

The Kvaser t Programming Language

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1 t Programming

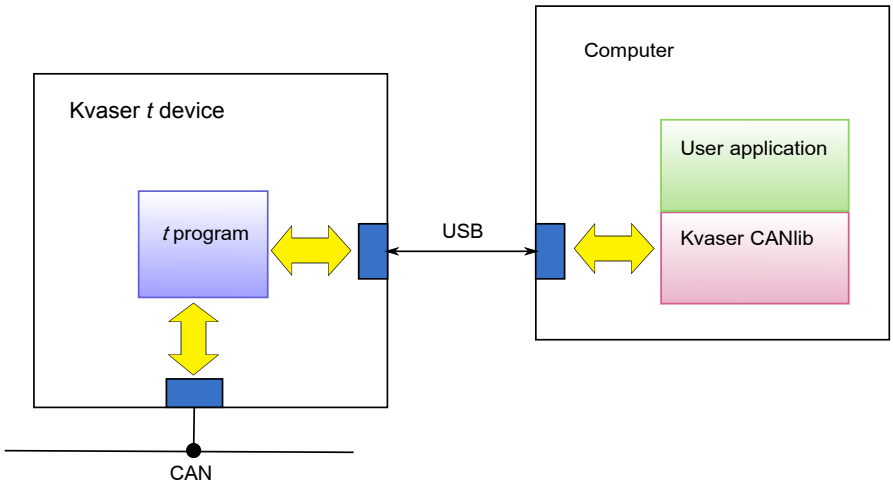
1.1 Overview

The Kvaser *t* programming language is event oriented and modeled after C. It can be used to customize the behavior of Kvaser Memorator Pro 2xHS v2 and other Kvaser *t* capable devices.

A *t* program is invoked via hooks, which are entry points that are executed at the occurrence of certain events. These events can be, for example, the arrival of specific CAN messages, timer expiration, or external input.

The addition of *t* programs running directly on a Kvaser Device makes it possible to react much quicker to CAN bus events (for example to speed up file transfer protocols or to simulate missing hardware). Some Kvaser devices can also operate completely autonomously, e.g. Kvaser Memorator Pro 2xHS v2.

In this document, “Kvaser *t*”, “*t*”, “the *t* language”, and “the *t* programming language” are used as synonyms for the language. A piece of software written using it is a *t* program or possibly a *t* script. No difference in meaning is intended between, for example, “a Kvaser *t* program” and “a *t* script”.



1.1.1 Creating a *t* Program

First of all, decide what you want to happen in your program. Do you want to receive a message, send a message, or a combination of both?

You must decide what will trigger an action in your code. You can trigger on execution start/stop, on a key press, on a timer, or on reception of a message.

If you want to receive CAN messages, use the on CanMessage construct. After receiving a message, you may print to a log file, send a message, update a counter, etc.

If you want to send messages, decide how the transmission will be triggered. As mentioned above, there are different ways of triggering in the system.

Use your favorite text editor to create the *t* program.

If you are familiar with C programming this will all be straightforward!

1.1.2 Using a *t* Program

When you have written your *t* program, you need to compile the file using the supplied command line compiler. Any syntactic or semantic errors in the file are diagnosed by the compiler and must be corrected before the compiler will produce a binary format file as output.

This is an example of how to use the *t* language compiler:

```
> scc.exe test.t
```

The command will produce a binary output file named test.txe that can then be loaded and executed. Running long program segments may adversely affect the general system operation. Do not write code that loops "forever"!

1.1.3 Version of *t* compiler

The compiler version number consists of three parts: MAJOR.MINOR.BUILD. Updates in the MAJOR part indicates significant changes that needs support from new firmware. This also means that older scripts may need to be recompiled before they can be executed on a newer firmware. See the release notes for information about which compiler versions a specific firmware supports.

The current version of the compiler is printed when invoked without any arguments.

As of this writing, the latest version of the *t* compiler is version 3.13.

1.1.3.1 Running via CANlib

To test the program, you must download the compiled binary file to your Kvaser Device via CANlib. You can also download data files via CANlib. CANlib provides functions for starting and stopping the *t* program. There are also functions for communicating with the *t* program. The following example uses the Kvaser *t* utility (a program that wraps CANlib's *t* related functions) to download and start the compiled *t* program:

```
> tutil.exe -channel=0 -slot=0 -load test.txe -start
```

Or, if the *t* program is stored on the SD card, this command starts the program:

```
> tutil.exe -channel=0 -slot=0 -loadlocal test.txe -start
```

For help on how to use the Kvaser *t* utility, use the following command:

```
> tutil.exe -?
```

Strings printed by the *t* program can be captured by the *t* utility with the following command:

```
> tutil.exe -channel=0 -listen -1
```

Where '-1' means "forever".

1.1.3.2 Running in Standalone Mode

To run the *t* program in standalone mode (e.g. Kvaser Memorator Pro 2xHS v2 connected to a CAN bus and not a USB bus), you must compile your program(s) and then download the generated binary file(s) with the Kvaser Memorator Config Tools.

1.1.4 Inherited Settings Versus *t* Program Settings

As already stated, there are two ways of starting a *t* program - a configuration downloaded by the Kvaser Memorator Config Tools or a CANlib application like tutil.exe. The bus parameters for the CAN bus must be set before the bus can be used. This can be done either via CANlib, the Kvaser Memorator Config Tools, or directly in a *t* program. Additionally, to send and recieve CAN FD messages in a *t* program, the CAN FD communication mode and the bus parameters for the arbitration phase and the data phase, must be set through a *t* program.

The simple rule is: the last one to set the bus parameters "wins".

1.1.4.1 Start-up Sequence in Standalone Mode

When in standalone mode, the *t* program starts automatically when the device powers on.

In this case, the bus settings from the log configuration are used. The program does not need to setup the bus or go bus-on since these steps have already been handled before the program starts.

However, the *t* program may change the bus settings. The following is the start-up sequence in standalone mode:

1. The device is connected to the CAN bus; power on
2. The device reads configuration
3. The device sets the bus parameters and goes bus-on
4. The *t* program loads, starts, and optionally changes the bus parameters

1.1.4.2 Start-up with CANlib Application

When using CANlib to start a *t* program, the CANlib program or the *t* program must set the bus parameters and activate a channel on the bus. If the CANlib program sets the bus parameters, the *t* program can still re-configure the bus settings.

1.2 Introduction to the *t* Language for CAN

If you have programmed in C or C++, most of the *t* language will look very familiar. However, the event based nature of *t* means that a *t* program looks slightly different. Some C language features are missing, such as unsigned integers, union types and pointers, while some features from other languages have been incorporated.

1.2.1 Simple Example

```
on start {
  canBusOff();
  canSetBitrate(canBITRATE_1M);
  canSetBusOutputControl(canDRIVER_SILENT);
  canBusOn();
}

on stop {
  canBusOff();
}

on CanMessage 54321x {
  printf("Hello, User!\n");
}
```

This program simply prints the text “Hello, User!” to the standard output when the program detects a CAN message with the extended identifier 54321 (decimal) is received.

1.2.2 More Complex Example

```
variables {
  const int can_channel = 0;
  const int can_bitrate = 1000000;
  Timer sendTimer;
  int   value;
}

on start {
  printf("Hello again! It's the Second Example speaking..\n");
  printf("Send message 1000 and I will send another one.\n");
  value = 0;

  canBusOff(can_channel);
  canSetBitrate(can_channel, can_bitrate);
  canSetBusOutputControl(can_channel, canDRIVER_NORMAL);
  canBusOn(can_channel);

  sendTimer.timeout = 1000;    // Milliseconds
  timerStart(sendTimer, FOREVER);
}

on stop {
  canBusOff(can_channel);
}

on CanMessage<1> 1000 {
  CanMessage msg;
  msg.id      = 123;
  msg.dlc     = 8;
  msg.flags   = 0;
  msg.data    = "\x11\x22\x33\x44\x55\x66\x77\x88";
  canWrite(msg);
}

on Timer sendTimer {
  CanMessage msg;
  msg.id      = 1234;
  msg.dlc     = 2;
  msg.flags   = canMSG_EXT;
  msg.data[0] = value;
  msg.data[1] = value >> 8;
  value++;
  canWrite(msg);
}
```

This program will send one CAN message with standard identifier 123 (decimal) each time a CAN message with identifier 1000 is received on channel 1. The

program will also send a CAN message with extended identifier 1234 once every second.

1.2.3 Receive Example

```
on start {
  printf("Hello again! It's the Third Example speaking.\n");
  printf("Receive a message.\n");
}

on CanMessage<*> [*] {
  printf("Pling! Message %d received, with %d bytes of data:",
         this.id, this.dlc);
  for(int i = 0; i < this.dlc; i++) {
    printf("%02x ", this.data[i]);
  }
  printf("\n");
}
```

This program will receive any CAN message and print the message's data to the standard output.

1.3 Elements of a *t* Program

A *t* program consists of a sequence of constructs. The order is irrelevant, except that a construct is not visible before it is declared. None of the constructs are mandatory, and there can be any number of any construct. One or more CAN database files can also be used.

The possible constructs are:

- `variables` section, contains definitions of global variables, constants, and types
- `envvar` section, contains declarations of communication variables
- event hook, connects a desired code response to a specific event
- function definition, a piece of code that can be called from elsewhere in the program
- function declaration, establishes a function's interface without providing the function definition

1.3.1 The `variables` Section

All variables, constants, and types that need to be global (accessible from multiple hooks or functions) must be defined in a `variables` section. This is equivalent to defining something in global scope in a C program.

Example

```
variables {
  const int LENGTH = 80;
  const char filename[13] = "file.dat";
  int count = 0;
  char text[LENGTH] = filename;
  float x, y;
}
```

1.3.2 The `envvar` Section

Environment variables are used to communicate between different *t* programs or with a host computer using CANlib. Environment variables are defined in the `envvar` section, and just like variables in the `variables` section, environment variables are global.

Example

```
envvar {
  int   option;
  char  message[8];
  float angle;
}
```

1.3.3 Event Hooks

All events that a *t* program will react to are specified using various `on` event hooks. In effect, these are functions which are called when the specific events occur. Among other events, the program can react to the arrival of a CAN message, the elapse of a timer, or the start of the program itself.

Example

```
on start {
  count = 0;
}

on CanMessage 100 {
  length  = this.dlc;
  message = this.data;
}
```

1.3.4 Function Definitions

You can define your own functions in *t*. This can greatly enhance the usability of the language. Each function definition is placed at the outermost level in the program file, in the same way as a `variables` section.

Example

```
void send (int id, const byte data[])
{
  CanMessage msg;
  msg.flags = canMSG_EXT;
  msg.id    = id;
  msg.dlc   = data.count;
  msg.data  = data;
  canWrite(msg);
}
```

1.3.5 Function Declarations

Sometimes using a function before the function is defined is necessary or preferable. For that reason, the language supports function declarations. The function declaration prepares the compiler by describing the function's interface.

Example

```
void report(char text[]);
float getAngle(void);
```

1.3.6 CAN Databases (.dbc Files)

While writing a *t* program without CAN database files is possible, using a CAN database file is a good idea. By using a CAN database file, the compiler can generate `typedef` and `struct` members to match the signals in the database, as well as automatically handle any specified scaling of the signals.

Example

```
on CanMessage StartRamps {
  ramp_amp    = this.Amplitude.Phys;
  ramp_offset = this.Offset.Phys;
}
```

When compiling this program, we need to add the database containing "StartRamps" like this:

```
> scc.exe -dbase=my_database.dbc my_prog.t
```

When working with multiple databases, two databases might define the same message. To clarify which definition should be used, a logical name should be assigned to the database. For example, if we have two databases with "rpm" as shown below:

database1.dbc:

```
...
BO_ 43 rpm: 8 Vector__XXX
 SG_ value : 0|16@1+ (1,0) [0|5000] "RPM" Vector__XXX
```

database2.dbc:

```
...
BO_ 143 rpm: 8 Vector__XXX
 SG_ value : 0|16@1+ (1,0) [0|20000] "RPM" Vector__XXX
```

Then we need to establish a unique logical name for the database during compilation:

```
> scc.exe -dbase=my@database1.dbc -dbase=their@database2.dbc
  my_prog.t
```

Now the logical name can be used in the program:

Example

```
on CanMessage my_rpm {
  // ID = 43, RPM: 0 - 5000
}

on CanMessage their_rpm {
  // ID = 143, RPM: 0 - 20000
}
```

Note that the compiler does not take max/min values from the database into account when generating code for signal access. This means that a read/write from/to a signal outside the signal's bounds will NOT cause an exception or saturation.

Also note that the *t* language does not support unsigned integer or double types. This means unsigned to signed conversions could produce the wrong result. Also, signals defined as type double in the database cannot be used.

For more information on how to compile with a database file, see:

```
> scc.exe -?
```

1.3.7 Exception Handling

The *t* program environment has a built in exception handler that will print some useful information and then stop the program where the exception occurred. For examples on how to write your own handler, see Section 2.10.2.10, `exception`, on Page 39.

If an exception hook is not provided, the program will be stopped.

1.4 Device dependent functionality

Some devices have physical limits that renders some functions unusable, e.g. the `timeGetDate` function would not do anything useful on a device that does not have a real time clock. Consult the device User Guide for information about any restrictions regarding t functionality.

2 *t* Language Reference

This document describes the *t* language as implemented in version 3.13 of the *t* compiler (scc.exe).

2.1 Types

t has a small number of predefined types, which can be used as building blocks for more complex types. The run-time library defines additional complex types and more can be automatically generated when using database files.

2.1.1 Predefined Types

The following types are predefined:

Type	Meaning
`float`	A 32-bit floating point number
`int`	A 32-bit signed integer
`char`	An 8-bit character (signed integer)
`byte`	An 8-bit unsigned integer

The `char` and `byte` types are always treated as `int` in expressions (after sign extending for `char`).

When an operator can take `float` arguments, if one of the operands is an `int` and the other operand is a `float`, the `int` is converted to `float` before being used.

For operators that only take `int` arguments, any `float` is converted to an `int` before being used. Automatic type conversion from `float` to `int` is also done for array indexing and `switch` statements.

2.1.2 Run-time Library Types

The run-time library defines the following types:

Type	Use
`FileHandle`	Opaque type for dealing with files
`XmlHandle`	Opaque type for dealing with XML files
`CanTpHandle`	Opaque type for dealing with CAN transport protocol sessions
`LedHandle`	Opaque type for dealing with LEDs
`EnvVar`	Opaque type for dealing with environment variables
`Timer`	Partly opaque type for dealing with timers – see 2.34.1
`CanMessage`	Both sent and received CAN messages are of this type – see 2.34.2
`CanMessageFd`	Both sent and received CAN FD messages are of this type – see 2.34.3
`CanTpMessage`	Used to report CAN transport protocol events – see 2.34.4
`IoEvent`	Used for I/O events, see 2.34.8
`tm`	Calendar data and time – see 2.34.5
`ExceptionData`	Contains information about an exception – see 2.34.6

2.1.3 Type declarations

New data types are created through type declarations. Type declarations are indicated by `typedef`. Currently, `typedef` only supports the structure complex data type (similar to C structures and Pascal records) which is indicated using the keyword `struct`.

A structure is composed of a list of variable declarations. Each declared variable is considered a member of the structure.

A structure member behaves like any other variable of the same type with one exception. Currently, a structure member that is a predefined type cannot be passed by reference unless the member is an array. Arrays are always passed by reference.

A structure can only be given values by assigning a value to each contained member. Assigning values to the whole structure is currently not supported.

Syntax

```
typedef struct '{'
  struct_body
'}' ident ';'
```

struct_body is one or more member declarations using the same syntax as variable declarations. *ident* is the name of the type being defined.

Example

```
variables {
  typedef struct {
    byte data[4];
  } Temporary;

  typedef struct {
```

```
    int control[3];
    Temporary temp;
    CanMessage msg;
  } aacinfo;
}
...

aacinfo aac;
aac.control[0] = 0x251;
aac.temp.data  = 0;
```

2.1.4 Explicit Type Conversion (typecast)

In addition to the automatic type conversion described in section 2.1.1, explicit type casts can be performed for the following data types: `float`, `int`, `char`, and `byte`. The syntax is the same as C.

Syntax

```
'(' type_name ')' expression
```

type_name is the desired resulting data type and *expression* is the value being converted.

Example

```
int p         = (int)M_PI;
int y         = x * (int)round(f(t));
float seconds = (float)milliseconds / 1000;
int delta     = (char)msg.data[2];
log((byte)++seqno);
```

2.1.5 Arrays

t supports arrays of any data type. Arrays are always range checked on use, meaning any attempt to use an array to access memory outside the array's range will cause an exception. The number of elements in an array can be accessed using the array variable's `count` member.

An array element behaves like any other variable of the same type with one exception. Currently, an array element that is a predefined type cannot be passed by reference. If the array element is a structure, the element can be passed by reference since structures are always passed by reference.

Array assignment is supported for arrays of predefined data types. If a scalar value is assigned to the array, all elements in the array will be set to the scalar value. If the assignment is another array, all data will be copied into the destination array. If the assignment is from a smaller array, old data is left at the end of the destination array. If the assignment is from a larger array, any extra data at the end is ignored.

Wherever an array can be used, so can a slice of the array. A slice is simply a reference to a subset of elements in the array. A slice's subset can be created in three different ways:

- the '..' range operator specifies a start and end index
- the ',' range operator specifies a start index and a total element count
- the '+' operator specifies a start index

Example

```
a = b
vector[i]      = t / 3;
counts[0 .. 5] = 0;           // Elements 0, 1, ..., 5
data[n * 8, 8] = msg.data;    // Elements 8n, 8n + 1, ..., 8n + 7
total = my_sum(v + (f - 1)); // Elements v + f - 1, v + f, ...
                              // v is an array, f is a number
i     = messages.count;
```

The parenthesis are necessary for the calculation of *total* in the example above. If the parenthesis were removed, the compiler would consider $v + f$ a temporary array and the -1 would be an attempt at a negative offset. If $f - 1$ produces a negative value during execution, the resulting negative offset will be treated like any other out-of-range access (i.e. an exception will be thrown).

Note: *t* only supports one-dimensional arrays. The effect of multiple dimensions can be achieved by using arrays of structures containing arrays.

2.2 Variables and constants

A variable or constant is defined in a `variables` section (which makes the object globally visible) or in a block (which makes the object local to that block). Like in C++, variables and constants can be defined anywhere within a block, not just at the beginning of a block. Also like C++, a variable can be defined in a for-loop statement. In this case, the variable's scope is limited to the loop.

Example

```
{
  int total = 3;
  x = y * 3 + total;
  const float angle = M_PI * 0.75;
  float length = vector * sin(angle);
  for(int n = 0; n < total; n++) {
    ...
  }
  ...
}
```

A variable initializer defined in a `variables` section is executed during program initialization.

2.2.1 Variable Definitions

In variable definitions the data type *datatype* is either a predefined type or a user-defined type, *size* is a constant expression, and *initializer* is appropriate for the associated data type.

Syntax

```
datatype ident [ '[' size ']' ] [ '=' initializer ]
   [ ',' ident [ '[' size ']' ] [ '=' initializer ] ... ] ';'
```

Note: No default initialization is performed for any variable. Default initialization for references is "BAD".

2.2.1.1 Static Variables

Inside a block, a variable's storage class can be specified as static. Like in C, this means that the variable's value is retained upon exiting and re-entering the block. If the static variable uses an initializer, the initializer will only be executed on the first pass of the variable definition.

Example

```
int engineSpeed, engineType = 3;
float height     = length * tan(angle);
char text[20]    = "Hello World!", data[2] = {7, Max_size - 2};
static int count = 0;
```

2.2.2 Variable Initializers

Scalar variable initializers are not restricted, whether defined in a `variables` section or a block. However, an array initializer must be a constant expression.

Arrays can be initialized using a list of expressions. Arrays of type `char` or `byte` can also use a special string initializer. Initializing with a string is equivalent to putting all the separate characters in sequence in a normal array initializer, except that the string always contains an implicit '\0' at the end of the array. The string initializer can be replaced by a defined `char` array constant.

The compiler will indicate an error if the initializer is too large to fit in the array. But if the initializer is smaller than the array, the remaining elements will be undefined.

Example

```
float angles[2] = {M_PI * 0.5, M_PI * 1.3};
char texts[10]  = "\x02Hi\x05Hello";
```

2.2.3 Constant Definitions

A constant is defined in a `variables` section (making the constant visible globally) or inside a block (making the constant local to the block).

The constant expression (*constexpr*) which defines the constant's value may only use other constants. However, the expression can be arbitrarily complex, since the expression is evaluated at compile time.

Only `float`, `int`, and array of `char` constants are allowed.

Syntax

```
const ( int | float ) ident '=' constexpr
                          [ ',' ident '=' constexpr ... ] ';'
const char ident '[' ']' '=' string ';'
```

Example

```
const float pi = 3.141592;
const int loops = 100, maxloops = loops * 3;
const char filename[] = "report.txt";
```

2.2.4 Reference Variable Definitions

It is possible to create a reference to a variable, or part of a variable, with the same result as if it had been passed as a reference argument to a function (see Section 2.5.1, Function definitions, on Page 21). That is, any access using the reference will operate directly on the original variable, or part of variable. Reference variables are mainly useful to simplify code.

The references themselves are not assignable, and can thus only be set using an initializer. This also means that it is impossible to ever have a reference to something that is out of scope.

The compiler will automatically infer the type of the reference from its initializer.

Syntax

```
auto ident '=' '&' expr ';'
```

Example

```
auto fileno = &filename[6..7];
auto values = &table[n].row[i].col;
auto speed  = &msg.data[2];
```

2.2.5 Reserved Keywords

The following keywords are reserved and may not be used as identifiers:

```
__internal, __pragma_internal, action, and, auto, bool, break,
byte, CanMessage, CanMessageFd, CanTpMessage, case, catch,
char, class, const, continue, default, delete, do, double,
else, enum, envvar, exception, export, extern, false, float,
for, goto, if, init, input, int, key, long, monitor, mutex,
namespace, new, not, on, or, output, postfilter, prefilter,
private, protected, public, register, return, semaphore, short,
short, signal, signed, sizeof, start, startup, static, stop,
stopped, string, struct, switch, thread, throw, timer, true,
try, typedef, union, unsigned, using, va_arg, va_end, va_list,
va_start, variables, while, void, volatile, xor
```

2.3 Serialization and Deserialization

When using data files, or when communicating with another program, it is often useful to be able to convert data from structure form to an array of bytes, and the other way around. This is called serialization and deserialization, respectively. In *t* this is done by simply assigning an arbitrary structure to an appropriately sized array of `char` / `byte`, and vice versa.

The result of serialization is what is sometimes called a packed array with the contents from the structure. That is, there is no padding between values for alignment. Also, any compiler/runtime internal parts of the structure in question have been removed. Values of type`int` and `float` are stored in little endian format (i.e. with the least significant byte first).

To find out how many bytes are needed for a serialized structure, use `sizeof()` (see Section 2.32.3, `sizeof`, on Page 80).

Example

```
char buf[sizeof(CanMessage)];
CanMessage incoming_msg, outgoing_msg;
...
buf = incoming_msg;
fileWriteBlock(outfile, buf);
...
fileReadBlock(infile, buf);
outgoing_msg = buf;
```

2.4 Environment Variables

An environment variable can only be defined in an `envvar` section. Like a variable defined in a `variables` section, an environment variable is visible globally. Further, an environment variable is visible to other *t* programs as well as a connected host computer.

The lifespan of an environment variable is from when the first *t* program using the environment variable loads until the last *t* program using the environment variable unloads. All *t* programs using the same environment variable must be loaded before accessing it. To access environment variables on a host computer, use the Kvaser CANlib script API for environment variables.

Unlike ordinary variables, environment variables cannot be initialized or accessed directly in the *t* program. Rather, consider them handles and use `envvarSetValue` and `envvarGetValue` to access their contents.

When a script is started, the environment variables will be updated during the start up. Environment variables should therefore not be accessed in the `on start` hook, where the environment variables may be out of date.

Syntax

```
int   ident ';'
float ident ';'
char  ident '[' size ']' ';'
```

ident is the name of the environment variable and *size* is a constant expression. *size* is limited to ENVVAR_MAX_SIZE. The three data types shown are the only environment variable data types supported.

Example

```
envvar {
  int CANidToPC;
}

on CanMessage * {
  envvarSetValue(CANidToPC, this.id);
}
```

2.5 Functions

Like in C, functions are subroutines used to encapsulate a section of code to give it a clear interface and make it reusable. Functions can call each other and themselves, freely.

2.5.1 Function definitions

The function definition specifies the return type of the function, its name and parameters, and the function body.

Syntax

```
datatype ident '(' formal_parameters ')' fun_body
```

The function's return type is specified by *datatype*. *formal_parameters* is a sequence of:

```
[ const ] datatype [ '&' ] ident [ '[' ']' ]
  [ ',' [ const ] datatype [ '&' ] ident [ '[' ']' ] ... ]
```

When the formal parameter's name (*ident*) is preceded by '&', the parameter is passed by reference. If the formal parameter's name is succeeded by '[]', the parameter is an array.

The data types `int`, `float`, `char`, and `byte` are passed by value. To pass an `int`, `float`, `char`, or `byte` by reference; place an ampersand, '&', in front of the parameters name in the function declaration and in front of the argument when calling the function. Arrays and structures are always passed by reference.

Array and structure parameters may have their types preceded by the keyword `const`, which means the formal parameter may not be modified by the function. Passing a non-constant argument via a constant formal parameter is legal. However, passing a constant argument via a non-constant formal parameter is an error that is enforced by the compiler.

Though not supported in user code, the run time library makes use of a special case where the last parameter may be '...' (three consecutive periods). This indicates that the function takes a variable number of arguments.

Example

```
int testfunction (int inparam)
{
  return inparam;
}

void testfun2 (int &p, int q)
{
  p = 34;
  q = 23;
}
...
int i = 1, j = 2;
testfun2(&i, j);
```

After the call to *testfun2*, i will be 34 and j will be 2.

2.5.2 Function Declarations

Function declarations describe a function's interface allowing the function to be used before the function definition occurs. The function return type and parameter types must match those specified in the function definition.

Syntax

```
datatype ident '(' formal_parameters ')' ';'
```

formal_parameters are defined as in Section 2.5.1, Function definitions, on Page 21.

Example

```
int testfunction(int inparam);
void testfun2(int &p, int q);
```

2.5.3 Function overloading

A function name in *t* need not be unique. Like in C++, a function may be overloaded by defining several different functions with the same name but different formal parameters. However, each definition of the overloaded function must have the same return type.

When parsing a function call, the compiler will find the set of overloaded functions that could fit the arguments, with or without implicit casting. Then the compiler will begin a closer examination of the matches starting with the first argument. For every argument, any function that does not match as well as the closest matching function found will be excluded from further testing. If the compiler resolves to a single candidate, that candidate is chosen. Otherwise, an error is reported.

Exact matches are always preferred. Arrays, structures, and references need exact matches except for:

- byte and `char`, which are interchangeable (but with preference for an exact match)
- `CanMessage` and `CanMessage_X` (database defined message), where a formal parameter of type `CanMessage` can accept a `CanMessage_X`, but not the reverse.

A string constant matches both a constant `char` array and a constant `byte` array, with preference for the former.

For numeric types, automatic casting is done as necessary by order of preference (higher number preferred):

Actual parameter	Formal parameter	Preference
`int`	`int` / `byte` / `char`	2
	`float`	1
`float`	`float`	2
	`int` / `byte` / `char`	1

Note: There are no `byte/char` actual parameters, since these types are always implicitly cast to `int` when used. Thus, the compiler will not allow attempts to overload functions based on these types.
This means that functions can not differ only in what integer type a parameter has. While `byte/char` are considered identical for overloading purposes, `int` versus either of them is disallowed if there are no other distinguishing (as in non-castable) parameters.

Example

```
int f(int a, int b);
int f(int a);
int f(float a, byte b[]);
...
f(2, "Hi");      // '2' will be cast to float.
f(M_PI);         // M_PI will be cast to int.
```

2.6 Control Flow Statements

The statements in this section determine which parts of a program get executed, and in what order.

2.6.1 The `if` Statement

If the conditional expression (*cond_expr*) evaluates to a nonzero value, the condition is considered to be true and the code in *code_or_block_1* is executed. Otherwise, *code_or_block_2* is executed, if available.

Syntax

```
if '(' cond_expr ')'
  code_or_block_1
[ else
  code_or_block_2 ]
```

Example

```
if (speed >= 90) {
  printf("OK!");
} else {
  printf("Speed up!");
}
```

2.6.2 The `while` Statement

As long as the conditional expression *cond_expr* evaluates to a nonzero value, the conditional expression is considered true and the code in *code_or_block* is executed. *code_or_block* is executed after evaluating *cond_expr*. If the first evaluation of *cond_expr* evaluates to false, *code_or_block* is never executed.

Syntax

```
while '(' cond_expr ')'
  code_or_block
```

Example

```
while (speed++ < 90) {
  printf("Speed up!");
}
```

2.6.3 The `do` Statement

While the conditional expression *cond_expr* evaluates to a nonzero value the expression is considered true and the code in *code_or_block* is executed. *code_or_block* is executed before *cond_expr* is evaluated. The do statement guarantees that *code_or_block* is always executed at least once, unlike the while statement described above.

Syntax

```
do
  code_or_block
while '(' cond_expr ')' ';'
```

Example

```
do {
  printf("Speed up!");
} while (speed++ < 90);
```

2.6.4 The `for` Statement

First, the assignment *assignment1* is executed. For as many iterations as the conditional expression *cond_expr* evaluates to true, *code_or_block* is executed. The statement '*assignment2*' is executed after each iteration of the loop. If the first evaluation of *cond_expr* evaluates to false, *assignment2* and *code_or_block* are never executed.

Like in C++, *assignment1* may contain variable definitions. Variables defined in this manner will only have scope local to the loop.

Syntax

```
for '(' [ assignment1 ] ';' cond_expr ';' [ assignment2 ] ')'
  code_or_block
```

Example

```
for(int x = 0; x < array.count; x++) {
  array[x] = x * 2;
}
```

Note: In *t*, *cond_expr* cannot be empty.

2.6.5 The `switch` Statement

For selection between multiple choices, the `switch` statement can be useful. Only constant integer case expressions are allowed (`float` data types are cast to `int`). A default case will be executed if expr does not evaluate to any of the defined constant case expressions.

Like C/C++, the keyword break must be placed at the end of a case, or execution will fall through to the next case.

Syntax

```
switch '(' expr ')' '{'
  cases
'}'
```

Example

```
switch (x) {
case 1:
  printf("One\n");
  break;
case 2:
  printf("Two\n");
  break;
default:
  printf("Unknown\n");
  break;
}
```

2.6.6 The `return` Statement

The `return` statement terminates the function currently executing. Program control is returned back to the function from which the terminated function was called. A function that declares a return type of void cannot supply an expression *expr* as shown below. A function that declares a return type that is not void must supply an *expr*.

Syntax

```
return expr ';'
return ';'
```

2.6.7 The `break` Statement

A `break` statement terminates the nearest enclosing `while`, `do`, `for`, or `switch` statement. Execution resumes at the statement immediately following the terminated statement.

Syntax

```
break ';'
```

Example

```
for (x = 0; x < array.count; x++) {
  if (array[x] == searched_value) {
    break;
  }
}
```

2.6.8 The `continue` Statement

A `continue` statement causes the current iteration of the nearest enclosing `while`, `do`, or `for` statement to terminate. Unlike the `break` statement, the `continue` statement terminates only the current iteration.

Syntax

```
continue ';'
```

Example

```
for (x = 0; x < array.count; x++) {
  if (array[x] != searched_value) {
    continue;
  }
  count++;
  //... do some processing
}
```

2.7 Expressions

The following operators are defined. They are listed in the order of decreasing priority.

Operator	Meaning	Priority
(expr)	Parenthesis can be used to group expressions	13
++ variable	Increase the variable by one, then use the resulting value	12
-- variable	Decrease the variable by one, then use the resulting value	12
variable ++	Use the variable's value, then increase it by one	12
variable --	Use the variable's value, then decrease it by one	12
function call	Not an operator; inserted to show its relative priority	11
!	Logical NOT	10
~	Bitwise NOT	10
unary -	Define/change the sign of the operand	10
unary +	Define/change the sign of the operand	10
(type)	Cast to a given type	9
*	Multiply	8
/	Divide	8
%	Modulo	8
Binary +	Addition	7
Binary -	Subtraction	7
&	Bitwise AND	6
|	Bitwise OR	5
^	Bitwise XOR	5
<<	Left shift	4
>>	Right shift	4
==	Equal	3
!=	Not equal	3
>=	Greater than or equal	3
<=	Less than or equal	3
<	Less than	3
>	Greater than	3
&&	Logical AND	2
||	Logical OR	1

The operators *, /, %, +, -, &, |, ^, <<, and >> may be used in a more compact form when combined with the assignment operator =. The operation and the assignment are combined, like a += b which is equal to a = a + b.

Note: The && (logical AND) and || (logical OR) operators use short-circuit evaluation like C/C++.

Example

```
// There will never be an exception below, since the
// part of the expression to the right of && will not be
// evaluated if the part to the left of it is untrue.
if ((++i < values.count) && (values[i] != 0)) {
  return 1;
}
```

2.8 Blocks

To group code, enclose the statement(s) in curly braces, { and }. Such a group is called a block. *Variables and constants defined in a block have scope local to that block.*

Example

```
{
  int buf[80];   // Invisible outside this block!
  get_report(buf);
  printf("%s\n", buf);
}
```

2.9 Comments

C++ style comments can be used to make the *t* program more readable.

Example

```
// The end of this line is ignored by the compiler
/* and so is everything in here */
```

2.10 Hooks

Hooks are a central part of the *t* language. They are triggered when the specified external or internal event occurs. The language treats hooks as functions, most of which have an implicit parameter called `this`. The `this` parameter has different types for different hooks.

Like a function whose return type is `void`, it is possible to exit from a hook using a `return` statement.

The following hooks are currently defined:

Hook	Triggered when
`on start`	Program execution is started.
`on stop`	Program execution is stopped.
`on key` *key*	A key is pressed.
`on Timer` *timer*	A timer expires. Several timers can be forced to use the same handler.
`on envvar` *variable*	The specified environment variable is updated.
`on CanMessage` *message*	A CAN message arrives. Allows for symbols from a database, numbers, constant expressions and wildcards.
`on CanMessageFd` *message*	A CAN FD message arrives. Allows for symbols from a database, numbers, constant expressions and wildcards.
`on CanTpMessage` *event*	A CAN transport protocol message event occurs. Named events can be set up per transport protocol handle for: - transmission completed - start of arrival - arrival completed
`on IoEvent` *event*	An I/O event arrives. The cause of the event must be specified and can be e.g. that a voltage exceeded a threshold or that a digital input changed from HIGH to LOW.
`on exception`	An exception has occurred.

2.10.1 Hook Execution Order

The execution order of the hooks is independent of the order the hooks appear in the program file, except for hooks of the same type. Hooks of the same type are executed in the order they appear in the file. Figure 1 on Page 31 shows which hooks are run when the program is loaded, started, and stopped.

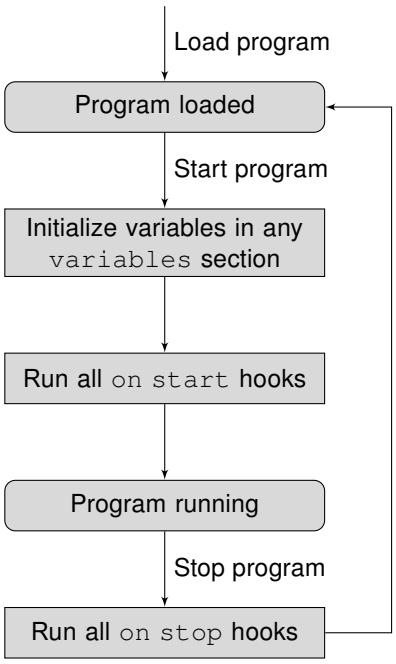


Figure 1: Hook execution order

2.10.2 Hook Details

2.10.2.1 `start`

The `on start` code block is run when program execution starts.

Syntax

```
on start block
```

Example

```
on start {
  printf("Program starting...\n");
}
```

2.10.2.2 `stop`

The `on stop` code block is run when program execution is stopped.

Syntax

```
on stop block
```

2.10.2.3 `key`

The `on key` code block is executed when the keyboard key(s) specified by the *key* argument is pressed. If more than one `on key` block is defined with the same key, the code contained in all the blocks will run in sequence.

As a special case, an asterisk '*' can be used as the *key* argument. This means that each time a key is pressed, the code block will be executed if a more specific `on key` for the pressed key does not exist.

Another special case is an asterisk in brackets. Using "[*]" as the key argument is the same as '*' except the code block will always be executed even if there is a more specific `on key` for the key pressed. The more specific `on key` will then be executed as normal.

Within the block, you can use this to refer to the key that triggered the hook.

Syntax

```
on key key block
```

Example

```
on key 'A' {
  // handle key 'A'
}

on key * {
  // Handle any key, except 'A' and '*'
}

on key '*' {
  // Handle key '*'
}

on key [*] {
  // Handle any key
  printf("'%c' pressed\n", this);
}
```

2.10.2.4 `Timer`

The `on Timer` block is automatically bound (by name) to a previously defined Timer variable. A timer may also be manually bound using `timerSetHandler()`. When using an array of timers, all timers will automatically bind by name to the same `on Timer` handler, but you can manually bind the timers to different `on Timer` blocks.

The `on Timer` code is run when the timer specified by the *timer* argument expires. If a timer expires without being bound to an `on Timer` block, the expiration will be ignored and no exception will be thrown.

By default, timers in *t* are single-shot. This means the timer expires only once and can then be re-enabled if required. Since the timer handler could have been delayed for various reasons, restarting the timer inside of the handler is likely to cause drift in the interval over time.

A timer can be setup as periodic. In this case, the timer can execute at a certain interval a number of times, or forever. While the timer handler's invocation could still be delayed, the next interval will be suitably shortened to compensate.

Within the *block*, `this` refers to the actual timer that expired and gives access to the timeout value and a user settable timer id.

The minimum timeout for a timer is 1 millisecond. Keep in mind that several timers can expire at the same time and in that case virtual machine has to be able to process them all. It will not be able to continue with processing consequent events and logging messages until it is done with handlers.

Syntax

```
on Timer timer block
```

Example

```
variables {
  Timer msgTimer;
}

on start {
  msgTimer.timeout = 100; // 100 ms
  msgTimer.id      = 42;
  timerStart(msgTimer);
}

on Timer msgTimer {
  timerStart(msgTimer);
  printf("Timer %d expired\n", this.id);
}
```

2.10.2.5 `envvar`

The `on envvar` hook is called when someone has updated an environment variable. In this context, updated includes the setting of the same value as before. The `on envvar` hook will also be called when a script is restarted, if the environment variables have been updated since the last run.

Syntax

```
on envvar envvar block
```

To get the value of the environment variable *envvar*, use `envvarGetValue()`.

Example

```
envvar {
  char Msg[128];
  int  Value;
}

on envvar Value {
  char tmp_msg[128];
  int  v;
  envvarGetValue(Msg, tmp_msg);
  envvarGetValue(Value, &v);
}
```

2.10.2.6 `CanMessage`

The `on CanMessage` code block is executed when the specified CAN message arrives. The block will not be executed for CAN FD messages, for which the `on CanMessageFd` hook is used instead.

Using `postfilter` is equivalent to not specifying a *filter*. In this case the on CanMessage hook is invoked after any trigger block filtering (see Section 2.26.1, `filterDropMessage`, on Page 70). With *prefilter*, the hook is invoked before the trigger block filtering.

If no *channel* is specified, the CAN channel associated with the program is implicitly used. A '*' signifies reception from any channel.

For *message*, the *number* and *constant_expression* correspond to the identifier of the CAN message. They can be followed by one or more of the following letters:

- X or x The identifier is an extended (29-bit) identifier.
- R or r The message is a remote frame.

When ident is used, the string is expected to correspond to a message definition in a CAN message database specified when compiling (see Section 1.3.6, CAN Databases (.dbc Files), on Page 12).

As a special case, an asterisk '*' can be used as the *message*. This means that each time a CAN message arrives the code block will be executed if a more specific `on CanMessage` block does not exist for the received message identifier.

Another special case is an asterisk in brackets. Using "[*]" is the same as '*' except the code block will be executed even if a more specific `on CanMessage` block exists for the received message identifier. The more specific `on CanMessage` block will then be executed as normal.

When specified, *mask* is used to decide which bits in the incoming message identifier should be checked against the *message*. Any bits not set in the *mask* are irrelevant to the comparison.

Within the *block*, this is used to reference the CAN message that triggered the action.

Error frames are only received when using the special `on CanMessage errorframe` hook. In this case, the contents of `this` are undefined except for the `canMSG_ERROR_FRAME` flag.

Syntax

```
on [ filter ] CanMessage [ channel ] message [ mask ] block
on [ filter ] CanMessage [ channel ] errorframe block
```

where

```
filter  := prefilter
         | postfilter
channel := '<' '*' '>'
         | '<' constant_expression ) '>'
message := ident
         | number [ x ] [ r ]
         | '(' constant_expression ')' [ x ] [ r ]
         | '*'
         | '[' '*' ']'
mask    := '&' number
         | '&' '(' constant_expression ')'
```

Example

```
on CanMessage<*> 0xF00400x & 0xf00fff {
  // Handle all non-FD messages with 29-bit IDs, where
  // (id & 0xf00f00) == 0xF00400 (hex)
}

on CanMessage 123rx {
  // Handle remote request of 29-bit identifier 123 (decimal)
  // on the channel associated with the program.
}

on CanMessage (msgId) {
  // Handle messages with message id defined by the constant
  // msgId on the channel associated with the program.
}

on prefilter CanMessage TrigData {
  // Handle the TrigData (database name) message, before the
  // trigger mechanism, on the channel associated with the
  // program
}

on CanMessage<0> (engine_msg + 3) x {
  // Handle engine message 4 on channel 0 here.
}

on CanMessage * {
```

```
  // Handle any non-FD message, except 0xF00400x, 123rx, ...
  // on the channel associated with the program.
}

on CanMessage<1> [*] {
  // Handle any non-FD message on channel 1.
}
```

2.10.2.7 `CanMessageFd`

The `on CanMessageFd` code block is executed when the specified CAN FD message arrives. A CAN FD message is distinguished from an ordinary CAN message by having the `canMSGFD_FDF` flag set. As in `on CanMessage`, the *number* and the *constant_expression* correspond to the identifier of the CAN FD message, and can be followed by an `x`, which signifies that the identifier is an extended (29-bit identifier).

All that applies to `on CanMessage` also applies to `on CanMessageFd`, with the following exceptions:

- Remote frames are not part of CAN FD messages, so unlike `on CanMessage`, the `r` (signifying a remote frame) is not allowed after the identifier.
- An error frame is always considered an ordinary CAN message and thus only captured in `on CanMessage`.

Syntax

```
on [ filter ] CanMessageFd [ channel ] message [ mask ] block
```

where

```
filter  := prefilter
         | postfilter
channel := '<' '*' '>'
         | '<' constant_expression ) '>'
message := ident
         | number [ x ] [ r ]
         | '(' constant_expression ')' [ x ] [ r ]
         | '*'
         | '[' '*' ']'
mask    := '&' number
         | '&' '(' constant_expression ')'
```

Example

```
on CanMessageFd<*> 0xF00400x & 0xf00fff {
  // Handle all CAN FD messages with 29-bit IDs, where
  // (id & 0xf00f00) == 0xF00400 (hex)
```

```
}

on CanMessageFd 123x {
  // Handle 29-bit identifier 123 (decimal)
  // on the channel associated with the program.
}

on CanMessageFd (msgId) {
  // Handle messages with message id defined by the constant
  // msgId on the channel associated with the program.
}

on prefilter CanMessageFd TrigData {
  // Handle the TrigData (database name) message, before the
  // trigger mechanism, on the channel associated with the
  // program
}

on CanMessageFd<0> (engine_msg + 3) x {
  // Handle engine message 4 on channel 0 here.
}

on CanMessageFd * {
  // Handle any CAN FD message, except 0xF00400x, 123x, ...
  // on the channel associated with the program.
}

on CanMessageFd<1> [*] {
  // Handle any CAN FD message on channel 1.
}
```

2.10.2.8 `CanTpMessage`

The on `CanTpMessage` block is executed when an event connected to *name* occurs. The connection is established using `canTpSetHandler()`.

Within the *block*, this refers to a `CanTpMessage` where a result code and a user settable timer id are always present. For a successful reception event, the data member is also populated.

Syntax

```
on CanTpMessage name block
```

Example

```
variables {
  CanTpHandle cantp;
}

on start {
  canTpOpen(cantp, 4, 6, "ISO-15765",
            iso15765_Fixed | iso15765_Physical);
```

```
  canTpSetAttr(cantp, iso15765_RxTimeout, 1000);
  canTpSetHandler(cantp, "cantpHandler",
                  iso15765_RxIndication);
}

on CanTpMessage "cantpHandler" {
  if (this.result != canTp_OK) {
    printf("CanTp receive error: %d\n", this.result);
  } else {
    printf("Received: %s\n", this.data);
  }
}
```

2.10.2.9 `IoEvent`

The `on IoEvent` code block is executed when the specified I/O event arrives. The source of the event is a called a pin and there are two different input pin types, analog and digital. Use `kvIoPinGetInfo()` to check which type a pin has and if it is an input or output pin. See Section 2.35.19.4, Properties, on Page 90 for further information on pins.

Digital input pins generate events for rising and falling edges, `kvIO_EVENT_RISING_EDGE` and `kvIO_EVENT_FALLING_EDGE`.

Analog input pins generate events when the voltage exceeds or falls below a threshold, `kvIO_EVENT_VALUE_ABOVE` and `kvIO_EVENT_VALUE_BELOW`. It it also possible to get an event when the voltage changes a significant amount, `kvIO_EVENT_VALUE_CHANGED`, by using hysteresis, see `kvIoPinSetInfo()`.

Note: kvIoConfirmConfig() will fail if the pin type doesn't match the type expected by the event, e.g. using analog events on digital pins or using output pins.

Syntax

```
on IoEvent < pin >  [type]  [value]
```

where

```
pin   := number
type  := 'kvIO_EVENT_RISING_EDGE', 'kvIO_EVENT_FALLING_EDGE'
       | 'kvIO_EVENT_VALUE_ABOVE', 'kvIO_EVENT_VALUE_BELOW',
         'kvIO_EVENT_VALUE_CHANGED'
value := number
       | '(' constant_expression ')'
```

Example

```
on IoEvent < 16 >  kvIO_EVENT_RISING_EDGE {
  // Rising edge on digital input pin number 16 detected.
```

```
}

on IoEvent < 4 >  kvIO_EVENT_VALUE_ABOVE 6.5 {
  // Voltage exceeds 6.5V on analog input pin 4.
  printf("Voltage: %f.\n", this.value);
}

on IoEvent < 0 >  kvIO_EVENT_CONFIG_CHANGED {
  /* The configuration has changed. Check configuration
     and call kvIoConfirmConfig() to accept the new
     configuration. */
}
```

2.10.2.10 `exception`

The `on exception` code block is executed when an unrecoverable situation within a function occurs.

Syntax

```
on exception block
```

block can contain variable definitions; such definitions are local to *block*. If more than one `on exception` code block is defined, each code block will execute in sequence.

Within *block*, `this` references the error that triggered the exception (see Section 2.34.6, `ExceptionData`, on Page 82). Only read access is allowed, since `this` is constant in an `on exception` block.

Execution of the code directly after the function call that triggered the exception will be aborted.

Example

```
// Example of an exception handler that notifies the user
// by blinking the power LED.

variables {
  Timer ex_timer;
  LedHandle ex_led;
  int ex_led_state[2] = {LED_STATE_OFF, LED_STATE_ON};
}

on exception {
  ledOpen(ex_led, LED0);
  ex_timer.timeout = 777; // ms
  ex_timer.id = 0;
  timerStart(ex_timer, FOREVER);
}

on Timer ex_timer {
  ledSet(ex_led, ex_led_state[this.id]);
```

```
  this.id ^= 1;
}
```

Example

```
void dump_exception(const ExceptionData e);
void dump_ints(const int data[]);

on exception {
  dump_exception(this);
}

// Exception data dump in the same format as the built-in one.
// (See sample files for a version that uses no local data.)
void dump_exception (const ExceptionData e)
{
  printf("Execution error %d at %d after %d cycles.\n",
         e.error, e.pc, e.cycle);
  if (e.line) {
    printf("Execution stopped after/at line %d.\n", e.line);
  } else {
    printf("Line number information excluded from code.\n");
  }
  printf("Stack (%d):\n", e.stack.count);

  int fp = e.locals;
  for(int sp = e.stack.count - 1; sp >= 0; sp--) {
    int frame_size = e.stack[fp - 1];
    if (sp >= fp + frame_size) {
      printf("%4d: 0x%08x %11d\n", sp, e.stack[sp],
          e.stack[sp]);
    } else {
      if (frame_size) {
        printf("Locals (%d @ 0x%08x):\n",
               frame_size * 4, e.stack_base + fp * 4);
        dump_ints(e.stack[fp, frame_size]);
      }
      sp -= frame_size;
      sp--;
      fp  = e.stack[sp--];
      if (sp >= 0) {
        printf("Return address: %d\n", e.stack[sp]);
      }
    }
  }

  printf("Globals (%d):\n", e.globals.count);
  dump_ints(e.globals);
}

// Dump integers with address, hex and ASCII.
void dump_ints (const int data[])
{
  char buf[80];
```

```
    for(int i = 0; i < data.count; i += 4) {
      int j;
      for(j = 0; (j < 4) && (i + j < data.count); j++) {
        sprintf(buf + j * 9, "%08x ", data[i + j]);
      }
      buf[j * 9 .. 4 * 9 - 1] = ' ';
      buf[4 * 9, 16]          = '.';
      for(j = 0; (j < 16) && (i + j / 4 < data.count); j++) {
        byte b = data[i + j / 4] >> (8 * (j % 4));
        if ((b >= 32) && (b < 127)) {
          buf[4 * 9 + j] = b;
        }
      }
      buf[4 * 9 + j] = '\0';
      printf("%04x: %s\n", i * 4, buf);
    }
  }
```

2.11 Using CAN Databases

When you connect one or more CAN database files to an interface, all messages in the databases become available as types, prefixed by the string:

```
CanMessage_
```

For example, if a message *SpeedData* is defined in the database, you can define a variable *spd* like this:

```
CanMessage_SpeedData spd;
```

Assuming the message *SpeedData* consists of the signal *Speed*, you can then use

```
spd.Speed.Raw
```

or

```
spd.Speed.Phys
```

to access the *Speed* signal in the message. The former will access the “raw” value of the signal – the actual contents of the CAN message regardless of the scaling defined in the database. The latter will access the scaled value according to the database definition. Floating point values of 16, 32 and 64 bit size are supported (IEEE754-2008), as specified in the database. Since *t* only has a 32 bit floating point type, automatic conversion is done on fetch/store.

2.12 `#include`

t allows a source code file to refer to another code file by including the file. This will behave exactly as if the contents of the included file had been inserted at that point in the source code.

Syntax

```
#include " file_name "
```

If you use < and > around the file name, the compiler will search in a system directory.

Example

```
#include <linlib.t>
```

2.13 #error

To enforce compilation errors, for example while using conditional compilation (see Section 2.15 Conditional Compilation), a special directive can be used. The supplied text will be output by the compiler as an error message.

Example

```
#error too large buffer requested.
```

2.14 #warning

To enforce compilation warnings, for example while using conditional compilation (see Section 2.15 Conditional Compilation), a special directive can be used. The supplied text will be output by the compiler as an warning message.

Example

```
#warning buffer may be too small
```

2.15 Conditional Compilation

Unlike C/C++, *t* does not have a pre-processor. However, the ability to do conditional compilation, even controlled by options passed to the compiler on the command line, is still available.

2.15.1 Command Line Options

Both integer and string values can be passed on the command line. They end up as constant declarations in a compiler generated `variables` section, situated just before the first line of user code. There is no limit to the number of constants set up this way.

Syntax (on the compiler command line)

–Dconstant_integer_name=number
–Dconstant_string_name[]=text

Example

```
scc -Dcount=10 -Dsize=80 "-Dgreeting[]=Hello World!" program.t
```

The command line above will cause the following to be compiled as if it had been at the top of source code file:

Example

```
variables {
  const int count = 10;
  const int size = 80;
  const char greeting[] = "Hello World!";
}
```

The text given for a named constant is copied into the `variables` section as is, without any checking whatsoever. Any errors will be caught by the compiler and the reported line number will be consistent with the example `variables` section above.

2.15.2 `#if / #else / #endif`

Conditional compilation in *t* is done as part of the language itself. Thus, any named integer constant in scope is at the disposal of a conditional. No expressions are allowed in the conditionals themselves, but the full constant expression calculation capabilities of *t* can be used earlier to set things up.

As in other Boolean expressions, zero is considered false and any other value true.

Nesting of conditional compilation directives is not supported.

Syntax

```
#if ( ident | integer )
...
[ #else ]
...
#endif
```

Example

```
variables {
  const int dump_data = DEBUG && VERBOSE;
}

#if dump_data
void dumpToFile(int data[])
{
...
}
#else
void dumpToFile(int data[]) { /* Do nothing */ }
#endif
```

2.15.3 `#ifdef / #ifndef`

Conditional compilation in *t* is done as part of the language itself. Thus, any identifier in scope is considered defined.

Nesting of conditional compilation directives is not supported.

Syntax

```
#ifdef ident
...
[ #else ]
...
#endif

#ifndef ident
...
[ #else ]
...
#endif
```

Example

```
#ifndef output
void output(char *text)
{
  printf("%s\n", text);
}
#endif

#ifdef DEBUG
variables {
  char dbgbuf[1024];
}
#endif
```

2.16 Predefined Output Functions

2.16.1 `printf`

Prints the string *fmt* to the standard output. The string *fmt* may contain formatting characters just like the C language `printf()`.

Syntax

```
void printf(const char fmt[], ...)
```

If the standard output is not displayed anywhere, you will not see any output from the `printf` calls.

The format string can contain regular characters and conversion specifiers. Regular characters are simply printed. Conversion specifiers begin with a percent symbol and are shown below:

Conversion specifier	Meaning
%d	Prints argument as a signed decimal number
%c	Prints argument as a character
%s	Prints argument as a string
%x	Prints argument as a hexadecimal number
%u	Prints argument as an unsigned decimal number
%f, %g	Prints argument as a floating-point number
%%	Prints a percent sign

%d, %u, %x, and %s can take a number directly after the %, which specifies the number of characters the result should use (right justified). %d, %u, and %x can have an initial zero that specifies that the fill characters to the left should be zeros instead of the default space.

2.17 Predefined File I/O Functions

This section describes the functions that are predefined in *t* for doing input/output on files.

2.17.1 `fileOpen`

Opens the file with the given filename using the specified flags. A negative error code is returned on failure.

Syntax

```
int fileOpen(FileHandle file, const char filename[])
int fileOpen(FileHandle file, const char filename[], int flags)
```

The handle *file* is used to refer to the file. The possible *flags* are:

`OPEN_READ`	Only read is allowed from the file
`OPEN_WRITE`	Read and write is allowed
`OPEN_APPEND`	Like `OPEN_WRITE`, but an automatic seek to the end is done
`OPEN_TRUNCATE`	Like `OPEN_WRITE`, but any previous contents are deleted

No value in *flags* is equivalent to `OPEN_WRITE`.

2.17.2 `fileClose`

Closes the file whose handle is *file* (previously returned from `fileOpen`).

Syntax

```
void fileClose(FileHandle file)
```

2.17.3 `fileGets`

Reads a line from *file*. The result is placed in *buffer*. You may specify the maximum length to read.

The number of characters read is returned when successful. Otherwise, a negative error code is returned.

Syntax

```
int fileGets(const FileHandle file, char buffer[])
int fileGets(const FileHandle file, char buffer[],
             int bufferSize)
```

2.17.4 `fileReadBlock`

Reads a block from *file*. The result is placed in *buffer*. You may specify the length to read.

The number of characters read is returned when successful. Otherwise, a negative error code is returned.

Syntax

```
int fileReadBlock(const FileHandle file, char buffer[])
int fileReadBlock(const FileHandle file, char buffer[],
                  int bufferSize)
```

2.17.5 `filePuts`

Writes the string *buffer* to *file*. You may specify the maximum length to write.

The number of characters written is returned on success. Otherwise, a negative error code is returned.

Syntax

```
int filePuts(const FileHandle file, const char buffer[])
int filePuts(const FileHandle file, const char buffer[],
             int bufferSize)
```

2.17.6 `fileWriteBlock`

Writes the block *buffer* to *file*. You may specify the length to write.

The number of characters written is returned on success. A negative error code is returned on failure.

Syntax

```
int fileWriteBlock(const FileHandle file, const char buffer[])
int fileWriteBlock(const FileHandle file, const char buffer[],
                   int bufferSize)
```

2.17.7 fileSeek

Repositions the offset of the *file*. The *whence* argument determines how offset is used to reposition. If *whence* is SEEK_CUR, the new position is *offset* bytes from the current position. If *whence* is SEEK_SET, the new position is *offset* bytes from the start of the file. If *whence* is SEEK_END, the new position is *offset* bytes from the end of the file.

If the operation was successful, the resulting offset location, in bytes, from the beginning of the file is returned. Otherwise, a negative error code is returned.

Syntax

```
int fileSeek(const FileHandle file, int offset, int whence)
```

Note: fileSeek will not extend a file. For example, a fileSeek beyond the end of the file will set the position to the end of file.

2.17.8 fileDelete

Deletes the file whose name is passed in *filename*.

A negative error code is returned on failure.

Syntax

```
int fileDelete(const char filename[])
```

2.18 Predefined XML Functions

The XML parser is not a full-featured one, but the parser can handle data organized in structure/array form and attributes. Unless otherwise specified, parsing is restarted from the beginning of the data for every access.

The XML parser is not capable of accessing extra data that comes after a sub-tag. This should never happen in an XML file that describes an actual data structure, however, this practice is common in XHTML, for example to add a line break (“<br/>”).

Also, the XML parser cannot deal with entities and other things that are not necessary to describe a data structure.

2.18.1 xmlOpen

Opens the file with the given *filename* for XML access using OPEN_READ mode. The *handle* can then be used to refer to the file.

A negative error code is returned on failure.

Syntax

```
int xmlOpen(XmlHandle handle, const char filename[])
```

2.18.2 `xmlClose`

Closes the XML access handle.

Syntax

```
void xmlClose(XmlHandle handle)
```

2.18.3 `xmlGet`

Finds a specific item or attribute in the XML data referred to by *handle*. The supplied buffer *buf* will be used to store the result. Optionally, the *position* in the XML data where searching for the tag is to begin can be specified. The *position* will then be updated to point to where the tag was found.

Syntax

```
int xmlGet(XmlHandle handle, char buf[], ...)
int xmlGet(XmlHandle handle, char buf[], int &position, ...)
```

The field/attribute to search for is specified using a sequence of strings, or string and number pairs.

- Strings are checked against the XML tags hierarchically. As a special case, the very last string may instead refer to an attribute.
- Numbers signify indexing into a sequential list of the same tag type. A missing index is equivalent to 0.
- At the very end, XML_ATTR can be used to specify that the final string is an attribute to access.
- XML_DATA may optionally be used at the end to specify that the tag data should be accessed. An asterisk (‘*’) may be used to match an arbitrary tag/attribute string.

Indexing works as expected, with any tag/attribute at the same hierarchical level matching. If XML_TAG is used at the end, the name of the tag will be fetched instead of the tag’s data.

Example file

```
<Whatever>Aberforth
  <Misc>Bellatrix
    <Someone>Cedric</Someone>
  </Misc>
  <Data>
    <Something>Dedalus</Something>
    <Something>Ellerby</Something>
    <Nothing/>
  </Data>
  <Data>
    <Something>Fulbert</Something>
    <SomethingElse what="Gellert" who="Hagrid" />
  </Data>
</Whatever>
```

Example *t* code

```
variables {
  char name1[80];
  char name2[80];
}
on start {
  name1[0] = 0;
  name2[0] = 0;
  XmlHandle file;
  if (xmlOpen(file, "params.xml") >= 0) {
    xmlGet(file, name1, "Whatever", "Data", "Something", 1);
    xmlGet(file, name2, "Whatever", "Data", 1, "SomethingElse",
           "who", XML_ATTR);
    xmlClose(file);
  }
}
```

2.19 Predefined Math Functions

The trigonometric functions for sine, cosine, and tangent of an angle all assume the argument is expressed in radians. In the same way, the return values of the inverse trigonometric functions are expressed in radians.

So, when your angle is expressed in degrees, this is the formula:

```
radians = degrees * M_PI / 180
```

2.19.1 `sin`

Returns the sine of *x*. The return value will be between -1.0 and 1.0, inclusive.

An exception is thrown if *x* is infinite.

Syntax

```
float sin(float x)
```

2.19.2 `cos`

Returns the cosine of *x*. The return value will be between -1.0 and 1.0, inclusive.

An exception is thrown if *x* is infinite.

Syntax

```
float cos(float x)
```

2.19.3 `tan`

Returns the tangent of *x*.

An exception is thrown if *x* is infinite.

Syntax

```
float tan(float x)
```

2.19.4 `asin`

Returns the arcsine of *x*; that is the value whose sine is *x*.

An exception is thrown if *x* falls outside the range -1.0 to 1.0. Otherwise, the function returns the arcsine in radians. The returned value is mathematically defined to be between -M_PI / 2 and M_PI / 2, inclusive.

Syntax

```
float asin(float x)
```

2.19.5 `acos`

Returns the arccosine of *x*; that is the value whose cosine is *x*.

An exception is thrown if *x* falls outside the range -1.0 to 1.0. Otherwise, the function returns the arccosine in radians. The returned value is mathematically defined to be between 0 and M_PI, inclusive.

Syntax

```
float acos(float x)
```

2.19.6 `atan`

Returns the arctangent of *x*; that is the value whose tangent is *x*. The arctangent is returned in radians and it is mathematically defined to be between -M_PI / 2 and M_PI / 2, inclusive.

Syntax

```
float atan(float x)
```

2.19.7 abs

Returns the absolute value of the argument.

Syntax

```
float abs(float x)
```

2.19.8 ceil

Returns the smallest integer value not less than *x*.

Syntax

```
float ceil(float x)
```

2.19.9 floor

Returns the largest integer value not greater than *x*.

Syntax

```
float floor(float x)
```

2.19.10 randomize

Initializes the random number generator with a physically random
(see Section 2.27.4, `cryptoRandom`, on Page 73) seed or with a specified one.

The sequence of numbers returned by `random()` after specifying a given *seed* is always the same.

Syntax

```
void randomize()
void randomize(int seed)
```

2.19.11 random

The WELL512 pseudo random number generator is used to generate a random number modulo *x*. Unless `randomize()` is used, the seed at startup is physically random.

While the random numbers given by WELL512 are of very good quality, `cryptoRandom()` should be used if cryptographic security is required [1].

Returns an integer random number in the interval 0 .. *x*-1, for *x* > 0. The full 32 bit number is given for *x* == 0. For *x* < 0, the results are undefined.

Syntax

```
int random(int x)
```

2.19.12 sqrt

Returns the square root of *x*.

An exception is thrown if *x* is negative.

Syntax

```
float sqrt(float x)
```

2.19.13 exp

Returns the value of the natural exponential function at the floating-point parameter *x*. That is, *e* to the power of *x*.

Syntax

```
float exp(float x)
```

2.19.14 exp10

Returns 10 to the power of *x*.

Syntax

```
float exp10(float x)
```

2.19.15 round

Returns *x* rounded to the nearest integer. Numbers half-way between two integers are rounded away from zero.

Syntax

```
float round(float x)
```

2.19.16 `log`

Returns the natural logarithm of *x*.

An exception is thrown if *x* is negative.

Syntax

```
float log(float x)
```

2.19.17 `log10`

Returns the base 10 logarithm of *x*.

An exception is thrown if *x* is negative.

Syntax

```
float log10(float x)
```

2.20 Predefined String Functions

Strings in *t* are null-terminated character arrays like in C. This means the last byte contains the character code 0 which represents the ASCII NUL character. The language also takes advantage of the fact that an array's size is known.

If no maximum lengths are specified for these functions, the lengths of the relevant array arguments are used instead. Accesses outside the arrays cannot be caused by these functions.

2.20.1 `strlen`

Returns the length of the string *s*, not including any terminating null character. A maximum *length* can be specified.

Syntax

```
int strlen(const char s[])
int strlen(const char s[], int length)
```

2.20.2 `strcpy`

Copies the string *src* (adding a terminating null character, if there is room) to the string *dest*. A maximum *length* can be specified.

Returns the number of characters that were copied.

Syntax

```
int strcpy(char dest[], const char src[])
int strcpy(char dest[], const char src[], int length)
```

Note: Only the portion that will fit in *dest* is copied.

2.20.3 `strcat`

Appends the string *src* to the string *dest*, overwriting the terminating null character at the end of *dest*, and adding a terminating null character to the end. A maximum *length* can be specified.

Returns the number of characters that were appended.

Syntax

```
int strcat(char dest[], const char src[])
int strcat(char dest[], const char src[], int length)
```

Note: Only the portion that will fit in *dest* is copied.

2.20.4 `strcmp`

Returns an integer less than zero if *s1* is found to be less than *s2*. Returns an integer equal to 0 if *s1* matches *s2*. Returns an integer greater than zero if *s1* is found to be greater than *s2*. A maximum *length* can be specified.

Syntax

```
int strcmp(const char s1[], const char s2[])
int strcmp(const char s1[], const char s2[], int length)
```

2.20.5 `sprintf`

Behaves like `printf()` but puts the result into the string *str*. The receiving string must be sufficiently long.

Returns the number of characters put into *str* on success. A negative error code is returned on failure.

Syntax

```
int sprintf(char str[], const char fmt[], ...)
```

2.20.6 `atoi`

Discards any leading white space in the string *s*, then interprets the rest as an integer in ASCII format. Interpreting stops when the end of the string is reached or when a character that cannot be interpreted as part of the integer is encountered. For example, the character is not of the base being used.

Returns the integer found in the string *s*.

Syntax

```
int atoi(const char s[])
int atoi(const char s[], int base)
```

Unless specified, *base* defaults to 10. A base of zero, or one that is too large to be represented using ‘a’–‘z’, will cause an exception to be thrown.

Example

```
code = atoi("11001101011110101", 2);
data = atoi("-84820473");
```

2.20.7 `atof`

Discards any leading white space in the string *s*, then interprets the rest as a floating point number in ASCII format. Interpreting stops when the end of the string is reached or a character that cannot be interpreted as part of the floating point number is encountered. Decimal point is accepted, as is ‘e’ notation for exponent.

Returns the `float` found in the string *s*.

Syntax

```
float atof(const char s[])
```

Example

```
angle    = atof("-2.3425561134");
distance = atof("3.5e5");
```

2.20.8 `itoa`

Converts *number* into the specified *base* and places the result in *buffer*. A buffer size can be specified.

Base 10 numbers will be handled as signed. All other bases as unsigned. Normally bases higher than 10 will have the alphabetic digits in lower case. Negating the base forces alphabetic digits into upper case instead.

Returns the number of characters put into *str* on success. A negative error code is returned on failure.

Syntax

```
int itoa(int number, char buffer[], int base)
int itoa(int number, char buffer[], int base, int bufferSize)
```

2.21 Predefined CAN Related Functions

2.21.1 `canWrite`

This function queues the CAN message *msg* for transmission. The message is sent on the channel that the program is connected to if *channel* is not specified.

Returns a negative error code on failure (queue full is always a possibility).

Syntax

```
int canWrite(const CanMessage msg)
int canWrite(int channel, const CanMessage msg)
int canWrite(const CanMessageFd msg)
int canWrite(int channel, const CanMessageFd msg)
```

The following members in *msg* must be filled out:

id	The identifier of the message
dlc	The length of the message. If this value is greater than 8, the value will still be passed on to the CAN driver, which will make an attempt to send using the value. More than 8 data bytes will only be sent if the message is a CAN FD message and the target channel is set to CAN FD mode.
flags	A combination of CAN message flags. See Section 2.35.3, CAN Message Flags, on Page 85 for further information.
data	The data in the message.

2.21.2 `canGetTimestamp`

Provides access to the timestamp that every received CanMessage and CanMessageFd contains.

The function considers *scale* to be an unsigned integer. A *scale* value of 0 is a special case interpreted as one larger than the maximum unsigned integer. The result is that the function will return the high integer of the timestamp in response. The optional *remainder* will contain the remainder of the integer division of the timestamp by *scale*.

Returns the result of an integer division of the timestamp (microseconds) from *msg* by *scale*.

Syntax

```
int canGetTimestamp(const CanMessage msg, int scale)
int canGetTimestamp(const CanMessage msg, int scale,
                    int &remainder)
int canGetTimestamp(const CanMessageFd msg, int scale)
int canGetTimestamp(const CanMessageFd msg, int scale,
                    int &remainder)
```

2.21.3 canSetBitrate

This function sets the nominal bitrate on the CAN bus to *bitrate*. The operation is performed on the CAN channel the program is connected to if *channel* is not specified. You have to be bus-off when you call this function.

Predefined bitrates are used to set all nominal bus timing parameters to compatible values. See `canSetBusParams()` for details on bus parameters. For valid predifined values, see Section 2.35.5, CAN Bitrates, on Page 85 for classic CAN, and see Section 2.35.6, CAN FD Bitrates, on Page 86 for CAN FD.

Returns the bitrate that was set, or a negative error code on failure.

Syntax

```
int canSetBitrate(int bitrate)
int canSetBitrate(int channel, int bitrate)
```

The various parameters are as follows:

bitrate	The desired bitrate in bits per second, or as a predefined value; see Section 2.35.5, CAN Bitrates, on Page 85 for classic CAN, and see Section 2.35.6, CAN FD Bitrates, on Page 86 for CAN FD.
channel	The CAN channel on which to set the bitrate.

2.21.4 canSetBitrateFd

This function sets the data phase bitrate in CAN FD mode on the CAN bus to *bitrate*. The operation is performed on the CAN channel the program is connected to if *channel* is not specified. You have to be bus-off when you call this function.

Predefined bitrates are used to set all CAN FD bus parameters to compatible values. See `canSetBusParamsFd()` for details on bus parameters, and Section 2.35.6, CAN FD Bitrates, on Page 86 for valid predefined *bitrate* values.

Returns the bitrate that was set, or a negative error code on failure.

Syntax

```
int canSetBitrateFd(int bitrate)
int canSetBitrateFd(int channel, int bitrate)
```

The various parameters are as follows:

bitrate	The desired data phase bitrate as a predefined value; see Section 2.35.6, CAN FD Bitrates, on Page 86.
channel	The CAN channel on which to set the bitrate.

2.21.5 `canSetBusParams`

This function sets the nominal bus timing parameters for the CAN bus in classic CAN. This function is also used for the arbitration phase when the channel is set in CAN FD mode. The function operates on the CAN channel the program is connected to if *channel* is not specified. You have to be bus-off when you call this function.

Instead of specifying all parameters, predefined bitrate can be used to set all nominal bus timing parameters to compatible values. For valid predifined values, see Section 2.35.5, CAN Bitrates, on Page 85 for classic CAN, and see Section 2.35.6, CAN FD Bitrates, on Page 86 for CAN FD.

Returns a negative error code on failure.

Syntax

```
int canSetBusParams(int bitrate, int tseg1, int tseg2, int sjw,
                    int samples)
int canSetBusParams(int channel, int bitrate, int tseg1,
                    int tseg2, int sjw, int samples)
```

The various parameters are as follows:

bitrate	The desired bitrate in bits per second, or a predefined value (see Section 2.35.5, CAN Bitrates, on Page 85 for classic CAN, and see Section 2.35.6, CAN FD Bitrates, on Page 86 for CAN FD).
tseg1	The desired number of quanta in time segment 1 (the number of quanta before the sampling point minus 1).
tseg2	The desired number of quanta in time segment 2 (the number of quanta after the sampling point).
sjw	The synchronization jump width is the maximum number of quanta that the CAN controller will add to or subtract from a bit in order to resynchronize the clock.
samples	The number of samples to be used per bit. Can be 1 or 3. Will default to 1 sample on devices not suporting 3.

2.21.6 `canSetBusParamsFd`

This function sets the bus timing parameters for the CAN bus for the data phase when the channel is set in CAN FD mode. The function operates on the CAN

channel the program is connected to if *channel* is not specified. You have to be bus-off when you call this function.

Instead of specifying all parameters, predefined bitrate can be used to set all CAN FD bus parameters to compatible values. See Section 2.35.6, CAN FD Bitrates, on Page 86 for valid predefined *bitrate* values.

Returns a negative error code on failure.

Syntax

```
int canSetBusParamsFd(int bitrate, int tseg1, int tseg2,
                      int sjw)
int canSetBusParamsFd(int channel, int bitrate, int tseg1,
                      int tseg2, int sjw)
```

The various parameters are as follows:

bitrate	The desired data phase bitrate in bits per second, or a predefined value from Section 2.35.6, CAN FD Bitrates, on Page 86.
tseg1	The desired number of quanta in time segment 1 (the number of quanta before the sampling point minus 1).
tseg2	The desired number of quanta in time segment 2 (the number of quanta after the sampling point).
sjw	The synchronization jump width is the maximum number of quanta that the CAN controller will add to or subtract from a bit in order to resynchronize the clock.

2.21.7 `canGetBusParams`

Gets the currently set classic CAN bus parameters including bus output control mode. The function operates on the CAN channel the program is connected to if *channel* is not specified.

Returns a negative error code on failure.

Syntax

```
int canGetBusParams(int &freq, int &tseg1, int &tseg2, int &sjw,
                    int &samples, int &mode)

int canGetBusParams(int channel, int &freq, int &tseg1,
                    int &tseg2, int &sjw, int &samples,
                    int &mode)

int canGetBusParams(int &freq, int &tseg1, int &tseg2, int &sjw,
                    int &samples)

int canGetBusParams(int channel, int &freq, int &tseg1,
                    int &tseg2, int &sjw, int &samples)
```

The various parameters are as follows:

freq	The bitrate in bits per second.
tseg1	The number of quanta in time segment 1 (the number of quanta before the sampling point minus 1).
tseg2	The number of quanta in time segment 2 (the number of quanta after the sampling point).
sjw	The synchronization jump width is the maximum number of quanta that the CAN controller will add to or subtract from a bit in order to resynchronize the clock.
samples	The number of samples to be used per bit. Can be 1 or 3.
mode	Bus output control mode, see Section 2.35.7, CAN Driver Modes, on Page 86 for valid mode values.

2.21.8 `canGetBusParamsFd`

Gets the currently set CAN FD bus parameters. The function operates on the CAN channel the program is connected to if *channel* is not specified.
See Section 2.21.6, `canSetBusParamsFd`, on Page 58 for details on the parameters.

Returns a negative error code on failure.

Syntax

```
int canGetBusParamsFd(int &freq, int &tseg1, int &tseg2,
                      int &sjw)

int canGetBusParamsFd(int channel, int &freq, int &tseg1,
                      int &tseg2, int &sjw)
```

The various parameters are as follows:

freq	The data phase bitrate in bits per second.
tseg1	The number of quanta in time segment 1 (the number of quanta before the sampling point minus 1).
tseg2	The number of quanta in time segment 2 (the number of quanta after the sampling point).
sjw	The synchronization jump width is the maximum number of quanta that the CAN controller will add to or subtract from a bit in order to resynchronize the clock.

2.21.9 `canBusOff`

This function takes the CAN channel off-bus. The function operates on the CAN channel the program is connected to if *channel* is not specified.

Returns a negative error code on failure.

Note: You might receive a few CAN messages after calling `canBusOff`. Those CAN messages were received before the CAN channel went off-bus and are already pending hook events, see Section 2.10, Hooks, on Page 29.

Syntax

```
int canBusOff()
int canBusOff(int channel)
```

2.21.10 canBusOn

This function takes the CAN channel on-bus. The function operates on the CAN channel the program is connected to if *channel* is not specified.

Returns a negative error code on failure.

Note: The bus parameters for the CAN bus must be set before the bus can be used, see Section 1.1.4, Inherited Settings Versus *t* Program Settings, on Page 7.

Syntax

```
int canBusOn()
int canBusOn(int channel)
```

2.21.11 canSetCommunicationMode

This function sets the communication mode. The function operates on the CAN channel the program is connected to if *channel* is not specified.
See Section 2.35.8, CAN Communication Modes, on Page 86 for valid *canMode* values. You have to be bus-off when you call this function.

To send CAN FD messages, the communication mode must be set to either `canMODE_CAN_FD` or `canMODE_CAN_FD_NONISO`. To send only classic CAN messages, the communication mode may be set to `canMODE_CAN`.

Returns a negative error code on failure.

Note: To send CAN FD messages, CAN FD bus parameters must also be set, see `canSetBusParamsFd()`, and `canSetBitrateFd()`.

Syntax

```
int canSetCommunicationMode(int canMode)
int canSetCommunicationMode(int channel, int canMode)
```

Example

```
variables {
  const int can_channel = 0;
}

on start {
  canBusOff(can_channel);
  canSetBusParams(can_channel, canFD_BITRATE_1M_80P, 0, 0, 0,
      0);
  canSetBusParamsFd(can_channel, canFD_BITRATE_2M_80P, 0, 0, 0);
  canSetCommunicationMode(can_channel, canMODE_CAN_FD);
  canBusOn(can_channel);
}

on stop {
  canBusOff(can_channel);
}
```

2.21.12 canGetCommunicationMode

Returns the current communication mode. The function operates on the CAN channel the program is connected to if *channel* is not specified.
See Section 2.35.8, CAN Communication Modes, on Page 86 for return values.

Returns a negative error code on failure.

Syntax

```
int canGetCommunicationMode()
int canGetCommunicationMode(int channel)
```

2.21.13 canGetBusOutputControl

Returns the current driver mode. The function operates on the CAN channel the program is connected to if *channel* is not specified. See Section 2.35.7, CAN Driver Modes, on Page 86 for return values.

Returns a negative error code on failure.

Syntax

```
int canGetBusOutputControl()
int canGetBusOutputControl(int channel)
```

2.21.14 canSetBusOutputControl

This function sets the driver mode. The function operates on the CAN channel the program is connected to if *channel* is not specified. See Section 2.35.7, CAN Driver Modes, on Page 86 for valid *mode* values. You have to be bus-off when you call this function.

Returns a negative error code on failure.

Syntax

```
int canSetBusOutputControl(int mode)
int canSetBusOutputControl(int channel, int mode)
```

2.22 Predefined Timer Related Functions

The following functions for interacting with timers are predefined.

2.22.1 timerStart

Starts the timer *t*. The number of *periods* for which the timer should run automatically can be specified.

Syntax

```
void timerStart(Timer t)
void timerStart(Timer t, int periods)
```

A single-shot timer can be reset inside the associated `on Timer` handler to get periodic behavior. However, this will not guarantee a consistent period because any delay in handling the timer will not affect the next period.

When a timer is set into periodic mode (`FOREVER` can be used to specify a limitless number of periods), there may still be delays for any specific handler invocation. But in this case, the delay will automatically be subtracted from the next delay. For N periods, the total time will be N times the timer's timeout (plus whatever the delay is for the Nth invocation).

A timer that has a timeout of zero will not be started. This also means that a periodic timer whose timeout is set to zero will stop after the timer's next invocation.

If the timer was already active, the timer will be deactivated first.

Example

```
variables {
  Timer refresh;
  int   rpm_value = 0;
}
```

```
on start {
  refresh.timeout = 100;          // 100 ms
  timerStart(refresh, FOREVER);
}

on Timer refresh {
  rpm_value++;
  if (rpm_value >= 8000) {
    rpm_value = 0;
  }
}
```

2.22.2 `timerCancel`

Stops the timer *t*, if the timer is running.

Returns a negative error code if the timer was not running.

Syntax

```
int timerCancel(Timer t)
```

2.22.3 `timerIsPending`

Returns 0 if the timer is not active (i.e. has not been started with `timerStart()`). If the timer is active, the number of milliseconds until the timer is due will be returned. (If the timer has expired but the associated handler has not yet executed, the function will return 1).

Syntax

```
int timerIsPending(const Timer t)
```

2.22.4 `timerSetHandler`

Sets the `on Timer` hook to use for timer *t*.

Often this function is not needed, since an on Timer hook can be specified for every timer. However, this function allows dynamically created timers to be connected to a hook, which can sometimes be useful. Or the function can be used to have a single handler for multiple timers.

The timer structure contains an integer id member that can be used to identify which timer caused the handler to be executed. The contents of that member are user defined.

Returns a negative error code if the specified handler does not exist.

Syntax

```
int timerSetHandler(Timer t, const char hook[])
```

Example

```
variables {
  Timer t;
  Timer t1;
  Timer t2;
}

on start {
  t.timeout = 1000;
  t.id      = 100;
  timerStart(t);

  t1.timeout = 2000;
  t1.id      = 1;
  timerSetHandler(t1, "timer_handler");
  timerStart(t1);

  t2.timeout = 3000;
  t2.id      = 2;
  timerSetHandler(t2, "timer_handler");
  timerStart(t2);
}

on Timer t {
  printf("timer t, id=%d", this);
}

on Timer "timer_handler" {
  printf("timer t1 or t2, id=%d", this);
}
```

2.23 Predefined Environment Variable Functions

Environment variables cannot be accessed directly like ordinary variables in a *t* program. The functions in this section are used to access their values.

2.23.1 `envvarSetValue`

Sets the environment variable *envvar* to *value*. The actual update will be queued and therefore delayed until the execution of the current hook has finished. A notification that *envvar* is updated is then propagated to all programs who declare the same environment variable and have a corresponding `on envvar` hook. These on envvar hooks are called. A host computer connected to the program can also get a notification if `canSetNotify()` is configured correctly.

Do not set the same environment variable that you are handling in an `on envvar` hook, since that would cause an infinite loop.

The environment variables are queued in a special queue where each environment variable can only reside once. Each time an environment variable is updated, the variable is placed at the end of the queue. This means that if the variable was in

the queue already, the variable will be moved back with the new value and the older value is lost.

Returns the number of bytes put into *envvar*.

Syntax

```
int envvarSetValue(EnvVar envvar, int   value)
int envvarSetValue(EnvVar envvar, float value)
int envvarSetValue(EnvVar envvar, const char value[])
int envvarSetValue(EnvVar envvar, const char value[], int
    length)
```

2.23.2 `envvarGetValue`

Retrieves the last known value of the environment variable *envvar*. The result is undefined if *envvar* is not initialized.

Returns the number of bytes fetched from *envvar*.

Syntax

```
int envvarGetValue(const EnvVar envvar, int   &value)
int envvarGetValue(const EnvVar envvar, float &value)
int envvarGetValue(const EnvVar envvar, char   value[])
int envvarGetValue(const EnvVar envvar, char   value[],
                   int maxlength)
```

2.24 Predefined CAN Transport Protocol Related Functions

The built-in CAN transport protocols can be used to simplify programming. Data will be transferred in the background, but certain events can be used to notify the program about what is happening.

The built-in CAN transport protocols are currently only supported for classic CAN. Only one instance of the built-in CAN transport protocol can be open per program slot.

2.24.1 `canTpOpen`

Sets up a CAN transport (CanTP) session, to be referred to via the *handle*, for the specified *protocol* (currently only ISO-15765 is available). Receive and transmit identifiers are given by *rxid* and *txid*, respectively. Unless receive / transmit address mode is specified (via *addr_mode_rx* and, optionally, *addr_mode_tx*), the session will use Normal Physical 29 bit mode.

The possible address modes for ISO-15765 are:

- 11 / 29 bit
- Physical / Functional
- Normal / Fixed / Extended / Mixed
- Local / Remote.

Returns a negative error code on failure.

Syntax

```
int canTpOpen(CanTpHandle handle, int rxid, int txid,
              const char protocol[])
int canTpOpen(CanTpHandle handle, int rxid, int txid,
              const char protocol[],
              int addr_mode_rx)
int canTpOpen(CanTpHandle handle, int rxid, int txid,
              const char protocol[],
              int addr_mode_rx, int addr_mode_tx)
```

2.24.2 `canTpClose`

Terminates the CanTP session referred to by *handle*.

Syntax

```
void canTpClose(CanTpHandle handle)
```

2.24.3 `canTpTransmit`

Transmit *data* using the CanTp session referred to by *handle*, possibly specifying the maximum length.

For ISO-15765, transmit is not possible when a receive is under way (a separate CanTp session may be used to accomplish that).

The maximum transfer length for ISO-15765 is 4095 bytes.

Returns a negative error code on failure.

Syntax

```
int canTpTransmit(const CanTpHandle handle, const byte data[])
int canTpTransmit(const CanTpHandle handle, const byte data[],
                  int length)
```

2.24.4 `canTpAbort`

Abort any current activity on the CanTp session referred to by *handle*.

Returns a negative error code on failure.

Syntax

```
int canTpAbort(const CanTpHandle handle)
```

2.24.5 `canTpSetHandler`

Set a common handler, *hook*, for the CanTp session referred to by *handle*, or specify that the handler should deal with a specific CanTp *event*.

Returns a negative error code on failure.

Syntax

```
canTpSetHandler(const CanTpHandle handle, const char hook[])
canTpSetHandler(const CanTpHandle handle, const char hook[],
                int event)
```

For ISO-15765, the following events are available:

TxConfirmation	Confirmation that a packet has been transmitted, or a failure code.
RxIndication	Data received, or failure code.
FfIndication	Data is incoming.

2.24.6 `canTpSetAttr`

For the CanTp session referred to by *handle*, set the given attribute *attr* to the specified *value*.

Returns the value set or a negative error code on failure.

Syntax

```
int canTpSetAttr(const CanTpHandle handle, int attr, int value)
```

Most of the attributes are protocol specific, but the following applies to all CAN transport protocols:

canTp_Id	A user supplied id (for use when needed). Ends up in CanTpMessage (this) on events.

For ISO-15765 the following are available (prefixed by iso15765_):

BS	Receive_bs, supplied in transmitted messages.
STmin	Separation Time minimum, supplied in transmitted messages.
TxTimeout	Transmit timeout in milliseconds. Transmit will fail for longer control flow delays.
RxTimeout	Receive timeout in milliseconds. Reception will fail for longer delays.
WFTmax	Wait For Transmit (number of times allowed).
Channel	CAN channel to use (default channel is used otherwise).
Mask	Mask for accepting received CAN messages (also set by canTpOpen()).
Code	Id for accepting received CAN messages (also set by canTpOpen()).

A CAN id matches when:

```
identifier & Mask == Code & Mask
```

2.24.7 canTpGetAttr

For the CanTp session referred to by *handle*, get the specified *attribute*. The attributes are protocol specific. See `canTpSetAttr()`.

Returns the value of the attribute or a negative error code on failure.

Syntax

```
int canTpGetAttr(const CanTpHandle handle int attr)
```

2.25 Predefined *t* Program Related Functions

2.25.1 scriptLoad

Load a *t* program file called *filename*, using default CAN channel *channel*, into free program slot *slot*. The program should be stored on the SD disk. The actual load of the file is done when the current hook has finished. This means the return code only reflects the execution of the `scriptLoad` command.

Returns zero on success or a negative error code on failure.

Syntax

```
int scriptLoad(int slot, int channel, const char filename[])
```

Example

```
// This program loads another t program on start

variables {
  char file[10] = "test2.txe";
  int slot = 1; // a program slot that is free
  int channel = 0;  // default CAN channel
}
on start {
  printf("LOAD!");
  int res = scriptLoad(slot, channel, file);
  printf("scriptLoad, result=%d\n", res);
}
```

Note: Depending on hardware, there can be a limited number of program slots for storing loaded programs.

2.25.2 scriptUnload

Unload the *t* program loaded in program slot *slot*. The actual unload of the program is performed when the current hook has finished. This means the return code only reflects the execution of the *scriptUnload* command.

Returns zero on success or a negative error code on failure.

Syntax

```
int scriptUnload(int slot)
```

2.25.3 scriptStart

Start an already loaded program that resides in program slot *slot*. The actual start of the program is performed when the current hook has finished. This means the return code only reflects the execution of the `scriptStart` command.

Returns zero on success.

Syntax

```
int scriptStart(int slot)
```

2.25.4 scriptStop

Stop a started program that resides in program slot *slot*. The actual stop of the program is performed when the current hook has finished. This means the return code only reflects the execution of the `scriptStop` command.

Returns zero on success or a negative error code on failure.

Syntax

```
int scriptStop(int slot)
```

Example

```
// This program will make sure that there is another program
// running as long as this program is running

variables {
  int slot = 2; // a program slot that is free
  int channel = 0;  // default CAN channel
}

on start {
  scriptLoad(slot, channel, "test3.txe");
  scriptStart(slot);
}

on stop {
  scriptStop(slot);
  scriptUnload(slot);
}
```

2.26 Predefined Logger Related Functions

2.26.1 filterDropMessage

This function can only be used in logger mode, in program slot 0 in an `on CanMessage` hook. When a CAN message is filtered using `filterDropMessage()`, the message will not be stored in the log file. Nor will the message be handled by the built-in trigger mechanism.

A CAN message stopped in an `on prefilter CanMessage` will not be handled by any `on CanMessage` hook.

Removes the current message from the logger chain.

Returns a negative error code on failure.

Syntax

```
int filterDropMessage()
```

2.26.2 loggerStatus

This function can only be used in logger mode and in program slot 0.

Returns the current logger status (see Section 2.35.13, Logger Status, on Page 88).

Syntax

```
int loggerStatus()
```

2.26.3 loggerStart

This function can only be used in logger mode and in program slot 0. This function makes the device start recording CAN frames using the current bus settings and stores a trigger event in the log file. If the device is already recording, only a trigger event is stored.

Returns the current logger status (see Section 2.35.13, Logger Status, on Page 88).

Syntax

```
int loggerStart()
```

Note: This function will not work if "Log everything" is selected in the Memorator configuration.

2.26.4 loggerStop

This function can only be used in logger mode and in program slot 0. This function makes the device stop recording to the log file. The device will not stop listening for CAN frames, but will stop recording them.

Returns the current logger status (see Section 2.35.13, Logger Status, on Page 88).

Syntax

```
int loggerStop()
```

Note: This function will not work if "Log everything" is selected in the Memorator configuration.

2.26.5 loggerSetPretrigger

This function can only be used in logger mode and in program slot 0. This function sets the pretrigger time. The parameter *ms* is the pretrigger time in milliseconds. If a pretrigger time is already set, from a previous call to loggerSetPretrigger or from configuration file, the pretrigger wont change, and a negative error code will be returned.

Returns zero on success or a negative error code on failure.

Syntax

```
int loggerSetPretrigger(int ms)
```

Note: The amount of disk space reserved for the pretrigger is calculated from a worst case scenario, where full bus load on all available channels is assumed. Thus, use long pretrigger time with caution.

2.27 Predefined Crypto Related Functions

2.27.1 cryptoHash

Calculates the *digest* of *source* using a specified type of hash algorithm. The *length* of the data to be hashed can be specified.

If *digest* is not large enough to hold the hash, bytes to the right will be discarded.

Returns the normal size of the hash on success. A negative error code is returned on failure.

Syntax

```
int cryptoHash(int type, byte digest[], const byte source[])
int cryptoHash(int type, byte digest[], const byte source[],
               int length)
```

2.27.2 cryptoEncipher

Enciphers *source* by applying a specified *type* of cipher algorithm and a *password*. The length of the data to be enciphered can be specified. The enciphered result ends up in *dest*.

Depending on the cipher used, there may be length requirements on *source* and *password*.

Returns a negative error code on failure.

Syntax

```
int cryptoEncipher(int type, byte dest[], const byte source[],
                   const byte password[])
int cryptoEncipher(int type, byte dest[], const byte source[],
                   int length, const byte password[])
```

2.27.3 cryptoDecipher

Deciphers *source* by applying a specified *type* of cipher algorithm and a *password*. The *length* of the data to be deciphered can be specified. The deciphered result ends up in *dest*. Depending on the cipher used, there may be length requirements on *source* and *password*.

Returns a negative error code on failure.

Syntax

```
int cryptoDecipher(int type, byte dest[], const byte source[],
                   const byte password[])
int cryptoDecipher(int type, byte dest[], const byte source[],
                   int length, const byte password[])
```

2.27.4 cryptoRandom

Makes use of physical randomness in the device to generate a random number. When an actual hardware random number generator is not available, some kind of entropy extraction is used instead.

Returns a 32 bit random number.

Syntax

```
int cryptoRandom()
```

2.28 Predefined System Related Functions

2.28.1 sysGetValue

Enables the fetching of various system values. The desired information *type* is specified (see Section 2.35.15, System, on Page 89 for a list of available types) and the result is returned in *value* or *data*.

Returns a negative error code on failure. The result ends up in value or data.

Syntax

```
int sysGetValue(int type, int &value)
int sysGetValue(int type, byte data[])
```

Example

```
variables {
  int ean_high;
  int ean_low;
```

```
  int serno;
}

on start {
  printf("[START]\n");

  sysGetValue(SYS_EAN_HIGH,  &ean_high);
  sysGetValue(SYS_EAN_LOW,   &ean_low);
  sysGetValue(SYS_SERIAL_NO, &serno);

  printf("SYS_EAN_HIGH:%d\n", ean_high);
  printf("SYS_EAN_LOW:%d\n", ean_low);
  printf("SERIAL_NUMBER:%d\n", serno);
}
```

2.29 Predefined Customer Data Related Functions

2.29.1 `customerDataGetLength`

Enables the fetching of customer data values. The desired information *user_id(oem_id)* is specified and the length, in bytes, of the contents are returned in *value*.

Returns a negative error code on failure. Returns 0 if OK.

Syntax

```
int customerdataGetLength(int user_id, int param_id, int
    &value)
```

2.29.2 `customerDataGetValue`

Enables the fetching of customer data values. The desired information *user_id(oem_id)* is specified and the contents are returned in *data*. *Param_id* must be zero (presently not implemented).

Returns a negative error code on failure. Returns 0 if OK.

Syntax

```
int customerdataGetValue(int user_id, int param_id, byte data[])
```

2.30 Predefined LED Functions

2.30.1 `ledOpen`

Opens a handle to a LED and reserves the LED for a program. The LED will not be affected by system events as long as the handle is open. The predefined values for

ledNumber are LED0, LED1, etc. (see Section 2.35.17, LED Constants, on Page 89). *Param_id* must be zero (presently not implemented).

Returns zero on success or a negative error code on failure.

Syntax

```
int ledOpen(LedHandle led, int ledNumber)
```

2.30.2 ledClose

Close a handle to a LED and allow the LED to be controlled by system events again.

Syntax

```
void ledClose(LedHandle led)
```

2.30.3 ledSet

Set the state for a LED. The two available states are `LED_STATE_ON` and `LED_STATE_OFF`. For further information see Section 2.35.17, LED Constants, on Page 89.

Returns zero on success or a negative error code on failure.

Syntax

```
int ledSet(const LedHandle led, int ledState)
```

2.31 Predefined I/O Functions

I/O functions use a pin number to access each pin on the connected I/O modules. Available pins are given consecutive integer pin numbers starting with `0` for the first pin on the first module, `1` for the second pin on the first module, and so on until the last pin on the last module.

The user should examine the pins with `kvIoGetNumberOfPins` and `kvIoPinGetInfo` to verify that the configuration is as expected. The configuration must then be confirmed with `kvIoConfirmConfig` before the pins can be used.

Each *t* program must confirm the configuration before the pins can be used in that program and the confirmation is lost if the program is stopped.

Note: Note that using any other functions than `kvIoGetNumberOfPins` and `kvIoPinGetInfo` before the configuration has been confirmed will return an error code.

Removing, adding or changing the order of the I/O modules will change the pin numbers and an `kvIO_EVENT_CONFIG_CHANGED` event is sent to all running programs to notify them that the pin numbers have changed.

The pins are enumerated to match the new configuration and the programs must re-examine the pins and call `kvIoConfirmConfig` before the pins can be used again.

2.31.1 kvIoConfirmConfig

Confirm the configuration.

Returns zero on success or a negative error code on failure.

Syntax

```
int kvIoConfirmConfig(void)
```

2.31.2 kvIoGetNumberOfPins

Get the number of I/O pins. Can be called before `kvIoConfirmConfig`.

Returns zero on success or a negative error code on failure.

Syntax

```
int kvIoGetNumberOfPins(int &pinCount)
```

2.31.3 kvIoPinGetInfo

Get I/O pin properties, see 2.35.19.4 for property item codes and if the returned value is integer or float. Can be called before `kvIoConfirmConfig`.

Returns zero on success or a negative error code on failure.

Syntax

```
int kvIoPinGetInfo(int pin, int item, int &value)
int kvIoPinGetInfo(int pin, int item, float &value)
```

2.31.4 kvIoPinSetInfo

Set I/O pin properties, see 2.35.19.4 for property item codes that can be changed and if the value is integer or float.

Returns zero on success or a negative error code on failure.

Syntax

```
int kvIoPinSetInfo(int pin, int item, int value)
int kvIoPinSetInfo(int pin, int item, float value)
```

2.31.5 `kvIoPinSetDigital`

Set a digital output pin. Setting *value* to zero is LOW and any non-zero value is HIGH.

Returns zero on success or a negative error code on failure.

Syntax

```
int kvIoPinSetDigital(int pin, int value)
```

2.31.6 `kvIoPinGetDigital`

Get value from a digital input pin. Getting a *value* equal to zero corresponds to LOW and any non-zero value is HIGH.

Returns zero on success or a negative error code on failure.

Syntax

```
int kvIoPinGetDigital(int pin, int &value)
```

2.31.7 `kvIoPinSetAnalog`

Set the voltage level on an analog output pin.

Returns zero on success or a negative error code on failure.

Syntax

```
int kvIoPinSetAnalog(int pin, float value)
```

2.31.8 `kvIoPinGetAnalog`

Get the voltage level from an analog input pin.

Returns zero on success or a negative error code on failure.

Syntax

```
int kvIoPinGetAnalog(int pin, float &value)
```

2.31.9 `kvIoPinSetRelay`

Set a relay output pin. Setting *value* to zero is OFF and any non-zero value is ON.

Returns zero on success or a negative error code on failure.

Syntax

```
int kvIoPinSetRelay(int pin, int value)
```

2.31.10 kvIoPinGetOutputDigital

Get the latest set value from a digital output pin. This function reads values from memory which is not necessarily the same as the actual voltage level that is present on the output pin. Getting a *value* equal to zero corresponds to LOW and any non-zero value is HIGH.

Returns zero on success or a negative error code on failure.

Syntax

```
int kvIoPinGetOutputDigital(int pin, int &value)
```

2.31.11 kvIoPinGetOutputAnalog

Get the latest set voltage level from an analog output pin. This function reads values from memory which is not necessarily the same as the actual voltage level that is present on the output pin.

Returns zero on success or a negative error code on failure.

Syntax

```
int kvIoPinGetOutputAnalog(int pin, float &value)
```

2.31.12 kvIoPinGetOutputRelay

Get the latest set value of a relay output pin. If *value* equals zero, the relay has been switched OFF any non-zero value means that it has been switched ON. This function reads values from memory which is not necessarily the same as the actual switch state that is present on the relay pin.

Returns zero on success or a negative error code on failure.

Syntax

```
int kvIoPinGetOutputRelay(int pin, int &value)
```

2.31.13 kvIoGetModulePins

This function is used to read all the pins on one module in a single call. The supplied buffer is filled with one of the following structs:

`kvIoModuleDigital`	This struct describes a digital add-on module.
`kvIoModuleAnalog`	This struct describes an analog add-on module.
`kvIoModuleRelay`	This struct represents a relay add-on module.
`kvIoModuleInternal`	This struct represents an internal module.

Use sizeof (2.32.3) to give the function the correct buflen value. Returns zero on success or a negative error code on failure.

Syntax

```
int kvIoGetModulePins(int module, kvIoModuleDigital buffer, int
    buflen)
int kvIoGetModulePins(int module, kvIoModuleAnalog buffer, int
    buflen)
int kvIoGetModulePins(int module, kvIoModuleRelay buffer, int
    buflen)
int kvIoGetModulePins(int module, kvIoModuleInternal buffer,
    int buflen)
```

2.31.14 kvIoSetModulePins

This function is used to set all the pins on one module in a single call. The supplied buffer should be one of the following structs: Note that the input Pins are ignored.

kvIoModuleDigital	This struct describes a digital add-on module.
kvIoModuleAnalog	This struct describes an analog add-on module.
kvIoModuleRelay	This struct represents a relay add-on module.
kvIoModuleInternal	This struct represents an internal module.

Use sizeof (2.32.3) to give the function the correct buflen value. Returns zero on success or a negative error code on failure.

Syntax

```
int kvIoSetModulePins(int module, kvIoModuleDigital buffer, int
    buflen)
int kvIoSetModulePins(int module, kvIoModuleAnalog buffer, int
    buflen)
int kvIoSetModulePins(int module, kvIoModuleRelay buffer, int
    buflen)
int kvIoSetModulePins(int module, kvIoModuleInternal buffer,
    int buflen)
```

2.32 Other Predefined Functions

2.32.1 timeGetDate

Provides time and date as a `struct tm` (see Section 2.34.5, `tm`, on Page 82), as an integer, or as a string. The integer represents time in the standard Unix epoch (i.e. the number of seconds since 00:00:00 UTC on 1 January 1970).

When there is no *time* input parameter, the current clock time is used.

If *buf* is too small, characters to the right will be discarded.

Syntax

```
void timeGetDate(tm t)
void timeGetDate(int &time)
void timeGetDate(char buf[])
void timeGetDate(int time, char buf[])
```

2.32.2 `timeGetLocal`

Accesses the time since the device was started (synchronized with the CAN message timestamps). The optional *remainder* will contain the remainder of the integer division of the timestamp by *scale*.

Returns the result of an integer division of the time since the device was started (microseconds) by *scale*.

The function considers *scale* to be an unsigned integer. A *scale* value of 0 is a special case interpreted as one larger than the maximum unsigned integer. This will cause the function to return the high integer of the time value.

Syntax

```
int timeGetLocal(int scale)
int timeGetLocal(int scale, int &remainder)
```

2.32.3 `sizeof`

This is really a language/compiler feature rather than a function, and is mainly useful for serialization and deserialization (see Section 2.3, Serialization and Deserialization, on Page 20).

Only constant, variable and type names are allowed as “parameter”.

Returns the “packed” size in bytes, suitable for serialization/deserialization (see Section 2.3, Serialization and Deserialization, on Page 20 for details), of the specified type or variable.

Note: To get the number of elements in an array, use `.count` instead (see Section 2.1.5, Arrays, on Page 16).

2.33 Predefined Symbols

2.33.1 `this`

The symbol `this` can be used inside a message handler to refer to the message being handled.

Example

```
on CanMessage 123 {
  printf("%d\n" this.id);
}
```

This handler would print ‘123’ to the standard output each time a CAN message with identifier 123 arrived. Inside a CanMessage handler, `this` has the type `CanMessage`.

2.34 Predefined Types

This section describes the data types that are predefined in the run-time library.

2.34.1 Timer

```
typedef struct {
  int timeout;     // Period time in milliseconds
  int id;          // User supplied id (for use when needed)
} Timer;
```

Defines a timer.

2.34.2 CanMessage

```
typedef struct {
  byte channel;    // Channel received message arrived on
  byte flags;      // CAN message flags, for extended id etc
  byte dlc;        // Number of bytes (normally) in CAN message
  int  id;         // CAN id of message
  byte data[8];    // CAN message data
} CanMessage;
```

Defines a CAN message.

Note: The time stamp on an incoming message is not directly accessible. `canGetTimestamp()` must be used to access the time stamp.

2.34.3 CanMessageFd

```
typedef struct {
  byte channel;    // Channel received message arrived on
  byte dlc;        // Number of bytes in CAN FD message
  int  flags;      // CAN FD message flags
  int  id;         // CAN id of message
  byte data[64];   // CAN FD message data
} CanMessageFd;
```

Defines a CAN FD message.

Note: The time stamp on an incoming message is not directly accessible. `canGetTimestamp()` must be used to access the time stamp.

2.34.4 CanTpMessage

```
typedef struct {
  int  id;       // User supplied id (for use when needed)
  int  result;   // Error code
  byte data[];   // Received data
} CanTpMessage;
```

Defines the data received by a CanTp handler.

2.34.5 tm

```
typedef struct {
  int tm_sec;      // seconds after the minute
  int tm_min;      // minutes after the hour
  int tm_hour;     // hours since midnight
  int tm_mday;     // day of the month
  int tm_mon;      // months since January
  int tm_year;     // years since 1900
  int tm_wday;     // days since Sunday
  int tm_yday;     // days since January 1
  int tm_isdst;    // Daylight Saving Time flag
} tm;
```

Defines the time format.

2.34.6 ExceptionData

```
typedef struct {
  int  current_thread;     // # of thread where exception
     occurred
  int  error;              // Exception number
  int  line;               // Line (if accessible)
  int  pc;                 // Program counter
  int  cycle;              // # of executed cycles
  int  locals;             // Index to local variables on stack
  int  stack[];            // The stack
  int  globals[];          // The global variables
  int  stack_base;         // Base address of the stack
} ExceptionData;
```

This built-in type defines an exception. When received in an `on exception`, the data is `const`.

2.34.7 Types for Database Defined Signals

```
typedef struct {
  int Raw;
  int Phys;
};


typedef struct {
  float Raw;
  float Phys;
};
```

These two built-in types are used to define signals from database files. If your message is defined in a database file, you can manipulate the message's signals by assigning values to their `.Raw` or `.Phys` components. Raw means the value

actually transmitted in the CAN messages. Phys means the physical value, scaled according to the parameters defined for that signal in the database.

The scaling rules are:

```
Physical value = (raw value) * factor + offset Raw value =
((physical value) - offset) / factor
```

Suppose you have a database where the message *EngineData* contains the signal *EngineTemp* with a range from −50 °C to 150 °C, the offset is specified as -50 and the factor as 0.01, and the data format is an unsigned 16-bit integer.

```
CanMessage_EngineData.EngineTemp.Phys = 75;
```

The assignment above means that a raw value of (75 - (- 50)) / 0.01 = 12500 would be assigned to the two bytes that make up the *EngineTemp* in the CAN message *EngineData*.

```
CanMessage_EngineData.EngineTemp.Raw = 75;
```

This assignment would just assign 75 to the two bytes that make up the EngineTemp signal representing a temperature of 75*0.01 + (- 50) = −49.25 °C.

2.34.8 `IoEvent`

```
typedef struct {
  int pin;      // Pin that generated the event
  int event;    // Event type
  float value;  // Event value
} IoEvent;
```

Defines the data received by an IoEvent handler, see 2.35.19.5 for values for `event`.

2.34.9 `kvIoModuleDigital`

```
typedef struct {
  int type; // The type of module.
  byte DO_0_7;   // Digital Out
  byte DO_8_15;  // Digital Out
  byte DI_0_7;   // Digital In
  byte DI_8_15;  // Digital In
} kvIoModuleDigital;
```

This define is used in `kvIoGetModulePins` and `kvIoSetModulePins`. This struct represents a digital add-on module. For `type` see Module type.

2.34.10 kvIoModuleAnalog

```
typedef struct {
  int type;  // The type of module.
  float AO1; // Analog Out
  float AO2; // Analog Out
  float AO3; // Analog Out
  float AO4; // Analog Out
  float AI1; // Analog In
  float AI2; // Analog In
  float AI3; // Analog In
  float AI4; // Analog In
} kvIoModuleAnalog;
```

This define is used in `kvIoGetModulePins` and `kvIoSetModulePins`. This struct represents a analog add-on module. For `type` see Module type.

2.34.11 kvIoModuleRelay

```
typedef struct {
  int type; // The type of module.
  byte RO_0_7; // Relay Out
  byte DI_0_7; // Digital In
} kvIoModuleRelay;
```

This define is used in `kvIoGetModulePins` and `kvIoSetModulePins`. This struct represents a relay add-on module. For `type` see Module type.

2.34.12 kvIoModuleInternal

```
typedef struct {
  int type;              // The type of module.
  unsigned char DO : 1; // Digital Out
  unsigned char DI : 1; // Digital In
} kvioModuleInternal;
```

This define is used in `kvIoGetModulePins` and `kvIoSetModulePins`. This struct represents a internal module. For `type` see Module type.

2.35 Predefined Constants

2.35.1 Maths

M_PI	3.14159265359
M_E	2.71828182846

2.35.2 Timer Period Counts

FOREVER	
ONCE	

2.35.3 CAN Message Flags

canMSG_RTR	Marks a Remote-Frame. Can also be used for transmitting messages. Not available for CAN FD messages.
canMSG_EXT	For received messages, set if the CAN message has an extended identifier. To send a CAN message with a 29 bit identifier, this flag must be set when calling `canWrite()`.
canMSG_ERROR_FRAME	Marks error frames.
canMSGERR_OVERRUN	Marks that overrun occured. Is ignored on outgoing messages.

2.35.4 CAN FD Message Flags

canFDMSG_FDF	Marks that a frame is a CAN FD frame.
canFDMSG_BRS	Marks that the data phase of a CAN FD frame is bitrate switched.
canFDMSG_SINGLE_SHOT	Marks that a single attempt at sending message should be made. No retransmissions will be made upon failure.

2.35.5 CAN Bitrates

canBITRATE_1M	1 Mbit/s	75% sample point
canBITRATE_500K	500 kbit/s	75% sample point
canBITRATE_250K	250 kbit/s	75% sample point
canBITRATE_125K	125 kbit/s	75% sample point
canBITRATE_100K	100 kbit/s	75% sample point
canBITRATE_83K	83.333 kbit/s	75% sample point
canBITRATE_62K	62.5 kbit/s	75% sample point
canBITRATE_50K	50 kbit/s	75% sample point

2.35.6 CAN FD Bitrates

canFD_BITRATE_500K_80P	500 kbit/s	80% sample point
canFD_BITRATE_1M_80P	1 Mbit/s	80% sample point
canFD_BITRATE_2M_80P	2 Mbit/s	80% sample point
canFD_BITRATE_2M_60P	2 Mbit/s	60% sample point
canFD_BITRATE_4M_80P	4 Mbit/s	80% sample point
canFD_BITRATE_8M_80P	8 Mbit/s	80% sample point
canFD_BITRATE_8M_60P	8 Mbit/s	60% sample point

2.35.7 CAN Driver Modes

canDRIVER_NORMAL	
canDRIVER_SILENT	

2.35.8 CAN Communication Modes

canMODE_CAN	The channel will only be able to send and recieve classic CAN messages.
canMODE_CAN_FD	The channel will use the CAN FD protocol. This also means that messages with CAN FD message flags can now be used, see Section 2.35.4, CAN FD Message Flags, on Page 85.
canMODE_CAN_FD_NONISO	The channel will use the CAN FD NON-ISO protocol. This also means that messages with CAN FD message flags can now be used, see Section 2.35.4, CAN FD Message Flags, on Page 85.

2.35.9 CAN Status

canSTAT_BUS_OFF	
canSTAT_ERROR_PASSIVE	
canSTAT_ERROR_WARNING	
canSTAT_ERROR_ACTIVE	

2.35.10 CAN Transport Protocols

2.35.10.1 Error Codes

canTp_OK	No error detected.
canTp_TX_ERR_MASK	Covers all transmit errors.
canTp_RX_ERR_MASK	Covers all receive errors.
canTp_GEN_ERR_MASK	Covers all generic errors.
iso15765_OK	No error detected.
iso15765_TIMEOUT_A	
iso15765_TIMEOUT_Bs	
iso15765_TIMEOUT_Cr	
iso15765_WRONG_SN	
iso15765_INVALID_FS	
iso15765_UNEXP_PDU	
iso15765_WFT_OVRN	
iso15765_BUFFER_OVFLW	

2.35.10.2 Events

iso15765_TxConfirmation	
iso15765_RxIndication	
iso15765_FfIndication	

2.35.10.3 Attributes

canTp_Id	User supplied id (for use when needed).
iso15765_BS	
iso15765_STmin	
iso15765_TxTimeout	
iso15765_RxTimeout	
iso15765_WFTmax	
iso15765_Mask	
iso15765_Code	
iso15765_Channel	

2.35.10.4 Address Modes

iso15765_11bit	
iso15765_29bit	
iso15765_Physical	
iso15765_Functional	
iso15765_Normal	
iso15765_Fixed	
iso15765_Extended	
iso15765_Mixed	
iso15765_Local	
iso15765_Remote	

2.35.11 File Open

OPEN_READ	
OPEN_WRITE	
OPEN_APPEND	
OPEN_TRUNCATE	

2.35.12 File Seek

SEEK_CUR	
SEEK_SET	
SEEK_END	

2.35.13 Logger Status

LOGGER_STATE_UNINITIALIZED	This is returned when the logger mechanism isn't running.
LOGGER_STATE_IDLE	This is returned when the device is in logger mode, but not storing anything to the log file. Usually seen when the device is waiting for a trigger to happen.
LOGGER_STATE_STORING	This is returned when the device is waiting for a trigger and the pre-trigger is activated (i.e. buffering the pre-trigger on the disk).
LOGGER_STATE_LOGGING	This is returned when the device is logging data.
LOGGER_STATE_DISK_FULL	This is returned when the disk is full.
LOGGER_STATE_FAULT	This is returned when the logger mechanisms encounters an error that can't be handle, like the disk is removed.
LOGGER_STATE_UNKNOWN	This should not happen.

2.35.14 Crypto

CRYPTO_MD5	MD5 hash
CRYPTO_SHA1	SHA-1 hash
CRYPTO_AES128	AES-128 cipher (padding: None, mode: ECB)
CRYPTO_MD5_SIZE	Size of MD5 digest
CRYPTO_SHA1_SIZE	Size of SHA-1 digest
CRYPTO_HASH_SIZE	Maximum size of supported hashes
CRYPTO_AES128_BLOCK	Data block granularity for AES-128

2.35.15 System

SYS_EAN_HIGH	Vendor ID part of EAN (int)
SYS_EAN_LOW	Product ID part of EAN (int)
SYS_SERIAL_NO	Product serial number (int)
SYS_SD_CID	SD card CID information
SYS_SD_CID_SIZE	Size of SD card CID information

2.35.16 User Parameters

USER_PARAM_SIZE (not used)	User parameter size number (int)
USER_PARAM (not used)	User parameter (bytearray)
USER_PARAM_MAX_SIZE	Max size of the user parameters

2.35.17 LED Constants

Different Kvaser Devices can have up to twelve LED indicators. Normally LED0 stands for PWR indicator, deviations are specified in respective device's user guide.

LED0	The first LED
LED1	The second LED
LED2	The third LED
LED3	The fourth LED
LED4	The fifth LED
LED5	The sixth LED
...	
LED11	The twelfth LED
LED_STATE_ON	Turn the LED on
LED_STATE_OFF	Turn the LED off

2.35.18 Envvar Constants

ENVVAR_MAX_SIZE	4096

2.35.19 I/O Pin Constants

2.35.19.1 Module type

kvIO_MODULE_TYPE_DIGITAL	Module with digital pins
kvIO_MODULE_TYPE_ANALOG	Module with analog pins
kvIO_MODULE_TYPE_RELAY	Module with relay and digital pins
kvIO_MODULE_TYPE_INTERNAL	Built-in module with digital pins

2.35.19.2 Pin type

kvIO_PIN_TYPE_DIGITAL	Digital pin
kvIO_PIN_TYPE_ANALOG	Analog pin
kvIO_PIN_TYPE_RELAY	Relay pin

2.35.19.3 Direction

kvIO_PIN_DIRECTION_IN	Input pin
kvIO_PIN_DIRECTION_OUT	Output pin

2.35.19.4 Properties

The following macros can be used with `kvIoPinGetInfo` (2.31.3) to get the value of each property. The value range for each property is specified in the manufacturer's user manual.

`kvIO_INFO_GET_MODULE_TYPE`	The type of I/O module that the pin belongs to. Integer. Read-only. See ch. 2.35.19.1 for definitions
`kvIO_INFO_GET_MODULE_NUMBER`	The number that represents the add-on module the pin belongs to, starting from 0. Read-only.
`kvIO_INFO_GET_SERIAL_NUMBER`	The serial number of the add-on module the pin belongs to. Read-only.
`kvIO_INFO_GET_FW_VERSION`	The number that represents the software of the module the pin belongs to. Read-only.
`kvIO_INFO_GET_DIRECTION`	Pin direction. Integer. Read-only. See ch. 2.35.19.3 for definitions
`kvIO_INFO_GET_PIN_TYPE`	Pin type. Integer. Read-only. See ch. 2.35.19.2 for definitions.
`kvIO_INFO_GET_NUMBER_OF_BITS`	Resolution in number of bits. Integer. Read-only.
`kvIO_INFO_GET_RANGE_MIN`	Lower range limit in volts. Float. Read-only. N/A for relay pins.
`kvIO_INFO_GET_RANGE_MAX`	Upper range limit in volts. Float. Read-only. N/A for relay pins.
`kvIO_INFO_GET_DI_LOW_HIGH_FILTER`	Filter time in micro seconds when a digital input pin goes from LOW to HIGH. Integer.
`kvIO_INFO_GET_DI_HIGH_LOW_FILTER`	Filter time in micro seconds when a digital input pin goes from HIGH to LOW. Integer.
`kvIO_INFO_GET_AI_LP_FILTER_ORDER`	The low-pass filter order for an analog input pin. Integer.
`kvIO_INFO_GET_AI_HYSTERESIS`	The hysteresis in volt for an analog input pin, i.e. the amount the input have to change before the sampled value is updated. Float.

Some properties are user configurable. The following macros can be used with `kvIoPinSetInfo` (2.31.3) to set the value of these properties. The value range for each property is specified in the manufacturer's user manual.

`kvIO_INFO_SET_DI_LOW_HIGH_FILTER`	Filter time in micro seconds when a digital input pin goes from LOW to HIGH. Integer.
`kvIO_INFO_SET_DI_HIGH_LOW_FILTER`	Filter time in micro seconds when a digital input pin goes from HIGH to LOW. Integer.
`kvIO_INFO_SET_AI_LP_FILTER_ORDER`	The low-pass filter order for an analog input pin. Integer.
`kvIO_INFO_SET_AI_HYSTERESIS`	The hysteresis in volt for an analog input pin, i.e. the amount the input have to change before the sampled value is updated. Float.

2.35.19.5 Event Codes

`kvIO_EVENT_CONFIG_CHANGED`	The I/O configuration has changed.
`kvIO_EVENT_VALUE_ABOVE`	Analog input value above upper limit.
`kvIO_EVENT_VALUE_BELOW`	Analog input value below lower limit.
`kvIO_EVENT_VALUE_CHANGED`	Analog input value change exceeds hysteresis.
`kvIO_EVENT_RISING_EDGE`	Digital input went from LOW to HIGH.
`kvIO_EVENT_FALLING_EDGE`	Digital input went from HIGH to LOW.

References

[1] F. Panneton, P. L'Ecuyer, and M. Matsumoto, *Improved Long-Period Generators Based on Linear Recurrences Modulo 2* ACM Transactions on Mathematical Software, 32, 1 (2006), 1-16

3 Document Revision History

Version history for document UG_98032_kvaser_t_userguide:

Revision	Date	Changes
-	2011-09-19	Initial version.
4.6	2017-02-03	Updated timer descriptions (according to changes in VM).
4.7	2017-04-19	The XML-parser now handles comments and prolog. Requires updated firmware. Padding and mode information added to CRYPTO_AES128.
4.8	2017-08-14	Increased compiler version to 3.6, requires updated firmware. Added parameter descriptions to canGetBusParams and canGetBusParamsFd. Added function loggerSetPretrigger. Renamed flag canMSG_SINGLE_SHOT to canFDMSG_SINGLE_SHOT.
4.9	2018-01-30	Increased compiler version to 3.7, added #include <> syntax to search system directory.
4.10	2018-05-04	Increased compiler version to 3.8. Minor buf fix.
4.11	2018-06-14	Noted that only one cantp instance are allowed per slot.
4.12	2018-09-11	Increased compiler version to 3.9, added support for I/O.
4.13	2018-10-04	IoEvents are checked when calling kvIoConfirmConfig() and not on script start.
4.14	2019-02-04	Increased compiler version to 3.10, updated support for I/O.
4.15	2019-08-09	Url protocol updated.
4.16	2019-09-20	Increased compiler version to 3.11, added kvIO_MODULE_TYPE_INTERNAL.
4.17	2021-01-07	Increased compiler version to 3.12, added constant canFD_BITRATE_500K_80P and support for J1939 databases. Added a note about receiving CAN messages after calling canBusOff. Replaced Kvaser Eagle with Kvaser Memorator Pro 2xHS v2. Updated CAN FD sample to use canFD_BITRATE_XXX.
4.18	2022-03-21	Increased compiler version to 3.13, added constant canFD_BITRATE_2M_60P. Minor textual changes.
4.19	2024-03-15	Updated Kvaser logo.
4.20	2025-01-13	Added an example of how to get system values.