard input/output (IoDevice). Possible options are:

binary Makes get_chars/2,3 and get_line/1,2 return binaries instead of lists of chars.
list Makes get_chars/2,3 and get_line/1,2 return lists of chars, which is the default.

expand_fun Provide a function for tab-completion (expansion) like the erlang shell. This function is called when the user presses the Tab key. The expansion is active when calling line-reading functions such as get_line/1,2.

The function is called with the current line, upto the cursor, as a reversed string. It should return a three-tuple: {yes, no, string(), [string(), ...]}. The first element gives a beep if no, otherwise the expansion is silent, the second is a string that will be entered at the cursor position, and the third is a list of possible expansions. If this list is non-empty, the list will be printed and the current input line will be written once again.

Trivial example (beep on anything except empty line, which is expanded to “quit”):

fun("") -> {yes, "quit", []};
(_) -> {no, ", ["quit"]} end

Note:
The binary option does not work against IO servers on remote nodes running an older version of Erlang/OTP than R9C.
write([IoDevice,] Term) -> ok

Types:
- IoDevice = io_device()
- Term = term()

Writes the term Term to the standard output (IoDevice).

read([IoDevice,] Prompt) -> Result

Types:
- IoDevice = io_device()
- Prompt = atom() | string()
- Result = {ok, Term} | eof | {error, ErrorInfo}
- Term = term()
- ErrorInfo - see section Error Information below

Reads a term Term from the standard input (IoDevice), prompting it with Prompt. It returns:

- {ok, Term} The parsing was successful.
- eof End of file was encountered.
- {error, ErrorInfo} The parsing failed.

read(IoDevice, Prompt, StartLine) -> Result

Types:
- IoDevice = io_device()
- Prompt = atom() | string()
- StartLine = int()
- Result = {ok, Term, EndLine} | {eof, EndLine} | {error, ErrorInfo, EndLine}
- Term = term()
- EndLine = int()
- ErrorInfo - see section Error Information below

Reads a term Term from IoDevice, prompting it with Prompt. Reading starts at line number StartLine. It returns:

- {ok, Term, EndLine} The parsing was successful.
- {eof, EndLine} End of file was encountered.
- {error, ErrorInfo, EndLine} The parsing failed.

fwrite(Format) ->
fwrite([IoDevice,] Format, Data) -> ok

format(Format) ->
format([IoDevice,] Format, Data) -> ok

Types:
- IoDevice = io_device()
- Format = atom() | string()
- Data = [term()]
Writes the items in Data ([]) on the standard output (IoDevice) in accordance with Format. Format contains plain characters which are copied to the output device, and control sequences for formatting, see below. If Format is an atom, it is first converted to a list with the aid of atom_to_list/1.

```
1> io:fwrite("Hello world!"n", []).
Hello world!
ok
```

The general format of a control sequence is ~F.P.PadC. The character C determines the type of control sequence to be used, F and P are optional numeric arguments. If F, P, or Pad is *, the next argument in Data is used as the numeric value of F or P.

F is the field width of the printed argument. A negative value means that the argument will be left justified within the field, otherwise it will be right justified. If no field width is specified, the required print width will be used. If the field width specified is too small, then the whole field will be filled with * characters.

P is the precision of the printed argument. A default value is used if no precision is specified. The interpretation of precision depends on the control sequences. Unless otherwise specified, the argument within is used to determine print width.

Pad is the padding character. This is the character used to pad the printed representation of the argument so that it conforms to the specified field width and precision. Only one padding character can be specified and, whenever applicable, it is used for both the field width and precision. The default padding character is ' ' (space).

The following control sequences are available:

- The character ~ is written.
- The argument is a number that will be interpreted as an ASCII code. The precision is the number of times the character is printed and it defaults to the field width, which in turn defaults to 1. The following example illustrates:

```
2> io:fwrite("~10.5c~10.5c~5c"n", [$a, $b, $c]).
| aaaaa|aaaaa |ccccc|
ok
```

- The argument is a float which is written as [-]ddd.ddd, where the precision is the number of digits after the decimal point. The default precision is 6 and it cannot be less than 1.
- The argument is a float which is written as [-]d.dde+--ddd, where the precision is the number of digits written. The default precision is 6 and it cannot be less than 2. The following example illustrates:

```
2> io:fwrite("~10.5c~10.5c~5c"n", [$a, $b, $c]).
| aaaaa|aaaaa |ccccc|
ok
```

- The argument is a float which is written as f, if it is >= 0.1 and < 10000.0. Otherwise, it is written in the e format. The precision is the number of significant digits. It defaults to 6 and should not be less than 2. If the absolute value of the float does not allow it to be written in the f format with the desired number of significant digits, it is also written in the e format.
s Prints the argument with the string syntax. The argument is a list of characters (possibly not a flat list), or an atom. The characters are printed without quotes. In this format, the printed argument is truncated to the given precision and field width.

This format can be used for printing any object and truncating the output so it fits a specified field:

3> io:fwrite("|\-10w\-\n", [[hey, hey, hey]]).
|**********|
ok
4> io:fwrite("|\-10s\-\n", [io:lib:write([hey, hey, hey])]).
|hey,hey,h|
ok

w Writes data with the standard syntax. This is used to output Erlang terms. Atoms are printed within quotes if they contain embedded non-printable characters, and floats are printed in the default g format.

p Writes the data with standard syntax in the same way as ~w, but breaks terms whose printed representation is longer than one line into many lines and indents each line sensibly. It also tries to detect lists of printable characters and to output these as strings. For example:

5> T = [{attributes,[[{id,age,1.50000},{mode,explicit}],
  {typename,"INTEGER"}],[{id,cho},{mode,explicit},{typename,'Cho'}]],
  {typename,'Person'},[tag,['PRIVATE',3]},{mode,implicit}].
... 
6> io:fwrite("~w\n", [T]).
[{attributes,[[{id,age,1.50000},{mode,explicit}],
  {typename,[73,78,84,71,69,82]}],[{id,cho},{mode,explicit}],
  {typename,'Cho'}]],
  {typename,'Person'},[tag,['PRIVATE',3]},{mode,implicit}]
ok
7> io:fwrite("~p\n", [T]).
[{attributes,[[{id,age,1.50000},
  {mode,explicit}],
  {typename,"INTEGER"}],[{id,cho},{mode,explicit}],
  {typename,'Cho'}]],
  {typename,'Person'},
  [tag,['PRIVATE',3]},
  {mode,implicit}]
ok

The field width specifies the maximum line length. It defaults to 80. The precision specifies the initial indentation of the term. It defaults to the number of characters printed on this line in the same call to io:fwrite or io:format. For example, using T above:

8> io:fwrite("Here T = ~p\n", [T]).
Here T = [{attributes,[[{id,age,1.50000},
  {mode,explicit}],
  {typename,"INTEGER"}],[{id,cho},{mode,explicit}],
  {typename,'Cho'}]],
  {typename,'Person'},
  [tag,['PRIVATE',3]},
  {mode,implicit}]
W  Writes data in the same way as `~w`, but takes an extra argument which is the maximum depth to which terms are printed. Anything below this depth is replaced with `...`.

For example, using `T` above:

```
9> io:fwrite("~W~n", [T,9]).
ok
```

If the maximum depth has been reached, then it is impossible to read in the resultant output. Also, the `|...|` form in a tuple denotes that there are more elements in the tuple but these are below the print depth.

P  Writes data in the same way as `~p`, but takes an extra argument which is the maximum depth to which terms are printed. Anything below this depth is replaced with `...`.

For example:

```
10> io:fwrite("~P~n", [T,9]).
ok
```

B  Writes an integer in base 2..36, the default base is 10. A leading dash is printed for negative integers.

The precision field selects base. For example:

```
11> io:format("~.16B~n", [31]).
ok
```

```
12> io:format("~.2B~n", [-19]).
-10011
ok
```

```
13> io:format("~.36B~n", [5*36+35]).
5Z
ok
```
Like B, but takes an extra argument that is a prefix to insert before the number, but after the leading dash, if any. The prefix can be a possibly deep list of characters or an atom.

14> io:format("~X-n", [31,"10#"]).
10#31
ok
15> io:format("~.16X-n", [31,"0x"]).
-0x1F
ok

# Like B, but prints the number with an Erlang style '#'-separated base prefix.

16> io:format("~.10#-n", [31]).
10#31
ok
17> io:format("~.16#-n", [-31]).
-16#1F
ok

b Like B, but prints lowercase letters.
x Like X, but prints lowercase letters.
+ Like #, but prints lowercase letters.

n Writes a new line.
i Ignores the next term.

Returns:
ok The formatting succeeded.

If an error occurs, there is no output. For example:

18> io:fwrite(" ~s ~w ~i ~w ~c ~n",['abc def', 'abc def', [foo, 1],[foo, 1], 65]).
abc def 'abc def' [foo, 1] A
ok
19> io:fwrite("~s", [65]).
** exited: {badarg,[{io,format,[<0.22.0>,"~-s","A"],
{erl_eval,do_apply,5},
{shell,exprs,6},
{shell,eval_loop,2}]}}**

In this example, an attempt was made to output the single character '65' with the aid of the string formatting directive "~s".

The two functions fwrite and format are identical. The old name format has been retained for backwards compatibility, while the new name fwrite has been added as a logical complement to fread.

fwrite([IoDevice,] Prompt, Format) -> Result
Types:
- `IoDevice = io_device()`
- `Prompt = atom() | string()`
- `Format = string()`
- `Result = {ok, Terms} | eof | {error, What}`
- `Terms = [term()]`
- `What = term()`

Reads characters from the standard input (`IoDevice`), prompting it with `Prompt`. Interprets the characters in accordance with `Format`. `Format` contains control sequences which direct the interpretation of the input.

`Format` may contain:

- White space characters (SPACE, TAB and NEWLINE) which cause input to be read to the next non-white space character.
- Ordinary characters which must match the next input character.
- Control sequences, which have the general format `~*FC`. The character `*` is an optional return suppression character. It provides a method to specify a field which is to be omitted. `F` is the field width of the input field and `C` determines the type of control sequence.

Unless otherwise specified, leading white-space is ignored for all control sequences. An input field cannot be more than one line wide. The following control sequences are available:

- `~` A single `~` is expected in the input.
- `d` A decimal integer is expected.
- `u` An unsigned integer in base 2..36 is expected. The field width parameter is used to specify base. Leading white-space characters are not skipped.
- `-` An optional sign character is expected. A sign character `-' gives the return value `-1`. Sign character `'+` or none gives `1`. The field width parameter is ignored. Leading white-space characters are not skipped.
- `#` An integer in base 2..36 with Erlang-style base prefix (for example "16#ffff") is expected.
- `f` A floating point number is expected. It must follow the Erlang floating point number syntax.
- `s` A string of non-white-space characters is read. If a field width has been specified, this number of characters are read and all trailing white-space characters are stripped. An Erlang string (list of characters) is returned.
- `a` Similar to `s`, but the resulting string is converted into an atom.
- `c` The number of characters equal to the field width are read (default is 1) and returned as an Erlang string. However, leading and trailing white-space characters are not omitted as they are with `s`. All characters are returned.
- `l` Returns the number of characters which have been scanned up to that point, including white-space characters.

It returns:

- `{ok, Terms}` The read was successful and `Terms` is the list of successfully matched and read items.
- `eof` End of file was encountered.
- `{error, What}` The read operation failed and the parameter `What` gives a hint about the error.
Examples:

20> io:fread('enter>', "f-f-f").
enter> 1.9 35.5e3 15.0
{ok, [1.90000, 3.55000e+4, 15.0000]}

21> io:fread('enter>', "10f-d").
enter> 5.67899
{ok, [5.67800, 99]}

22> io:fread('enter>', "10s:10c:1").
enter> alan: joe
{ok, ["alan", " joe "]}

scan_erl_exprs(Prompt) ->
scan_erl_exprs([IoDevice,] Prompt, StartLine) -> Result

Types:
- IoDevice = io_device()
- Prompt = atom() | string()
- StartLine = int()
- Result = (ok, Tokens, EndLine) | {eof, EndLine} | {error, ErrorInfo, EndLine}
- Tokens - see erl_scan(3)
- EndLine = int()
- ErrorInfo - see section Error Information below

Reads data from the standard input (IoDevice), prompting it with Prompt. Reading
starts at line number StartLine (1). The data is tokenized as if it were a sequence
of Erlang expressions until a final '.' is reached. This token is also returned. It returns:

- {ok, Tokens, EndLine} The tokenization succeeded.
- {eof, EndLine} End of file was encountered.
- {error, ErrorInfo, EndLine} An error occurred.

Example:

23> io:scan_erl_exprs('enter>').
enter>abc(), "hey".
{ok, [[atom,1,abc],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',')',1],['(',

scan_erl_form(Prompt) ->
scan_erl_form([IoDevice,] Prompt, StartLine) -> Result

Types:
- IoDevice = io_device()
- Prompt = atom() | string()
- StartLine = int()
- Result = (ok, Tokens, EndLine) | {eof, EndLine} | {error, ErrorInfo, EndLine}
- Tokens - see erl_scan(3)
EndLine = int()
ErrorInfo – see section Error Information below

Reads data from the standard input (IoDevice), prompting it with Prompt. Starts reading at line number StartLine (1). The data is tokenized as if it were an Erlang form - one of the valid Erlang expressions in an Erlang source file - until a final '.' is reached. This last token is also returned. The return values are the same as for scan_erl_exprs/1,2,3 above.

```
paste
parse_erl_exprs(Prompt) ->
paste
parse_erl_exprs([IoDevice,] Prompt, StartLine) -> Result

Types:
- IoDevice = io_device()
- Prompt = atom() | string()
- StartLine = int()
- Result = {ok, Expr_list, EndLine} | {eof, EndLine} | {error, ErrorInfo, EndLine}
- Expr_list – see erl_parse(3)
- EndLine = int()
- ErrorInfo – see section Error Information below

Reads data from the standard input (IoDevice), prompting it with Prompt. Starts reading at line number StartLine (1). The data is tokenized and parsed as if it were a sequence of Erlang expressions until a final '.' is reached. It returns:

- {ok, Expr_list, EndLine} The parsing was successful.
- {eof, EndLine} End of file was encountered.
- {error, ErrorInfo, EndLine} An error occurred.

Example:
```
25> io:parse_erl_exprs('enter>').
enter> abc(), "hey".
{ok, [{call, 1, {atom, 1, abc}, []}, {string, 1, "hey"}], 2}
26> io:parse_erl_exprs ('enter>').
enter> abc("hey").
{error, [{1, erl_parse, ["syntax error before: ", ["\.", "]"]}], 2}
```

```
paste
parse_erl_form(Prompt) ->
paste
parse_erl_form([IoDevice,] Prompt, StartLine) -> Result

Types:
- IoDevice = io_device()
- Prompt = atom() | string()
- StartLine = int()
- Result = {ok, AbsForm, EndLine} | {eof, EndLine} | {error, ErrorInfo, EndLine}
- AbsForm – see erl_parse(3)
- EndLine = int()
- ErrorInfo – see section Error Information below
Reads data from the standard input (IoDevice), prompting it with Prompt. Starts reading at line number StartLine (1). The data is tokenized and parsed as if it were an Erlang form - one of the valid Erlang expressions in an Erlang source file - until a final '.' is reached. It returns:

- {ok, AbsForm, EndLine} The parsing was successful.
- {eof, EndLine} End of file was encountered.
- {error, ErrorInfo, EndLine} An error occurred.

**Standard Input/Output**

All Erlang processes have a default standard IO device. This device is used when no IoDevice argument is specified in the above function calls. However, it is sometimes desirable to use an explicit IoDevice argument which refers to the default IO device. This is the case with functions that can access either a file or the default IO device. The atom standard_io has this special meaning. The following example illustrates this:

```
27> io:read('enter>').'.
   enter>foo.
   {ok,foo}
28> io:read(standard_io, 'enter>').'.
   enter>bar.
   {ok,bar}
```

There is always a process registered under the name of user. This can be used for sending output to the user.

**Error Information**

The ErrorInfo mentioned above is the standard ErrorInfo structure which is returned from all IO modules. It has the format:

```
{ErrorLine, Module, ErrorDescriptor}
```

A string which describes the error is obtained with the following call:

```
apply(Module, format_error, ErrorDescriptor)
```
io_lib

Erlang Module

This module contains functions for converting to and from strings (lists of characters). They are used for implementing the functions in the io module. There is no guarantee that the character lists returned from some of the functions are flat, they can be deep lists. lists:flatten/1 can be used for flattening deep lists.

DATA TYPES

chars() = [char() | chars()]

Exports

nl() -> chars()

Returns a character list which represents a new line character.

write(Term) ->
write(Term, Depth) -> chars()

Types:

• Term = term()
• Depth = int()

Returns a character list which represents Term. The Depth (-1) argument controls the depth of the structures written. When the specified depth is reached, everything below this level is replaced by “...”. For example:

1> lists:flatten(io_lib:write([1, [2], [3], [4, 5], 6, 7, 8, 9])).
"[1, [2], [3], [4, 5], 6, 7, 8, 9]"
2> lists:flatten(io_lib:write([1, [2], [3], [4, 5], 6, 7, 8, 9], 5)).
"[1, [2], [3], [...] | ...]"

print(Term) ->
print(Term, Column, LineLength, Depth) -> chars()

Types:

• Term = term()
• Column = LineLength = Depth = int()
Also returns a list of characters which represents Term, but breaks representations which are longer than one line into many lines and indents each line sensibly. It also tries to detect and output lists of printable characters as strings. Column is the starting column (1), LineLength the maximum line length (80), and Depth (-1) the maximum print depth.

fwrite(Format, Data) ->
format(Format, Data) -> chars()

Types:
- Format = string()
- Data = [term()]

Returns a character list which represents Data formatted in accordance with Format. See io:fwrite/1,2,3 [page 200] for a detailed description of the available formatting options. A fault is generated if there is an error in the format string or argument list.

fread(Format, String) -> Result

Types:
- Format = String = string()
- Result = [ok, InputList, LeftOverChars] | [more, RestFormat, Nchars, InputStack] | [error, What]
- InputList = chars()
- LeftOverChars = string()
- RestFormat = string()
- Nchars = int()
- InputStack = chars()
- What = term()

Tries to read String in accordance with the control sequences in Format. See io:fread/3 [page 204] for a detailed description of the available formatting options. It is assumed that String contains whole lines. It returns:

{ok, InputList, LeftOverChars} The string was read. InputList is the list of successfully matched and read items, and LeftOverChars are the input characters not used.

{more, RestFormat, Nchars, InputStack} The string was read, but more input is needed in order to complete the original format string. RestFormat is the remaining format string, Nchars the number of characters scanned, and InputStack is the reversed list of inputs matched up to that point.

{error, What} The read operation failed and the parameter What gives a hint about the error.

Example:

3> io_lib:fread("~f~f~f", "15.6 17.3e-6 24.5").
{ok,[15.6000,1.73000e-5,24.5000],[]}

fread(Continuation, String, Format) -> Return

Types:
Continuation = see below
String = Format = string()
Return = \{done, Result, LeftOverChars\} \| \{more, Continuation\}
Result = \{ok, InputList\} \| eof \| \{error, What\}
InputList = chars()
What = term()()
LeftOverChars = string()

This is the re-entrant formatted reader. The continuation of the first call to the
functions must be \[]. Refer to Armstrong, Virding, Williams, 'Concurrent
Programming in Erlang', Chapter 13 for a complete description of how the re-entrant
input scheme works.
The function returns:

\{done, Result, LeftOverChars\} The input is complete. The result is one of the
following:
\{ok, InputList\} The string was read. InputList is the list of successfully
matched and read items, and LeftOverChars are the remaining characters.
eof End of file has been encountered. LeftOverChars are the input characters not
used.
\{error, What\} An error occurred and the parameter What gives a hint about the
error.
\{more, Continuation\} More data is required to build a term. Continuation must be
passed to fread/3, when more data becomes available.

write_atom(Atom) -> chars()
Types:
\* Atom = atom()
Returns the list of characters needed to print the atom Atom.

write_string(String) -> chars()
Types:
\* String = string()
Returns the list of characters needed to print String as a string.

write_char(Integer) -> chars()
Types:
\* Integer = int()
Returns the list of characters needed to print a character constant.

indentation(String, StartIndent) -> int()
Types:
\* String = string()
\* StartIndent = int()
Returns the indentation if String has been printed, starting at StartIndent.

\[
\text{char\_list}(\text{Term}) \rightarrow \text{bool()}
\]

Types:
- Term = term()

Returns true if Term is a flat list of characters, otherwise it returns false.

\[
\text{deep\_char\_list}(\text{Term}) \rightarrow \text{bool()}
\]

Types:
- Term = term()

Returns true if Term is a, possibly deep, list of characters, otherwise it returns false.

\[
\text{printable\_list}(\text{Term}) \rightarrow \text{bool()}
\]

Types:
- Term = term()

Returns true if Term is a flat list of printable characters, otherwise it returns false.
lib
---
Erlang Module

**Warning:**
This module is retained for compatibility. It may disappear without warning in a future release.

## Exports

**flush_receive()** -> void()
Flushes the message buffer of the current process.

**error_message(Format, Args)** -> ok
Types:
- **Format** = string()
- **Args** = [term()]
Prints error message Args in accordance with Format. Similar to io:format/2, see io(3) [page 200].

**proname()** -> atom()
Returns the name of the script that started the current Erlang session.

**nonl(String1)** -> String2
Types:
- **String1** = **String2** = string()
Removes the last newline character, if any, in String1.

**send(To, Msg)**
Types:
- **To** = pid() | Name | {Name,Node}
- **Name** = **Node** = atom()
- **Msg** = term()
This function to makes it possible to send a message using the apply/3 BIF.
sendw(To, Msg)

Types:
- To = pid() | Name | {Name, Node}
- Name = Node = atom()
- Msg = term()

As send/2, but waits for an answer. It is implemented as follows:

```
sendw(To, Msg) ->
    To ! {self(), Msg},
    receive
    Reply -> Reply
    end.
```

The message returned is not necessarily a reply to the message sent.
lists

Erlang Module

This module contains functions for list processing. The functions are organized in two groups: those in the first group perform a particular operation on one or more lists, whereas those in the second group are higher-order functions, using a fun as argument to perform an operation on one list.

Unless otherwise stated, all functions assume that position numbering starts at 1. That is, the first element of a list is at position 1.

Exports

append(ListOfLists) -> List1
Types:
- ListOfLists = [List]
  - List = List1 = [term()]

Returns a list in which all the sub-lists of ListOfLists have been appended. For example:

```
> lists:append([[1, 2, 3], [a, b], [4, 5, 6]]).
[1,2,3,a,b,4,5,6]
```

append(List1, List2) -> List3
Types:
- List1 = List2 = List3 = [term()]

Returns a new list List3 which is made from the elements of List1 followed by the elements of List2. For example:

```
> lists:append("abc", "def").
"abcdef"
```

lists:append(A, B) is equivalent to A ++ B.

concat(Things) -> string()
Types:
- Things = [Thing]
  - Thing = atom() | integer() | float() | string()
Concatenates the text representation of the elements of Things. The elements of Things can be atoms, integers, floats or strings.

```prolog
> lists:concat([doc, '/',' file, '.' , 3]).
"doc/file.3"
```

delete(Elem, List1) -> List2

Types:
- Elem = term()
- List1 = List2 = [term()]

Returns a copy of List1 where the first occurrence of Elem, if present, is deleted.

duplicate(N, Elem) -> List

Types:
- N = int()
- Elem = term()
- List = [term()]

Returns a list which contains N copies of the term Elem. For example:

```prolog
> lists:duplicate(5, xx).
[xx,xx,xx,xx,xx]
```

flatlength(DeepList) -> int()

Types:
- DeepList = [term() | DeepList]

Equivalent to length(flatten(DeepList)), but more efficient.

flatten(DeepList) -> List

Types:
- DeepList = [term() | DeepList]
- List = [term()]

Returns a flattened version of DeepList.

flatten(DeepList, Tail) -> List

Types:
- DeepList = [term() | DeepList]
- Tail = List = [term()]

Returns a flattened version of DeepList with the tail Tail appended.

keydelete(Key, N, TupleList1) -> TupleList2

Types:
- Key = term()
- N = 1..size(Tuple)
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- TupleList1 = TupleList2 = [Tuple]
- Tuple = tuple()

Returns a copy of TupleList1 where the first occurrence of a tuple whose Nth element is Key is deleted, if present.

keymember(Key, N, TupleList) -> bool()

Types:
- Key = term()
- N = 1..size(Tuple)
- TupleList = [Tuple]
- Tuple = tuple()

Returns true if there is a tuple in TupleList whose Nth element is Key, otherwise false.

keymerge(N, TupleList1, TupleList2) -> TupleList3

Types:
- N = 1..size(Tuple)
- TupleList1 = TupleList2 = TupleList3 = [Tuple]
- Tuple = tuple()

Returns the sorted list formed by merging TupleList1 and TupleList2. The sorting is performed on the Nth element of each tuple. Both TupleList1 and TupleList2 must be key-sorted prior to evaluating this function. When two keys are equal, elements from TupleList1 are picked before elements from TupleList2.

keyreplace(Key, N, TupleList1, NewTuple) -> TupleList2

Types:
- Key = term()
- N = 1..size(Tuple)
- TupleList1 = TupleList2 = [Tuple]
- NewTuple = Tuple = tuple()

Returns a copy of TupleList1, where the first occurrence of a tuple whose Nth element is Key, if present, is replaced with NewTuple.

keysearch(Key, N, TupleList) -> {value, Tuple} | false

Types:
- Key = term()
- N = 1..size(Tuple)
- TupleList = [Tuple]
- Tuple = tuple()

Searches the list of the tuples TupleList for a tuple whose Nth element is Key. Returns {value, Tuple} if such a tuple is found, or false otherwise.

keysort(N, TupleList1) -> TupleList2

Types:
**N** = 1..size(Tuple)

TupleList1 = TupleList2 = [Tuple]

Tuple = tuple()

Returns a list containing the sorted elements of TupleList1. Sorting is performed on the Nth element of the tuples.

last(List) -> Last

Types:
- List = [term()], length(List)>0
- Last = term()

Returns the last element in List.

max(List) -> Max

Types:
- List = [term()], length(List)>0
- Max = term()

Returns the maximum element of List.

member(Elem, List) -> bool()

Types:
- Elem = term()
- List = [term()]

Returns true if Elem is an element of List, otherwise false.

merge(ListOfLists) -> List1

Types:
- ListOfLists = [List]
- List = List1 = [term()]

Returns the sorted list formed by merging all the sub-lists of ListOfLists. All sub-lists must be sorted prior to evaluating this function.

merge(List1, List2) -> List3

Types:
- List1 = List2 = List3 = [term()]

Returns the sorted list formed by merging List1 and List2. Both List1 and List2 must be sorted prior to evaluating this function.

merge(Fun, List1, List2) -> List3

Types:
- Fun = fun(A, B) -> bool()
- List1 = [A]
- List2 = [B]
- List3 = [A | B]
merge3(List1, List2, List3) -> List4
Types:
- List1 = List2 = List3 = List4 = [term()]
Returns the sorted list formed by merging List1, List2 and List3. All of List1, List2 and List3 must be sorted prior to evaluating this function.

min(List) -> Min
Types:
- List = [term()], length(List) > 0
- Min = term()
Returns the minimum element of List.

nth(N, List) -> Elem
Types:
- N = 1..length(List)
- List = [term()]
- Elem = term()
Returns the Nth element of List. For example:

> lists:nth(3, [a, b, c, d, e]).
c

nthtail(N, List1) -> Tail
Types:
- N = 0..length(List1)
- List1 = Tail = [term()]
Returns the Nth tail of List, that is, the sublist of List starting at N+1 and continuing up to the end of the list. For example:

> lists:nthtail(3, [a, b, c, d, e]).
d,e
tl(tl(tl([a, b, c, d, e]))). [d,e]
> lists:nthtail(0, [a, b, c, d, e]). [a,b,c,d,e]
> lists:nthtail(5, [a, b, c, d, e]). []

prefix(List1, List2) -> bool()
reverse(List1) -> List2

Types:
- List1 = List2 = [term()]

Returns true if List1 is a prefix of List2, otherwise false.

reverse(List1, Tail) -> List2

Types:
- List1 = Tail = List2 = [term()]

Returns a list with the top level elements in List1 in reverse order, with the tail Tail appended. For example:

```prolog
> lists:reverse([1, 2, 3, 4], [a, b, c]).
[4, 3, 2, 1, a, b, c]
```

seq(From, To) -> Seq
seq(From, To, Incr) -> Seq

Types:
- From = To = Incr = int()
- Seq = [int()]

Returns a sequence of integers which starts with From and contains the successive results of adding Incr to the previous element, until To has been reached or passed (in the latter case, To is not an element of the sequence). Incr defaults to 1.

Failure: If To<From and Incr is positive, or if To>From and Incr is negative, or if Incr==0 and From/=To.

Examples:

```prolog
> lists:seq(1, 10).
[1, 2, 3, 4, 5, 6, 7, 8, 9, 10]
> lists:seq(1, 20, 3).
[1, 4, 7, 10, 13, 16, 19]
> lists:seq(1, 1, 0).
[1]
```

sort(List1) -> List2

Types:
- List1 = List2 = [term()]

Returns a list containing the sorted elements of List1.

sort(Fun, List1) -> List2

Types:
Fun = fun(Elem1, Elem2) -> bool()
Elem1 = Elem2 = term()
List1 = List2 = [term()]

Returns a list containing the sorted elements of List1, according to the ordering function Fun. Fun(A, B) should return true if A comes before B in the ordering, false otherwise.

split(N, List1) -> {List2, List3}

Types:
- N = 0..length(List1)
- List1 = List2 = List3 = [term()]

Splits List1 into List2 and List3. List2 contains the first N elements and List3 the rest of the elements (the Nth tail).

sublist(List1, Len) -> List2

Types:
- List1 = List2 = [term()]
- Len = int()

Returns the sub-list of List1 starting at position 1 and with (max) Len elements. It is not an error for Len to exceed the length of the list – in that case the whole list is returned.

sublist(List1, Start, Len) -> List2

Types:
- List1 = List2 = [term()]
- Start = 1..(length(List1)+1)
- Len = int()

Returns the sub-list of List1 starting at Start and with (max) Len elements. It is not an error for Start+Len to exceed the length of the list.

> lists:sublist([1,2,3,4], 2, 2).
[2,3]
> lists:sublist([1,2,3,4], 2, 5).
[2,3,4]
> lists:sublist([1,2,3,4], 5, 2).
[]

subtract(List1, List2) -> List3

Types:
- List1 = List2 = List3 = [term()]

Returns a new list List3 which is a copy of List1, subjected to the following procedure: for each element in List2, its first occurrence in List1 is removed. For example:
> lists:subtract("123212", "212").
"312".

lists:subtract(A,B) is equivalent to A -- B.

suffix(List1, List2) -> bool()
Returns true if List1 is a suffix of List2, otherwise false.

sum(List) -> number()
Types: List = [number()]
Returns the sum of the elements in List.

ukeymerge(N, TupleList1, TupleList2) -> TupleList3
Types:
• N = 1..size(Tuple)
• TupleList1 = TupleList2 = TupleList3 = [Tuple]
• Tuple = tuple()
Returns the sorted list formed by merging TupleList1 and TupleList2 while removing consecutive duplicates. The sorting is performed on the Nth element of each tuple. Both TupleList1 and TupleList2 must be key-sorted and contain no duplicates prior to evaluating this function. When two keys are equal, elements from TupleList1 are picked before elements from TupleList2.

ukeysort(N, TupleList1) -> TupleList2
Types:
• N = 1..size(Tuple)
• TupleList1 = TupleList2 = [Tuple]
• Tuple = tuple()
Returns a list containing the sorted elements of TupleList1 with consecutive duplicates removed. Sorting is performed on the Nth element of the tuples.

umerge(ListOfLists) -> List1
Types:
• ListOfLists = [List]
• List = List1 = [term()]
Returns the sorted list formed by merging all the sub-lists of ListOfLists while removing duplicates. All sub-lists must be sorted and contain no duplicates prior to evaluating this function.

umerge(List1, List2) -> List3
Types:
• List1 = List2 = List3 = [term()]
Returns the sorted list formed by merging \texttt{List1} and \texttt{List2} while removing duplicates. Both \texttt{List1} and \texttt{List2} must be sorted and contain no duplicates prior to evaluating this function.

\begin{verbatim}
\textbf{umerge}([\texttt{Fun}, \texttt{List1}, \texttt{List2}]) -> \texttt{List3} \\
\end{verbatim}

Types:
- \texttt{Fun} = fun\((A, B)\) -> bool()
- \texttt{List1} =\([A]\)
- \texttt{List2} =\([B]\)
- \texttt{List3} =\([A \mid B]\)
- \texttt{A} = \texttt{B} = term()

Returns the sorted list formed by merging \texttt{List1} and \texttt{List2} while removing consecutive duplicates. Both \texttt{List1} and \texttt{List2} must be sorted according to the ordering function \texttt{Fun} and contain no duplicates prior to evaluating this function. \texttt{Fun}(A, B) should return \texttt{true} if \texttt{A} equals or comes before \texttt{B} in the ordering, \texttt{false} otherwise.

\begin{verbatim}
\textbf{umerge3}([\texttt{List1}, \texttt{List2}, \texttt{List3}]) -> \texttt{List4} \\
\end{verbatim}

Types:
- \texttt{List1} = \texttt{List2} = \texttt{List3} = \texttt{List4} = \{term()\}

Returns the sorted list formed by merging \texttt{List1}, \texttt{List2} and \texttt{List3} while removing duplicates. All of \texttt{List1}, \texttt{List2} and \texttt{List3} must be sorted and contain no duplicates prior to evaluating this function.

\begin{verbatim}
\textbf{unzip}([\texttt{List1}]) -> \{[\texttt{List2}, \texttt{List3}]\} \\
\end{verbatim}

Types:
- \texttt{List1} =\([\{X, Y\}]\)
- \texttt{List2} =\([X]\)
- \texttt{List3} =\([Y]\)
- \texttt{X} = \texttt{Y} = term()

"Unzips" a list of two-tuples into two lists, where the first list contains the first element of each tuple, and the second list contains the second element of each tuple.

\begin{verbatim}
\textbf{unzip3}([\texttt{List1}]) -> \{[\texttt{List2}, \texttt{List3}, \texttt{List4}]\} \\
\end{verbatim}

Types:
- \texttt{List1} =\([\{X, Y, Z\}]\)
- \texttt{List2} =\([X]\)
- \texttt{List3} =\([Y]\)
- \texttt{List4} =\([Z]\)
- \texttt{X} = \texttt{Y} = \texttt{Z} = term()

"Unzips" a list of three-tuples into three lists, where the first list contains the first element of each tuple, the second list contains the second element of each tuple, and the third list contains the third element of each tuple.

\begin{verbatim}
\textbf{usort}([\texttt{List1}]) -> \texttt{List2} \\
\end{verbatim}

Types:
- List1 = List2 = [term()]

Returns a list containing the sorted elements of List1 without duplicates.

usort(Fun, List1) -> List2

Types:
- Fun = fun(Elem1, Elem2) -> bool()
- Elem1 = Elem2 = term()
- List1 = List2 = [term()]

Returns a list containing the sorted elements of List1 with consecutive duplicates removed, according to the ordering function Fun. Fun(A, B) should return true if A equals or comes before B in the ordering, false otherwise.

zip(List1, List2) -> List3

Types:
- List1 = [X]
- List2 = [Y]
- List3 = [{X, Y}]
- X = Y = term()

“Zips” two lists of equal length into one list of two-tuples, where the first element of each tuple is taken from the first list and the second element is taken from corresponding element in the second list.

zip3(List1, List2, List3) -> List4

Types:
- List1 = [X]
- List2 = [Y]
- List3 = [Z]
- List3 = [{X, Y, Z}]
- X = Y = Z = term()

“Zips” three lists of equal length into one list of three-tuples, where the first element of each tuple is taken from the first list, the second element is taken from corresponding element in the second list, and the third element is taken from the corresponding element in the third list.

zipwith(Combine, List1, List2) -> List3

Types:
- Combine = fun(X, Y) -> T
- List1 = [X]
- List2 = [Y]
- List3 = [T]
- X = Y = T = term()
Combine the elements of two lists of equal length into one list. For each pair \( X, Y \) of list elements from the two lists, the element in the result list will be \( \text{Combine}(X, Y) \).

\[
\text{zipwith} \left( \text{fun}(X, Y) \rightarrow \{X, Y\} \text{ end}, \text{List1}, \text{List2} \right)
\]

is equivalent to \( \text{zip} \left( \text{List1}, \text{List2} \right) \).

Examples:
\[
> \text{lists:zipwith} \left( \text{fun}(X, Y) \rightarrow X+Y \text{ end}, [1,2,3], [4,5,6] \right).
[5,7,9]
\]

\[
\text{zipwith3} \left( \text{Combine}, \text{List1}, \text{List2}, \text{List3} \right) \rightarrow \text{List4}
\]

Types:
- \( \text{Combine} = \text{fun}(X, Y, Z) \rightarrow T \)
- \( \text{List1} = \{X\} \)
- \( \text{List2} = \{Y\} \)
- \( \text{List3} = \{Z\} \)
- \( \text{List4} = \{T\} \)
- \( X = Y = Z = T = \text{term()} \)

Combine the elements of three lists of equal length into one list. For each triple \( X, Y, Z \) of list elements from the three lists, the element in the result list will be \( \text{Combine}(X, Y, Z) \).

\[
\text{zipwith3} \left( \text{fun}(X, Y, Z) \rightarrow \{X,Y,Z\} \text{ end}, \text{List1}, \text{List2}, \text{List3} \right)
\]

is equivalent to \( \text{zip3} \left( \text{List1}, \text{List2}, \text{List3} \right) \).

Examples:
\[
> \text{lists:zipwith3} \left( \text{fun}(X, Y, Z) \rightarrow X+Y+Z \text{ end}, [1,2,3], [4,5,6], [7,8,9] \right).
[12,15,18]
\]
\[
> \text{lists:zipwith3} \left( \text{fun}(X, Y, Z) \rightarrow \{X,Y,Z\} \text{ end}, [a,b,c], [x,y,z], [1,2,3] \right).
[[a,x,1],[b,y,2],[c,z,3]]
\]

\[
\text{all} \left( \text{Pred}, \text{List} \right) \rightarrow \text{bool()}
\]

Types:
- \( \text{Pred} = \text{fun}(\text{Elem}) \rightarrow \text{bool()} \)
- \( \text{Elem} = \text{term()} \)
- \( \text{List} = \{\text{term()}\} \)

Returns \text{true} if \( \text{Pred}(\text{Elem}) \) returns \text{true} for all elements \( \text{Elem} \) in \( \text{List} \), otherwise \text{false}.

\[
\text{any} \left( \text{Pred}, \text{List} \right) \rightarrow \text{bool()}
\]

Types:
- \( \text{Pred} = \text{fun}(\text{Elem}) \rightarrow \text{bool()} \)
- \( \text{Elem} = \text{term()} \)
- \( \text{List} = \{\text{term()}\} \)

Returns \text{true} if \( \text{Pred}(\text{Elem}) \) returns \text{true} for at least one element \( \text{Elem} \) in \( \text{List} \).
dropwhile(Pred, List1) -> List2

Types:
- Pred = fun(Elem) -> bool()
- Elem = term()
- List1 = List2 = [term()]

Drops elements Elem from List1 while Pred(Elem) returns true and returns the remaining list.

filter(Pred, List1) -> List2

Types:
- Pred = fun(Elem) -> bool()
- Elem = term()
- List1 = List2 = [term()]

List2 is a list of all elements Elem in List1 for which Pred(Elem) returns true.

flatmap(Fun, List1) -> List2

Types:
- Fun = fun(A) -> [B]
- List1 = [A]
- List2 = [B]
- A = B = term()

Takes a function from As to lists of Bs, and a list of As (List1) and produces a list of Bs by applying the function to every element in List1 and appending the resulting lists. That is, flatmap behaves as if it had been defined as follows:

\[
\text{flatmap}(\text{Fun}, \text{List1}) \rightarrow \text{append}(\text{map}(\text{Fun}, \text{List1}))
\]

Example:

\[
> \text{lists:flatmap(fun(X) - } \rightarrow [X,X] \text{ end, [a,b,c])}.
\]

\[ [a,a,b,b,c,c] \]

foldl(Fun, Acc0, List) -> Acc1

Types:
- Fun = fun(Elem, AccIn) -> AccOut
- Elem = term()
- Acc0 = Acc1 = AccIn = AccOut = term()
- List = [term()]

Calls Fun(Elem, AccIn) on successive elements A of List, starting with AccIn == Acc0. Fun/2 must return a new accumulator which is passed to the next call. The function returns the final value of the accumulator. Acc0 is returned if the list is empty. For example:
foldl(Fun, Acc0, List) -> Acc1

Types:
- Fun = fun(Elem, AccIn) -> AccOut
- Elem = term()
- Acc0 = Acc1 = AccIn = AccOut = term()
- List = [term()]

Like foldl/3, but the list is traversed from right to left. For example:

```erlang
> P = fun(A, AccIn) -> io:format("-p ", [A]), AccIn end.
#Fun<erl_eval.12.2225172>
> lists:foldl(P, void, [1,2,3]).
1 2 3 void
> lists:foldr(P, void, [1,2,3]).
3 2 1 void
```

foldl/3 is tail recursive and would usually be preferred to foldr/3.

foreach(Fun, List) -> void()

Types:
- Fun = fun(Elem) -> void()
- Elem = term()
- List = [term()]

Calls Fun(Elem) for each element Elem in List. This function is used for its side effects and the evaluation order is defined to be the same as the order of the elements in the list.

keymap(Fun, N, TupleList1) -> TupleList2

Types:
- Fun = fun(Term1) -> Term2
- Term1 = Term2 = term()
- N = 1..size(Tuple)
- TupleList1 = TupleList2 = [tuple()]

Returns a list of tuples where, for each tuple in TupleList1, the Nth element Term1 of the tuple has been replaced with the result of calling Fun(Term1).

Examples:

```erlang
> Fun = fun(Atom) -> atom_to_list(Atom) end.
#Fun<erl_eval.6.10732646>
> lists:keymap(Fun, 2, [{name, jane, 22}, {name, lizzie, 20}, {name, lydia, 15}]).
[{name,"jane",22},{name,"lizzie",20},{name,"lydia",15}]
```
map(Fun, List1) -> List2

Types:
- Fun = fun(A) -> B
- List1 = [A]
- List2 = [B]
- A = B = term()

Takes a function from As to Bs, and a list of As and produces a list of Bs by applying the function to every element in the list. This function is used to obtain the return values. The evaluation order is implementation dependent.

mapfoldl(Fun, Acc0, List1) -> {List2, Acc1}

Types:
- Fun = fun(A, AccIn) -> {B, AccOut}
- Acc0 = Acc1 = AccIn = AccOut = term()
- List1 = [A]
- List2 = [B]
- A = B = term()

mapfold combines the operations of map/2 and foldl/3 into one pass. An example, summing the elements in a list and double them at the same time:

> lists:mapfoldl(fun(X, Sum) -> {2*X, X+Sum} end, 0, [1,2,3,4,5]).
{[2,4,6,8,10],15}

mapfoldr(Fun, Acc0, List1) -> {List2, Acc1}

Types:
- Fun = fun(A, AccIn) -> {B, AccOut}
- Acc0 = Acc1 = AccIn = AccOut = term()
- List1 = [A]
- List2 = [B]
- A = B = term()

mapfold combines the operations of map/2 and foldr/3 into one pass.

partition(Pred, List) -> {Satisfying, NonSatisfying}

Types:
- Pred = fun(Elem) -> bool()
- Elem = term()
- List = Satisfying = NonSatisfying = [term()]

Partitions List into two lists, where the first list contains all elements for which Pred(Elem) returns true, and the second list contains all elements for which Pred(Elem) returns false.

Examples:
lists:partition(fun(A) -\ A \text{ rem } 2 == 1 \end, \ [1,2,3,4,5,6,7])
\{(1,3,5,7), [2,4,6]\}

> lists:partition(fun(A) -\ \text{is} \textunderscore \text{atom}(A) \end, \ [a,b,1,c,d,2,3,4,e])
\{(a,b,c,d,e), [1,2,3,4]\}

See also \texttt{splitwith/2} for a different way to partition a list.

\begin{verbatim}
splitwith(Pred, List) -> \{List1, List2\}

Types:
- Pred = fun(Elem) -> bool()
- Elem = term()
- List = List1 = List2 = [term()]

Partitions \texttt{List} into two lists according to \texttt{Pred}. \texttt{splitwith/2} behaves as if it is defined as follows:

splitwidth(Pred, List) ->
  \{\texttt{takewhile(Pred, List)}, \texttt{dropwhile(Pred, List)}\}.

Examples:
> lists:splitwith(fun(A) -\ A \text{ rem } 2 == 1 \end, \ [1,2,3,4,5,6,7])
\{[1], [2,3,4,5,6,7]\}

> lists:splitwith(fun(A) -\ \text{is} \textunderscore \text{atom}(A) \end, \ [a,b,1,c,d,2,3,4,e])
\{(a,b), [1,c,d,2,3,4,e]\}
\end{verbatim}

See also \texttt{partition/2} for a different way to partition a list.

\begin{verbatim}
takewhile(Pred, List1) -> List2

Types:
- Pred = fun(Elem) -> bool()
- Elem = term()
- List1 = List2 = [term()]

Takes elements \texttt{Elem} from \texttt{List1} while \texttt{Pred(Elem)} returns \texttt{true}, that is, the function returns the longest prefix of the list for which all elements satisfy the predicate.
\end{verbatim}
The `log-mf-h` is a gen_event handler module which can be installed in any gen_event process. It logs onto disk all events which are sent to an event manager. Each event is written as a binary which makes the logging very fast. However, a tool such as the Report Browser (rb) must be used in order to read the files. The events are written to multiple files. When all files have been used, the first one is re-used and overwritten. The directory location, the number of files, and the size of each file are configurable. The directory will include one file called `index`, and report files 1, 2, ... .

Exports

```
init(Dir, MaxBytes, MaxFiles)
init(Dir, MaxBytes, MaxFiles, Pred) -> Args
```

Types:
- ` Dir = string()`
- ` MaxBytes = integer()`
- ` MaxFiles = 0 < integer() < 256`
- ` Pred = fun(Event) -> boolean()`
- ` Event = term()`
- ` Args = args()`

Initiates the event handler. This function returns `Args`, which should be used in a call to `gen_event:add_handler(EventMgr, log-mf-h, Args)`.

`Dir` specifies which directory to use for the log files. `MaxBytes` specifies the size of each individual file. `MaxFiles` specifies how many files are used. `Pred` is a predicate function used to filter the events. If no predicate function is specified, all events are logged.

See Also

```
gen_event(3) [page 168], rb(3)
```
**math**

Erlang Module

This module provides an interface to a number of mathematical functions.

**Note:**
Not all functions are implemented on all platforms. In particular, the `erf/1` and `erfc/1` functions are not implemented on Windows.

**Exports**

```
pi() -> float()

A useful number.
```

```
sin(X)
cos(X)
tan(X)
asin(X)
acos(X)
atan(X)
atan2(Y, X)
sinh(X)
cosh(X)
tanh(X)
asinh(X)
acosh(X)
atanh(X)
exp(X)
log(X)
log10(X)
pow(X, Y)
sqrt(X)
```

**Types:**
- `X = Y = number()

A collection of math functions which return floats. Arguments are numbers.
erf(X) -> float()

Types:
- X = number()

Returns the error function of X, where

\[ \text{erf}(X) = \frac{2}{\sqrt{\pi}} \int_0^X \exp(-t^2) dt \]

erfc(X) -> float()

Types:
- X = number()

erfc(X) returns 1.0 - erf(X), computed by methods that avoid cancellation for large X.

Bugs

As these are the C library, the bugs are the same.
This module implements the parse_transform that makes calls to ets and dbg:fun2ms/1 translate into literal match specifications. It also implements the back end for the same functions when called from the Erlang shell.

The translations from fun's to match_specs is accessed through the two "pseudo functions" ets:fun2ms/1 and dbg:fun2ms/1.

Actually this introduction is more or less an introduction to the whole concept of match specifications. Since everyone trying to use ets:select or dbg seems to end up reading this page, it seems in good place to explain a little more than just what this module does.

There are some caveats one should be aware of, please read through the whole manual page if it's the first time you're using the transformations.

Match specifications are used more or less as filters. They resemble usual Erlang matching in a list comprehension or in a fun used in conjunction with lists:foldl etc.

The syntax of pure match specifications is somewhat awkward though, as they are made up purely by Erlang terms and there is no syntax in the language to make the match specifications more readable.

As the match specifications execution and structure is quite like that of a fun, it would for most programmers be more straightforward to simply write it using the familiar fun syntax and having that translated into a match specification automatically. Of course a real fun is more powerful than the match specifications allow, but bearing the match specifications in mind, and what they can do, it's still more convenient to write it all as a fun. This module contains the code that simply translates the fun syntax into match_spec terms.

Let's start with an ets example. Using ets:select and a match specification, one can filter out rows of a table and construct a list of tuples containing relevant parts of the data in these rows. Of course one could use ets:foldl instead, but the select call is far more efficient. Without the translation, one has to struggle with writing match specifications terms to accommodate this, or one has to resort to the less powerful ets:match(object) calls, or simply give up and use the more inefficient method of ets:foldl. Using the ets:fun2ms transformation, a ets:select call is at least as easy to write as any of the alternatives.

As an example, consider a simple table of employees:

```erlang
-record(emp, {empno, %Employee number as a string, the key
     surname, %Surname of the employee
givenname, %Given name of employee
dept, %Department one of {dev,sales,prod,adm}
     empyear}). %Year the employee was employed
```

We create the table using:

```erlang
ets:new(emp_tab, [{keypos, #emp.empno}, named_table, ordered_set]).
```
Let's also fill it with some randomly chosen data for the examples:

```
[{emp,"011103","Black","Alfred",sales,2000},
 {emp,"041231","Doe","John",prod,2001},
 {emp,"052341","Smith","John",dev,1997},
 {emp,"076324","Smith","Ella",sales,1995},
 {emp,"122334","Weston","Anna",prod,2002},
 {emp,"535216","Chalker","Samuel",adm,1998},
 {emp,"789789","Harrysson","Joe",adm,1996},
 {emp,"963721","Scott","Juliana",dev,2003},
 {emp,"989891","Brown","Gabriel",prod,1999}]
```

Now, the amount of data in the table is of course too small to justify complicated ets searches, but on real tables, using select to get exactly the data you want will increase efficiency remarkably.

Let's say for example that we'd want the employee numbers of everyone in the sales department. One might use ets:match in such a situation:

```
1> ets:match(emp_tab, {'_', '$1', '_', '_', sales, '_'}).%OK
[["011103"],["076324"]]
```

Even though ets:match does not require a full match specification, but a simpler type, it's still somewhat unreadable, and one has little control over the returned result, it's always a list of lists. OK, one might use ets:foldl or ets:foldr instead:

```
ets:foldr(fun(#emp{empno = E, dept = sales},Acc) -> [E | Acc];
         (_,Acc) -> Acc
diff,
         [],
         emp_tab).%OK
```

Running that would result in ["011103", "076324"], which at least gets rid of the extra lists. The fun is also quite straightforward, so the only problem is that all the data from the table has to be transferred from the table to the calling process for filtering. That's inefficient compared to the ets:match call where the filtering can be done "inside" the emulator and only the result is transferred to the process. Remember that ets tables are all about efficiency, if it wasn't for efficiency all of ets could be implemented in Erlang, as a process receiving requests and sending answers back. One uses ets because one wants performance, and therefore one wouldn't want all of the table transferred to the process for filtering. OK, let's look at a pure ets:select call that does what the ets:foldr does:

```
ets:select(emp_tab, [{#emp{empno = '$1', dept = sales, _='_'},[],['$1']}]).
```

Even though the record syntax is used, it's still somewhat hard to read and even harder to write. The first element of the tuple, #emp{empno = '$1', dept = sales, _='_'}, tells what to match, elements not matching this will not be returned at all, as in the ets:match example. The second element, the empty list is a list of guard expressions, which we need none, and the third element is the list of expressions constructing the return value (in ets this almost always is a list containing one single term). In our case '$1' is bound to the employee number in the head (first element of tuple), and hence it is the employee number that is returned. The result is ["011103", "076324"], just as in the ets:foldr example, but the result is retrieved much more efficiently in terms of execution speed and memory consumption.

We have one efficient but hardly readable way of doing it and one inefficient but fairly readable (at least to the skilled Erlang programmer) way of doing it. With the use of
ets:fun2ms, one could have something that is as efficient as possible but still is written as a filter using the fun syntax:

-include_lib("stdlib/include/ms_transform.hrl").

% ...  

ets:select(emp_tab, ets:fun2ms(
    fun(#emp{empno = E, dept = sales}) ->
    E
    end)).

This may not be the shortest of the expressions, but it requires no special knowledge of match specifications to read. The fun's head should simply match what you want to filter out and the body returns what you want returned. As long as the fun can be kept within the limits of the match specifications, there is no need to transfer all data of the table to the process for filtering as in the ets:foldr example. In fact it's even easier to read then the ets:foldr example, as the select call in itself discards anything that doesn't match, while the fun of the foldr call needs to handle both the elements matching and the ones not matching.

It's worth noting in the above ets:fun2ms example that one needs to include ms_transform.hrl in the source code, as this is what triggers the parse transformation of the ets:fun2ms call to a valid match specification. This also implies that the transformation is done at compile time (except when called from the shell of course) and therefore will take no resources at all in runtime. So although you use the more intuitive fun syntax, it gets as efficient in runtime as writing match specifications by hand.

Let's look at some more ets examples. Let's say one wants to get all the employee numbers of any employee hired before the year 2000. Using ets:match isn't an alternative here as relational operators cannot be expressed there. Once again, an ets:foldr could do it (slowly, but correct):

ets:foldr(fun(#emp{empno = E, empyear = Y},Acc) when Y < 2000 -> [E | Acc];
    (_,Acc) -> Acc
    end,
    [],
    emp_tab).

The result will be ["052341", "076324", "535216", "789789", "989891"], as expected. Now the equivalent expression using a handwritten match specification would look something like this:

ets:select(emp_tab,[
    #emp{empno = '$1', empyear = '$2', _='_'},
    [{'<', '$2', 2000}],
    ['$1']])

This gives the same result, the [{'<', '$2', 2000}] is in the guard part and therefore discards anything that does not have a empyear (bound to '$2' in the head) less than 2000, just as the guard in the foldl example. Let's jump on to writing it using ets:fun2ms
-include_lib("stdlib/include/ms_transform.hrl").

% ...

ets:select(emp_tab, ets:fun2ms(
    fun(#emp{empno = E, empyear = Y}) when Y < 2000 ->
    E
    end)).

Obviously readability is gained by using the parse transformation.

I'll show some more examples without the tiresome comparing-to-alternatives stuff.
Let's say we'd want the whole object matching instead of only one element. We could of course assign a variable to every part of the record and build it up once again in the body of the fun, but it's easier to do like this:

```erlang
ets:select(emp_tab, ets:fun2ms(
    fun(Obj = #emp{empno = E, empyear = Y})
    when Y < 2000 ->
    Obj
    end)).
```

Just as in ordinary Erlang matching, you can bind a variable to the whole matched object using a “match in then match”, i.e. a =. Unfortunately this is not general in fun’s translated to match specifications, only on the “top level”, i.e. matching the whole object arriving to be matched into a separate variable, is it allowed. For the one's used to writing match specifications by hand, I'll have to mention that the variable A will simply be translated into '$'. It's not general, but it has very common usage, why it is handled as a special, but useful, case. If this bothers you, the pseudo function object also returns the whole matched object, see the part about caveats and limitations below.

Let's do something in the fun's body too: Let's say that someone realizes that there are a few people having an employee number beginning with a zero (0), which shouldn't be allowed. All those should have their numbers changed to begin with a one (1) instead and one wants the list [['Old empno', 'New empno']] created:

```erlang
ets:select(emp_tab, ets:fun2ms(
    fun(#emp{empno = [$0 | Rest]}) ->
    {[$0|Rest],[$1|Rest]}
    end)).
```

As a matter of fact, this query hits the feature of partially bound keys in the table type ordered_set, so that not the whole table need be searched, only the part of the table containing keys beginning with 0 is in fact looked into.

The fun of course can have several clauses, so that if one could do the following: For each employee, if he or she is hired prior to 1997, return the tuple {inventory, <employee number>}, for each hired 1997 or later, but before 2001, return {rookie, <employee number>}, for all others return {newbie, <employee number>}. All except for the ones named Smith as they would be affronted by anything other than the tag guru and that is also what's returned for their numbers {guru, <employee number>}:

```erlang
ets:select(emp_tab, ets:fun2ms(
    fun(#emp{empno = E, surname = "Smith"}) ->
    {guru,E};
    (#emp{empno = E, empyear = Y}) when Y < 1997 ->
    {inventory, E};
    ... end).
```

The result will be:

```erlang
[{rookie, "011103"},
 {rookie, "041231"},
 {guru, "052341"},
 {guru, "076324"},
 {newbie, "122334"},
 {rookie, "535216"},
 {inventory, "789789"},
 {newbie, "963721"},
 {rookie, "989891"}]
```

and so the Smith's will be happy...

So, what more can you do? Well, the simple answer would be; look in the documentation of match specifications in ERTS users guide. However let's briefly go through the most useful "built in functions" that you can use when the fun is to be translated into a match specification by ets:fun2ms (it's worth mentioning, although it might be obvious to some, that calling other functions than the one's allowed in match specifications cannot be done. No "usual" Erlang code can be executed by the fun being translated by fun2ms, the fun is after all limited exactly to the power of the match specifications, which is unfortunate, but the price one has to pay for the execution speed of an ets:select compared to ets:foldl/foldr).

The head of the fun is obviously a head matching (or mismatching) one parameter, one object of the table we select from. The object is always a single variable (can be _ or a tuple, as that's what's in ets, dets and mnesia tables (the match specification returned by ets:fun2ms can of course be used with dets:select and mnesia:select as well as with ets:select). The use of _ in the head is allowed (and encouraged) on the top level.

The guard section can contain any guard expression of Erlang. Even the "old" type test are allowed on the toplevel of the guard (integer(X) instead of is_integer(X)). As the new type tests (the is_tests) are in practice just guard bif's they can also be called from within the body of the fun, but so they can in ordinary Erlang code. Also arithmetics is allowed, as well as ordinary guard bif's. Here's a list of bif's and expressions:

- The type tests: is_atom, is_constant, is_float, is_integer, is_list, is_number, is_pid, is_port, is_reference, is_tuple, is_binary, is_function, is_record
- The boolean operators: not, and, or, andalso, orelse
- The relational operators: >, >=, <, =<, =:=, ==, /=, /=
- Arithmetics: +, -, *, div, rem
- Bitwise operators: band, bor, bxor, bnot, bsl, bsr
- The guard bif's: abs, element, hd, length, node, round, size, tl, trunc, self
- The obsolete type test (only in guards): atom, constant, float, integer, list, number, pid, port, reference, tuple, binary, function, record
Contrary to the fact with “handwritten” match specifications, the is_record guard works as in ordinary Erlang code.

Semicolons (;) in guards are allowed, the result will be (as expected) one “match_spec-clause” for each semicolon-separated part of the guard. The semantics being identical to the Erlang semantics.

The body of the fun is used to construct the resulting value. When selecting from tables one usually just construct a suitable term here, using ordinary Erlang term construction, like tuple parentheses, list brackets and variables matched out in the head, possibly in conjunction with the occasional constant. Whatever expressions are allowed in guards are also allowed here, but there are no special functions except object and bindings (see further down), which returns the whole matched object and all known variable bindings respectively.

The dbg variants of match specifications have an imperative approach to the match specification body, the ets dialect hasn’t. The fun body for ets:fun2ms returns the result without side effects, and as matching (=) in the body of the match specifications is not allowed (for performance reasons) the only thing left, more or less, is term construction...

Let’s move on to the dbg dialect, the slightly different match specifications translated by dbg:fun2ms.

The same reasons for using the parse transformation applies to dbg, maybe even more so as filtering using Erlang code is simply not a good idea when tracing (except afterwards, if you trace to file). The concept is similar to that of ets:fun2ms except that you usually use it directly from the shell (which can also be done with ets:fun2ms).

Let’s manufacture a toy module to trace on

```erlang
-module(toy).
-export([start/1, store/2, retrieve/1]).
start(Args) ->
  toy_table = ets:new(toy_table,Args).
store(Key, Value) ->
  ets:insert(toy_table,{Key,Value}).
retrieve(Key) ->
  [{Key, Value}] = ets:lookup(toy_table,Key),
  Value.
```

During model testing, the first test bails out with a \{badmatch,16\} in \{toy,start,1\}, why?

We suspect the ets call, as we match hard on the return value, but want only the particular new call with toy_table as first parameter. So we start a default tracer on the node:

```erlang
1> dbg:tracer().
{ok,<0.88.0>}
```

And so we turn on call tracing for all processes, we are going to make a pretty restrictive trace pattern, so there’s no need to call trace only a few processes (it usually isn’t):

```erlang
2> dbg:p(all,call).
{ok,[\{matched,nonode@nohost,25\}]}
It's time to specify the filter. We want to view calls that resemble
\texttt{ets:new(toy_table,\textless\text{something}\rangle)}:

3> \texttt{dbg:tp(ets,new,dbg:fun2ms(fun([toy_table,\_]) -> true end)).}
\{ok,[[matched,nonode@nohost,1]},[saved,1]]\}

As can be seen, the \texttt{fun}'s used with \texttt{dbg:fun2ms} takes a single list as parameter instead
of a single tuple. The list matches a list of the parameters to the traced function. A
single variable may also be used of course. The body of the \texttt{fun} expresses in a more
imperative way actions to be taken if the \texttt{fun} head (and the \texttt{guards}) matches. I return
\texttt{true} here, but it's only because the body of a \texttt{fun} cannot be empty, the return value will
be discarded.

When we run the test of our module now, we get the following trace output:

\texttt{(\langle0.86.0\rangle \text{ call \texttt{ets:new(toy_table,\{ordered_set\})}})}

Let's play we haven't spotted the problem yet, and want to see what \texttt{ets:new} returns.
We do a slightly different trace pattern:

4> \texttt{dbg:tp(ets,new,dbg:fun2ms(fun([toy_table,\_]) -> return\_trace() end)).}

Resulting in the following trace output when we run the test:

\texttt{(\langle0.86.0\rangle \text{ call \texttt{ets:new(toy_table,\{ordered_set\})}})
\langle0.86.0\rangle \text{ returned from \texttt{ets:new/2 \to 24}}}

The call to \texttt{return\_trace}, makes a trace message appear when the function returns. It
applies only to the specific function call triggering the match specification (and
matching the head/guards of the match specification). This is the by far the most
common call in the body of a \texttt{dbg} match specification.

As the test now fails with \{\texttt{badmatch,24}\}, it's obvious that the \texttt{badmatch} is because the
atom \texttt{toy\_table} does not match the number returned for an unnamed table. So we
spotted the problem, the table should be named and the arguments supplied by our test
program does not include \texttt{named\_table}. We rewrite the start function to:

\texttt{start(Args) \rightarrow}
\begin{verbatim}
    toy_table = ets:new(toy_table,\{named_table |Args\}).
\end{verbatim}

And with the same tracing turned on, we get the following trace output:

\texttt{(\langle0.86.0\rangle \text{ call \texttt{ets:new(toy_table,\{named_table,ordered_set\})}})
\langle0.86.0\rangle \text{ returned from \texttt{ets:new/2 \to toy_table}}}

Very well. Let's say the module now passes all testing and goes into the system. After a
while someone realizes that the table \texttt{toy\_table} grows while the system is running and
that for some reason there are a lot of elements with atom's as keys. You had expected
only integer keys and so does the rest of the system. Well, obviously not all of the
system. You turn on call tracing and try to see calls to your module with an atom as the
key:

1> \texttt{dbg:tracer().}
\{ok,\langle0.88.0\rangle\}
2> \texttt{dbg:p(all,call).}
\{ok,[[matched,nonode@nohost,25]]\}
3> \texttt{dbg:tpl(toy,store,dbg:fun2ms(fun([\_],\_) when is\_atom(A) -> true end)).}
\{ok,[[matched,nonode@nohost,1]},[saved,1]]\}
We use `dbg:tpl` here to make sure to catch local calls (let's say the module has grown since the smaller version and we're not sure this inserting of atoms is not done locally...). When in doubt always use local call tracing.

Let's say nothing happens when we trace in this way. Our function is never called with these parameters. We make the conclusion that someone else (some other module) is doing it and we realize that we must trace on `ets:insert` and want to see the calling function. The calling function may be retrieved using the match specification function `caller` and to get it into the trace message, one has to use the match spec function `message`. The filter call looks like this (looking for calls to `ets:insert`):

```
4> dbg:tpl(ets,insert,dbg:fun2ms(fun([toy_table,{A,_}]) when is_atom(A) ->
                                 message(caller())
                             end)).
{ok,{matched,nonode@nohost,1},{saved,2}}
```

The caller will now appear in the “additional message” part of the trace output, and so after a while, the following output comes:

```
(0.86.0) call ets:insert(toy_table,{garbage,can})  (\mod,\fun,2)
```

You have found out that the function `\fun` of the module `\mod`, with arity 2, is the one causing all this trouble.

This was just a toy example, but it illustrated the most used calls in match specifications for `dbg`. The other, more esoterical calls are listed and explained in the Users guide of the ERTS application, they really are beyond the scope of this document.

To end this chatty introduction with something more precise, here follows some parts about caveats and restrictions concerning the fun's used in conjunction with `ets:fun2ms` and `dbg:fun2ms`:

**Warning:**
To use the pseudo functions triggering the translation, one has to include the header file `ms_transform.hrl` in the source code. Failure to do so will possibly result in runtime errors rather than compile time, as the expression may be valid as a plain Erlang program without translation.

**Warning:**
The fun has to be literally constructed inside the parameter list to the pseudo functions. The fun cannot be bound to a variable first and then passed to `ets:fun2ms` or `dbg:fun2ms`, i.e this will work: `ets:fun2ms(fun(A) -> A end)` but not this: `F = fun(A) -> A end, ets:fun2ms(F)`. The later will result in a compile time error if the header is included, otherwise a runtime error. Even if the later construction would ever appear to work, it really doesn't, so don't ever use it.

Several restrictions apply to the fun that is being translated into a match_spec. To put it simple you cannot use anything in the fun that you cannot use in a match_spec. This means that, among others, the following restrictions apply to the fun itself:

- Functions written in Erlang cannot be called, neither local functions, global functions or real fun's
- Everything that is written as a function call will be translated into a match_spec call to a builtin function, so that the call is_list(X) will be translated to
  `{'is_list', '$1'}` (`'$1'` is just an example, the numbering may vary). If one tries to call a function that is not a match_spec builtin, it will cause an error.

- Variables occurring in the head of the fun will be replaced by match_spec variables in the order of occurrence, so that the fragment fun([A,B,C]) will be replaced by `{'$1', '$2', '$3'}` etc. Every occurrence of such a variable later in the match_spec will be replaced by a match_spec variable in the same way, so that the fun fun([A,B]) when is_atom(A) -> B end will be translated into
  `[[{'$1', '$2'}, [{'is_atom', '$1'}], ['$2']]]`.

- Variables that are not appearing in the head are imported from the environment and made into match_spec const expressions. Example from the shell:

  1> X = 25.
  25
  2> ets:fun2ms(fun({A,B}) when A > X -> B end).
  `[[{'$1', '$2'}, [{'>', '$1', {const,25}}], ['$2']]]`

- Matching with = cannot be used in the body. It can only be used on the top level in the head of the fun. Example from the shell again:

  1> ets:fun2ms(fun({A,[B|C]} = D) when A > B -> D end).
  `[[{'$1', '$2', '$3'}, [{'>', '$1', '$2', '$3'}], ['$._']]]`

  2> ets:fun2ms(fun({A,[B|C]=D}) when A > B -> D end).
  Error: fun with head matching ('=' in head) cannot be translated into match_spec
  {error,transform_error}

  3> ets:fun2ms(fun({A,_}) when A > B -> D end).
  Error: fun with body matching ('=' in body) is illegal as match_spec
  {error,transform_error}

  All variables are bound in the head of a match_spec, so the translator cannot allow multiple bindings. The special case when matching is done on the top level makes the variable bind to `$._` in the resulting match_spec, it is to allow a more natural access to the whole matched object. The pseudo function object() could be used instead, see below. The following expressions are translated equally:

  ets:match_object(Table, {'$1',test,'$2'}). ... is the same as...
  ets:select(Table, ets:fun2ms(fun({A,test,B}) -> object() end)).

  (This was just an example, in this simple case the former expression is probably preferable in terms of readability). The ets:select/2 call will conceptually look like this in the resulting code:

  ets:select(Table, `[[{'$1',test,'$2'}, [], ['$._']]]`).

  Matching on the top level of the fun head might feel like a more natural way to access `$._`, see above.
• Term constructions/literals are translated as much as is needed to get them into valid match specs, so that tuples are made into match spec tuple constructions (a one element tuple containing the tuple) and constant expressions are used when importing variables from the environment. Records are also translated into plain tuple constructions, calls to element etc. The guard test is_record/2 is translated into match_spec code using the three parameter version that's built into match specs, so that is_record(A,t) is translated into \{is_record,'$1',t,5\} given that the record size of record type t is 5.

• Language constructions like case, if, catch etc that are not present in match specs are not allowed.

• If the header file ms_transform.hrl is not included, the fun won't be translated, which may result in a runtime error (depending on if the fun is valid in a pure Erlang context). Be absolutely sure that the header is included when using ets and dbg:fun2ms/1 in compiled code.

• If the pseudo function triggering the translation is ets:fun2ms/1, the fun’s head must contain a single variable or a single tuple. If the pseudo function is dbg:fun2ms/1 the fun's head must contain a single variable or a single list.

The translation from fun's to match specs is done at compile time, so runtime performance is not affected by using these pseudo functions. The compile time might be somewhat longer though.

For more information about match specs, please read about them in ERTS users guide.

Exports

parse_transform(Forms,Options) -> Forms

Types:
• Forms = Erlang abstract code format, see the erl_parse module description
• Options = Option list, required but not used

Implements the actual transformation at compile time. This function is called by the compiler to do the source code transformation if and when the ms_transform.hrl header file is included in your source code. See the ets and dbg:fun2ms/1 function manual pages for documentation on how to use this parse_transform, see the match_spec chapter in ERTS users guide for a description of match specifications.

transform_from_shell(Dialect,Clauses,BoundEnvironment) -> term()

Types:
• Dialect = ets | dbg
• Clauses = Erlang abstract form for a single fun
• BoundEnvironment = [{atom(), term()}, ...], list of variable bindings in the shell environment

Implements the actual transformation when the fun2ms functions are called from the shell. In this case the abstract form is for one single fun (parsed by the Erlang shell), and all imported variables should be in the key-value list passed as BoundEnvironment. The result is a term, normalized, i.e. not in abstract format.
format_error(Errcode) -> ErrMessage

Types:
- Errcode = term()
- ErrMessage = string()

Takes an error code returned by one of the other functions in the module and creates a textual description of the error. Fairly uninteresting function actually.
orddict

Erlang Module

Orddict implements a Key-Value dictionary. An orddict is a representation of a dictionary, where a list of pairs is used to store the keys and values. The list is ordered after the keys.

This module provides exactly the same interface as the module dict but with a defined representation.

See Also

dict(3) [page 82], gb_trees(3) [page 163]
**ordsets**

Erlang Module

Sets are collections of elements with no duplicate elements. An ordset is a representation of a set, where an ordered list is used to store the elements of the set. An ordered list is more efficient than an unordered list.

This module provides exactly the same interface as the module `sets` but with a defined representation.

**See Also**

`gb_sets(3)` [page 157], `sets(3)` [page 285]
pg
Erlang Module

This (experimental) module implements process groups. A process group is a group of processes that can be accessed by a common name. For example, a group named `foobar` can include a set of processes as members of this group and they can be located on different nodes.

When messages are sent to the named group, all members of the group receive the message. The messages are serialized. If the process `P1` sends the message `M1` to the group, and process `P2` simultaneously sends message `M2`, then all members of the group receive the two messages in the same order. If members of a group terminate, they are automatically removed from the group.

This module is not complete. The module is inspired by the ISIS system and the causal order protocol of the ISIS system should also be implemented. At the moment, all messages are serialized by sending them through a group master process.

Exports

```
create(PgName) -> ok | {error, Reason}
 Types:
  • PgName = term()
  • Reason = already_created | term()

create(PgName, Node) -> ok | {error, Reason}
 Types:
  • PgName = term()
  • Node = node()
  • Reason = already_created | term()

join(PgName, Pid) -> Members
 Types:
  • PgName = term()
  • Pid = pid()
  • Members = [pid()]
```
Joins the pid Pid to the process group PgName. Returns a list of all old members of the group.

send(PgName, Msg) -> void()

Types:

- PgName = Msg = term()

Sends the tuple \{pg_message, From, PgName, Msg\} to all members of the process group PgName.

Failure: \{badarg, \{PgName, Msg\}\} if PgName is not a process group (a globally registered name).

esend(PgName, Msg) -> void()

Types:

- PgName = Msg = term()

Sends the tuple \{pg_message, From, PgName, Msg\} to all members of the process group PgName, except ourselves.

Failure: \{badarg, \{PgName, Msg\}\} if PgName is not a process group (a globally registered name).

members(PgName) -> Members

Types:

- PgName = term()
- Members = [pid()]

Returns a list of all members of the process group PgName.
pool can be used to run a set of Erlang nodes as a pool of computational processors. It is organized as a master and a set of slave nodes and includes the following features:

- The slave nodes send regular reports to the master about their current load.
- Queries can be sent to the master to determine which node will have the least load.

The BIF `statistics(run_queue)` is used for estimating future loads. It returns the length of the queue of ready to run processes in the Erlang runtime system.

The slave nodes are started with the `slave` module. This effects, tty IO, file IO, and code loading.

If the master node fails, the entire pool will exit.

**Exports**

```
start(Name) ->
start(Name, Args) -> Nodes
```

Types:
- `Name = atom()`
- `Args = string()`
- `Nodes = [node()]`

Starts a new pool. The file `.hosts.erlang` is read to find host names where the pool nodes can be started. See section Files [page 249] below. The start-up procedure fails if the file is not found.

The slave nodes are started with `slave:start/2,3`, passing along `Name` and, if provided, `Args`. `Name` is used as the first part of the node names, `Args` is used to specify command line arguments. See `slave(3)` [page 298].

Access rights must be set so that all nodes in the pool have the authority to access each other.

The function is synchronous and all the nodes, as well as all the system servers, are running when it returns a value.

```
attach(Node) -> allready_attached | attached
```

Types:
- `Node = node()`
This function ensures that a pool master is running and includes \texttt{Node} in the pool master's pool of nodes.

\texttt{stop()} \rightarrow \texttt{stopped}

Stops the pool and kills all the slave nodes.

\texttt{get\_nodes()} \rightarrow \texttt{Nodes}

\textbf{Types:}
- \texttt{Nodes} = \texttt{[node()]}  
  Returns a list of the current member nodes of the pool.

\texttt{pspawn(Mod, Fun, Args)} \rightarrow \texttt{pid()}

\textbf{Types:}
- \texttt{Mod} = \texttt{Fun} = \texttt{atom()}
- \texttt{Args} = \texttt{[term()]}  
  Spawns a process on the pool node which is expected to have the lowest future load.

\texttt{pspawn\_link(Mod, Fun, Args)} \rightarrow \texttt{pid()}

\textbf{Types:}
- \texttt{Mod} = \texttt{Fun} = \texttt{atom()}
- \texttt{Args} = \texttt{[term()]}  
  Spawn links a process on the pool node which is expected to have the lowest future load.

\texttt{get\_node()} \rightarrow \texttt{node()}

Returns the node with the expected lowest future load.

\section*{Files}

\texttt{.hosts.erlang} is used to pick hosts where nodes can be started. See \texttt{[net\_adm(3)]} for information about format and location of this file.

\texttt{$HOME/.erlang.slave.out.HOST} is used for all additional IO that may come from the slave nodes on standard IO. If the start-up procedure does not work, this file may indicate the reason.
The `proc_lib` module is used to initialize some useful information when a process starts. The registered names, or the process identities, of the parent process, and the parent ancestors, are stored together with information about the function initially called in the process.

A crash report is generated if the process terminates with a reason other than `normal` or `shutdown`. `shutdown` is used to terminate an abnormal process in a controlled manner. A crash report contains the previously stored information such as ancestors and initial function, the termination reason, and information regarding other processes which terminate as a result of this process terminating.

The crash report is sent to the `error_logger`. An event handler has to be installed in the `error_logger` event manager in order to handle these reports. The crash report is tagged `crash_report` and the `format/1` function should be called in order to format the report.

**Exports**

```
spawns(Fun) -> Pid
spawns(Node,Fun) -> Pid
spawns(Module,Fun,Args) -> Pid
spawns(Node,Module,Fun,Args) -> Pid
```

Types:
- Fun = fun() -> void()
- Module = atom()
- Func = atom()
- Args = [Arg]
- Arg = term()
- Node = atom()
- Pid = pid()

Spawns a new process and initializes it as described above. The process is spawned using the `spawn` BIFs. The process can be spawned on another `Node`.

```
spawn_link(Fun) -> Pid
spawn_link(Node,Fun) -> Pid
spawn_link(Module,Fun,Args) -> Pid
spawn_link(Node,Module,Fun,Args) -> Pid
```

Types:
Spawns a new process and initializes it as described above. The process is spawned using the \texttt{spawn} \texttt{opt} BIFs. The process can be spawned on another \texttt{Node}.

\begin{verbatim}
spawn_opt(Fun,Opts) -> Pid
spawn_opt(Node,Fun,Opts) -> Pid
spawn_opt(Module,Func,Args,Opts) -> Pid
spawn_opt(Node,Module,Func,Args,Opts) -> Pid
\end{verbatim}

Types:
- \texttt{Fun = fun() -&gt; void()}
- \texttt{Module = atom()}
- \texttt{Func = atom()}
- \texttt{Args = [Arg]}
- \texttt{Arg = term()}
- \texttt{Node = atom()}
- \texttt{O pts = list()}
- \texttt{Pid = pid()}

Spawns a new process and initializes it as described above. The process is spawned using the \texttt{spawn\_opt} BIFs. The process can be spawned on another \texttt{Node}.

\begin{verbatim}
start(Module,Func,Args) -> Ret
start(Module,Func,Args,Time) -> Ret
start(Module,Func,Args,Time,SpawnOpts) -> Ret
start\_link(Module,Func,Args) -> Ret
start\_link(Module,Func,Args,Time) -> Ret
start\_link(Module,Func,Args,Time,SpawnOpts) -> Ret
\end{verbatim}

Types:
- \texttt{Module = atom()}
- \texttt{Func = atom()}
- \texttt{Args = [Arg]}
- \texttt{Arg = term()}
- \texttt{Time = integer &gt;= 0 | infinity}
- \texttt{SpawnO pts = list()}
- \texttt{Ret = term() | \{error, Reason\}}
Starts a new process synchronously. Spawns the process using `proc_lib:spawn/3` or `proc_lib:spawn_link/3`, and waits for the process to start. When the process has started, it must call `proc_lib:init_ack(Parent, Ret)` or `proc_lib:init_ack(Ret)`, where `Parent` is the process that evaluates `start`. At this time, `Ret` is returned from `start`.

If the `start_link` function is used and the process crashes before `proc_lib:init_ack` is called, `{error, Reason}` is returned if the calling process traps exits.

If `Time` is specified as an integer, this function waits for `Time` milliseconds for the process to start (`proc_lib:init_ack`). If it has not started within this time, `{error, timeout}` is returned, and the process is killed.

The `SpawnOpts` argument, if given, will be passed as the last argument to the `spawn_opt/4` BIF. Refer to the `erlang` module for information about the `spawn_opt` options.

```
init_ack(Parent, Ret) -> void()
init_ack(Ret) -> void()
```

**Types:**

- `Parent = pid()`
- `Ret = term()`

This function is used by a process that has been started by a `proc_lib:start` function. It tells `Parent` that the process has initialized itself, has started, or has failed to initialize itself. The `init_ack/1` function uses the parent value previously stored by the `proc_lib:start` function. If the `init_ack` function is not called (e.g. if the init function crashes) and `proc_lib:start/3` is used, that function never returns and the parent hangs forever. This can be avoided by using a time out in the call to `start`, or by using `start_link`.

The following example illustrates how this function and `proc_lib:start_link` are used.

```
-module(my_proc).
-export([start_link/0]).
start_link() ->
    proc_lib:start_link(my_proc, init, [self()]).
init(Parent) ->
    case do_initialization() of
        ok ->
            proc_lib:init_ack(Parent, {ok, self()});
        {error, Reason} ->
            exit(Reason)
    end,
    loop().
loop() ->
    receive
        ....
    format(CrashReport) -> string()
```

**Types:**

- `CrashReport = void()`
Formats a previously generated crash report. The formatted report is returned as a string.

\[
\text{initial
call(PidOrPinfo)} \rightarrow \{\text{Module,Function,Args} \mid \text{Fun} \mid \text{false}
\]

Types:
- PidOrPinfo = pid() | \{X,Y,Z\} | ProcInfo
- X = Y = Z = int()
- ProcInfo = [void()]
- Module = atom()
- Fun = fun() -> void()
- Function = atom()
- Args = [term()]

Extracts the initial call of a process that was spawned using the spawn functions described above. PidOrPinfo can either be a Pid, an integer tuple (from which a pid can be created), or the process information of a process (fetched through an \text{erlang:process_info/1} function call).

\[
\text{translate
call(PidOrPinfo)} \rightarrow \{\text{Module,Function,Arity} \mid \text{Fun}
\]

Types:
- PidOrPinfo = pid() | \{X,Y,Z\} | ProcInfo
- X = Y = Z = int()
- ProcInfo = [void()]
- Module = atom()
- Fun = fun() -> void()
- Function = atom()
- Arity = int()

Extracts the initial call of a process which was spawned using the spawn functions described above. If the initial call is to one of the system defined behaviours such as \text{gen_server} or \text{gen_event}, it is translated to more useful information. If a \text{gen_server} is spawned, the returned \text{Module} is the name of the callback module and \text{Function} is \text{init} (the function that initiates the new server).

A \text{supervisor} and a \text{supervisor_bridge} are also \text{gen_server} processes. In order to return information that this process is a \text{supervisor} and the name of the call-back module, \text{Module} is \text{supervisor} and \text{Function} is the name of the supervisor callback module. \text{Arity} is 1 since the \text{init/1} function is called initially in the callback module.

By default, \{\text{proc_lib},init\#p,5\} is returned if no information about the initial call can be found. It is assumed that the caller knows that the process has been spawned with the \text{proc_lib} module.

PidOrPinfo can either be a Pid, an integer tuple (from which a pid can be created), or the process information of a process (fetched through an \text{erlang:process_info/1} function call).

This function is used by the \text{c:i/0} and \text{c:regs/0} functions in order to present process information.

\[
\text{hibernate(Module, Function, Arguments)}
\]

Types:
hibernate/3 gives a way to put a process started using one of the functions in the proc_lib module into a wait state where its memory allocation has been reduced as much as possible, which is useful if the process does not expect to receive any messages in the near future.

The process will be awakened when a message is sent to it, and control will resume in Module:Function with the arguments given by ArgumentList.

If the process has any message in its message queue, the process will be awakened immediately in the same way as described above.

Note: The actual work is done by the erlang:hibernate/3 BIF. To ensure that exception handling and logging continues to work in a process started by proc_lib, always use proc_lib:hibernate rather than erlang:hibernate/3.

See Also

error_logger(3)
proplists

Erlang Module

Property lists are ordinary lists containing entries in the form of either tuples, whose first elements are keys used for lookup and insertion, or atoms, which work as shorthand for tuples \{Atom, true\}. (Other terms are allowed in the lists, but are ignored by this module.) If there is more than one entry in a list for a certain key, the first occurrence normally overrides any later (irrespective of the arity of the tuples).

Property lists are useful for representing inherited properties, such as options passed to a function where a user may specify options overriding the default settings, object properties, annotations, etc.

Exports

append_values(Key, List) -> List

Types:
- Key = term()
- List = [term()]

Similar to get_all_values/2, but each value is wrapped in a list unless it is already itself a list, and the resulting list of lists is concatenated. This is often useful for "incremental" options; e.g., append_values(a, [[a, [1,2]], [b, 0], {a, 3}, {c, -1}, {a, [4]]]) will return the list [1,2,3,4].

compact(List) -> List

Types:
- List = [term()]

Minimizes the representation of all entries in the list. This is equivalent to [property(P) || P <- List].
See also: property/1, unfold/1.

delete(Key, List) -> List

Types:
- Key = term()
- List = [term()]

Deletes all entries associated with Key from List.

expand(Expansions, List) -> List

Types:
• Key = term()
• Expansions = [{Property,[term()]}, ...
• Property = atom() | tuple()

Expands particular properties to corresponding sets of properties (or other terms). For each pair Property, Expansion in Expansions, if E is the first entry in List with the same key as Property, and E and Property have equivalent normal forms, then E is replaced with the terms in Expansion, and any following entries with the same key are deleted from List.

For example, the following expressions all return [fie, bar, baz, fum]:
- expand([{{foo, bar}, baz}], [fie, foo, fum])
- expand([{{foo, true}, [bar, baz]}], [fie, foo, fum])
- expand([{{foo, false}, [bar, baz]}], [fie, {foo, false}, fum])

However, no expansion is done in the following call:
- expand([{{foo, true}, [bar, baz]}], [foo, false], fie, foo, fum)

because {foo, false} shadows foo.

Note that if the original property term is to be preserved in the result when expanded, it must be included in the expansion list. The inserted terms are not expanded recursively. If Expansions contains more than one property with the same key, only the first occurrence is used.

See also: normalize/2.

get_all_values(Key, List) -> [term()]

Types:
• Key = term()
• List = [term()]

Similar to get_value/2, but returns the list of values for all entries {Key, Value} in List. If no such entry exists, the result is the empty list.

See also: get_value/2.

get_bool(Key, List) -> bool()

Types:
• Key = term()
• List = [term()]

Returns the value of a boolean key/value option. If lookup(Key, List) would yield {Key, true}, this function returns true; otherwise false is returned.

See also: get_value/2, lookup/2.

get_keys(List) -> [term()]

Types:
• List = [term()]
Returns an unordered list of the keys used in List, not containing duplicates.

get_value(Key, List) -> term()

Types:
- Key = term()
- List = [term()]

Equivalent to get_value(Key, List, undefined).

get_value(Key, List, Default) -> term()

Types:
- Key = term()
- Default = term()
- List = [term()]

Returns the value of a simple key/value property in List. If lookup(Key, List) would yield \{Key, Value\}, this function returns the corresponding Value, otherwise Default is returned. See also: get_all_values/2, get_bool/2, get_value/1, lookup/2.

is_defined(Key, List) -> bool()

Types:
- Key = term()
- List = [term()]

Returns true if List contains at least one entry associated with Key, otherwise false is returned.

lookup(Key, List) -> none | tuple()

Types:
- Key = term()
- List = [term()]

Returns the first entry associated with Key in List, if one exists, otherwise returns none. For an atom A in the list, the tuple \{A, true\} is the entry associated with A. See also: get_bool/2, get_value/2, lookup_all/2.

lookup_all(Key, List) -> [tuple()]

Types:
- Key = term()
- List = [term()]

Returns the list of all entries associated with Key in List. If no such entry exists, the result is the empty list. See also: lookup/2.

normalize(List, Stages) -> List

Types:
- List = [term()]
- Stages = [Operation]
- Operation = (aliases, Aliases) | (negations, Negations) | (expand, Expansions)
- Aliases = [{Key, Key}]
- Negations = [{Key, Key}]
- Key = term()
- Expansions = [{Property, [term()]}, {Property, [term()]}, [Property, [term()]]]
- Property = atom() | tuple()

Passes List through a sequence of substitution/expansion stages. For an aliases operation, the function substitute,aliases/2 is applied using the given list of aliases; for a negations operation, substitute, negations/2 is applied using the given negation list; for an expand operation, the function expand/2 is applied using the given list of expansions. The final result is automatically compacted (cf. compact/1).

Typically you want to substitute negations first, then aliases, then perform one or more expansions (sometimes you want to pre-expand particular entries before doing the main expansion). You might want to substitute negations and/or aliases repeatedly, to allow such forms in the right-hand side of aliases and expansion lists.

See also: compact/1, expand/2, substitute,aliases/2, substitute,negations/2.

property(Property) --> Property

Types:
- Property = atom() | tuple()

Creates a normal form (minimal) representation of a property. If Property is {Key, true} where Key is an atom, this returns Key, otherwise the whole term Property is returned.

See also: property/2.

property(Key, Value) --> Property

Types:
- Key = term()
- Value = term()
- Property = atom() | tuple()

Creates a normal form (minimal) representation of a simple key/value property. Returns Key if Value is true and Key is an atom, otherwise a tuple {Key, Value} is returned.

See also: property/1.

split(List, Keys) --> {Lists, Rest}

Types:
- List = [term()]
- Keys = [term()]
- Lists = [[term()]]
- Rest = [term()]
Partitions List into a list of sublists and a remainder. Lists contains one sublist for each key in Keys, in the corresponding order. The relative order of the elements in each sublist is preserved from the original List. Rest contains the elements in List that are not associated with any of the given keys, also with their original relative order preserved.

Example: split([[c, 2], {e, 1}, a, {c, 3, 4}, d, {b, 5}, b, [a, b, c]]) returns

```
([a], [{b, 5}, b], [{c, 2}, {c, 3, 4}]), [{e, 1}, d])
```

**substituteAliases(Aliases, List) -> List**

Types:
- Aliases = [{Key, Key}]
- Key = term()
- List = [term()]

Substitutes keys of properties. For each entry in List, if it is associated with some key K1 such that \{K1, K2\} occurs in Aliases, the key of the entry is changed to Key2. If the same K1 occurs more than once in Aliases, only the first occurrence is used.

Example: substituteAliases([[color, colour]], L) will replace all tuples \{color, ...\} in L with \{colour, ...\}, and all atoms color with colour.

See also: normalize/2, substituteNegations/2.

**substituteNegations(Negations, List) -> List**

Types:
- Negations = [{Key, Key}]
- Key = term()
- List = [term()]

Substitutes keys of boolean-valued properties and simultaneously negates their values. For each entry in List, if it is associated with some key K1 such that {K1, K2} occurs in Negations, then if the entry was \{K1, true\} it will be replaced with \{K2, false\}, otherwise it will be replaced with \{K2, true\}, thus changing the name of the option and simultaneously negating the value given by getBool(List). If the same K1 occurs more than once in Negations, only the first occurrence is used.

Example: substituteNegations([[no foo, foo]], L) will replace any atom no foo
or tuple \{no foo, true\} in L with \{foo, false\}, and any other tuple \{no foo, ...\}
with \{foo, true\}.

See also: getBool/2, normalize/2, substituteAliases/2.

**unfold(List) -> List**

Types:
- List = [term()]

Unfolds all occurrences of atoms in List to tuples \{Atom, true\}.
The qlc module provides a query interface to Mnesia, ETS, Dets and other data structures that implement an iterator style traversal of objects.

Overview

The qlc module implements a query interface to QLC tables. Typical QLC tables are ETS, Dets, and Mnesia tables. There is also support for user defined tables, see the Implementing a QLC table section. A query is stated using Query List Comprehensions (QLCs). These are similar to ordinary list comprehensions as described in the Erlang Reference Manual and Programming Examples except that variables introduced in patterns cannot be used in list expressions. The answers to a query are determined by data in QLC tables that fulfill the constraints expressed by the QLCs of the query.

QLCs should not be confused with the language construct query ListComprehension end used by Mnemosyne. The qlc module recognizes the first argument of every call to qlc:q/1,2 as QLCs, and nothing else. The semantics are very different: Mnemosyne uses ideas borrowed from Prolog while the QLCs introduced in this module are all Erlang. In fact, in the absence of optimizations and options such as cache and unique (see below), every QLC free of QLC tables evaluates to the same list of answers as the identical ordinary list comprehension. It is the aim of this module to replace Mnemosyne and to be more versatile by means of QLC tables.

While ordinary list comprehensions evaluate to lists, calling qlc:q/1,2 [page 269] returns a Query Handle. To obtain all the answers to a query, qlc:eval/1,2 [page 267] should be called with the query handle as first argument. Query handles are essentially funs created in the module calling q/1,2. As the funs refer to the module's code, one should be careful not to keep query handles too long if the module's code is to be replaced. Code replacement is described in the [Erlang Reference Manual]. The list of answers can also be traversed in chunks by use of a Query Cursor. Query cursors are created by calling qlc:cursor/1,2 [page 266] with a query handle as first argument. Query cursors are essentially Erlang processes. One answer at a time is sent from the query cursor process to the process that created the cursor.

Syntax

Syntactically QLCs have the same parts as ordinary list comprehensions:

[Expression || Qualifier1, Qualifier2, ...]
Expression (the template) is an arbitrary Erlang expression. Qualifiers are either filters or generators. Filters are Erlang expressions returning \texttt{bool()}. Generators have the form \texttt{Pattern \textasciitilde ListExpression}, where \texttt{ListExpression} is an expression evaluating to a query handle or a list. Query handles are returned from \texttt{qlc:table/2, qlc:append/1,2, qlc:sort/1,2, qlc:keysort/2,3, qlc:q/1,2, and qlc:string_to_handle/1,2,3}.

Evaluation

The evaluation of a query handle begins by the inspection of options and the collection of information about tables. As a result qualifiers are modified during the optimization phase. Next all list expressions are evaluated. If a cursor has been created evaluation takes place in the cursor process. For those list expressions that are QLCs, the list expressions of the QLCs’ generators are evaluated as well. One has to be careful if list expressions have side effects since the order in which list expressions are evaluated is unspecified. Finally the answers are found by evaluating the qualifiers from left to right, backtracking when some filter returns \texttt{false}, or collecting the template when all filters return \texttt{true}.

Common options

The following options are accepted by \texttt{cursor/2, eval/2, fold/4, and info/2}:

- \{\texttt{unique_all, true}\} adds a \{\texttt{unique,true}\} option to every list expression of the query. Default is \{\texttt{unique_all,false}\}. The option \texttt{unique_all} is equivalent to \{\texttt{unique,true}\}.
- \{\texttt{cache_all, true}\} adds a \{\texttt{cache,true}\} option to every list expression of the query except tables and lists. Default is \{\texttt{cache_all,false}\}. The option \texttt{cache_all} is equivalent to \{\texttt{cache_all,true}\}.

Common data types

- \texttt{QueryCursor} = \{\texttt{qlc_cursor, term()}\}
- \texttt{QueryHandle} = \{\texttt{qlc_handle, term()}\}
- \texttt{QueryHandleOrList} = \texttt{QueryHandle | list()}
- \texttt{Answers} = \{\texttt{Answer}\}
- \texttt{Answer} = \texttt{term()}
- \texttt{AbstractExpression} = -parse trees for Erlang expressions, see the \{abstract format\} documentation in ERTS User’s Guide-
- \texttt{MatchExpression} = -match specifications, see the \{match specification\} documentation in the ERTS User’s Guide and ms\texttt{transform(3)} [page 233]-
- \texttt{SpawnOptions} = default | \texttt{spawn_options()}
- \texttt{SortOptions} = \{\texttt{SortOption}\} | \texttt{SortOption}
- \texttt{SortOption} = \{\texttt{compressed, bool() | \{no_files, NoFiles\} | \{order, Order\} | \{size, Size\} | \{tmpdir, TempDirectory\} | \{unique, bool()\}} -see file\texttt{sorter(3)} [page 143]-
- \texttt{Order} = ascending | descending | \texttt{OrderFun}
• OrderFun = fun(Term, Term) -> bool()
• TempDirectory = "" | filename()
• Size = int() > 0
• NoFiles = int() > 1
• KeyPos = int() > 0 | [int() > 0]
• bool() = true | false
• filename() = -see filename(3) [page 151]-
• spawn_options() = -see [erlang(3)]-

Future plans

Support for faster join of two tables will be added not later than in R11. Depending on preferences and priorities some high level optimizations may be added in the future.

Getting started

As already mentioned queries are stated in the list comprehension syntax as described in the [Erlang Reference Manual]. In the following some familiarity with list comprehensions is assumed. There are examples in [Programming Examples] that can get you started. It should be stressed that list comprehensions do not add any computational power to the language; anything that can be done with list comprehensions can also be done without them. But they add a syntax for expressing simple search problems which is compact and clear once you get used to it.

Many list comprehension expressions can be evaluated by the qlc module. Exceptions are expressions such that variables introduced in patterns (or filters) are used in some generator later in the list comprehension. As an example consider an implementation of lists:append(L): [X || Y <- L, X <- Y]. Y is introduced in the first generator and used in the second. The ordinary list comprehension is normally to be preferred when there is a choice as to which to use. One difference is that qlc:eval/1,2 collects answers in a list which is finally reversed, while list comprehensions collect answers on the stack which is finally unwound.

What the qlc module primarily adds to list comprehensions is that data can be read from QLC tables in small chunks. A QLC table is created by calling qlc:table/2. Usually qlc:table/2 is not called directly from the query but via an interface function of some data structure. There are a few examples of such functions in Erlang/OTP: mnesia:table/1,2, ets:table/1,2, and dets:table/1,2. For a given data structure there can be several functions that create QLC tables, but common for all these functions is that they return a query handle created by qlc:table/2. Using the QLC tables provided by OTP is probably sufficient in most cases, but for the more advanced user the section Implementing a QLC table [page 264] describes the implementation of a function calling qlc:table/2.

Besides qlc:table/2 there are other functions that return query handles. They might not be used as often as tables, but are useful from time to time. qlc:append traverses objects from several tables or lists after each other. If, for instance, you want to traverse all answers to a query QH and then finish off by a term \(\text{finished}\), you can do that by calling qlc:append(QH, \{[\text{finished}]\}). append first returns all objects of QH, then
If there is one tuple \{\texttt{finished}\} among the answers to QH it will be returned twice from \texttt{append}.

As another example, consider concatenating the answers to two queries QH1 and QH2 while removing all duplicates. The means to accomplish this is to use the \texttt{unique} option:

\begin{verbatim}
qlc:q([X || X <- qlc:append(QH1, QH2)], \{unique, true\})
\end{verbatim}

The cost is substantial: every returned answer will be stored in an ETS table. Before returning an answer it is looked up in the ETS table to check if it has already been returned. Without the \texttt{unique} options all answers to QH1 would be returned followed by all answers to QH2. The \texttt{unique} options keeps the order between the remaining answers.

If the order of the answers is not important there is the alternative to sort the answers uniquely:

\begin{verbatim}
qlc:sort(qlc:q([X || X <- qlc:append(QH1, QH2)], \{unique, true\})).
\end{verbatim}

This query also removes duplicates but the answers will be sorted. If there are many answers temporary files will be used. Note that in order to get the first unique answer all answers have to be found and sorted.

To return just a few answers cursors can be used. The following code returns no more than five answers using an ETS table for storing the unique answers:

\begin{verbatim}
C = qlc:cursor(qlc:q([X || X <- qlc:append(QH1, QH2)], \{unique,true\})),
R = qlc:next_answers(C, 5),
ok = qlc:delete_cursor(C),
R.
\end{verbatim}

Query list comprehensions are convenient for stating conditions on data from two or more tables. An example that does a natural join on two tables on position 2:

\begin{verbatim}
qlc:q([[X1,X2,X3,Y1] || \{X1,X2,X3} <- QH1, \{Y1,Y2} <- QH2, X2 =:= Y2])
\end{verbatim}

If QH1 and QH2 both are tables and X2 or Y2 is a key or index position then the join can be done quickly by looking up key values. In this first version of the \texttt{qlc} module this has not yet been implemented. Instead the filter will always be applied to every possible pair of answers to QH1 and QH2, one at a time. If there are M answers to QH1 and N answers to QH2 the filter will be run M*N times.

If QH2 is a call to the function for \texttt{gb_trees} as defined in the Implementing a QLC table [page 264] section, \texttt{gb\_table:table/1}, the iterator for the gb-tree will be initiated for each answer to QH1 after which the objects of the gb-tree will be returned one by one. This is probably the most efficient way of traversing the table in that case since it takes minimal computational power to get next object. But if QH2 is not a table but a more complicated QLC, it can be more efficient use some RAM memory for collecting the answers in a cache, particularly if there are only a few answers. It must then be assumed that evaluating QH2 has no side effects so that the meaning of the query does not change if QH2 is evaluated only once. One way of caching the answers is to evaluate QH2 first of all and substitute the list of answers for QH2 in the query. Another way is to use the \texttt{cache} option. It is stated like this:

\begin{verbatim}
QH2' = qlc:q([X || X <- QH2], \{cache, true\})
\end{verbatim}

or just
QH2' = qlc:q([X || X <- QH2], cache)

The effect of the cache option is that when the generator QH2' is run the first time every answer is stored in an ETS table. When next answer of QH1 is tried, answers to QH2' are copied from the ETS table which is very fast. As for the unique option the cost is a possibly substantial amount of RAM memory.

There is an option cache_all that can be set to true when evaluating a query. It adds a cache option to every list expression except QLC tables and lists on all levels of the query. This can be used for testing if caching would improve efficiency at all. If the answer is yes further testing is needed to pinpoint the generators that should be cached.

Implementing a QLC table

As an example of how to use the qlc:table/2 [page 269] function the implementation of a QLC table for the gb_trees [page 163] module is given:

```erlang
-module(gb_table).
-import(gb_trees, [iterator/1, lookup/2, next/1]).
-export([table/1]).

table(T) ->
    TF = fun() -> qlc_next(next(iterator(T))) end,
    InfoFun = fun(num_of_objects) -> size(T);
              (keypos) -> 1;
              (_) -> undefined
           end,
    LookupFun =
        fun(1, Ks) ->
            lists:flatmap(fun(K) ->
                case gb_trees:lookup(K, T) of
                    {value, V} -> [{K,V}];
                    none -> []
                end
            end, Ks)
        end,
    FormatFun =
        fun(all) ->
            Vals = a_few(T),
            case gb_trees:from_orddict([Vals]);
            ({lookup, 1, KeyValues}) ->
                ValsS = io_lib:format("gb_trees:from_orddict(~w)",
                    [a_few(T)],
                    io_lib:format("lists:flatmap(fun(K) -> "
                    "case gb_trees:lookup(K, ~s) of "
                    "{value, V} -> [{K,V}];none -> [] end "
                    "end, ~w)",
                    [ValsS, KeyValues])
            end,
    
    qlc:table(TF, [{info_fun, InfoFun}, {format_fun, FormatFun},
                    {lookup_fun, LookupFun}]).
```

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qlc_next({X, V, S}) ->
    [{X, V} | fun() -> qlc_next(next(S)) end];
qlc_next(none) ->
    [].
a_few(T) ->
    a_few(iterator(T), 7).
a_few(_I, 0) ->
    more;
a_few(I0, N) ->
    case next(I0) of
      {X, V, I} ->
        [{X, V} | a_few(I, N-1)];
      none ->
        []
    end.

TF is the traversal function. The qlc module requires that there is a way of traversing all objects of the data structure; in gb_trees there is an iterator function suitable for that purpose. Note that for each object returned a new fun is created. As long as the list is not terminated by [] it is assumed that the tail of the list is a nullary function and that calling the function returns further objects (and functions).

The lookup function is optional. It is assumed that the lookup function always finds values much faster than it would take to traverse the table. The first argument is the position of the key. Since qlc_next returns the objects as {Key,Value} pairs the position is 1. Note that the lookup function should return {Key,Value} pairs, just as the traversal function does.

The format function is also optional. It is called by qlc:info to give feedback at runtime of how the query will be evaluated. One should try to give as good feedback as possible without showing too much details. In the example at most 7 objects of the table are shown. The format function handles two cases: all means that all objects of the table will be traversed; {lookup,1,KeyValues} means that the lookup function will be used for looking up key values.

Whether the whole table will be traversed or just some keys looked up depends on how the query is stated. It the query has the form

qlc:q([T || P <- LE, F])

and P is a tuple, the qlc module analyzes P and F in compile time to find positions of the tuple P that are matched or compared to constants. If such a position at runtime turns out to be the key position, the lookup function can be used, otherwise all objects of the table have to be traversed. It is the info function InfoFun that returns the key position. There can be index positions as well, also returned by the info function. An index is an extra table that makes lookup on some position fast. Mnesia maintains indices upon request, thereby introducing so called secondary keys. The key is always preferred before secondary keys regardless of the number of constants to look up.
Exports

append(QHL) -> QH

Types:
- QHL = [QueryHandleOrList]
- QH = QueryHandle

Returns a query handle. When evaluating the query handle QH all answers to the first query handle in QHL is returned followed by all answers to the rest of the query handles in QHL.

append(QH1, QH2) -> QH3

Types:
- QH1 = QH2 = QueryHandleOrList
- QH3 = QueryHandle

Returns a query handle. When evaluating the query handle QH3 all answers to QH1 are returned followed by all answers to QH2. append(QH1, QH2) is equivalent to append([QH1, QH2]).

cursor(QueryHandleOrList [, Options]) -> QueryCursor

Types:
- Options = [Option] | Option
- Option = {cache_all, bool()} | cache_all | {spawn_options, SpawnOptions} | {unique_all, bool()} | unique_all

Creates a query cursor and makes the calling process the owner of the cursor. The cursor is to be used as argument to next_answers/1,2 and (eventually) delete_cursor/1. Calls erlang:spawn_opt to spawn and link a process which will evaluate the query handle. The value of the option spawn_options is used as last argument when calling spawn_opt. The default value is [link].

```
1> QH = qlc:q([(X,Y) || X <- [a,b], Y <- [1,2]]),
   QC = qlc:cursor(QH),
   qlc:next_answers(QC, 1).
   [{a,1}]
2> qlc:next_answers(QC, 1).
   [{a,2}]
3> qlc:next_answers(QC, all_remaining).
   [{b,1},{b,2}]
4> qlc:delete_cursor(QC).
   ok
```

delete_cursor(QueryCursor) -> ok

Deletes a query cursor. Only the owner of the cursor can delete the cursor.

eval(QueryHandleOrList [, Options]) -> Answers | Error
e(QueryHandleOrList [, Options]) -> Answers

Types:
• Options = [Option] | Option
  • Option = {cache_all, bool()} | cache_all | {unique_all, bool()} | unique_all
• Error = {error, module(), Reason}
• Reason = as returned by file_sorter(3)

Evaluates a query handle in the calling process and collects all answers in a list.

1> QH = qlc:q([[X,Y] || X <- [a,b], Y <- [1,2]]),
   qlc:eval(QH).
[[a,1],[a,2],[b,1],[b,2]]

fold(Function, Acc0, QueryHandleOrList [, Options]) -> Acc1 | Error

Types:
• Function = fun(Answer, AccIn) -> AccOut
• Acc0 = Acc1 = AccIn = AccOut = term()
• Options = [Option] | Option
  • Option = {cache_all, bool()} | cache_all | {unique_all, bool()} | unique_all
• Error = {error, module(), Reason}
• Reason = as returned by file_sorter(3)

Calls Function on successive answers to the query handle together with an extra argument AccIn. The query handle and the function are evaluated in the calling process. Function must return a new accumulator which is passed to the next call. Acc0 is returned if there are no answers to the query handle.

1> QH = [1,2,3,4,5,6],
   qlc:fold(fun(X, Sum) -> X + Sum end, 0, QH).
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format_error(Error) -> Chars

Types:
• Error = {error, module(), term()}
• Chars = [char() | Chars]

Returns a descriptive string in English of an error tuple returned by some of the functions of the qlc module or the parse transform. This function is mainly used by the compiler invoking the parse transform.

info(QueryHandleOrList [, Options]) -> Info

Types:
• Options = [Option] | Option
  • Option = EvalOption | ReturnOption
    • EvalOption = {cache_all, bool()} | cache_all | {unique_all, bool()} | unique_all
    • ReturnOption = {flat, bool()} | {format, Format} | {n_elements, NElements}
• Format = abstract_code | string
• NElements = infinity | int() > 0
• Info = AbstractExpression | string()
Returns information about a query handle. The information describes the simplifications and optimizations that are the results of preparing the query for evaluation. This function is probably useful mostly during debugging.

The information has the form of an Erlang expression where QLCs most likely occur. Depending on the format functions of mentioned QLC tables it may not be absolutely accurate.

The default is to return a sequence of QLCs in a block, but if the option `flat,false` is given, one single QLC is returned. The default is to return a string, but if the option `format,abstract_code` is given, abstract code is returned instead. The default is to return all elements in lists, but if the `{n,elements,NElements}` option is given, only a limited number of elements are returned.

```erlang
1> QH = qlc:q([\([X,Y] \leftarrow [x,y], Y \leftarrow [a,b]\)],
            io:format("\"\s\"~n", [qlc:info(QH, unique_all)])).
```

In this example two simple QLCs have been inserted just to hold the `{unique,true}` option.

```
begin
  V1 = qlc:q([ SQV ||
              SQV <- [x,y]
            ],[{unique,true}]),
  V2 = qlc:q([ SQV ||
              SQV <- [a,b]
            ],[{unique,true}]),
  qlc:q([ \{X,Y\} ||
          X <- V1, Y <- V2
        ],[{unique,true}])
end
```

next_answers(QueryCursor [, NumberOfAnswers]) -> Answers | Error

Types:
- NumberOfAnswers = all_remaining | int() > 0
- Error = {error, module(), Reason}
- Reason = as returned by file_sorter(3)

keysor(KeyPos, QH1 [, SortOptions]) -> QH2

Types:
- QH1 = QueryHandleOrList
- QH2 = QueryHandle

Returns a query handle. When evaluating the query handle QH2 the answers to the query handle QH1 are sorted by file_sorter:keysort/4 [page 143] according to the options. The sorter will use temporary files only if QH1 does not evaluate to a list and the size of the binary representation of the answers exceeds Size bytes, where Size is the value of the size option.
Returns some or all of the remaining answers to a query cursor. Only the owner of Cursor can retrieve answers.

The optional argument NumberOfAnswers determines the maximum number of answers returned. The default value is 10. If less than the requested number of answers is returned, subsequent calls to next_answers will return [].

```
q(QueryListComprehension [, Options]) -> QueryHandle
```

**Types:**
- QueryListComprehension = literal query list comprehension
- Options = [Option] | Option
  - Option = {MaxLookup, MaxLookup} || Cache, bool() || cache || {unique, bool()} || unique
- MaxLookup = int() >= 0 || infinity

Returns a query handle for a query list comprehension. The query list comprehension must be the first argument to qlc:q/1,2 or it will be evaluated as an ordinary list comprehension. It is also necessary to add the line

```
-includeflib("stdlib/include/qlc.hrl")
```

to the source file. This causes a parse transform to substitute a fun for the query list comprehension. The (compiled) fun will be called when the query handle is evaluated. When calling qlc:q/1,2 from the Erlang shell the parse transform is automatically called. When this happens the fun substituted for the query list comprehension is not compiled but will be evaluated by erl_eval(3). This is also true when expressions are evaluated by means of file:eval/1,2 or in the debugger.

To be very explicit, this will not work:

```
... A = [X || {X} <- [{1},{2}]], QH = qlc:q(A), ...
```

The variable A will be bound to the evaluated value of the list comprehension ([1,2]). The compiler complains with an error message ("argument is not a query list comprehension"); the shell process stops with a badarg reason.

The {cache,true} option can be used to cache the answers to a query list comprehension. The answers are stored in one ETS table for each cached query list comprehension. When a cached query list comprehension is evaluated again, answers are fetched from the table without any further computations. As a consequence, when all answers to a cached query list comprehension have been found, the ETS tables used for caching answers to the query list comprehension's qualifiers can be emptied. The option cache is equivalent to {cache,true}.

The cache option has no effect if it is known that the query list comprehension will be evaluated at most once. This is always true for the top-most query list comprehension and also for the list expression of the first generator in a list of qualifiers. Note that in the presence of side effects in filters or callback functions the answers to query list comprehensions can be affected by the cache option.

The {unique,true} option can be used to remove duplicate answers to a query list comprehension. The unique answers are stored in one ETS table for each query list comprehension. The table is emptied every time it is known that there are no more answers to the query list comprehension. The option unique is equivalent to
If the unique option is combined with the cache option, two ETS tables are used, but the full answers are stored in one table only.

Sometimes (see qlc:table/2 [page 272] below) traversal of tables can be done by looking up key values, which is supposed to be fast. Under certain (rare) circumstances it could happen that there are too many key values to look up. The \{max_lookup,MaxLookup\} option can then be used to limit the number of lookups: if more than MaxLookup lookups would be required no lookups are done but the table traversed instead. The default value is infinity which means that there is no limit on the number of keys to look up.

\[
1> T = \text{gb_trees:empty()},
\]
\[
\text{QH} = \text{qlc:q}([X \mid \{X,Y\} \leftarrow \text{gb_table:table}(T),
\]
\[
((X =:= 1) \text{ or } (X =:= 2)),
\]
\[
((Y =:= a) \text{ or } (Y =:= b) \text{ or } (Y =:= c))),
\]
\[
\text{io:format}("s\ n", [\text{qlc:info}(\text{QH})]).
\]
\[
\text{qlc:q}(\{ X \mid
\]
\[
\text{lists:flatmap}(\text{fun } (K) \rightarrow
\]
\[
\begin{cases}
\text{case gb_trees:lookup}(K,\text{gb_trees:from_orddict}([]) \rightarrow
\]
\[
\{\text{value},V\} \rightarrow [\{K,V\}];
\end{cases}
\]
\[
\text{none} \rightarrow []
\]
\[
\text{end end}, [\{1,a\},\{1,b\},\{1,c\},\{2,a\},\{2,b\},\{2,c\}],
\]
\[
(X =:= 1) \text{ or } (X =:= 2),
\]
\[
(Y =:= a) \text{ or } (Y =:= b) \text{ or } (Y =:= c)
\]
\[
\}
\]
\[
\text{ok}
\]
\[
2>
\]

In this example using the \text{gb_trees} module from the Implementing a QLC table [page 264] section there are six keys to look up: \{1,a\}, \{1,b\}, \{1,c\}, \{2,a\}, \{2,b\}, and \{2,c\}. The reason is that the two elements of the key \{X,Y\} are matched separately.

\text{sort/1,2 and keysort/2,3} can also be used for caching answers and for removing duplicates. When sorting answers are cached in a list, possibly stored on a temporary file, and no ETS tables are used.

\text{sort(QH1 [, SortOptions])} \rightarrow \text{QH2}

Types:
- \text{QH1 = QueryHandleOrList}
- \text{QH2 = QueryHandle}

Returns a query handle. When evaluating the query handle \text{QH2} the answers to the query handle \text{QH1} are sorted by \text{file_sorter:sort/3} [page 143] according to the options. The sorter will use temporary files only if \text{QH1} does not evaluate to a list and the size of the binary representation of the answers exceeds \text{Size} bytes, where \text{Size} is the value of the size option.

\text{string_to_handle(QueryString [, Options [, Bindings]])} \rightarrow \text{QueryHandle | Error}

Types:
- \text{QueryString = string()}
- \text{Options = [Option] | Option}
A string version of \texttt{qlc:q/1}. When the query handle is evaluated the fun created by the parse transform is interpreted by \texttt{erl_eval(3)}. The query string is to be one single query list comprehension terminated by a period.

\begin{verbatim}
1> L = [1,2,3],
Bs = erl_eval:add_binding(\"L\", L, erl_eval:new_bindings()),
QH = qlc:string_to_handle(\"[X+1 || X <- L].\", [], Bs),
qlc:eval(QH).
[2,3,4]
\end{verbatim}

This function is probably useful mostly when called from outside of Erlang, for instance from a driver written in C.

\begin{verbatim}
table(TraverseFun, Options) -> QueryHandle

Types:
  TraverseFun = TraverseFun0 | fun(MatchExpression) -> Objects
  TraverseFun0 = fun() -> Objects
  Objects = [] | [term() | Objects]
  ObjectList = TraverseFun0 | Objects
  Options = [Option] | Option
  Option = {format_fun, FormatFun} | {info_fun, InfoFun} | {lookup_fun,
           LookupFun} | {parent_fun, ParentFun} | {post_fun, PostFun} | {pre_fun, PreFun}
  FormatFun = undefined | fun(SelectedObjects) -> FormatedTable
  SelectedObjects = all | {match_spec, MatchExpression} | {lookup, {Position, Keys}}
  FormatedTable = [Mod, Fun, Args] | AbstractExpression | character_list()
  InfoFun = undefined | fun(InfoTag) -> InfoValue
  InfoTag = indices | is_unique_objects | keypos | num_of_objects
  InfoValue = undefined | term()
  LookupFun = undefined | fun(Position, Keys) -> [term()]
  ParentFun = undefined | fun() -> ParentFunValue
  PostFun = undefined | fun() -> void()
  PreFun = undefined | fun((PreArg)) -> void()
  PreArg = {parent_value, ParentFunValue} | {stop_fun, StopFun}
  ParentFunValue = undefined | term()
  StopFun = undefined | fun() -> void()
  Position = int() > 0
  Keys = [term()]
  Mod = Fun = atom()
  Args = [term()]
\end{verbatim}
Returns a query handle for a QLC table. In Erlang/OTP there is support for ETS, Dets and Mnesia tables, but it is also possible to turn many other data structures into QLC tables. The way to accomplish this is to let function(s) in the module implementing the data structure create a query handle by calling `qlc:table/2`. The different ways to traverse the table as well as properties of the table are handled by callback functions provided as options to `qlc:table/2`.

The callback function `TraverseFun` is used for traversing the table. It is to return a list of objects terminated by either `[]` or a nullary fun to be used for traversing the not yet traversed objects of the table. Unary `TraverseFun`s are to accept a match specification as argument. The match specification is created by the parse transform by analyzing the pattern of the generator calling `qlc:table/2` and filters using variables introduced in the pattern. If the parse transform cannot find a match specification equivalent to the pattern and filters, `TraverseFun` will be called with a match specification returning every object. Modules that can utilize match specifications for optimized traversal of tables should call `qlc:table/2` with a unary `TraverseFun` while other modules can provide a nullary `TraverseFun`. `ets:table/2` is an example of the former; `gb_table:table/1` in the Implementing a QLC table [page 264] section is an example of the latter.

`PreFun` is a unary callback function that is called once before the table is read for the first time. If the call fails, the query evaluation fails. Similarly, the nullary callback function `PostFun` is called once after the table was last read. The return value, which is caught, is ignored. If `PreFun` has been called for a table, `PostFun` is guaranteed to be called for that table, even if the evaluation of the query fails for some reason. The order in which `Pre` (post) funs for different tables are evaluated is not specified. Other table access than reading, such as calling `InfoFun`, is assumed to be O.K. at any time. The argument `PreArgs` is a list of tagged values. Currently there are two tags `parent_value` and `stop_fun`, used by Mnesia for managing transactions. The value of `parent_value` is the value returned by `ParentFun`, or `undefined` if there is no `ParentFun`. `ParentFun` is called once just before the call of `PreFun` in the context of the process calling `eval`, `fold`, or `cursor`. The value of `stop_fun` is a nullary fun that deletes the cursor if called from the parent, or `undefined` if there is no cursor.

The binary callback function `LookupFun` is used for looking up objects in the table. The first argument `Position` is the key position or an index position and the second argument `Keys` is a sorted list of unique values. The return value is to be a list of all objects (tuples) such that the element at `Position` is a member of `Keys`. `LookupFun` is called instead of traversing the table if the parse transform at compile time can find out that the filters match and compare the element at `Position` in such a way that only `Keys` need to be looked up in order to find all potential answers. The key position is obtained by calling `InfoFun(keypos)` and the index positions by calling `InfoFun(indices)`. If the key position can be used for lookup it is always chosen, otherwise the index position requiring the least number of lookups is chosen. If there is a tie between two index positions the one occurring first in the list returned by `InfoFun` is chosen. Positions requiring more than `max_lookup` [page 270] lookups are ignored.

The unary callback function `InfoFun` is to return information about the table. `undefined` should be returned if the value of some tag is unknown:

- `indices`. Returns a list of indexed positions, a list of positive integers.
- `is_unique_objects`. Returns true if the objects returned by `TraverseFun` are unique.
- `keypos`. Returns the position of the table's key, a positive integer.
num_of_objects. Returns the number of objects in the table, a non-negative integer.

The unary callback function FormatFun is used by qlc:info/1,2 for displaying the call that created the table's query handle. The default value undefined is displayed as a call to '$MOD':'$FUN'/0, otherwise it is up to FormatFun to present the selected objects in a suitable way. If a character list is chosen for presentation it must be an Erlang expression that can be scanned and parsed (a trailing dot will be added by qlc:info though). The argument to FormatFun describes the optimizations done as a result of analyzing the filter(s). The possible values are:

- [lookup, Position, Keys]. LookupFun is used for looking up objects in the table.
- [match_spec, MatchExpression]. No way of finding all possible answers by looking up keys was found, but the filters could be transformed into a match specification. All answers are found by calling TraverseFun(MatchExpression).
- all. No optimization was found. A match specification matching all objects will be used if TraverseFun is unary.

See ets(3) [page 141], dets(3) [page 80] and [mnesia(3)] for the various options recognized by table/1,2 in respective module.

See Also

dets(3) [page 66], [Erlang Reference Manual], erl_eval(3) [page 100], [erlang(3)], ets(3) [page 123], [file(3)], filesorter(3) [page 143], [mnemosyne(3)], [mnesia(3)], [Programming Examples], shell(3) [page 288]
This module implements FIFO queues in an efficient manner. All operations has an amortised \( O(1) \) running time, except \( \text{len/1}, \text{reverse/1}, \text{join/2} \) and \( \text{split/2} \) that probably are \( O(n) \).

Exports

\text{cons(Item, Q1)} \to Q2

Types:
- \( \text{Item} = \text{term()} \)
- \( Q1 = Q2 = \text{queue()} \)

Inserts \text{Item} at the head of queue \( Q1 \). Returns the new queue \( Q2 \).

\text{daeh(Q)} \to \text{Item}

The same as \text{last(Q)} and the opposite of \text{head(Q)}.

\text{from_list(L)} \to \text{queue()}

Types:
- \( L = \text{list()} \)

Returns a queue containing the items in \( L \), in the same order - the head item of the list will be the head item of the queue.

\text{head(Q)} \to \text{Item}

Types:
- \( \text{Item} = \text{term()} \)
- \( Q = \text{queue()} \)

Returns \text{Item} from the head of queue \( Q \).

Fails with reason \text{empty} if \( Q \) is empty.

\text{in(Item, Q1)} \to Q2

Types:
- \( \text{Item} = \text{term()} \)
- \( Q1 = Q2 = \text{queue()} \)
Inserts Item at the tail of queue Q1. Returns a new queue Q2. This is the same as snoc(Q1, Item).

\( \text{in}_r(\text{Item}, Q1) \rightarrow Q2 \)

Types:
- Item = term()
- Q1 = Q2 = queue()

Inserts Item at the head of queue Q1. Returns a new queue Q2. This is the same as cons(Item, Q1).

\( \text{init}(Q1) \rightarrow Q2 \)

Types:
- Item = term()
- Q1 = Q2 = queue()

Returns a queue Q2 that is the result of removing the last item from Q1. This is the opposite of tail(Q1).

Fails with reason empty if Q1 is empty.

\( \text{is_empty}(Q) \rightarrow \text{true} \mid \text{false} \)

Types:
- Q = queue()

Tests if Q is empty and returns true if so and false otherwise.

\( \text{join}(Q1, Q2) \rightarrow Q3 \)

Types:
- Q1 = Q2 = Q3 = queue()

Returns a queue Q3 that is the result of joining Q1 and Q2 with Q1 before (at the head) Q2.

\( \text{la}it(Q1) \rightarrow Q2 \)

The same as \( \text{init}(Q1) \) and the opposite of tail(Q1).

\( \text{last}(Q) \rightarrow \text{Item} \)

Types:
- Item = term()
- Q = queue()

Returns the last item of queue Q. This is the opposite of head(Q).

Fails with reason empty if Q is empty.

\( \text{len}(Q) \rightarrow N \)

Types:
- Q = queue()
- N = integer()
Calculates and returns the length of queue Q.

new() -> Q
Types:
• Q = queue()
Returns an empty queue.

out(Q1) -> Result
Types:
• Result = [{value, Item}, Q2] | {empty, Q1}
• Q1 = Q2 = queue()
Removes the head item from the queue Q1. Returns the tuple [{value, Item}, Q2], where Item is the item removed and Q2 is the new queue. If Q1 is empty, the tuple {empty, Q1} is returned.

out_r(Q1) -> Result
Types:
• Result = [{value, Item}, Q2] | {empty, Q1}
• Q1 = Q2 = queue()
Removes the last item from the queue Q1. Returns the tuple [{value, Item}, Q2], where Item is the item removed and Q2 is the new queue. If Q1 is empty, the tuple {empty, Q1} is returned.

reverse(Q1) -> Q2
Types:
• Q1 = Q2 = queue()
Returns a queue Q2 that contains the items of Q1 in the reverse order.

snoc(Q1, Item) -> Q2
Types:
• Item = term()
• Q1 = Q2 = queue()
Inserts Item as the last item of queue Q1. Returns the new queue Q2. This is the opposite of cons(Item, Q1).

split(N, Q1) -> {Q2, Q3}
Types:
• N = integer()
• Q1 = Q2 = Q3 = queue()
Splits Q1 into a queue Q2 of length N with items from the head end, and a queue Q3 with the rest of the items.

tail(Q1) -> Q2
Types:
- Item = term()
- Q₁ = Q₂ = queue()

Returns a queue Q₂ that is the result of removing the head item from Q₁.
Fails with reason empty if Q₁ is empty.

to_list(Q) -> list()

Types:
- Q = queue()

Returns a list of the items in the queue, with the head item of the queue as the head of the list.

The current algorithm is a modification of the version attributed to Richard A. O'Keefe in the standard Prolog library.

Every time a random number is requested, a state is used to calculate it, and a new state produced. The state can either be implicit (kept in the process dictionary) or be an explicit argument and return value. In this implementation, the state (the type `ran()` consists of a tuple of three integers.

Exports

seed() -> ran()

Seeds random number generation with default (fixed) values in the process dictionary, and returns the old state.

seed(A1, A2, A3) -> ran()

Types:
• A1 = A2 = A3 = int()

Seeds random number generation with integer values in the process dictionary, and returns the old state.

seed0() -> ran()

Returns the default state.

uniform() -> float()

Returns a random float uniformly distributed between 0.0 and 1.0, updating the state in the process dictionary.

uniform(N) -> int()

Types:
• N = int()

Given an integer N ≥ 1, `uniform/1` returns a random integer uniformly distributed between 1 and N, updating the state in the process dictionary.
uniform(State0) -> {float(), State1}

Types:
- State0 = State1 = ran()

Given a state, uniform/1 returns a random float uniformly distributed between 0.0 and 1.0, and a new state.

uniform(N, State0) -> {int(), State1}

Types:
- N = int()
- State0 = State1 = ran()

Given an integer \( N \geq 1 \) and a state, uniform/2 returns a random integer uniformly distributed between 1 and \( N \), and a new state.

Note

Some of the functions use the process dictionary variable random_seed to remember the current seed.

If a process calls uniform/0 or uniform/1 without setting a seed first, seed/0 is called automatically.
This module contains functions for regular expression matching and substitution.

Exports

match(String, RegExp) -> MatchRes

Types:

- String = RegExp = string()
- MatchRes = {match,Start,Length} | nomatch | {error,erordesc()}
- Start = Length = integer()

Finds the first, longest match of the regular expression RegExp in String. This function searches for the longest possible match and returns the first one found if there are several expressions of the same length. It returns as follows:

- {match,Start,Length} if the match succeeded. Start is the starting position of the match, and Length is the length of the matching string.
- nomatch if there were no matching characters.
- {error,Error} if there was an error in RegExp.

first_match(String, RegExp) -> MatchRes

Types:

- String = RegExp = string()
- MatchRes = {match,Start,Length} | nomatch | {error,erordesc()}
- Start = Length = integer()

Finds the first match of the regular expression RegExp in String. This call is usually faster than match and it is also a useful way to ascertain that a match exists. It returns as follows:

- {match,Start,Length} if the match succeeded. Start is the starting position of the match and Length is the length of the matching string.
- nomatch if there were no matching characters.
- {error,Error} if there was an error in RegExp.

matches(String, RegExp) -> MatchRes

Types:

- String = RegExp = string()
- \textbf{MatchRes} = \{ \text{match, Matches} \} \mid \{ \text{error, \texttt{errordesc()}} \}
- \textbf{Matches} = \text{list()}

Finds all non-overlapping matches of the expression \texttt{RegExp} in \texttt{String}. It returns as follows:

\{ \text{match, Matches} \} if the regular expression was correct. The list will be empty if there was no match. Each element in the list looks like \{ \text{Start, Length} \}, where \text{Start} is the starting position of the match, and \text{Length} is the length of the matching string.

\{ \text{error, Error} \} if there was an error in \texttt{RegExp}.

\texttt{sub(String, RegExp, New) -> SubRes}

\textbf{Types:}
- \texttt{String} = \texttt{RegExp} = \texttt{New} = \texttt{string()}
- \textbf{SubRes} = \{ \text{ok, NewString, RepCount} \} \mid \{ \text{error, \texttt{errordesc()}} \}
- \textbf{RepCount} = \text{integer()}

Substitutes the first occurrence of a substring matching \texttt{RegExp} in \texttt{String} with the string \texttt{New}. A \& in the string \texttt{New} is replaced by the matched substring of \texttt{String}. \& puts a literal \& into the replacement string. It returns as follows:

\{ \text{ok, NewString, RepCount} \} if \texttt{RegExp} is correct. \text{RepCount} is the number of replacements which have been made (this will be either 0 or 1).

\{ \text{error, Error} \} if there is an error in \texttt{RegExp}.

\texttt{gsub(String, RegExp, New) -> SubRes}

\textbf{Types:}
- \texttt{String} = \texttt{RegExp} = \texttt{New} = \texttt{string()}
- \textbf{SubRes} = \{ \text{ok, NewString, RepCount} \} \mid \{ \text{error, \texttt{errordesc()}} \}
- \textbf{RepCount} = \text{integer()}

The same as \texttt{sub}, except that all non-overlapping occurrences of a substring matching \texttt{RegExp} in \texttt{String} are replaced by the string \texttt{New}. It returns:

\{ \text{ok, NewString, RepCount} \} if \texttt{RegExp} is correct. \text{RepCount} is the number of replacements which have been made.

\{ \text{error, Error} \} if there is an error in \texttt{RegExp}.

\texttt{split(String, RegExp) -> SplitRes}

\textbf{Types:}
- \texttt{String} = \texttt{RegExp} = \texttt{string()}
- \textbf{SubRes} = \{ \text{ok, FieldList} \} \mid \{ \text{error, \texttt{errordesc()}} \}
- \textbf{FieldList} = \text{[string()]}  

\texttt{String} is split into fields (sub-strings) by the regular expression \texttt{RegExp}. If the separator expression is " " (a single space), then the fields are separated by blanks and/or tabs and leading and trailing blanks and tabs are discarded. For all other values of the separator, leading and trailing blanks and tabs are not discarded. It returns:
{ok, FieldList} to indicate that the string has been split up into the fields of FieldList.
{error, Error} if there is an error in RegExp.

\texttt{sh\_to\_awk(ShRegExp) \rightarrow AwkRegExp}

Types:
\begin{itemize}
\item ShRegExp AwkRegExp = string()
\item SubRes = {ok, NewString, RepCount} | {error, errordesc()}
\item RepCount = integer()
\end{itemize}
Converts the sh type regular expression ShRegExp into a full AWK regular expression. Returns the converted regular expression string. sh expressions are used in the shell for matching file names and have the following special characters:

* matches any string including the null string.
? matches any single character.
[... ] matches any of the enclosed characters. Character ranges are specified by a pair of characters separated by a -. If the first character after [ is a !, then any character not enclosed is matched.

It may sometimes be more practical to use sh type expansions as they are simpler and easier to use, even though they are not as powerful.

\texttt{parse(RegExp) \rightarrow ParseRes}

Types:
\begin{itemize}
\item RegExp = string()
\item ParseRes = {ok, RE} | {error, errordesc()} \end{itemize}
 Parses the regular expression RegExp and builds the internal representation used in the other regular expression functions. Such representations can be used in all of the other functions instead of a regular expression string. This is more efficient when the same regular expression is used in many strings. It returns:

\{ok, RE\} if RegExp is correct and RE is the internal representation.
{error, Error} if there is an error in RegExpString.

\texttt{format\_error(ErrorDescriptor) \rightarrow Chars}

Types:
\begin{itemize}
\item ErrorDescriptor = errordesc()
\item Chars = [char()] | Chars
\end{itemize}
Returns a string which describes the error ErrorDescriptor returned when there is an error in a regular expression.
Regular Expressions

The regular expressions allowed here is a subset of the set found in egrep and in the AWK programming language, as defined in the book, The AWK Programming Language, by A. V. Aho, B. W. Kernighan, P. J. Weinberger. They are composed of the following characters:

- `c` matches the non-metacharacter `c`.
- `\c` matches the escape sequence or literal character `c`.
- `.` matches any character.
- `^` matches the beginning of a string.
- `$` matches the end of a string.
- `[abc...]` character class, which matches any of the characters abc... Character ranges are specified by a pair of characters separated by a `-`.
- `[^abc...]` negated character class, which matches any character except abc...
- `r1 | r2` alternation. It matches either r1 or r2.
- `r1r2` concatenation. It matches r1 and then r2.
- `r+` matches one or more rs
- `r*` matches zero or more rs
- `r?` matches zero or one rs
- `(r)` grouping. It matches r.

The escape sequences allowed are the same as for Erlang strings:

- `\b` backspace
- `\f` form feed
- `\n` newline (line feed)
- `\r` carriage return
- `\t` tab
- `\e` escape
- `\v` vertical tab
- `\s` space
- `\d` delete
- `\ddd` the octal value ddd
- `\c` any other character literally, for example `\` for backslash, `\"` for `"`)

To make these functions easier to use, in combination with the function `io:get_line` which terminates the input line with a new line, the $ characters also matches a string ending with "...\n". The following examples define Erlang data types:

Atoms     `[a-z][0-9a-zA-Z]*`

Variables `[A-Z][0-9a-zA-Z]*`

Floats    `\(+|\-)?[0-9]*\.[0-9]+((E|e)(\+|\-)?[0-9]+)?$`
Regular expressions are written as Erlang strings when used with the functions in this module. This means that any \ or " characters in a regular expression string must be written with \ as they are also escape characters for the string. For example, the regular expression string for Erlang floats is:


It is not really necessary to have the escape sequences as part of the regular expression syntax as they can always be generated directly in the string. They are included for completeness and can be useful when generating regular expressions, or when they are entered other than with Erlang strings.
Sets are collections of elements with no duplicate elements. The representation of a set is not defined.

Exports

new() -> Set
Types:
- Set = set()
Returns a new empty ordered set.

is_set(Set) -> bool()
Types:
- Set = term()
Returns true if Set is an ordered set of elements, otherwise false.

size(Set) -> int()
Types:
- Set = term()
Returns the number of elements in Set.

to_list(Set) -> List
Types:
- Set = set()
- List = [term()]
Returns the elements of Set as a list.

from_list(List) -> Set
Types:
- List = [term()]
- Set = set()
Returns an ordered set of the elements in List.

is_element(Element, Set) -> bool()
Types:
- `Element = term()`
- `Set = set()`

Returns `true` if `Element` is an element of `Set`, otherwise `false`.

`add_element(Element, Set1) -> Set2`

Types:
- `Element = term()`
- `Set1 = Set2 = set()`

Returns a new ordered set formed from `Set1` with `Element` inserted.

`del_element(Element, Set1) -> Set2`

Types:
- `Element = term()`
- `Set1 = Set2 = set()`

Returns `Set1`, but with `Element` removed.

`union(Set1, Set2) -> Set3`

Types:
- `Set1 = Set2 = Set3 = set()`

Returns the merged (union) set of `Set1` and `Set2`.

`union(SetList) -> Set`

Types:
- `SetList = [set()]`
- `Set = set()`

Returns the merged (union) set of the list of sets.

`intersection(Set1, Set2) -> Set3`

Types:
- `Set1 = Set2 = Set3 = set()`

Returns the intersection of `Set1` and `Set2`.

`intersection(SetList) -> Set`

Types:
- `SetList = [set()]`
- `Set = set()`

Returns the intersection of the non-empty list of sets.

`subtract(Set1, Set2) -> Set3`

Types:
- `Set1 = Set2 = Set3 = set()`
Returns only the elements of Set1 which are not also elements of Set2.

\[
\text{is-subset} \text{(Set1, Set2)} \rightarrow \text{bool()}
\]

Types:
- Set1 = Set2 = set()
Returns true when every element of Set1 is also a member of Set2, otherwise false.

\[
\text{fold} \text{(Function, Acc0, Set)} \rightarrow \text{Acc1}
\]

Types:
- Function = fun (E, AccIn) \rightarrow AccOut
- Acc0 = Acc1 = AccIn = AccOut = term()
- Set = set()
Fold Function over every element in Set returning the final value of the accumulator.

\[
\text{filter} \text{(Pred, Set1)} \rightarrow \text{Set2}
\]

Types:
- Pred = fun (E) \rightarrow bool()
- Set1 = Set2 = set()
Filter elements in Set1 with boolean function Fun.

See Also

ordsets(3) [page 245], gb_sets(3) [page 157]
The module shell implements an Erlang shell. The shell is a user interface program for entering expression sequences. The expressions are evaluated and a value is returned. A history mechanism saves previous commands and their values, which can then be incorporated in later commands. How many commands and results to save can be determined by the user, either interactively, by calling shell:history/1 and shell:results/1, or by setting the application configuration parameters shell:history_length and shell:saved_results for the application stdlib.

Variable bindings, and local process dictionary changes which are generated in user expressions, are preserved and the variables can be used in later commands to access their values. The bindings can also be forgotten so the variables can be re-used.

The special shell commands all have the syntax of (local) function calls. They are evaluated as normal function calls and many commands can be used in one expression sequence.

If a command (local function call) is not recognized by the shell, an attempt is first made to find the function in the module user_default, where customized local commands can be placed. If found, then the function is evaluated. Otherwise, an attempt is made to evaluate the function in the module shell_default. The module user_default must be explicitly loaded.

The shell also permits the user to start multiple concurrent jobs. A job can be regarded as a set of processes which can communicate with the shell.

There is some support for reading and printing records in the shell. During compilation record expressions are translated to tuple expressions. In runtime it is not known whether a tuple actually represents a record. Nor are the record definitions used by the compiler available at runtime. So in order to read the record syntax and print tuples as records when possible, record definitions have to be maintained by the shell itself. The shell commands for reading, defining, forgetting, listing, and printing records are described below. Note that each job has its own set of record definitions. To facilitate matters record definitions in the modules shell_default and user_default (if loaded) are read each time a new job is started. For instance, adding the line

```
-include_lib("kernel/include/file.hrl").
```

to user_default makes the definition of file_info readily available in the shell.

The shell runs in two modes:

- Normal (possibly restricted) mode, in which commands can be edited and expressions evaluated.
- Job Control Mode JCL, in which jobs can be started, killed, detached and connected.

Only the currently connected job can 'talk' to the shell.
Shell Commands

b() Prints the current variable bindings.
f() Removes all variable bindings.
f(X) Removes the binding of variable X.
h() Prints the history list.

default:

history(N) Sets the number of previous commands to keep in the history list to N. The previous number is returned. The default number is 20.
results(N) Sets the number of results from previous commands to keep in the history list to N. The previous number is returned. The default number is 20.
e(N) Repeats the command N, if N is positive. If it is negative, the Nth previous command is repeated (i.e., e(-1) repeats the previous command).
v(N) Uses the return value of the command N in the current command, if N is positive. If it is negative, the return value of the Nth previous command is used (i.e., v(-1) uses the value of the previous command).

default:

help() Evaluates shell.default:help().
c(File) Evaluates shell.default:c(File). This compiles and loads code in File and purges old versions of code, if necessary. Assumes that the file and module names are the same.

default:

rd(RecordName, RecordDefinition) Defines a record in the shell. RecordName is an atom and RecordDefinition lists the field names and the default values. Usually record definitions are made known to the shell by use of the rr commands described below, but sometimes it is handy to define records on the fly.
rf() Removes all record definitions, then reads record definitions from the modules shell.default and user.default (if loaded). Returns the names of the records defined.
rf(RecordNames) Removes selected record definitions. RecordNames is a record name or a list of record names. Use ’’ to remove all record definitions.

rl() Prints all record definitions.
rl(RecordNames) Prints selected record definitions. RecordNames is a record name or a list of record names.

rp(Term) Prints a term using the record definitions known to the shell. All of Term is printed; the depth is not limited as is the case when a return value is printed.
rr(Module) Reads record definitions from a module’s BEAM file. If there are no record definitions in the BEAM file, the source file is located and read instead. Returns the names of the record definitions read. Module is an atom.

rr(Wildcard) Reads record definitions from files. Existing definitions of any of the record names read are replaced. Wildcard is a wildcard string as defined in filelib(3) but not an atom.

rr(WildcardOrModule, RecordNames) Reads record definitions from files but discards record names not mentioned in RecordNames (a record name or a list of record names).

rr(WildcardOrModule, RecordNames, Options) Reads record definitions from files. The compiler options {i,Dir},{d,Macro}, and {d,Macro,Value} are recognized and used for setting up the include path and macro definitions. Use ’’ as value of RecordNames to read all record definitions.
Example

The following example is a long dialogue with the shell. Commands starting with `>` are inputs to the shell. All other lines are output from the shell. All commands in this example are explained at the end of the dialogue.

strider 1> erl
Erlang (BEAM) emulator version 5.3 [hipe] [threads:0]

Eshell V5.3 (abort with `Q)
1> Str = "abcd".
"abcd"
2> L = length(Str).
4
3> Descriptor = [L, list_to_atom(Str)].
{4,abcd}
4> L.
4
5> b().
Descriptor = {4,abcd}
L = 4
Str = "abcd"
ok
6> f(L).
ok
7> b().
Descriptor = {4,abcd}
Str = "abcd"
ok
8> f(L).
** 1: variable 'L' is unbound **
9> {L, _} = Descriptor.
{4,abcd}
10> L.
4
** exited: [{badmatch,[[4,abcd]],[[erl_eval,expr,3]]} **
12> P. 
** 1: variable 'P' is unbound **
13> Descriptor.
{4,abcd}
14> [P, Q] = Descriptor.
{4,abcd}
15> P.
4
16> f().
ok
17> put(aa, hello).
undefined
18> get(aa).
hello
19> Y = test1:demo(1).
20> get().
    [{aa,worked}]
21> put(aa, hello).
    worked
22> Z = test1:demo(2).

=ERROR REPORT==== 19-Feb-2003::10:04:14 ===
Error in process <0.40.0> with exit value: {{badmatch,1},
    [{test1,demo,1},
    {erl_eval,expr,4},{shell,eval_loop,2}]}
** exited: {{badmatch,1},
    [{test1,demo,1},
    {erl_eval,expr,4},{shell,eval_loop,2}]}} **
23> Z.
** 1: variable 'Z' is unbound **
24> get(aa).
    hello
25> erase(), put(aa, hello).
    undefined
26> spawn(test1, demo, [1]).
    <0.57.0>
27> get(aa).
    hello
28> io:format("hello hello
").
    hello hello
    ok
29> e(28).
    hello hello
    ok
30> v(28).
    ok
31> c(ex).
    {ok,ex}
32> rr(ex).
    [rec]
33> rl(rec).
    -record(rec, {a,
          b = val()}).
    ok
34> #rec{}.
** exited: {undef,[{shell_default,val,[]}],
    {erl_eval,do_apply,5},
    {erl_eval,expr_list,6},
    {erl_eval,expr,5},
    {shell,eval_loop,2}]} **
35> #rec{b = 3}.
    {rec,undefined,3}
36> rp(v(-1)).
    #rec{a = undefined,
          b = 3}
    ok
37> rd(rec, {f = orddict:new()}).
    rec
38> rp(#rec{}).
    #rec{f = []}
ok
39> rd(rec, {c}), A.
** 1: variable 'A' is unbound **
40> rp(#rec{}).
#rec{c = undefined}
ok
41> test1:loop(0).
Hello Number: 0
Hello Number: 1
Hello Number: 2
Hello Number: 3

User switch command
  --> i
  --> c
  
Hello Number: 3374
Hello Number: 3375
Hello Number: 3376
Hello Number: 3377
Hello Number: 3378
** exited: killed **
42> halt().
strider 2>

Comments

Command 1 sets the variable Str to the string "abcd".
Command 2 sets L to the length of the string evaluating the BIF atom_to_list.
Command 3 builds the tuple Descriptor.
Command 4 prints the value of the variable L.
Command 5 evaluates the internal shell command b(), which is an abbreviation of "bindings". This prints the current shell variables and their bindings. The ok at the end is the return value of the b() function.
Command 6 f(L) evaluates the internal shell command f(L) (abbreviation of “forget”). The value of the variable L is removed.
Command 7 prints the new bindings.
Command 8 shows that L is no longer bound to a value.
Command 9 performs a pattern matching operation on Descriptor, binding a new value to L.
Command 10 prints the current value of L.
Command 11 tries to match {P, Q, R} against Descriptor which is {4, abc}. The match fails and none of the new variables become bound. The printout starting with "** exited:" is not the value of the expression (the expression had no value because its evaluation failed), but rather a warning printed by the system to inform the user that an error has occurred. The values of the other variables (L, Str, etc.) are unchanged.
Commands 12 and 13 show that \( P \) is unbound because the previous command failed, and that \texttt{Descriptor} has not changed.

Commands 14 and 15 show a correct match where \( P \) and \( Q \) are bound.

Command 16 clears all bindings.

The next few commands assume that \texttt{test1:demo(X)} is defined in the following way:

\[
\texttt{demo(X) -> put(aa, worked), X = 1, X + 10.}
\]

Commands 17 and 18 set and inspect the value of the item \texttt{aa} in the process dictionary.

Command 19 evaluates \texttt{test1:demo(1)}. The evaluation succeeds and the changes made in the process dictionary become visible to the shell. The new value of the dictionary item \texttt{aa} can be seen in command 20.

Commands 21 and 22 change the value of the dictionary item \texttt{aa} to \texttt{hello} and call \texttt{test1:demo(2)}. Evaluation fails and the changes made to the dictionary in \texttt{test1:demo(2)}, before the error occurred, are discarded.

Commands 23 and 24 show that \( Z \) was not bound and that the dictionary item \texttt{aa} has retained its original value.

Commands 25, 26 and 27 show the effect of evaluating \texttt{test1:demo(1)} in the background. In this case, the expression is evaluated in a newly spawned process. Any changes made in the process dictionary are local to the newly spawned process and therefore not visible to the shell.

Commands 28, 29 and 30 use the history facilities of the shell.

Command 29 is \texttt{e(28)}. This re-evaluates command 28. Command 30 is \texttt{v(28)}. This uses the value (result) of command 28. In the cases of a pure function (a function with no side effects), the result is the same. For a function with side effects, the result can be different.

The next few commands show some record manipulation. It is assumed that \texttt{ex.erl} defines a record like this:

\[
\texttt{-record(rec, f(a, b = val())).}
\]

\[
\texttt{val() -> 3.}
\]

Commands 31 and 32 compiles the file \texttt{ex.erl} and reads the record definitions in \texttt{ex.beam}. If the compiler did not output any record definitions on the BEAM file, \texttt{rr(ex)} tries to read record definitions from the source file instead.

Command 33 prints the definition of the record named \texttt{rec}.

Command 34 tries to create a \texttt{rec} record, but fails since the function \texttt{val/0} is undefined. Command 35 shows the workaround: explicitly assign values to record fields that cannot otherwise be initialized.

Command 36 prints the newly created record using record definitions maintained by the shell.

Command 37 defines a record directly in the shell. The definition replaces the one read from the file \texttt{ex.beam}.

Command 38 creates a record using the new definition, and prints the result.
Command 39 and 40 show that record definitions are updated as side effects. The evaluation of the command fails but the definition of `rec` has been carried out.

For the next command, it is assumed that `test1:loop(N)` is defined in the following way:

```erlang
loop(N) ->
    io:format("Hello Number: ~w~n", [N]),
    loop(N+1).
```

Command 41 evaluates `test1:loop(0)`, which puts the system into an infinite loop. At this point the user types `Control G`, which suspends output from the current process, which is stuck in a loop, and activates JCL mode. In JCL mode the user can start and stop jobs.

In this particular case, the `i` command ("interrupt") is used to terminate the looping program, and the `c` command is used to connect to the shell again. Since the process was running in the background before we killed it, there will be more printouts before the "** exited: killed **" message is shown.

The `halt()` command exits the Erlang runtime system.

**JCL Mode**

When the shell starts, it starts a single evaluator process. This process, together with any local processes which it spawns, is referred to as a *job*. Only the current job, which is said to be *connected*, can perform operations with standard IO. All other jobs, which are said to be *detached*, are blocked if they attempt to use standard IO.

All jobs which do not use standard IO run in the normal way.

The shell escape key `^G` (Control G) detaches the current job and activates JCL mode. The JCL mode prompt is "--->". If "?" is entered at the prompt, the following help message is displayed:

```
---> ?
c [nn] - connect to job
i [nn] - interrupt job
k [nn] - kill job
j - list all jobs
s - start local shell
r [node] - start remote shell
q - quit Erlang
? | h - this message
```

The JCL commands have the following meaning:

- `c [nn]` Connects to job number `<nn>` or the current job. The standard shell is resumed. Operations which use standard IO by the current job will be interleaved with user inputs to the shell.
- `i [nn]` Stops the current evaluator process for job number `nn` or the current job, but does not kill the shell process. Accordingly, any variable bindings and the process dictionary will be preserved and the job can be connected again. This command can be used to interrupt an endless loop.
k \[nn\] Kills job number \(nn\) or the current job. All spawned processes in the job are killed, provided they have not evaluated the group_leader/1 BIF and are located on the local machine. Processes spawned on remote nodes will not be killed.

j Lists all jobs. A list of all known jobs is printed. The current job name is prefixed with '*'.

s Starts a new job. This will be assigned the new index \[nn\] which can be used in references.

r \[node\] Starts a remote job on \(node\). This is used in distributed Erlang to allow a shell running on one node to control a number of applications running on a network of nodes.

q Quits Erlang. Note that this option is disabled if Erlang is started with the ignore break, +Bi, system flag (which may be useful e.g. when running a restricted shell, see below).

? Displays this message.

It is possible to alter the behaviour of shell escape by means of the stdlib application variable shell_esc. The value of the variable can be either jcl \(\text{erl -stdlib shell_esc jcl}\) or abort \(\text{erl -stdlib shell_esc abort}\). The first option sets ^G to activate JCL mode (which is also default behaviour). The latter sets ^G to terminate the current shell and start a new one. JCL mode can not be invoked when shell_esc is set to abort.

If you want an Erlang node to have a remote job active from the start (rather than the default local job), you start Erlang with the -remsh flag. Example: \(\text{erl -sname this_node -remsh other_node@other_host}\)

### Restricted Shell

The shell may be started in a restricted mode. In this mode, the shell evaluates a function call only if allowed. This feature makes it possible to, for example, prevent a user from accidentally calling a function from the prompt that could harm a running system (useful in combination with the the system flag +Bi).

When the restricted shell evaluates an expression and encounters a function call, it calls a predicate function (with information about the function call in question). This predicate function returns true to let the shell go ahead with the evaluation, or false to abort it. There are two possible predicate functions for the user to implement:

```erlang
local_allowed(Func, ArgList, State) -> \{true,NewState\} | \{false,NewState\}
```

To determine if the call to the local function \(Func\) with arguments \(ArgList\) should be allowed.

```erlang
non_local_allowed(FuncSpec, ArgList, State) -> \{true,NewState\} | \{false,NewState\}
```

To determine if the call to non-local function \(FuncSpec\) (\(\{Module,Func\}\) or a fun) with arguments \(ArgList\) should be allowed.

These predicate functions are in fact called from local and non-local evaluation function handlers, described in the erl_eval [page 100] manual page. (Arguments in \(ArgList\) are evaluated before the predicates are called).

The State argument is a tuple \(\{ShellState,ExprState\}\). The return value \(NewState\) has the same form. This may be used to carry a state between calls to the predicate...
functions. Data saved in ShellState lives through an entire shell session. Data saved in ExprState lives only through the evaluation of the current expression.

There are two ways to start a restricted shell session:

- Use the stdlib application variable restricted_shell and specify, as its value, the name of the predicate function module. Example (with predicate functions implemented in pred_mod.erl):
  $$ \text{erl -stdlib restricted_shell pred_mod} $$
- From a normal shell session, call function shell:start_restricted/1. This exits the current evaluator and starts a new one in restricted mode.

Notes:

- When restricted shell mode is activated or deactivated, new jobs started on the node will run in restricted or normal mode respectively.
- If restricted mode has been enabled on a particular node, remote shells connecting to this node will also run in restricted mode.
- The predicate functions can not be used to allow or disallow execution of functions called from compiled code (only functions called from expressions entered at the shell prompt).

Exports

**history**(N) -> integer()

Types:

- N = integer()

Sets the number of previous commands to keep in the history list to N. The previous number is returned. The default number is 20.

**results**(N) -> integer()

Types:

- N = integer()

Sets the number of results from previous commands to keep in the history list to N. The previous number is returned. The default number is 20.

**start_restricted**(Module) -> ok

Types:

- Module = atom()

Exits a normal shell and starts a restricted shell. Module specifies the module for the predicate functions local_allowed/3 and non_local_allowed/3. The function is meant to be called from the shell.

**stop_restricted**() -> ok

Exits a restricted shell and starts a normal shell. The function is meant to be called from the shell.
The functions in `shell_default` are called when no module name is given in a shell command. Consider the following shell dialogue:

```
1 > lists:reverse("abc").
"cba"
2 > c(foo).
{ok, foo}
```

In command one, the module `lists` is called. In command two, no module name is specified. The shell searches the modules `user_default` followed by `shell_default` for the function `foo/1`.

`shell_default` is intended for "system wide" customizations to the shell. `user_default` is intended for "local" or individual user customizations.

**Hint**

To add your own commands to the shell, create a module called `user_default` and add the commands you want. Then add the following line as the first line in your `.erlang` file in your home directory:

```
code:load_abs("$PATH/user_default").
```

`$PATH` is the directory where your `user_default` module can be found.
This module provides functions for starting Erlang slave nodes. All slave nodes which are started by a master will terminate automatically when the master terminates. All TTY output produced at the slave will be sent back to the master node. File I/O is done via the master.

Slave nodes on other hosts than the current one are started with the program `rsh`. The user must be allowed to `rsh` to the remote hosts without being prompted for a password. This can be arranged in a number of ways (refer to the `rsh` documentation for details). A slave node started on the same host as the master inherits certain environment values from the master, such as the current directory and the environment variables. For what can be assumed about the environment when a slave is started on another host, read the documentation for the `rsh` program.

An alternative to the `rsh` program can be specified on the command line to `erl` as follows: `-rsh Program`.

The slave node should use the same file system at the master. At least, Erlang/OTP should be installed in the same place on both computers and the same version of Erlang should be used.

Currently, a node running on Windows NT can only start slave nodes on the host on which it is running.

The master node must be alive.

Exports

```erlang
start(Host) ->
start(Host, Name) ->
start(Host, Name, Args) -> {ok, Node} | {error, Reason}
```

Types:
- `Host = Name = atom()`
- `Args = string()`
- `Node = node()`
- `Reason = timeout | no_rsh | {already_running, Node}`
Starts a slave node on the host Host. Host names need not necessarily be specified as fully qualified names; short names can also be used. This is the same condition that applies to names of distributed Erlang nodes.

The name of the started node will be Name@Host. If no name is provided, the name will be the same as the node which executes the call (with the exception of the host name part of the node name).

The slave node resets its user process so that all terminal I/O which is produced at the slave is automatically relayed to the master. Also, the file process will be relayed to the master.

The Arg argument is used to set erl command line arguments. If provided, it is passed to the new node and can be used for a variety of purposes. See [erl(1)]

As an example, suppose that we want to start a slave node at host H with the node name Name@H, and we also want the slave node to have the following properties:

- directory Dir should be added to the code path;
- the Mnesia directory should be set to M;
- the unix DISPLAY environment variable should be set to the display of the master node.

The following code is executed to achieve this:

```
E = " -env DISPLAY " ++ net_adm:localhost() ++ ":0 ",
Arg = "-mnesia_dir " ++ M ++ " -pa " ++ Dir ++ E,
slave:start(H, Name, Arg).
```

If successful, the function returns {ok, Node}, where Node is the name of the new node. Otherwise it returns {error, Reason}, where Reason can be one of:

- timeout The master node failed to get in contact with the slave node. This can happen in a number of circumstances:
  - Erlang/OTP is not installed on the remote host
  - the file system on the other host has a different structure to the the master
  - the Erlang nodes have different cookies.

- no_rsh There is no rsh program on the computer.

- {already_running, Node} A node with the name Name@Host already exists.

```
start_link(Host) ->
start_link(Host, Name) ->
start_link(Host, Name, Args) -> {ok, Node} | {error, Reason}
```

Types:

- Host = Name = atom()
- Args = string()
- Node = node()
- Reason = timeout | no_rsh | {already_running, Node}

Starts a slave node in the same way as start/1,2,3, except that the slave node is linked to the currently executing process. If that process terminates, the slave node also terminates.

See start/1,2,3 for a description of arguments and return values.
stop(Node) -> ok
Types:
- Node = node()
Stops (kills) a node.

pseudo([Master | ServerList]) -> ok
Types:
- Master = node()
- ServerList = [atom()]
Calls pseudo(Master, ServerList). If we want to start a node from the command line and set up a number of pseudo servers, an Erlang runtime system can be started as follows:

```
% erl -name abc -s slave pseudo klacke@super x --
```

pseudo(Master, ServerList) -> ok
Types:
- Master = node()
- ServerList = [atom()]
Starts a number of pseudo servers. A pseudo server is a server with a registered name which does absolutely nothing but pass on all message to the real server which executes at a master node. A pseudo server is an intermediary which only has the same registered name as the real server.

For example, if we have started a slave node N and want to execute pxw graphics code on this node, we can start the server pxw_server as a pseudo server at the slave node. The following code illustrates:

```
rpc:call(N, slave, pseudo, [node(), [pxw_server]])
```

relay(Pid)
Types:
- Pid = pid()
Runs a pseudo server. This function never returns any value and the process which executes the function will receive messages. All messages received will simply be passed on to Pid.
The **sofs** module implements operations on finite sets and relations represented as sets. Intuitively, a set is a collection of elements; every element belongs to the set, and the set contains every element.

Given a set \( A \) and a sentence \( S(x) \), where \( x \) is a free variable, a new set \( B \) whose elements are exactly those elements of \( A \) for which \( S(x) \) holds can be formed, this is denoted \( B = \{ x \in A : S(x) \} \). Sentences are expressed using the logical operators “for some” (or “there exists”), “for all”, “and”, “or”, “not”. If the existence of a set containing all the specified elements is known (as will always be the case in this module), we write \( B = \{ x : S(x) \} \).

The unordered set containing the elements \( a, b \) and \( c \) is denoted \( \{a,b,c\} \). This notation is not to be confused with tuples. The ordered pair of \( a \) and \( b \), with first coordinate \( a \) and second coordinate \( b \), is denoted \( (a,b) \). An ordered pair is an ordered set of two elements. In this module ordered sets can contain one, two or more elements, and parentheses are used to enclose the elements. Unordered sets and ordered sets are orthogonal, again in this module; there is no unordered set equal to any ordered set.

The set that contains no elements is called the empty set. If two sets \( A \) and \( B \) contain the same elements, then \( A \) is equal to \( B \), denoted \( A = B \). Two ordered sets are equal if they contain the same number of elements and have equal elements at each coordinate. If a set \( A \) contains all elements that \( B \) contains, then \( B \) is a subset of \( A \). The union of two sets \( A \) and \( B \) is the smallest set that contains all elements of \( A \) and all elements of \( B \). The intersection of two sets \( A \) and \( B \) is the set that contains all elements of \( A \) that belong to \( B \). Two sets are disjoint if their intersection is the empty set. The difference of two sets \( A \) and \( B \) is the set that contains all elements of \( A \) that do not belong to \( B \). The symmetric difference of two sets is the set that contains those element that belong to either of the two sets, but not both. The union of a collection of sets is the smallest set that contains all the elements that belong to at least one set of the collection. The intersection of a non-empty collection of sets is the set that contains all elements that belong to every set of the collection.

The Cartesian product of two sets \( X \) and \( Y \), denoted \( X \times Y \), is the set \( \{ a = (x,y) \mid \text{for some } x \in X \text{ and for some } y \in Y \} \). A relation is a subset of \( X \times Y \). Let \( R \) be a relation. The fact that \( (x,y) \) belongs to \( R \) is written as \( xRy \). Since relations are sets, the definitions of the last paragraph (subset, union, and so on) apply to relations as well. The domain of \( R \) is the set \( \{ x \mid (x,y) \in R \text{ for some } y \} \). The range of \( R \) is the set \( \{ y \mid (x,y) \in R \text{ for some } x \} \). The converse of \( R \) is the set \( \{ a = (y,x) \mid (x,y) \in R \} \). The image of \( A \) under \( R \) is the set \( \{ y \mid (x,y) \in R \text{ for some } x \in A \} \), and if \( B \) is a subset of \( Y \), then the inverse image of \( B \) is the set \( \{ x \mid (x,y) \in R \text{ for some } y \in B \} \). If \( R \) is a relation from \( X \) to \( Y \) and \( S \) is a relation from \( Y \) to \( Z \), then the relative product of \( R \) and \( S \) is the relation \( T \) from \( X \) to \( Z \) defined so that \( xTz \) if and only if there exists an element \( y \) in \( Y \) such that \( xRy \) and \( ySz \). The restriction of \( R \) to \( A \) is the set \( S \) defined so that \( xSy \) if and only if there exists an element \( x \) in \( A \) such that \( xRy \). If \( S \) is a restriction of \( R \) to \( A \), then \( R \) is an extension of \( S \) to \( X \). If \( X = Y \) then we call \( R \) a relation in \( X \). The field of a relation \( R \) in \( X \) is the union of \( X \) and \( \{ y \mid (x,y) \in R \text{ for some } x \in X \} \).
the domain of $R$ and the range of $R$. If $R$ is a relation in $X$, and if $S$ is defined so that $xSy$ if $xRy$ and not $x=y$, then $S$ is the strict relation corresponding to $R$, and vice versa, if $S$ is a relation in $X$, and if $R$ is defined so that $xRy$ if $xSy$ or $x=y$, then $R$ is the weak relation corresponding to $S$. A relation $R$ in $X$ is reflexive if $xRx$ for every element $x$ of $X$; it is symmetric if $xRy$ implies that $yRx$; and it is transitive if $xRy$ and $yRz$ imply that $xRz$.

A function $F$ is a relation, a subset of $XY$, such that the domain of $F$ is equal to $X$ and such that for every $x$ in $X$ there is a unique element $y$ in $Y$ with $(x,y)$ in $F$. The latter condition can be formulated as follows: if $xFy$ and $xFz$ then $y=z$. In this module, it will not be required that the domain of $F$ be equal to $X$ for a relation to be considered a function. Instead of writing $(x,y)\in F$ or $xFy$, we write $F(x)=y$ when $F$ is a function, and say that $F$ maps $x$ onto $y$, or that the value of $F$ at $x$ is $y$. Since functions are relations, the definitions of the last paragraph (domain, range, and so on) apply to functions as well. If the converse of a function $F$ is a function $F'$, then $F'$ is called the inverse of $F$.

The relative product of two functions $F_1$ and $F_2$ is called the composite of $F_1$ and $F_2$ if the range of $F_1$ is a subset of the domain of $F_2$. Sometimes, when the range of a function is more important than the function itself, the function is called a family. The domain of a family is called the index set, and the range is called the indexed set. If $x$ is a family from $I$ to $X$, then $x[i]$ denotes the value of the function at index $i$. The notation “a family in $X$” is used for such a family. When the indexed set is a set of subsets of a set $X$, then we call $x$ a family of subsets of $X$. If $x$ is a family of subsets of $X$, then the union of the range of $x$ is called the union of the family $x$. If $x$ is non-empty (the index set is non-empty), the intersection of the family $x$ is the intersection of the range of $x$. In this module, the only families that will be considered are families of subsets of some set $X$; in the following the word “family” will be used for such families of subsets.

A partition of a set $X$ is a collection $S$ of non-empty subsets of $X$ whose union is $X$ and whose elements are pairwise disjoint. A relation in a set is an equivalence relation if it is reflexive, symmetric and transitive. If $R$ is an equivalence relation in $X$, and $x$ is an element of $X$, the equivalence class of $x$ with respect to $R$ is the set of all those elements $y$ of $X$ for which $xRy$ holds. The equivalence classes constitute a partitioning of $X$. Conversely, if $C$ is a partition of $X$, then the relation that holds for any two elements of $X$ if they belong to the same equivalence class, is an equivalence relation induced by the partition $C$. If $R$ is an equivalence relation in $X$, then the canonical map is the function that maps every element of $X$ onto its equivalence class.

Relations as defined above (as sets of ordered pairs) will form now on be referred to as binary relations. We call a set of ordered sets $(x[1],...,x[n])$ an (n-ary) relation, and say that the relation is a subset of the Cartesian product $X[1]...X[n]$ where $x[i]$ is an element of $X[i]$, $1<i<n$. The projection of an n-ary relation $R$ onto coordinate $i$ is the set $\{x[i] : (x[1],...,x[i],...,x[n]) \in R\}$ for some $x[j]$ in $X[j]$, $1<j<n$ and not $i=j$. The projections of a binary relation $R$ onto the first and second coordinates are the domain and the range of $R$ respectively. The relative product of binary relations can be generalized to n-ary relations as follows. Let $TR$ be an ordered set $(R[1],...,R[n])$ of binary relations from $X$ to $Y[i]$ and $S$ a binary relation from $(Y[1]...Y[n])$ to $Z$. The relative product of $TR$ and $S$ is the binary relation $T$ from $X$ to $Z$ defined so that $xTz$ if and only if there exists an element $y[i]$ in $Y[i]$ for each $1<i<n$ such that $xR[i]y[i]$ and $y[1]...y[n]Sz$. Now let $TR$ be a an ordered set $(R[1],...,R[n])$ of binary relations from $X[i]$ to $Y[i]$ and $S$ a subset of $X[1]...X[n]$. The multiple relative product of $TR$ and $S$ is defined to be the set $\{z: z=(x[1],...,x[n]), (y[1],...,y[n]) for some (x[1],...,x[n]) in S and for some (x[i],y[i]) in R[i], 1<i<n\}$. The natural join of an n-ary relation $R$ and an m-ary relation $S$ on coordinate $i$ and $j$ is defined to be the set $\{z$:...
The sets recognized by this module will be represented by elements of the relation Sets, defined as the smallest set such that:

- for every atom T except ‘_’ and for every term X, \((T,X)\) belongs to Sets (atomic sets);
- \([\text{'_'},\text{[]}\]) belongs to Sets (the untyped empty set);
- for every tuple \(T = \{T[1],\ldots,T[n]\}\) and for every tuple \(X = \{X[1],\ldots,X[n]\}\), if \((T[i],X[i])\) belongs to Sets for every \(1 \leq i \leq n\) then \((T,X)\) belongs to Sets (ordered sets);
- for every term T, if X is the empty list or a non-empty sorted list \([X[1],\ldots,X[n]]\) without duplicates such that \((T,X[i])\) belongs to Sets for every \(1 \leq i \leq n\), then \((\{T\},X)\) belongs to Sets (typed unordered sets).

An external set is an element of the range of Sets. A type is an element of the domain of Sets. If \(S\) is an element \((T,X)\) of Sets, then \(T\) is a valid type of \(X\), \(T\) is the type of \(S\), and \(X\) is the external set of \(S\). The function Term/2 [page 312] creates a set from a type and an Erlang term turned into an external set.

The actual sets represented by Sets are the elements of the range of the function Set from Sets to Erlang terms and sets of Erlang terms:

- \(\text{Set}(T,\text{Term}) = \text{Term}\), where \(T\) is an atom;
- \(\text{Set}([T[1],\ldots,T[n]],[X[1],\ldots,X[n]]) = (\text{Set}(T[1],X[1]),\ldots,\text{Set}(T[n],X[n]))\);
- \(\text{Set}([T],[X[1],\ldots,X[n]]) = (\text{Set}(T,X[1]),\ldots,\text{Set}(T,X[n]))\);
- \(\text{Set}([T],[]) = \text{[]}\).

When there is no risk of confusion, elements of Sets will be identified with the sets they represent. For instance, if \(U\) is the result of calling union/2 with \(S1\) and \(S2\) as arguments, then \(U\) is said to be the union of \(S1\) and \(S2\). A more precise formulation would be that \(\text{Set}(U)\) is the union of \(\text{Set}(S1)\) and \(\text{Set}(S2)\).

The types are used to implement the various conditions that sets need to fulfill. As an example, consider the relative product of two sets \(R\) and \(S\), and recall that the relative product of \(R\) and \(S\) is defined if \(R\) is a binary relation to \(Y\) and \(S\) is a binary relation from \(Y\). The function that implements the relative product, relative_product/2 [page 319], checks that the arguments represent binary relations by matching \([A,B]\) against the type of the first argument (Arg1 say), and \([C,D]\) against the type of the second argument (Arg2 say). The fact that \([A,B]\) matches the type of \(\text{Arg1}\) is to be interpreted as \(\text{Arg1}\) representing a binary relation from \(X\) to \(Y\), where \(X\) is defined as all sets \(\text{Set}(x)\) for some element \(x\) in \(\text{Sets}\) the type of which is \(A\), and similarly for \(Y\). In the same way \(\text{Arg2}\) is interpreted as representing a binary relation from \(W\) to \(Z\). Finally it is checked that \(B\) matches \(C\), which is sufficient to ensure that \(W\) is equal to \(Y\). The untyped empty set is handled separately: its type, ‘_’, matches the type of any unordered set.

A few functions of this module (drestriction/3, family_projection/2, partition/2, partition_family/2, projection/2, restriction/3, substitution/2) accept an Erlang function as a means to modify each element of a given unordered set. Such a function, called SetFun in the following, can be specified as a functional object (fun), a tuple \(\{\text{external},\text{Fun}\}\), or an integer. If SetFun is specified as a fun, the fun is applied to each element of the given set and the return value is
assumed to be a set. If SetFun is specified as a tuple \{external, Fun\}, Fun is applied to
the external set of each element of the given set and the return value is assumed to be
an external set. Selecting the elements of an unordered set as external sets and
assembling a new unordered set from a list of external sets is in the present
implementation more efficient than modifying each element as a set. However, this
optimization can only be utilized when the elements of the unordered set are atomic or
ordered sets. It must also be the case that the type of the elements matches some clause
of Fun (the type of the created set is the result of applying Fun to the type of the given
set), and that Fun does nothing but selecting, duplicating or rearranging parts of the
elements. Specifying a SetFun as an integer I is equivalent to specifying \{external,
f\(\text{element}(I,X)\)\}, but is to be preferred since it makes it possible to handle
this case even more efficiently. Examples of SetFuns:

\{\text{sofs}, \text{union}\}
\text{fun}(S) \to \text{sofs:partition}(1, S) \text{ end}
\{\text{external}, \text{fun}(A) \to A \text{ end}\}
\{\text{external}, \text{fun}([A,_,C]) \to [C,A] \text{ end}\}
\{\text{external}, \text{fun}([_,[_,C]]) \to C \text{ end}\}
\{\text{external}, \text{fun}([_,[_,[_,E]=C]]) \to [E,[E,C]] \text{ end}\}

The order in which a SetFun is applied to the elements of an unordered set is not
specified, and may change in future versions of sofs.

The execution time of the functions of this module is dominated by the time it takes to
sort lists. When no sorting is needed, the execution time is in the worst case
proportional to the sum of the sizes of the input arguments and the returned value. A
few functions execute in constant time: \text{from_external}, \text{is_empty_set}, \text{is_set},
\text{is_set}, \text{to_external}, \text{type}.

The functions of this module exit the process with a \text{badarg}, \text{bad_function}, or
\text{type_mismatch} message when given badly formed arguments or sets the types of which
are not compatible.

Types

\text{anyset()} = \text{an unordered, ordered or atomic set-}
\text{binary_relation()} = \text{a binary relation-}
\text{bool()} = \text{true | false}
\text{external_set()} = \text{an external set-}
\text{family()} = \text{a family (of subsets)-}
\text{function()} = \text{a function-}
\text{ordset()} = \text{an ordered set-}
\text{relation()} = \text{an n-ary relation-}
\text{set()} = \text{an unordered set-}
\text{set_of_sets()} = \text{an unordered set of set()-}
\text{set_fun()} = \text{integer() \geq 1}
| \{\text{external}, \text{fun}(\text{external_set()}) \to \text{external_set()}
| \text{fun(anyset())} \to \text{anyset()}
\text{spec_fun()} = \{\text{external}, \text{fun}(\text{external_set()}) \to \text{bool()}
| \text{fun(anyset())} \to \text{bool()}
\text{type()} = \text{a type-}
Exports

a_function(Tuples [, Type]) -> Function

Types:
- Function = function()
- Tuples = [tuple()]
- Type = type()

Creates a function [page 302]. a_function(F, T) is equivalent to from_term(F, T), if
the result is a function. If no type [page 303] is explicitly given, [{atom, atom}] is used
as type of the function.

canonical_relation(SetOfSets) -> BinRel

Types:
- BinRel = binary_relation()
- SetOfSets = set_of_sets()

Returns the binary relation containing the elements (E, Set) such that Set belongs to
SetOfSets and E belongs to Set. If SetOfSets is a partition [page 302] of a set X and R
is the equivalence relation in X induced by SetOfSets, then the returned relation is the
canonical map [page 302] from X onto the equivalence classes with respect to R.

1> Ss = sofs:from_term([[a,b],[b,c]]),
   CR = sofs:canonical_relation(Ss),
   sofs:to_external(CR).
   [{[a,[a,b]], [b,[a,b]], [b,[b,c]], [c,[b,c]]}]

composite(Function1, Function2) -> Function3

Types:
- Function1 = Function2 = Function3 = function()

Returns the composite [page 302] of the functions Function1 and Function2.

1> F1 = sofs:a_function([[a,1],[b,2],[c,2]]),
   F2 = sofs:a_function([[1,x],[2,y],[3,z]]),
   F = sofs:composite(F1, F2),
   sofs:to_external(F).
   [[a,x],[b,y],[c,y]]

constant_function(Set, AnySet) -> Function

Types:
- AnySet = anyset()
- Function = function()
- Set = set()

Creates the function [page 302] that maps each element of the set Set onto AnySet.
1 > S = sofs:set([a,b]),
E = sofs:from_term(1),
R = sofs:constant_function(S, E),
sofs:to_external(R).
[\{a,1\},\{b,1\}]

converse(BinRel1) -> BinRel2

Types:
* BinRel1 = BinRel2 = binary_relation()

Returns the converse [page 301] of the binary relation BinRel1.

1 > R1 = sofs:relation([\{1,a\},\{2,b\},\{3,c\}]),
R2 = sofs:converse(R1),
sofs:to_external(R2).
[\{a,1\},\{a,3\},\{b,2\}]

difference(Set1, Set2) -> Set3

Types:
* Set1 = Set2 = Set3 = set()

Returns the difference [page 301] of the sets Set1 and Set2.

digraph_to_family(Graph [, Type]) -> Family

Types:
* Graph = digraph() -see digraph(3)-
* Family = family()
* Type = type()

Creates a family [page 302] from the directed graph Graph. Each vertex a of Graph is represented by a pair (a, [b[1], ..., b[n]]) where the b[i]'s are the out-neighbours of a. If no type is explicitly given, \{[atom],[atom]\} is used as type of the family. It is assumed that Type is a valid type [page 303] of the external set of the family.

If G is a directed graph, it holds that the vertices and edges of G are the same as the vertices and edges of family_to_digraph(digraph_to_family(G)).

domain(BinRel) -> Set

Types:
* BinRel = binary_relation()
* Set = set()

Returns the domain [page 301] of the binary relation BinRel.

1 > R = sofs:relation([\{1,a\},\{1,b\},\{2,b\},\{2,c\}]),
S = sofs:domain(R),
sofs:to_external(S).
[1,2]

drestriction(BinRel1, Set) -> BinRel2

Types:
BinRel1 = BinRel2 = binary_relation()
Set = set()

Returns the difference between the binary relation BinRel1 and the restriction [page 301] of BinRel1 to Set.

1> R1 = sofs:relation([[[1,a],[2,b],[3,c]]]),
   S = sofs:set([2,4,6]),
   R2 = sofs:drestriction(R1, S),
   sofs:to_external(R2).
   [(1,a),[3,c]]

drestriction(R, S) is equivalent to difference(R, restriction(R, S)).

drestriction(SetFun, Set1, Set2) -> Set3

Types:
SetFun = set_fun()
Set1 = Set2 = Set3 = set()

Returns a subset of Set1 containing those elements that do not yield an element in Set2
as the result of applying SetFun.

1> SetFun = {external, fun({A,B,C}) -> {B,C} end},
   R1 = sofs:relation([[[a,aa,1],[b,bb,2],[c,cc,3]]]),
   R2 = sofs:relation([[[bb,2],[cc,3],[dd,4]]]),
   R3 = sofs:drestriction(SetFun, R1, R2),
   sofs:to_external(R3).
   [[a,aa,1]]

drestriction(F, S1, S2) is equivalent to difference(S1, restriction(F, S1, S2)).

empty_set() -> Set

Types:
Set = set()

Returns the untyped empty set [page 303]. empty_set() is equivalent to
from_term([], []).

extension(BinRel1, Set, AnySet) -> BinRel2

Types:
AnySet = anyset()
BinRel1 = BinRel2 = binary_relation()
Set = set()

Returns the extension [page 301] of BinRel1 such that for each element E in Set that
does not belong to the domain [page 301] of BinRel1, BinRel2 contains the pair
(E, AnySet).

1> S = sofs:set([b,c]),
   A = sofs:empty_set(),
   R = sofs:family([[[a,[1,2]],{b,[3]]}]),
   X = sofs:extension(R, S, A),
   sofs:to_external(X).
   [[a,[1,2]],[b,[3]],[c,[]]]
family(Tuples [, Type]) -> Family

Types:
- Family = family()
- Tuples = [tuple()]
- Type = type()

Creates a family of subsets [page 302]. family(F,T) is equivalent to from_term(F,T), if the result is a family. If no type [page 303] is explicitly given, [{atom, [atom]}] is used as type of the family.

family_difference(Family1, Family2) -> Family3

Types:
- Family1 = Family2 = Family3 = family()

If Family1 and Family2 are families [page 302], then Family3 the family such that the index set is equal to the index set of Family1, and Family3[i] is the difference between Family1[i] and Family2[i] if Family2 maps i, Family1[i] otherwise.

family_domain(Family1) -> Family2

Types:
- Family1 = Family2 = family()

If Family1 is a family [page 302] and Family1[i] is a binary relation for every i in the index set of Family1, then Family2 is the family with the same index set as Family1 such that Family2[i] is the domain [page 301] of Family1[i].

family_field(Family1) -> Family2

Types:
- Family1 = Family2 = family()

If Family1 is a family [page 302] and Family1[i] is a binary relation for every i in the index set of Family1, then Family2 is the family with the same index set as Family1 such that Family2[i] is the field [page 301] of Family1[i].

family_field(Family1) is equivalent to family_union(family_domain(Family1), family_range(Family1)).
family_intersection(Family1) -> Family2

Types:
- Family1 = Family2 = family()

If Family1 is a family [page 302] and Family1[i] is a set of sets for every i in the index set of Family1, then Family2 is the family with the same index set as Family1 such that Family2[i] is the intersection [page 301] of Family1[i].

If Family1[i] is an empty set for some i, then the process exits with a badarg message.

```erlang
1> F1 = sofs:from_term([[a,[[1,2,3],[2,3,4]]],[b,[[x,y],[x,y]]]]),
   F2 = sofs:family_intersection(F1),
   sofs:to_external(F2).
{[a,[2,3]],[b,[x,y]]}
```

family_intersection(Family1, Family2) -> Family3

Types:
- Family1 = Family2 = Family3 = family()

If Family1 and Family2 are families [page 302], then Family3 is the family such that the index set is the intersection of Family1's and Family2's index sets, and Family3[i] is the intersection of Family1[i] and Family2[i].

```erlang
1> F1 = sofs:family([[a,[[1,2]],[b,[[3,4]]],[c,[[5,6]]]]),
   F2 = sofs:family([[b,[[4,5]],[c,[[7,8]],[d,[[9,10]]]]]),
   F3 = sofs:family_intersection(F1, F2),
   sofs:to_external(F3).
{[b,[4]],[c,[]]}
```

family_projection(SetFun, Family1) -> Family2

Types:
- SetFun = set_fun()
- Family1 = Family2 = family()
- Set = set()

If Family1 is a family [page 302] then Family2 is the family with the same index set as Family1 such that Family2[i] is the result of calling SetFun with Family1[i] as argument.

```erlang
1> F1 = sofs:from_term([[a,[[1,2],[2,3]]],[b,[[[]]]]]),
   F2 = sofs:family_projection({sofs, union}, F1),
   sofs:to_external(F2).
{[a,[1,2,3]],[b,[]]}
```

family_range(Family1) -> Family2

Types:
- Family1 = Family2 = family()

If Family1 is a family [page 302] and Family1[i] is a binary relation for every i in the index set of Family1, then Family2 is the family with the same index set as Family1 such that Family2[i] is the range [page 301] of Family1[i].
FR = sofs:from_term([[[a, [1, a], [2, b], [3, c]]], [b, []], [c, [[4, d], [5, e]]]]),
F = sofs:family_range(FR),
sofs:to_external(F).

family_specification(Fun, Family1) -> Family2

Types:
- Fun = spec_fun()
- Family1 = Family2 = family()

If Family1 is a family [page 302], then Family2 is the restriction [page 301] of Family1
to those elements i of the index set for which Fun applied to Family1[i] returns true. If
Fun is a tuple (external, Fun2), Fun2 is applied to the external set [page 303] of
Family1[i], otherwise Fun is applied to Family1[i].

F1 = sofs:family([[[f, a], [1, 2, 3]], [b, [1, 2]], [c, [1]]]),
SpecFun = fun(S) -> sofs:no_elements(S) =:= 2 end,
P2 = sofs:family_specification(SpecFun, F1),
sofs:to_external(P2).

family_to_digraph(Family [, GraphType]) -> Graph

Types:
- Graph = digraph()
- Family = family()
- GraphType = -see digraph(3)-

Creates a directed graph from the family [page 302] Family. For each pair
(a, [b[1], ..., b[n]]) of Family, the vertex a as well the edges (a, b[i]) for 1 <= i <= n are
added to a newly created directed graph.

If no graph type is given, digraph:new/1 is used for creating the directed graph,
otherwise the GraphType argument is passed on as second argument to
digraph:new/2.

If F is a family, it holds that F is a subset of
digraph_to_family(family_to_digraph(F), type(F)). Equality holds if
union of family(F) is a subset of domain(F).

Creating a cycle in an acyclic graph exits the process with a cyclic message.

family_to_relation(Family) -> BinRel

Types:
- Family = family()
- BinRel = binary_relation()

If Family is a family [page 302], then BinRel is the binary relation containing all pairs
(i, x) such that i belongs to the index set of Family and x belongs to Family[i].

F = sofs:family([[a, []], {b, [1]}, {c, [2, 3]}]),
R = sofs:family_to_relation(F),
sofs:to_external(R).

family_to_relation(Family) -> BinRel
family_union(Family1) -> Family2

Types:
- Family1 = Family2 = family()

If Family1 is a family [page 302] and Family1[i] is a set of sets for each i in the index set of Family1, then Family2 is the family with the same index set as Family1 such that Family2[i] is the union [page 301] of Family1[i].

1> F1 = sofs:from_term([[a,[[1,2],[2,3]]],[b,[]]]),
   F2 = sofs:family_union(F1),
   sofs:to_external(F2).

family_union(F) is equivalent to family_projection([sofs,union,F]).

family_union(Family1, Family2) -> Family3

Types:
- Family1 = Family2 = Family3 = family()

If Family1 and Family2 are families [page 302], then Family3 is the family such that the index set is the union of Family1's and Family2's index sets, and Family3[i] is the union of Family1[i] and Family2[i] if both maps i, Family1[i] or Family2[i] otherwise.

1> F1 = sofs:family([[a,[[1,2]]],[b,[[3,4],[c,[[5,6]]]]]],
   F2 = sofs:family([[b,[[4,5]]],[c,[[7,8]],d,[[9,10]]]]),
   F3 = sofs:family_union(F1, F2),
   sofs:to_external(F3).

field(BinRel) -> Set

Types:
- BinRel = binary_relation()
- Set = set()

Returns the field [page 301] of the binary relation BinRel.

1> R = sofs:relation([[1,a],[1,b],[2,b],[2,c]]),
   S = sofs:field(R),
   sofs:to_external(S).

field(R) is equivalent to union(domain(R), range(R)).

from_external(ExternalSet, Type) -> AnySet

Types:
- ExternalSet = external_set()
- AnySet = anyset()
- Type = type()

Creates a set from the external set [page 303] ExternalSet and the type [page 303] Type. It is assumed that Type is a valid type [page 303] of ExternalSet.

from_sets(ListOfSets) -> Set
Types:
- Set = set()
-ListOfSets = [anyset()]

Returns the unordered set [page 303] containing the sets of the list ListOfSets.

```
1> S1 = sofs:relation([fa,1,gb,2]),
   S2 = sofs:relation([fx,3,gy,4]),
   S = sofs:from_sets([S1,S2]),
   sofs:to_external(S).
[[fa,1,gb,2], [fx,3,gy,4]]
```

from_sets(TupleOfSets) -> Ordset

Types:
- Ordset = ordset()
- TupleOfSets = tuple-of(anyset())

Returns the ordered set [page 303] containing the sets of the non-empty tuple TupleOfSets.

from_term(Term [, Type]) -> AnySet

Types:
- AnySet = anyset()
- Term = term()
- Type = type()

Creates an element of Sets [page 303] by traversing the term Term, sorting lists, removing duplicates and deriving or verifying a valid type [page 303] for the so obtained external set. An explicitly given type [page 303] Type can be used to limit the depth of the traversal; an atomic type stops the traversal, as demonstrated by this example where “foo” and {“foo”} are left unmodified:

```
1> S = sofs:from_term([{{“foo”},[1,1]},{“foo”,[2,2]}], [{atom,[atom]}]),
   sofs:to_external(S).
[{{“foo”},[1]},{“foo”,[2]}]
```

from_term can be used for creating atomic or ordered sets. The only purpose of such a set is that of later building unordered sets since all functions in this module that do anything operate on unordered sets. Creating unordered sets from a collection of ordered sets may be the way to go if the ordered sets are big and one does not want to waste heap by rebuilding the elements of the unordered set. An example showing that a set can be built “layer by layer”:

```
1> A = sofs:from_term(a),
   S = sofs:set([1,2,3]),
   P1 = sofs:from_sets([A,S]),
   P2 = sofs:from_term([b,[6,5,4]]),
   Ss = sofs:from_sets([P1,P2]),
   sofs:to_external(Ss).
[[a,[1,2,3]],[b,[4,5,6]]]
```
Other functions that create sets are \texttt{from\_external/2} and \texttt{from\_sets/1}. Special cases of \texttt{from\_term/2} are \texttt{a\_function/1,2}, \texttt{empty\_set/0}, \texttt{family/1,2}, \texttt{relation/1,2}, and \texttt{set/1,2}.

\texttt{image(BinRel, Set1) -> Set2}

**Types:**
- \texttt{BinRel = binary\_relation()}
- \texttt{Set1 = Set2 = set()}

Returns the image [page 301] of the set \texttt{Set1} under the binary relation \texttt{BinRel}.

```prolog
1> R = sofs:relation([[1,a],[2,b],[2,c],[3,d]]),
   S1 = sofs:set([1,2]),
   S2 = sofs:image(R, S1),
   sofs:to\_external(S2).
[a,b,c]
```

\texttt{intersection(SetOfSets) -> Set}

**Types:**
- \texttt{Set = set()}
- \texttt{SetOfSets = set\_of\_sets()}

Returns the intersection [page 301] of the set of sets \texttt{SetOfSets}.

Intersecting an empty set of sets exits the process with a \texttt{badarg} message.

\texttt{intersection(Set1, Set2) -> Set3}

**Types:**
- \texttt{Set1 = Set2 = Set3 = set()}

Returns the intersection [page 301] of \texttt{Set1} and \texttt{Set2}.

\texttt{intersection\_of\_family(Family) -> Set}

**Types:**
- \texttt{Family = family()}
- \texttt{Set = set()}

Returns the intersection of the family [page 302] \texttt{Family}.

Intersecting an empty family exits the process with a \texttt{badarg} message.

```prolog
1> F = sofs:family([[a,[0,2,4]],[b,[0,1,2]],[c,[2,3]]]),
   S = sofs:intersection\_of\_family(F),
   sofs:to\_external(S).
[2]
```

\texttt{inverse(Function1) -> Function2}

**Types:**
- \texttt{Function1 = Function2 = function()}

Returns the inverse [page 302] of the function \texttt{Function1}.
1> R1 = sofs:relation([[1,a],[2,b],[3,c]]).
R2 = sofs:inverse(R1).
sofs:to_external(R2).
[1,a],[2,b],[3,c]]

inverse_image(BinRel, Set1) -> Set2
Types:
  • BinRel = binary_relation()
  • Set1 = Set2 = set()
Returns the inverse image [page 301] of Set1 under the binary relation BinRel.

1> R = sofs:relation([[1,a],[2,b],[2,c],[3,d]]),
S1 = sofs:set([c,d,e]),
S2 = sofs:inverse_image(R, S1),
sofs:to_external(S2).
[2,3]

is_a_function(BinRel) -> Bool
Types:
  • Bool = bool()
  • BinRel = binary_relation()
Returns true if the binary relation BinRel is a function [page 302] or the untyped empty set, false otherwise.

is_disjoint(Set1, Set2) -> Bool
Types:
  • Bool = bool()
  • Set1 = Set2 = set()
Returns true if Set1 and Set2 are disjoint [page 301], false otherwise.

is_empty_set(AnySet) -> Bool
Types:
  • AnySet = anyset()
  • Bool = bool()
Returns true if Set is an empty unordered set, false otherwise.

is_equal(AnySet1, AnySet2) -> Bool
Types:
  • AnySet1 = AnySet2 = anyset()
  • Bool = bool()
Returns true if the AnySet1 and AnySet2 are equal [page 301], false otherwise.

is_set(AnySet) -> Bool
Types:
- AnySet = anyset()
- Bool = bool()

Returns true if AnySet is an unordered set [page 303], and false if AnySet is an ordered set or an atomic set.

\text{is\_sofs\_set(Term) \rightarrow Bool}

Types:
- Bool = bool()
- Term = term()

Returns true if Term is an unordered set [page 303], an ordered set or an atomic set, false otherwise.

\text{is\_subset(Set1, Set2) \rightarrow Bool}

Types:
- Bool = bool()
- Set1 = Set2 = set()

Returns true if Set1 is a subset [page 301] of Set2, false otherwise.

\text{is\_type(Term) \rightarrow Bool}

Types:
- Bool = bool()
- Term = term()

Returns true if the term Term is a type [page 303].

\text{join(Relation1, I, Relation2, J) \rightarrow Relation3}

Types:
- Relation1 = Relation2 = Relation3 = relation()
- I = J = integer() > 0

Returns the natural join [page 302] of the relations Relation1 and Relation2 on coordinates I and J.

\text{J = sofs:join(R1, 3, R2, 1),}
\text{sofs:to\_external(J).}

\text{multiple\_relative\_product(TupleOfBinRels, BinRel1) \rightarrow BinRel2}

Types:
- TupleOfBinRels = tuple-of(BinRel)
- BinRel = BinRel1 = BinRel2 = binary\_relation()

If TupleOfBinRels is a non-empty tuple \{R[1],...,R[n]\} of binary relations and BinRel1 is a binary relation, then BinRel2 is the multiple relative product [page 302] of the ordered set \{R[i],...,R[n]\} and BinRel1.
1> Ri = sofs:relation([[a,i],[b,2],[c,3]]),
R = sofs:relation([[a,b],[b,c],[c,a]]),
MP = sofs:multiple_relative_product([Ri, Ri], R),
sofs:to_external(sofs:range(MP)).

[[1,2],[2,3],[3,1]]

no_elements(ASet) -> NoElements
Types:
- A Set = set() | ordset()
- NoElements = integer() >= 0
Returns the number of elements of the ordered or unordered set ASet.

partition(SetOfSets) -> Partition
Types:
- SetOfSets = set() of sets()
- Partition = set()
Returns the partition [page 302] of the union of the set of sets SetOfSets such that two
elements are considered equal if they belong to the same elements of SetOfSets.

1> Sets1 = sofs:from_term([[a,b,c],[d,e,f],[g,h,i]]),
Sets2 = sofs:from_term([[b,c,d],[e,f,g],[h,i,j]]),
P = sofs:partition(sofs:union(Sets1, Sets2)),
sofs:to_external(P).

[[[a],[b,c],[d]], [[e,f],[g],[h,i],[j]]]

partition(SetFun, Set) -> Partition
Types:
- SetFun = set_fun()
- Partition = set()
- Set = set()
Returns the partition [page 302] of Set such that two elements are considered equal if
the results of applying SetFun are equal.

1> Ss = sofs:from_term([[a],[b],[c,d],[e,f]]),
SetFun = fun(S) -> sofs:from_term(sofs:no_elements(S)) end,
P = sofs:partition(SetFun, Ss),
sofs:to_external(P).

[[[a],[b]], [[c,d],[e,f]]]

partition(SetFun, Set1, Set2) -> {Set3, Set4}
Types:
- SetFun = set_fun()
- Set1 = Set2 = Set3 = Set4 = set()
Returns a pair of sets that, regarded as constituting a set, forms a partition [page 302] of
Set1. If the result of applying SetFun to an element of Set1 yields an element in Set2,
the element belongs to Set3, otherwise the element belongs to Set4.
1 > R1 = sofs:relation([\([1, a]\), \([2, b]\), \([3, c]\)]),
    S = sofs:set([\([2, 4, 6]\)],
    \([R2, R3]\) = sofs:partition(1, R1, S),
    sofs:to_external(R2),
    sofs:to_external(R3)),
    \([\([1, a]\), \([1, a]\), \([3, c]\)]\)

partition(F, S1, S2) is equivalent to \{restriction(F, S1, S2),
    drestriction(F, S1, S2)\}.

**partition_family(SetFun, Set)**

Types:

- Family = family()
- SetFun = set fun()
- Set = set()

Returns the family [page 302] Family where the indexed set is a partition [page 302] of
Set such that two elements are considered equal if the results of applying SetFun are the
same value i. This i is the index that Family maps onto the equivalence class [page 302].

1 > S = sofs:relation([\([a, a, a, a]\), \([a, a, b, b]\), \([a, b, b, b]\)]),
    SetFun = \(\text{external, fun(\([A, .., C]\) \rightarrow \([A, C]\) end)}\),
    F = sofs:partition_family(SetFun, S),
    sofs:to_external(F).
    \([\([a, a]\), \([a, a, a]\)]\), \([\([a, b]\), \([a, a, b]\), \([a, b, b]\)]\)

**product(TupleOfSets)**

Types:

- Relation = relation()
- TupleOfSets = tuple of set()

If \((x[1], ..., x[n])\) is an element of the n-ary relation Relation, then \(x[i]\) is drawn from
element i of TupleOfSets.

1 > S1 = sofs:set([\([a, b]\)]),
    S2 = sofs:set([\([1, 2]\)]),
    S3 = sofs:set([\([x, y]\)]),
    P3 = sofs:product([S1, S2, S3]),
    sofs:to_external(P3).
    \([\([a, 1]\), \([a, 1]\), \([a, 2]\), \([a, 2]\), \([b, 1]\), \([b, 1]\), \([b, 2]\), \([b, 2]\)]\)

**product(Set1, Set2)**

Types:

- BinRel = binary relation()
- Set1 = Set2 = set()

Returns the Cartesian product [page 301] of Set1 and Set2.

1 > S1 = sofs:set([\([1, 2]\)]),
    S2 = sofs:set([\([a, b]\)]),
    R = sofs:product(S1, S2),
    sofs:to_external(R).
    \([\([1, a]\), \([1, b]\), \([2, a]\), \([2, b]\)]\)
product(S1, S2) is equivalent to product({S1, S2}).

projection(SetFun, Set1) -> Set2
Types:
- SetFun = set_fun()
- Set1 = Set2 = set()
Returns the set created by substituting each element of Set1 by the result of applying SetFun to the element.
If SetFun is a number i=1 and Set1 is a relation, then the returned set is the projection of Set1 onto coordinate i.

1> S1 = sofs:from_term([[1,a],{2,b},{3,a}]).
S2 = sofs:projection(2, S1),
sofs:to_external(S2).
[a,b]

range(BinRel) -> Set
Types:
- BinRel = binary_relation()
- Set = set()
Returns the range of the binary relation BinRel.

1> R = sofs:relation([[1,a],[1,b],[2,b],[2,c]]),
S = sofs:range(R),
sofs:to_external(S).
[a,b,c]

relation(Tuples [, Type]) -> Relation
Types:
- N = integer()
- Type = N | type()
- Relation = relation()
- Tuples = [tuple()]
Creates a relation. relation(R,T) is equivalent to from_term(R,T), if T is a type and the result is a relation. If Type is an integer N, then [{atom,...,atom}], where the size of the tuple is N, is used as type of the relation. If no type is explicitly given, the size of the first tuple of Tuples is used if there is such a tuple. relation([]) is equivalent to relation([],2).

relation_to_family(BinRel) -> Family
Types:
- Family = family()
- BinRel = binary_relation()
Returns the family [set page 302] Family such that the index set is equal to the domain of the binary relation BinRel, and Family[i] is the image of the set of i under BinRel.
1> R = sofs:relation([[b,1],[c,2],[c,3]]),
   F = sofs:relation_to_family(R),
   sofs:to_external(F),
   [[b,1],[c,[2,3]]]

relative_product(TupleOfBinRels [, BinRel1]) -> BinRel2

Types:
- TupleOfBinRels = tuple-of(BinRel)
- BinRel = BinRel1 = BinRel2 = binary_relation()

If TupleOfBinRels is a non-empty tuple \( \{R[1],\ldots,R[n]\} \) of binary relations and BinRel1 is a binary relation, then BinRel2 is the relative product [page 302] of the ordered set \( (R[1],\ldots,R[n]) \) and BinRel1.

If BinRel1 is omitted, the relation of equality between the elements of the Cartesian product [page 302] of the ranges of \( R[i] \), range\( R[1] \)\ldots range\( R[n] \), is used instead (intuitively, nothing is “lost”).

1> TR = sofs:relation([[1,a],[1,aa],[2,b]]),
   R1 = sofs:relation([[1,u],[2,v],[3,c]]),
   R2 = sofs:relative_product([[TR, R1]],
     sofs:to_external(R2),
     [{[1,a,u]},{1,aa,u}],[2,b,v]])

Note that \( \text{relative\_product}([R1],R2) \) is different from \( \text{relative\_product}(R1,R2) \); the tuple of one element is not identified with the element itself.

relative_product1(BinRel1, BinRel2) -> BinRel3

Types:
- BinRel1 = BinRel2 = BinRel3 = binary_relation()

Returns the relative product [page 301] of the binary relations BinRel1 and BinRel2.

relative_product1(BinRel1, BinRel2) -> BinRel3

Types:
- BinRel1 = BinRel2 = BinRel3 = binary_relation()

Returns the relative product [page 301] of the converse [page 301] of the binary relation BinRel1 and the binary relation BinRel2.

1> R1 = sofs:relation([[1,a],[1,aa],[2,b]]),
   R2 = sofs:relation([[1,u],[2,v],[3,c]]),
   R3 = sofs:relative_product1(R1, R2),
   sofs:to_external(R3),
   [{a,u},{aa,u},{b,v}]  

relative_product1(R1,R2) is equivalent to relative_product(converse(R1),R2).

restriction(BinRel1, Set) -> BinRel2

Types:
- BinRel1 = BinRel2 = binary_relation()
- Set = set()

Returns the restriction [page 301] of the binary relation BinRel1 to Set.
1> R1 = sofs:relation([[1,a],[2,b],[3,c]]),
   S = sofs:set([1,2,4]),
   R2 = sofs:restriction(R1, S),
   sofs:to_external(R2).
   [[1,a],[2,b]]

restriction(SetFun, Set1, Set2) -> Set3

Types:
  • SetFun = set_fun()
  • Set1 = Set2 = Set3 = set()

Returns a subset of Set1 containing those elements that yield an element in Set2 as the
result of applying SetFun.

1> S1 = sofs:relation([[1,a],[2,b],[3,c]]),
   S2 = sofs:set([b,c,d]),
   S3 = sofs:restriction(2, S1, S2),
   sofs:to_external(S3).
   [[2,b],[3,c]]

set(Terms [, Type]) -> Set

Types:
  • Set = set()
  • Terms = [term()]
  • Type = type()

Creates an unordered set [page 303]. set(L,T) is equivalent to from_term(L,T), if the
result is an unordered set. If no type [page 303] is explicitly given, [atom] is used as
type of the set.

specification(Fun, Set1) -> Set2

Types:
  • Fun = spec_fun()
  • Set1 = Set2 = set()

Returns the set containing every element of Set1 for which Fun returns true. If Fun is a
tuple [external,Fun2], Fun2 is applied to the external set [page 303] of each element,
otherwise Fun is applied to each element.

1> R1 = sofs:relation([[a,1],[b,2]]),
   R2 = sofs:relation([[x,1],[x,2],[y,3]]),
   S1 = sofs:from_sets([R1,R2]),
   S2 = sofs:specification([sofs,is_a_function], S1),
   sofs:to_external(S2).
   [[[[a,1],[b,2]]]

strict_relation(BinRel1) -> BinRel2

Types:
  • BinRel1 = BinRel2 = binary_relation()

Returns the strict relation [page 302] corresponding to the binary relation BinRel1.
\begin{verbatim}
1> R1 = sofs:relation([\{1,1\},\{1,2\},\{2,1\},\{2,2\}]),
   R2 = sofs:strict_relation(R1),
   sofs:to_external(R2).
\end{verbatim}

\begin{verbatim}
substitution(SetFun, Set1) \rightarrow Set2

Types:
- SetFun = set_fun()
- Set1 = Set2 = set()

Returns a function, the domain of which is Set1. The value of an element of the domain is the result of applying SetFun to the element.

\begin{verbatim}
1> L = \[[a,1],\{b,2\}\],
   sofs:to_external(sofs:projection(1,sofs:relation(L))).
2> sofs:to_external(sofs:projection(1,sofs:relation(L))).
3> sofs:to_external(sofs:substitution(1,sofs:relation(L))).
4> SetFun = fun([A,E] = \{A\} \rightarrow \{E,A\} end),
   sofs:to_external(sofs:projection(SetFun,sofs:relation(L))).
\end{verbatim}

The relation of equality between the elements of \{a,b,c\}:

\begin{verbatim}
1> I = sofs:substitution(fun(A) = A end, sofs:set([a,b,c])),
   sofs:to_external(I).
\end{verbatim}

Let SetOfSets be a set of sets and BinRel a binary relation. The function that maps each element Set of SetOfSets onto the image of Set under BinRel is returned by this function:

\begin{verbatim}
images(SetOfSets, BinRel) \rightarrow
   Fun = fun(Set) \rightarrow sofs:image(BinRel, Set) end,
   sofs:substitution(Fun, SetOfSets).
\end{verbatim}

Here might be the place to reveal something that was more or less stated before, namely that external unordered sets are represented as sorted lists. As a consequence, creating the image of a set under a relation \( R \) may traverse all elements of \( R \) (to that comes the sorting of results, the image). In \texttt{images/2}, \texttt{BinRel} will be traversed once for each element of \texttt{SetOfSets}, which may take too long. The following efficient function could be used instead under the assumption that the image of each element of \texttt{SetOfSets} under \texttt{BinRel} is non-empty:

\begin{verbatim}
images2(SetOfSets, BinRel) \rightarrow
   CR = sofs:canonical_relation(SetOfSets),
   R = sofs:relative_product1(CR, BinRel),
   sofs:relation_to_family(R).
\end{verbatim}

\begin{verbatim}
symdiff(Set1, Set2) \rightarrow Set3

Types:
- Set1 = Set2 = Set3 = set()

Returns the symmetric difference (or the Boolean sum) of \texttt{Set1} and \texttt{Set2}.
\end{verbatim}
1> S1 = sofs:set([1, 2, 3]),
   S2 = sofs:set([2, 3, 4]),
   P = sofs:symdiff(S1, S2),
   sofs:to_external(P).
   [1, 4]

symmetric_partition(Set1, Set2) -> {Set3, Set4, Set5}

Types:
  • Set1 = Set2 = Set3 = Set4 = Set5 = set()

Returns a triple of sets: Set3 contains the elements of Set1 that do not belong to Set2;
Set4 contains the elements of Set1 that belong to Set2; Set5 contains the elements of
Set2 that do not belong to Set1.

to_external(AnySet) -> ExternalSet

Types:
  • ExternalSet = external_set()
  • AnySet = anyset()

Returns the external set [page 303] of an atomic, ordered or unordered set.

to_sets(ASet) -> Sets

Types:
  • ASet = set() | ordset()
  • Sets = tuple_of(AnySet) | [AnySet]

Returns the elements of the ordered set ASet as a tuple of sets, and the elements of the
unordered set ASet as a sorted list of sets without duplicates.

type(AnySet) -> Type

Types:
  • AnySet = anyset()
  • Type = type()

Returns the type [page 303] of an atomic, ordered or unordered set.

union(SetOfSets) -> Set

Types:
  • Set = set()
  • SetOfSets = set_of_sets()

Returns the union [page 301] of the set of sets SetOfSets.

union(Set1, Set2) -> Set3

Types:
  • Set1 = Set2 = Set3 = set()

Returns the union [page 301] of Set1 and Set2.
union_of_family(Family) -> Set

Types:
- Family = family()
- Set = set()

Returns the union of the family [page 302] Family.

```erlang
1> F = sofs:family([[a,[0,2,4]],[b,[0,1,2]],[c,[2,3]]]),
   S = sofs:union_of_family(F),
   sofs:to_external(S).
[0,1,2,3,4]
```

weak_relation(BinRel1) -> BinRel2

Types:
- BinRel1 = BinRel2 = binary_relation()

Returns a subset S of the weak relation [page 302] W corresponding to the binary relation BinRel1. Let F be the field [page 301] of BinRel1. The subset S is defined so that x S y if x W y for some x in F and for some y in F.

```erlang
1> R1 = sofs:relation([[f1,1,g],[f1,2,g],[f3,1,g]]),
   R2 = sofs:weak_relation(R1),
   sofs:to_external(R2).
[[f1,1,g],[f1,2,g],[f2,2,g],[f3,1,g],[f3,3,g]]
```

See Also

dict(3) [page 82], digraph(3) [page 87], orddict(3) [page 244], ordsets(3) [page 245], sets(3) [page 285]
string
Erlang Module

This module contains functions for string processing.

Exports

len(String) -> Length
Types:
  • String = string()
  • Length = integer()
Returns the number of characters in the string.

equal(String1, String2) -> bool()
Types:
  • String1 = String2 = string()
Tests whether two strings are equal. Returns true if they are, otherwise false.

concat(String1, String2) -> String3
Types:
  • String1 = String2 = String3 = string()
Concatenates two strings to form a new string. Returns the new string.

chr(String, Character) -> Index
rchr(String, Character) -> Index
Types:
  • String = string()
  • Character = char()
  • Index = integer()
Returns the index of the first/last occurrence of Character in String. 0 is returned if Character does not occur.

str(String, SubString) -> Index
rstr(String, SubString) -> Index
Types:
  • String = SubString = string()
- **Index = integer()**
  
  Returns the position where the first/last occurrence of SubString begins in String. 0 is returned if SubString does not exist in String. For example:

  ```
  > string:Str(" Hello Hello World World ", "Hello World").
  8
  ```

- **span(String, Chars) -> Length**
  **cspan(String, Chars) -> Length**

  **Types:**
  - String = Chars = string()
  - Length = integer()

  Returns the length of the maximum initial segment of String, which consists entirely of characters from (not from) Chars.

  For example:

  ```
  > string:span("\t abcdef", " \t").
  5
  > string:cspan("\t abcdef", " \t").
  0
  ```

- **substr(String, Start) -> SubString**
  **substr(String, Start, Length) -> SubString**

  **Types:**
  - String = SubString = string()
  - Start = Length = integer()

  Returns a substring of String, starting at the position Start, and ending at the end of the string or at length Length.

  For example:

  ```
  > substr("Hello World", 4, 5).
  "lo Wo"
  ```

- **tokens(String, SeparatorList) -> Tokens**

  **Types:**
  - String = SeparatorList = string()
  - Tokens = [string()]

  Returns a list of tokens in String, separated by the characters in SeparatorList.

  For example:

  ```
  > tokens("abc defxghix jkl", "x ").
  ["abc", "def", "ghi", "jkl"]
  ```

- **chars(Character, Number) -> String**
  **chars(Character, Number, Tail) -> String**

  **Types:**
  - Character = char()
• Number = integer()
• String = string()

Returns a string consisting of Number of characters Character. Optionally, the string can end with the string Tail.

copies(String, Number) -> Copies

Types:
• String = Copies = string()
• Number = integer()

Returns a string containing String repeated Number times.

words(String) -> Count

words(String, Character) -> Count

Types:
• String = string()
• Character = char()
• Count = integer()

Returns the number of words in String, separated by blanks or Character.
For example:
> words(" Hello old boy!", $o).
4

sub_word(String, Number) -> Word

sub_word(String, Number, Character) -> Word

Types:
• String = Word = string()
• Character = char()
• Number = integer()

Returns the word in position Number of String. Words are separated by blanks or Characters.
For example:
> string:sub_word(" Hello old boy!",3,$o).
"ld b"

strip(String) -> Stripped

strip(String, Direction) -> Stripped

strip(String, Direction, Character) -> Stripped

Types:
• String = Stripped = string()
• Direction = left | right | both
• Character = char()
Returns a string, where leading and/or trailing blanks or a number of Character have been removed. Direction can be left, right, or both and indicates from which direction blanks are to be removed. The function strip/1 is equivalent to strip(String, both).
For example:
> string:strip("...Hello.....", both, $.).
"Hello"

left(String, Number) -> Left
left(String, Number, Character) -> Left

Types:
- String = Left = string()
- Character = char
- Number = integer()

Returns the String with the length adjusted in accordance with Number. The left margin is fixed. If the length(String) < Number, String is padded with blanks or Characters.
For example:
> string:left("Hello",10, $.").
"Hello....."

right(String, Number) -> Right
right(String, Number, Character) -> Right

Types:
- String = Right = string()
- Character = char
- Number = integer()

Returns the String with the length adjusted in accordance with Number. The right margin is fixed. If the length of (String) < Number, String is padded with blanks or Characters.
For example:
> string:right("Hello", 10, $.").
".....Hello"

centre(String, Number) -> Centered
centre(String, Number, Character) -> Centered

Types:
- String = Centered = string()
- Character = char
- Number = integer()

Returns a string, where String is centred in the string and surrounded by blanks or characters. The resulting string will have the length Number.
sub_string(String, Start, Stop) -> SubString

Types:
- String = SubString = string()
- Start = Stop = integer()

Returns a substring of String, starting at the position Start to the end of the string, or to and including the Stop position.

For example:

```
sub_string("Hello World", 4, 8).
"lo Wo"
```

to_float(String) -> {Float,Rest} | {error,Reason}

Types:
- String = string()
- Float = float()
- Rest = string()
- Reason = no_float | not_a_list

Argument String is expected to start with a valid text represented float (the digits being ASCII values). Remaining characters in the string after the float are returned in Rest.

Example:

```
> {F1,Fs} = string:to_float("1.0-1.0e-1"),
> {F2,[]} = string:to_float(Fs),
> F1+F2.
0.900000
> string:to_float("3/2=1.5").
{error,no_float}
> string:to_float("-1.5eX").
{-1.50000,"eX"}
```

to_integer(String) -> {Int,Rest} | {error,Reason}

Types:
- String = string()
- Int = integer()
- Rest = string()
- Reason = no_integer | not_a_list

Argument String is expected to start with a valid text represented integer (the digits being ASCII values). Remaining characters in the string after the integer are returned in Rest.

Example:
Notes

Some of the general string functions may seem to overlap each other. The reason for this is that this string package is the combination of two earlier packages and all the functions of both packages have been retained.

The regular expression functions have been moved to their own module regexp (see regexp(3) [page 280]). The old entry points still exist for backwards compatibility, but will be removed in a future release so that users are encouraged to use the module regexp.

Note:
Any undocumented functions in string should not be used.
Erlang Module

A behaviour module for implementing a supervisor, a process which supervises other processes called child processes. A child process can either be another supervisor or a worker process. Worker processes are normally implemented using one of the gen_event, gen_fsm, or gen_server behaviours. A supervisor implemented using this module will have a standard set of interface functions and include functionality for tracing and error reporting. Supervisors are used to build an hierarchical process structure called a supervision tree, a nice way to structure a fault tolerant application. Refer to OTP Design Principles for more information.

A supervisor assumes the definition of which child processes to supervise to be located in a callback module exporting a pre-defined set of functions. Unless otherwise stated, all functions in this module will fail if the specified supervisor does not exist or if bad arguments are given.

Supervision Principles

The supervisor is responsible for starting, stopping and monitoring its child processes. The basic idea of a supervisor is that it should keep its child processes alive by restarting them when necessary.

The children of a supervisor is defined as a list of child specifications. When the supervisor is started, the child processes are started in order from left to right according to this list. When the supervisor terminates, it first terminates its child processes in reversed start order, from right to left.

A supervisor can have one of the following restart strategies:

- one_for_one - if one child process terminates and should be restarted, only that child process is affected.
- one_for_all - if one child process terminates and should be restarted, all other child processes are terminated and then all child processes are restarted.
- rest_for_one - if one child process terminates and should be restarted, the 'rest' of the child processes - i.e. the child processes after the terminated child process in the start order - are terminated. Then the terminated child process and all child processes after it are restarted.
- simple_one_for_one - a simplified one_for_one supervisor, where all child processes are dynamically added instances of the same process type, i.e. running the same code.

The functions terminate_child/2, delete_child/2 and restart_child/2 are invalid for simple_one_for_one supervisors and will return {error, simple_one_for_one} if the specified supervisor uses this restart strategy.
To prevent a supervisor from getting into an infinite loop of child process terminations and restarts, a maximum restart frequency is defined using two integer values \( \text{MaxR} \) and \( \text{MaxT} \). If more than \( \text{MaxR} \) restarts occur within \( \text{MaxT} \) seconds, the supervisor terminates all child processes and then itself.

This is the type definition of a child specification:

\[
\text{child\_spec}() = \{\text{Id,StartFunc,Restart,Shutdown,Type,Modules}\}
\]

- \( \text{Id} \) is a name that is used to identify the child specification internally by the supervisor.
- \( \text{StartFunc} \) defines the function call used to start the child process. It should be a module-function-arguments tuple \( \{M,F,A\} \) used as \( \text{apply}(M,F,A) \).

The start function must create and link to the child process, and should return \( \{\text{ok,Child}\} \) or \( \{\text{ok,Child,Info}\} \) where \( \text{Child} \) is the pid of the child process and \( \text{Info} \) an arbitrary term which is ignored by the supervisor.

The start function can also return \( \text{ignore} \) if the child process for some reason cannot be started, in which case the child specification will be kept by the supervisor but the non-existing child process will be ignored.

If something goes wrong, the function may also return an error tuple \( \{\text{error,Error}\} \).

Note that the \text{start\_link} functions of the different behaviour modules fulfill the above requirements.

- \( \text{Restart} \) defines when a terminated child process should be restarted. A permanent child process should always be restarted, a temporary child process should never be restarted and a transient child process should be restarted only if it terminates abnormally, i.e. with another exit reason than \text{normal}.

- \( \text{Shutdown} \) defines how a child process should be terminated. \text{brutal\_kill} means the child process will be unconditionally terminated using \( \text{exit}(\text{Child,kill}) \). An integer timeout value means that the supervisor will tell the child process to terminate by calling \( \text{exit}(\text{Child,shutdown}) \) and then wait for an exit signal with reason \text{shutdown} back from the child process. If no exit signal is received within the specified time, the child process is unconditionally terminated using \( \text{exit}(\text{Child,kill}) \).

If the child process is another supervisor, \( \text{Shutdown} \) should be set to \text{infinity} to give the subtree ample time to shutdown.

Note that child processes implemented using the behaviour modules automatically adhere to the shutdown protocol.
Type specifies if the child process is a supervisor or a worker.

Modules is used by the release handler during code replacement to determine which processes are using a certain module. As a rule of thumb Modules should be a list with one element [Module], where Module is the callback module, if the child process is a supervisor, gen_server or gen_fsm. If the child process is an event manager (gen_event) with a dynamic set of callback modules, Modules should be dynamic. See OTP Design Principles for more information about release handling.

Internally, the supervisor also keeps track of the pid Child of the child process, or undefined if no pid exists.

**Exports**

start_link(Module, Args) -> Result
start_link(SupName, Module, Args) -> Result

Types:
- SupName = {local,Name} | {global,Name}
- Name = atom()
- Module = atom()
- Args = term()
- Result = {ok,Pid} | ignore | {error,Error}
- Pid = pid()
- Error = {already_started,Pid} | shutdown | term()

Creates a supervisor process as part of a supervision tree. The function will, among other things, ensure that the supervisor is linked to the calling process (its supervisor).

The created supervisor process calls Module:init/1 to find out about restart strategy, maximum restart frequency and child processes. To ensure a synchronized start-up procedure, start_link/2,3 does not return until Module:init/1 has returned and all child processes have been started.

If SupName={local,Name} the supervisor is registered locally as Name using register/2. If SupName={global,Name} the supervisor is registered globally as Name using global:register_name/2. If no name is provided, the supervisor is not registered.

Module is the name of the callback module.

Args is an arbitrary term which is passed as the argument to Module:init/1.

If the supervisor and its child processes are successfully created (i.e. if all child process start functions return {ok,Child}, {ok,Child,Info}, or ignore) the function returns {ok,Pid}, where Pid is the pid of the supervisor. If there already exists a process with the specified SupName the function returns {error,{already_started,Pid}}, where Pid is the pid of that process.

If Module:init/1 returns ignore, this function returns ignore as well and the supervisor terminates with reason normal. If Module:init/1 fails or returns an incorrect value, this function returns {error,Term} where Term is a term with information about the error, and the supervisor terminates with reason Term.

If any child process start function fails or returns an error tuple or an erroneous value, the function returns {error,shutdown} and the supervisor terminates all started child processes and then itself with reason shutdown.
start_child(SupRef, ChildSpec) -> Result

Types:
- SupRef = Name | {Name,Node} | {global,Name} | pid()
- Name = Node = atom()
- ChildSpec = child_spec() | [term()]
- Result = {ok,Child} | {ok,Child,Info} | {error,Error}
- Child = pid() | undefined
- Info = term()
- Error = already_present | already_started,Child | term()

Dynamically adds a child specification to the supervisor SupRef which starts the corresponding child process.

SupRef can be:
- the pid,
- Name, if the supervisor is locally registered,
- {Name,Node}, if the supervisor is locally registered at another node, or
- {global,Name}, if the supervisor is globally registered.

ChildSpec should be a valid child specification (unless the supervisor is a simple_one_for_one supervisor, see below). The child process will be started by using the start function as defined in the child specification.

If the case of a simple_one_for_one supervisor, the child specification defined in Module:init/1 will be used and ChildSpec should instead be an arbitrary list of terms List. The child process will then be started by appending List to the existing start function arguments, i.e. by calling apply(M, F, A++List) where {M,F,A} is the start function defined in the child specification.

If there already exists a child specification with the specified Id, ChildSpec is discarded and the function returns {error,already_present} or {error,already_started,Child}, depending on if the corresponding child process is running or not.

If the child process start function returns {ok,Child} or {ok,Child,Info}, the child specification and pid is added to the supervisor and the function returns the same value.

If the child process start function returns ignore, the child specification is added to the supervisor, the pid is set to undefined and the function returns {ok,undefined}.

If the child process start function returns an error tuple or an erroneous value, or if it fails, the child specification is discarded and the function returns {error,Error} where Error is a term containing information about the error and child specification.

terminate_child(SupRef, Id) -> Result

Types:
- SupRef = Name | {Name,Node} | {global,Name} | pid()
- Name = Node = atom()
- Id = term()
- Result = ok | {error,Error}
- Error = not_found | simple_one_for_one
Tells the supervisor $\text{SupRef}$ to terminate the child process corresponding to the child specification identified by $\text{Id}$. The process, if there is one, is terminated but the child specification is kept by the supervisor. This means that the child process may be later be restarted by the supervisor. The child process can also be restarted explicitly by calling $\text{restart\_child/2}$. Use $\text{delete\_child/2}$ to remove the child specification.

See $\text{start\_child/2}$ for a description of $\text{SupRef}$.

If successful, the function returns $\text{ok}$. If there is no child specification with the specified $\text{Id}$, the function returns $\{\text{error, not\_found}\}$.

$$\text{delete\_child(SupRef, Id)} \rightarrow \text{Result}$$

Types:
- $\text{SupRef} = \text{Name} | \{\text{Name,Node} \} | \{\text{global,Name} \} | \text{pid}()$
- $\text{Name} = \text{Node} = \text{atom}()$
- $\text{Id} = \text{term}()$
- $\text{Result} = \{\text{ok} \} | \{\text{error,Error} \}$
- $\text{Error} = \text{running} | \text{not\_found} | \text{simple\_one\_for\_one}$

Tells the supervisor $\text{SupRef}$ to delete the child specification identified by $\text{Id}$. The corresponding child process must not be running, use $\text{terminate\_child/2}$ to terminate it.

See $\text{start\_child/2}$ for a description of $\text{SupRef}$.

If successful, the function returns $\text{ok}$. If the child specification identified by $\text{Id}$ exists but the corresponding child process is running, the function returns $\{\text{error, running}\}$. If the child specification identified by $\text{Id}$ does not exist, the function returns $\{\text{error, not\_found}\}$.

$$\text{restart\_child(SupRef, Id)} \rightarrow \text{Result}$$

Types:
- $\text{SupRef} = \text{Name} | \{\text{Name,Node} \} | \{\text{global,Name} \} | \text{pid}()$
- $\text{Name} = \text{Node} = \text{atom}()$
- $\text{Id} = \text{term}()$
- $\text{Result} = \{\text{ok,Child} \} | \{\text{ok,Child,Info} \} | \{\text{error,Error} \}$
- $\text{Child} = \text{pid}() | \text{undefined}$
- $\text{Error} = \text{running} | \text{not\_found} | \text{simple\_one\_for\_one} | \text{term}()$

Tells the supervisor $\text{SupRef}$ to restart a child process corresponding to the child specification identified by $\text{Id}$. The child specification must exist and the corresponding child process must not be running.

See $\text{start\_child/2}$ for a description of $\text{SupRef}$.

If the child specification identified by $\text{Id}$ does not exist, the function returns $\{\text{error, not\_found}\}$. If the child specification exists but the corresponding process is already running, the function returns $\{\text{error, running}\}$.

If the child process start function returns $\{\text{ok,Child} \}$ or $\{\text{ok,Child,Info} \}$, the pid is added to the supervisor and the function returns the same value.

If the child process start function returns $\text{ignore}$, the pid remains set to $\text{undefined}$ and the function returns $\{\text{ok, undefined}\}$.
If the child process start function returns an error tuple or an erroneous value, or if it fails, the function returns \(<\text{error},\text{Error}\>)\) where \(\text{Error}\) is a term containing information about the error.

\[
\text{which\_children}(\text{SupRef}) \rightarrow \left[\{\text{Id},\text{Child},\text{Type},\text{Modules}\}\right]
\]

Types:
- \(\text{SupRef} = \text{Name} \mid \{\text{Name},\text{Node}\} \mid \{\text{global},\text{Name}\} \mid \text{pid()}\)
- \(\text{Name} = \text{Node} = \text{atom()}\)
- \(\text{Id} = \text{term()} \mid \text{undefined}\)
- \(\text{Child} = \text{pid()} \mid \text{undefined}\)
- \(\text{Type} = \text{worker} \mid \text{supervisor}\)
- \(\text{Modules} = \{\text{Module}\} \mid \text{dynamic}\)
- \(\text{Module} = \text{atom()}\)

Returns a list with information about all child specifications and child processes belonging to the supervisor \(\text{SupRef}\).

See \text{start\_child/2} for a description of \text{SupRef}.

The information given for each child specification/process is:
- \(\text{Id}\) - as defined in the child specification or \text{undefined} in the case of a simple, one for one supervisor.
- \(\text{Child}\) - the pid of the corresponding child process, or \text{undefined} if there is no such process.
- \(\text{Type}\) - as defined in the child specification.
- \(\text{Modules}\) - as defined in the child specification.

\[
\text{check\_childsPcs}([\text{ChildSpec}]) \rightarrow \text{Result}
\]

Types:
- \(\text{ChildSpec} = \text{child\_spec()}\)
- \(\text{Result} = \text{ok} \mid \{\text{error},\text{Error}\}\)
- \(\text{Error} = \text{term()}\)

This function takes a list of child specification as argument and returns \text{ok} if all of them are syntactically correct, or \(\{\text{error},\text{Error}\}\) otherwise.

**CALLBACK FUNCTIONS**

The following functions should be exported from a \text{supervisor} callback module.
Exports

Module:init(Args) -> Result

Types:
- Args = term()
- Result = {ok, [{RestartStrategy, MaxR, MaxT}], [ChildSpec]} | ignore
- RestartStrategy = one_for_all | one_for_one | rest_for_one | simple_one_for_one
- MaxR = MaxT = int() >= 0
- ChildSpec = child_spec()

Whenever a supervisor is started using supervisor:start_link/2,3, this function is called by the new process to find out about restart strategy, maximum restart frequency and child specifications.

Args is the Args argument provided to the start function.

RestartStrategy is the restart strategy and MaxR and MaxT defines the maximum restart frequency of the supervisor. [ChildSpec] is a list of valid child specifications defining which child processes the supervisor should start and monitor. See the discussion about Supervision Principles above.

Note that when the restart strategy is simple_one_for_one, the list of child specifications must be a list with one child specification only. (The Id is ignored). No child process is then started during the initialization phase, but all children are assumed to be started dynamically using supervisor:start_child/2.

The function may also return ignore.

SEE ALSO

gen_event(3) [page 168], gen_fsm(3) [page 178], gen_server(3) [page 189], sys(3) [page 340]
supervisor_bridge

Erlang Module

A behaviour module for implementing a supervisor_bridge, a process which connects a subsystem not designed according to the OTP design principles to a supervision tree.

The supervisor_bridge sits between a supervisor and the subsystem. It behaves like a real supervisor to its own supervisor, but has a different interface than a real supervisor to the subsystem. Refer to OTP Design Principles for more information.

A supervisor_bridge assumes the functions for starting and stopping the subsystem to be located in a callback module exporting a pre-defined set of functions.

The sys module can be used for debugging a supervisor_bridge.

Unless otherwise stated, all functions in this module will fail if the specified supervisor_bridge does not exist or if bad arguments are given.

Exports

\[
\text{start_link(Module, Args) \to Result}
\]

\[
\text{start_link(SupBridgeName, Module, Args) \to Result}
\]

Types:

- \(\text{SupBridgeName} = \{\text{local}, \text{Name}\} \mid \{\text{global}, \text{Name}\}\)
- \(\text{Name} = \text{atom}()\)
- \(\text{Module} = \text{atom}()\)
- \(\text{Args} = \text{term}()\)
- \(\text{Result} = \{\text{ok}, \text{Pid}\} \mid \text{ignore} \mid \{\text{error}, \text{Error}\}\)
- \(\text{Pid} = \text{pid}()\)
- \(\text{Error} = \{\text{already_started}, \text{Pid}\} \mid \text{term}()\)

Creates a supervisor_bridge process, linked to the calling process, which calls Module:init/1 to start the subsystem. To ensure a synchronized start-up procedure, this function does not return until Module:init/1 has returned.

If \(\text{SupBridgeName} = \{\text{local}, \text{Name}\}\) the supervisor_bridge is registered locally as \text{Name} using register/2. If \(\text{SupBridgeName} = \{\text{global}, \text{Name}\}\) the supervisor_bridge is registered globally as \text{Name} using global:register_name/2. If no name is provided, the supervisor_bridge is not registered. If there already exists a process with the specified \text{SupBridgeName} the function returns \{error,\{already_started, \text{Pid}\}\}, where \text{Pid} is the pid of that process.

\text{Module} is the name of the callback module.

\text{Args} is an arbitrary term which is passed as the argument to Module:init/1.

If the supervisor_bridge and the subsystem are successfully started the function returns \{ok, \text{Pid}\}, where \text{Pid} is the pid of the supervisor_bridge.
If `Module:init/1` returns `ignore`, this function returns `ignore` as well and the supervisor_bridge terminates with reason `normal`. If `Module:init/1` fails or returns an error tuple or an incorrect value, this function returns `{error,Term}` where `Term` is a term with information about the error, and the supervisor_bridge terminates with reason `Term`.

**CALLBACK FUNCTIONS**

The following functions should be exported from a supervisor_bridge callback module.

**Exports**

```
Module:init(Args) -> Result
```

**Types:**
- `Args = term()`
- `Result = {ok,Pid,State} | ignore | {error,Error}`
- `Pid = pid()`
- `State = term()`
- `Error = term()`

Whenever a supervisor_bridge is started using `supervisor_bridge:start_link/2,3`, this function is called by the new process to start the subsystem and initialize. `Args` is the `Args` argument provided to the start function. The function should return `{ok,Pid,State}` where `Pid` is the pid of the main process in the subsystem and `State` is any term. If later `Pid` terminates with a reason `Reason`, the supervisor_bridge will terminate with reason `Reason` as well. If later the supervisor_bridge is stopped by its supervisor with reason `Reason`, it will call `Module:terminate(Reason,State)` to terminate. If something goes wrong during the initialization the function should return `{error,Error}` where `Error` is any term, or `ignore`.

```
Module:terminate(Reason, State)
```

**Types:**
- `Reason = shutdown | term()`
- `State = term()`

This function is called by the supervisor_bridge when it is about to terminate. It should be the opposite of `Module:init/1` and stop the subsystem and do any necessary cleaning up. The return value is ignored. `Reason` is `shutdown` if the supervisor_bridge is terminated by its supervisor. If the supervisor_bridge terminates because a linked process (apart from the main process of the subsystem) has terminated with reason `Term`, `Reason` will be `Term`. `State` is taken from the return value of `Module:init/1`.
SEE ALSO

supervisor(3) [page 330], sys(3) [page 340]
This module contains functions for sending system messages used by programs, and messages used for debugging purposes.

Functions used for implementation of processes should also understand system messages such as debugging messages and code change. These functions must be used to implement the use of system messages for a process; either directly, or through standard behaviours, such as `gen_server`.

The following types are used in the functions defined below:

- **Name**: `pid() | atom() | {global, atom()}
- **Timeout**: `int() >= 0 | infinity
- **system_event()**: `{in, Msg} | `{in, Msg, From} | `{out, Msg, To} | `term()`

The default timeout is 5000 ms, unless otherwise specified. The `timeout` defines the time period to wait for the process to respond to a request. If the process does not respond, the function evaluates `exit(timeout, {M, F, A})`.

The functions make reference to a debug structure. The debug structure is a list of `dbg_opt()`. `dbg_opt()` is an internal data type used by the `handle_system_msg/6` function. No debugging is performed if it is an empty list.

## System Messages

Processes which are not implemented as one of the standard behaviours must still understand system messages. There are three different messages which must be understood:

- **Plain system messages**: These are received as `{system, From, Msg}`. The content and meaning of this message are not interpreted by the receiving process module. When a system message has been received, the function `sys:handle_system_msg/6` is called in order to handle the request.

- **Shutdown messages**: If the process traps exits, it must be able to handle a shut-down request from its parent, the supervisor. The message `{EXIT`, Parent, Reason}` from the parent is an order to terminate. The process must terminate when this message is received, normally with the same Reason as Parent.
• There is one more message which the process must understand if the modules used to implement the process change dynamically during runtime. An example of such a process is the gen_event processes. This message is \{get_modules, From\}. The reply to this message is \{From ! \{modules, Modules\}, where Modules is a list of the currently active modules in the process.

This message is used by the release handler to find which processes execute a certain module. The process may at a later time be suspended and ordered to perform a code change for one of its modules.

System Events

When debugging a process with the functions of this module, the process generates system_events which are then treated in the debug function. For example, trace formats the system events to the tty.

There are three predefined system events which are used when a process receives or sends a message. The process can also define its own system events. It is always up to the process itself to format these events.

Exports

log(Name,Flag)
log(Name,Flag,Timeout) -> ok | \{ok, [system_event()]\}

Types:
  • Flag = true | \{true, N\} | false | get | print
  • N = integer() > 0

Turns the logging of system events On or Off. If On, a maximum of \(N\) events are kept in the debug structure (the default is 10). If Flag is get, a list of all logged events is returned. If Flag is print, the logged events are printed to standard_input. The events are formatted with a function that is defined by the process that generated the event (with a call to sys:handle_debug/4).

log_to_file(Name,Flag)
log_to_file(Name,Flag,Timeout) -> ok | \{error, open_file\}

Types:
  • Flag = FileName | false
  • FileName = string()

Enables or disables the logging of all system events in textual format to the file. The events are formatted with a function that is defined by the process that generated the event (with a call to sys:handle_debug/4).

statistics(Name,Flag)
statistics(Name,Flag,Timeout) -> ok | \{ok, Statistics\}

Types:
  • Flag = true | false | get
• Statistics = [{start_time, {Date1, Time1}}, {current_time, {Date, Time2}},
  {reductions, integer()}, {messages_in, integer()}, {messages_out, integer()}]
• Date1 = Date2 = {Year, Month, Day}
• Time1 = Time2 = {Hour, Min, Sec}

Enables or disables the collection of statistics. If Flag is get, the statistical collection is
returned.

trace(Name, Flag)
trace(Name, Flag, Timeout) -> void()

Types:
• Flag = boolean()
Prints all system events on standard io. The events are formatted with a function that
is defined by the process that generated the event (with a call to sys:handle_debug/4).

no_debug(Name)
no_debug(Name, Timeout) -> void()

Turns off all debugging for the process. This includes functions that have been installed
explicitly with the install function, for example triggers.

suspend(Name)
suspend(Name, Timeout) -> void()

Suspends the process. When the process is suspended, it will only respond to other
system messages, but not other messages.

resume(Name)
resume(Name, Timeout) -> void()

Resumes a suspended process.

change_code(Name, Module, OldVsn, Extra)
change_code(Name, Module, OldVsn, Extra, Timeout) -> ok | {error, Reason}

Types:
• OldVsn = undefined | term()
• Module = atom()
• Extra = term()

Tells the process to change code. The process must be suspended to handle this
message. The Extra argument is reserved for each process to use as its own. The
function Mod:system_code_change/4 is called. OldVsn is the old version of the Module.

get_status(Name)
get_status(Name, Timeout) -> {status, Pid, {module, Mod}, [PDict, SysState, Parent,
  Dbg, Misc]}

Types:
• PDict = [{Key, Value}]
• SysState = running | suspended
• Parent = pid()
- \texttt{Dbg} = \{\texttt{dbg} \texttt{opt()}\}
- \texttt{Misc} = \texttt{term()}

Gets the status of the process.

\texttt{install(Name,\{Func,FuncState\})}
\texttt{install(Name,\{Func,FuncState\},Timeout)}

\textbf{Types:}
- \texttt{Func} = \texttt{dbg fun()}
- \texttt{dbg fun()} = \texttt{fun(FuncState, Event, ProcState) \rightarrow done | NewFuncState}
- \texttt{FuncState} = \texttt{term()}
- \texttt{Event} = \texttt{system\_event()}
- \texttt{ProcState} = \texttt{term()}
- \texttt{NewFuncState} = \texttt{term()}

This function makes it possible to install other debug functions than the ones defined above. An example of such a function is a trigger, a function that waits for some special event and performs some action when the event is generated. This could, for example, be turning on low level tracing.

\texttt{Func} is called whenever a system event is generated. This function should return \texttt{done}, or a new \texttt{func state}. In the first case, the function is removed. It is removed if the function fails.

\texttt{remove(Name,Func)}
\texttt{remove(Name,Func,Timeout) \rightarrow void()}

\textbf{Types:}
- \texttt{Func} = \texttt{dbg fun()}

Removes a previously installed debug function from the process. \texttt{Func} must be the same as previously installed.

\textbf{Process Implementation Functions}

The following functions are used when implementing a special process. This is an ordinary process which does not use a standard behaviour, but a process which understands the standard system messages.
Exports

debug_options(Options) -> [dbg_opt()]

Types:
- Options = [Opt]
- Opt = trace | log | statistics | {log_to_file, FileName} | {install, {Func, FuncState}}
- Func = dbg_fun()
- FuncState = term()

This function can be used by a process that initiates a debug structure from a list of options. The values of the Opt argument are the same as the corresponding functions.

get_debug(Item,Debug,Default) -> term() 

Types:
- Item = log | statistics
- Debug = [dbg_opt()]
- Default = term()

This function gets the data associated with a debug option. Default is returned if the Item is not found. Can be used by the process to retrieve debug data for printing before it terminates.

handle_debug([dbg_opt()],FormFunc,Extra,Event) -> [dbg_opt()]

Types:
- FormFunc = dbg_fun()
- Extra = term()
- Event = system_event()

This function is called by a process when it generates a system event. FormFunc is a formatting function which is called as FormFunc(Device, Event, Extra) in order to print the events, which is necessary if tracing is activated. Extra is any extra information which the process needs in the format function, for example the name of the process.

handle_system_msg(Msg,From,Parent,Module,Debug,Misc)

Types:
- Msg = term()
- From = pid()
- Parent = pid()
- Module = atom()
- Debug = [dbg_opt()]
- Misc = term()
This function is used by a process module that wishes to take care of system messages. The process receives a {system, From, Msg} message and passes the Msg and From to this function.

This function never returns. It calls the function Mod:system_continue(Parent, NDebug, Misc) where the process continues the execution, or Mod:system_terminate(Reason, Parent, Debug, Misc) if the process should terminate. The Module must export system_continue/3, system_terminate/4, and system_code_change/4 (see below).

The Misc argument can be used to save internal data in a process, for example its state. It is sent to Mod:system_continue/3 or Mod:system_terminate/4.

`print_log(Null) -> void()`

Types:
- `Null = [dbg_opt()]`

Prints the logged system events in the debug structure using FormFunc as defined when the event was generated by a call to handle_debug/4.

Mod:system_continue(Parent, Debug, Misc)

Types:
- `Parent = pid()`
- `Debug = [dbg_opt()]`
- `Misc = term()`

This function is called from sys:handle_system_msg/6 when the process should continue its execution (for example after it has been suspended). This function never returns.

Mod:system_terminate(Reason, Parent, Debug, Misc)

Types:
- `Reason = term()`
- `Parent = pid()`
- `Debug = [dbg_opt()]`
- `Misc = term()`

This function is called from sys:handle_system_msg/6 when the process should terminate. For example, this function is called when the process is suspended and its parent orders shut-down. It gives the process a chance to do a clean-up. This function never returns.

Mod:system_code_change(Misc, Module, OldVsn, Extra) -> {ok, NMisc}

Types:
- `Misc = term()`
- `OldVsn = undefined | term()`
- `Module = atom()`
- `Extra = term()`
- `NMisc = term()`
Called from sys:handle_system_msg/6 when the process should perform a code change. The code change is used when the internal data structure has changed. This function converts the Misc argument to the new data structure. OldVsn is the vsn attribute of the old version of the Module. If no such attribute was defined, the atom undefined is sent.
This module provides useful functions related to time. Unless otherwise stated, time is always measured in milliseconds. All timer functions return immediately, regardless of work carried out by another process.

Successful evaluations of the timer functions yield return values containing a timer reference, denoted TRef below. By using cancel/1, the returned reference can be used to cancel any requested action. A TRef is an Erlang term, the contents of which must not be altered.

The timeouts are not exact, but should be at least as long as requested.

Exports

**start()** -> **ok**

Starts the timer server. Normally, the server does not need to be started explicitly. It is started dynamically if it is needed. This is useful during development, but in a target system the server should be started explicitly. Use configuration parameters for kernel for this.

**apply_after(Time, Module, Function, Arguments)** -> **{ok, TRef} | {error, Reason}**

Types:
- **Time** = integer() in milliseconds
- **Module** = Function = atom()
- **Arguments** = [term()]

Evaluates apply(M, F, A) after Time amount of time has elapsed. Returns {ok, TRef}, or {error, Reason}.

**send_after(Time, Pid, Message)** -> **{ok, TRef} | {error, Reason}**

**send_after(Time, Message)** -> **{ok, TRef} | {error, Reason}**

Types:
- **Time** = integer() in milliseconds
- **Pid** = pid() | atom()
- **Message** = term()
- **Result** = {ok, TRef} | {error, Reason}

**send_after/3** Evaluates Pid ! Message after Time amount of time has elapsed. (Pid can also be an atom of a registered name.) Returns {ok, TRef}, or {error, Reason}. 
send_after/2 Same as send_after(Time, self(), Message).

exit_after(Time, Pid, Reason1) -> {ok, TRef} | {error,Reason2}
exit_after(Time, Reason1) -> {ok, TRef} | {error,Reason2}
kill_after(Time, Pid) -> {ok, TRef} | {error,Reason2}
kill_after(Time) -> {ok, TRef} | {error,Reason2}

Types:
- Time = integer() in milliseconds
- Pid = pid() | atom()
- Reason1 = Reason2 = term()

exit_after/3 Send an exit signal with reason Reason1 to Pid Pid. Returns \{ok, TRef\}, or \{error, Reason2\}.
exit_after/2 Same as exit_after(Time, self(), Reason1).
kill_after/2 Same as exit_after(Time, Pid, kill).
kill_after/1 Same as exit_after(Time, self(), kill).

apply_interval(Time, Module, Function, Arguments) -> {ok, TRef} | {error, Reason}

Types:
- Time = integer() in milliseconds
- Module = Function = atom()
- Arguments = [term()]

Evaluates apply(Module, Function, Arguments) repeatedly at intervals of Time. Returns \{ok, TRef\}, or \{error, Reason\}.

send_interval(Time, Pid, Message) -> {ok, TRef} | {error, Reason}
send_interval(Time, Message) -> {ok, TRef} | {error, Reason}

Types:
- Time = integer() in milliseconds
- Pid = pid() | atom()
- Message = term()
- Reason = term()

send_interval/3 Evaluates Pid ! Message repeatedly after Time amount of time has elapsed. (Pid can also be an atom of a registered name.) Returns \{ok, TRef\} or \{error, Reason\}.
send_interval/2 Same as send_interval(Time, self(), Message).

cancel(TRef) -> {ok, cancel} | {error, Reason}

Cancels a previously requested timeout. TRef is a unique timer reference returned by the timer function in question. Returns \{ok, cancel\}, or \{error, Reason\} when TRef is not a timer reference.

sleep(Time) -> ok
Types:
  - Time = integer() in milliseconds

Suspends the process calling this function for Time amount of milliseconds and then returns ok. Naturally, this function does not return immediately.

tc(Module, Function, Arguments) -> {Time, Value}

Types:
  - Module = Function = atom()
  - Arguments = [term()]
  - Time = integer() in microseconds
  - Value = term()

Evaluates apply(Module, Function, Arguments) and measures the elapsed real time. Returns {Time, Value}, where Time is the elapsed real time in microseconds, and Value is what is returned from the apply.

now_diff(T2, T1) -> Tdiff

Types:
  - T1 = T2 = {MegaSecs, Secs, MicroSecs}
  - Tdiff = MegaSecs = Secs = MicroSecs = integer()

Calculates the time difference Tdiff = T2 - T1 in microseconds, where T1 and T2 probably are timestamp tuples returned from erlang:now/0.

seconds(Seconds) -> Milliseconds

Returns the number of milliseconds in Seconds.

minutes(Minutes) -> Milliseconds

Return the number of milliseconds in Minutes.

hours(Hours) -> Milliseconds

Returns the number of milliseconds in Hours.

hms(Hours, Minutes, Seconds) -> Milliseconds

Returns the number of milliseconds in Hours + Minutes + Seconds.
Examples

This example illustrates how to print out “Hello World!” in 5 seconds:

```erlang
1> timer:apply_after(5000, io, format, ["~nHello World!~n", []]).
   {ok,TRef} Hello World!
2>
```

The following coding example illustrates a process which performs a certain action and if this action is not completed within a certain limit, then the process is killed.

```erlang
Pid = spawn(mod, fun, [foo, bar]),
%% If pid is not finished in 10 seconds, kill him
{ok, R} = timer:kill_after(timer:seconds(10), Pid),
...
%% We change our mind...
timer:cancel(R),
...```

**WARNING**

A timer can always be removed by calling `cancel/1`.

An interval timer, i.e. a timer created by evaluating any of the functions `apply_interval/4`, `send_interval/3`, and `send_interval/2`, is linked to the process towards which the timer performs its task.

A one-shot timer, i.e. a timer created by evaluating any of the functions `apply_after/4`, `send_after/3`, `send_after/2`, `exit_after/3`, `exit_after/2`, `kill_after/2`, and `kill_after/1` is not linked to any process. Hence, such a timer is removed only when it reaches its timeout, or if it is explicitly removed by a call to `cancel/1`. 
**win32reg**

Erlang Module

`win32reg` provides read and write access to the registry on Windows. It is essentially a port driver wrapped around the Win32 API calls for accessing the registry.

The registry is a hierarchical database, used to store various system and software information in Windows. It is available in Windows 95 and Windows NT. It contains installation data, and is updated by installers and system programs. The Erlang installer updates the registry by adding data that Erlang needs.

The registry contains keys and values. Keys are like the directories in a file system, they form a hierarchy. Values are like files, they have a name and a value, and also a type.

Paths to keys are left to right, with sub-keys to the right and backslash between keys. (Remember that backslashes must be doubled in Erlang strings.) Case is preserved but not significant. Example: "\\hkey\local\machine\software\Ericsson\Erlang\5.0" is the key for the installation data for the latest Erlang release.

There are six entry points in the Windows registry, top level keys. They can be abbreviated in the `win32reg` module as:

<table>
<thead>
<tr>
<th>Abbrev.</th>
<th>Registry key</th>
</tr>
</thead>
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<tr>
<td>hkcr</td>
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</tr>
<tr>
<td>current_user</td>
<td>HKEY_CURRENT_USER</td>
</tr>
<tr>
<td>hkcu</td>
<td>HKEY_CURRENT_USER</td>
</tr>
<tr>
<td>local_machine</td>
<td>HKEY_LOCAL_MACHINE</td>
</tr>
<tr>
<td>hklm</td>
<td>HKEY_LOCAL_MACHINE</td>
</tr>
<tr>
<td>users</td>
<td>HKEY_USERS</td>
</tr>
<tr>
<td>hku</td>
<td>HKEY_USERS</td>
</tr>
<tr>
<td>current_config</td>
<td>HKEY_CURRENT_CONFIG</td>
</tr>
<tr>
<td>hkcc</td>
<td>HKEY_CURRENT_CONFIG</td>
</tr>
<tr>
<td>dyn_data</td>
<td>HKEY_DYN_DATA</td>
</tr>
<tr>
<td>hkdd</td>
<td>HKEY_DYN_DATA</td>
</tr>
</tbody>
</table>

The key above could be written as "\\hklm\software\ericsson\erlang\5.0".

The `win32reg` module uses a current key. It works much like the current directory. From the current key, values can be fetched, sub-keys can be listed, and so on.

Under a key, any number of named values can be stored. They have name, and types and data.

Currently, the `win32reg` module supports storing only the following types: `REG_DWORD`, which is an integer, `REG_SZ` which is a string and `REG_BINARY` which is a binary. Other types can be read, and will be returned as binaries.

There is also a "default" value, which has the empty string as name. It is read and written with the atom `default` instead of the name.
Some registry values are stored as strings with references to environment variables, e.g. "%SystemRoot%Windows". SystemRoot is an environment variable, and should be replaced with its value. A function expand/1 is provided, so that environment variables surrounded in % can be expanded to their values.

For additional information on the Windows registry consult the Win32 Programmer’s Reference.

Exports

\texttt{change	extunderscore key(RegHandle, Key) \to ReturnValue}

Types:
\begin{itemize}
\item \texttt{RegHandle = term()}
\item \texttt{Key = string()}
\end{itemize}

Changes the current key to another key. Works like cd. The key can be specified as a relative path or as an absolute path, starting with \\.

\texttt{change	extunderscore key	extunderscore create(RegHandle, Key) \to ReturnValue}

Types:
\begin{itemize}
\item \texttt{RegHandle = term()}
\item \texttt{Key = string()}
\end{itemize}

Creates a key, or just changes to it, if it is already there. Works like a combination of mkdir and cd. Calls the Win32 API function RegCreateKeyEx().

The registry must have been opened in write-mode.

\texttt{close(RegHandle) \to ReturnValue}

Types:
\begin{itemize}
\item \texttt{RegHandle = term()}
\end{itemize}

Closes the registry. After that, the \texttt{RegHandle} cannot be used.

\texttt{current	extunderscore key(RegHandle) \to ReturnValue}

Types:
\begin{itemize}
\item \texttt{RegHandle = term()}
\item \texttt{ReturnValue = \{\texttt{ok, string()\}}}
\end{itemize}

Returns the path to the current key. This is the equivalent of \texttt{pwd}.

Note that the current key is stored in the driver, and might be invalid (e.g. if the key has been removed).

\texttt{delete	extunderscore key(RegHandle) \to ReturnValue}

Types:
\begin{itemize}
\item \texttt{RegHandle = term()}
\item \texttt{ReturnValue = \{\texttt{ok, ErrorId\}}}
\end{itemize}
Deletes the current key, if it is valid. Calls the Win32 API function RegDeleteKey(). Note that this call does not change the current key, (unlike change_key_create/2.) This means that after the call, the current key is invalid.

delete_value(RegHandle, Name) -> ReturnValue
Types:
  • RegHandle = term()
  • ReturnValue = ok | {error, ErrorId}
Deletes a named value on the current key. The atom default is used for the the default value.
The registry must have been opened in write-mode.

expand(String) -> ExpandedString
Types:
  • String = string()
  • ExpandedString = string()
Expands a string containing environment variables between percent characters. Anything between two % is taken for a environment variable, and is replaced by the value. Two consecutive % is replaced by one %.
A variable name that is not in the environment, will result in an error.

format_error(ErrorId) -> ErrorString
Types:
  • ErrorId = atom()
  • ErrorString = string()
Convert an POSIX errorcode to a string (by calling erl_posix_msg:message).

open(OpenModeList) -> ReturnValue
Types:
  • OpenModeList = [OpenMode]
      • OpenMode = read | write
Opens the registry for reading or writing. The current key will be the root (HKEY_CLASSES_ROOT). The read flag in the mode list can be omitted. Use change_key/2 with an absolute path after open.

set_value(RegHandle, Name, Value) -> ReturnValue
Types:
  • Name = string() | default
  • Value = string() | integer() | binary()
Sets the named (or default) value to value. Calls the Win32 API function
RegSetValueEx(). The value can be of three types, and the corresponding registry type
will be used. Currently the types supported are: REG\_DWORD for integers, REG\_SZ for
strings and REG\_BINARY for binaries. Other types cannot currently be added or changed.
The registry must have been opened in write-mode.

\[\text{sub\_keys} (\text{RegHandle}) \rightarrow \text{ReturnValue}\]

Types:
- \( \text{ReturnValue} = \{\text{ok}, \text{SubKeys}\} \mid \{\text{error}, \text{ErrorId}\} \)
- \( \text{SubKeys} = \{\text{SubKey}\} \)
- \( \text{SubKey} = \text{string()}) \)

Returns a list of subkeys to the current key. Calls the Win32 API function
EnumRegKeysEx().

Avoid calling this on the root keys, it can be slow.

\[\text{value} (\text{RegHandle}, \text{Name}) \rightarrow \text{ReturnValue}\]

Types:
- \( \text{Name} = \text{string()} \mid \text{default} \)
- \( \text{ReturnValue} = \{\text{ok}, \text{Value}\} \)
- \( \text{Value} = \text{string()} \mid \text{integer()} \mid \text{binary()} \)

Retrieves the named value (or default) on the current key. Registry values of type
REG\_SZ, are returned as strings. Type REG\_DWORD values are returned as integers. All
other types are returned as binaries.

\[\text{values} (\text{RegHandle}) \rightarrow \text{ReturnValue}\]

Types:
- \( \text{ReturnValue} = \{\text{ok}, \text{ValuePairs}\} \)
- \( \text{ValuePairs} = \{\text{ValuePair}\} \)
- \( \text{ValuePair} = \{\text{Name}, \text{Value}\} \)
- \( \text{Name} = \text{string()} \mid \text{default} \)
- \( \text{Value} = \text{string()} \mid \text{integer()} \mid \text{binary()} \)

Retrieves a list of all values on the current key. The values have types corresponding
to the registry types, see value. Calls the Win32 API function EnumRegValuesEx().

SEE ALSO

Win32 Programmer's Reference (from Microsoft)
erl\_posix\_msg
The Windows 95 Registry (book from O'Reily)
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