# TSK51x/TSK52x Embedded Tools Reference

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# Manual Purpose and Structure

### Windows Users

The documentation explains and describes how to use the TASKING TSK51x/TSK52x toolset to program a TSK51x/TSK52x processor.

You can use the tools either with the graphical Altium Designer or from the command line in a command prompt window.

### Structure

The toolset documentation consists of a user's manual (*Using the TSK51x/TSK52x Embedded Tools*), which includes a Getting Started section, and a separate reference manual (this manual).

Start by reading the *Getting Started* in Chapter 1 of the user's manual.

The other chapters in the user's manual explain how to use the compiler, assembler, linker and the various utilities.

Once you are familiar with these tools, you can use this reference manual to lookup specific options and details to make full use of the TASKING toolset.

The reference manual describes the C language implementation and the  assembly language.

# Short Table of Contents

# Conventions Used in this Manual

### *Notation for syntax*

The following notation is used to describe the syntax of command line input:

**bold** Type this part of the syntax literally.

*italics* Substitute the italic word by an instance. For example:

*filename*

Type the name of a file in place of the word *filename*.

{ } Encloses a list from which you must choose an item.

[ ] Encloses items that are optional. For example

**c51** [ **-?** ]

Both **c51** and **c51 -?** are valid commands.

| Separates items in a list. Read it as OR.

... You can repeat the preceding item zero or more times.

### *Example*

**c51** [*option*]... *filename*

You can read this line as follows: enter the command **c51** with or without an option, follow this by zero or more options and specify a *filename*. The following input lines are all valid:

```
c51 test.c
c51 -g test.c
c51 -g -s test.c
```

Not valid is:

```
c51 -g
```

According to the syntax description, you have to specify a filename.

### *Icons*

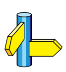
The following illustrations are used in this manual:


Note: notes give you extra information.


Warning: read the information carefully. It prevents you from making serious mistakes or from loosing information.


This illustration indicates actions you can perform with the mouse. Such as Altium Designer menu entries and dialogs.


Command line: type your input on the command line.


Reference: follow this reference to find related topics.

# Related Publications

### *C Standards*

- ISO/IEC 9899:1999(E), Programming languages - C [ISO/IEC]
  More information on the standards can be found at `http://www.ansi.org`
- DSP-C, An Extension to ISO/IEC 9899:1999(E),
  Programming languages - C [TASKING, TK0071-14]

### *MISRA-C*

- Guidelines for the Use of the C Language in Vehicle Based Software [MIRA limited, 1998]
  See also `http://www.misra.org.uk`
- MISRA-C:2004: Guidelines for the use of the C Language in critical systems [MIRA limited, 2004]
  See also `http://www.misra-c.com`

### *TASKING Tools*

- Using the TSK51x/TSK52x Embedded Tools
  [Altium, GU0107]
- TSK51x MCU Core Reference
  [Altium, CR0115]
- TSK52x MCU Core Reference
  [Altium, CR0116]

# 1 C Language

## Summary

This chapter describes the target specific features of the C language, including language extensions that are not standard in ISO-C. For example, pragmas are a way to control the compiler from within the C source.

## 1.1 Introduction

The TASKING C compiler fully supports the ISO C standard but adds possibilities to program the special functions of the TSK51x/TSK52x.

In addition to the standard C language, the compiler supports the following:

- extra data type `__bit`
- intrinsic (built-in) functions that result in target specific assembly instructions
- pragmas to control the compiler from within the C source
- predefined macros
- the possibility to use assembly instructions in the C source
- keywords to specify memory types for data and functions
- attribute to specify absolute addresses
- keywords for inlining functions and programming interrupt routines
- libraries

All non-standard keywords have two leading underscores (__).

In this chapter the target specific characteristics of the C language are described, including the above mentioned extensions.

## 1.2 Data Types

The TASKING C compiler for the TSK51x/TSK52x architecture (**c51**) supports the following data types:

| Type | C Type | Size (bit) | Align (bit) | Limits |
|---|---|---|---|---|
| Bit | `__bit` | 1 | 1 | 0 or 1 |
| Boolean | `_Bool` | 1 | 8 | 0 or 1 |
| Character | `char`<br>`signed char` | 8 | 8 | $-2^{7}$ .. $2^{7}-1$ |
| | `unsigned char` | 8 | 8 | 0 .. $2^{8}-1$ |
| Integral | `short`<br>`signed short`<br>`int`<br>`signed int` | 16 | 8 | $-2^{15}$ .. $2^{15}-1$ |
| | `enum` | 1<br>8<br>16 | 1<br>8<br>8 | 0 or 1<br>$-2^{7}$ .. $2^{7}-1$<br>$-2^{15}$ .. $2^{15}-1$ |
| | `unsigned short`<br>`unsigned int` | 16 | 8 | 0 .. $2^{16}-1$ |
| | `long`<br>`signed long` | 32 | 8 | $-2^{31}$ .. $2^{31}-1$ |
| | `unsigned long` | 32 | 8 | 0 .. $2^{32}-1$ |
| | `long long`<br>`signed long long` | 32 | 8 | $-2^{31}$ .. $2^{31}-1$ |
| | `unsigned long long` | 32 | 8 | 0 .. $2^{32}-1$ |
| Pointer | pointer to __sfr, __bsfr, __data, __bdata, __idata, __pdata or __bit | 8 | 8 | 0 .. $2^{8}-1$ |
| | pointer to function, __xdata or __rom | 16 | 8 | 0 .. $2^{16}-1$ |
| Floating-Point | `float` | 32 | 8 | -3.402E+38 .. -1.175E-38<br>1.175E-38 .. 3.402E+38 |
| | `double`<br>`long double` | 32 | 8 | -3.402E+38 .. -1.175E-38<br>1.175E-38 .. 3.402E+38 |

*Table 1-1: Data Types for the TSK51x/TSK52x*

The `long long` types are treated as `long`.

The `double` and `long double` types are always treated as `float`.

When you use the `enum` type, the compiler will use the smallest sufficient type (`__bit`, `char`, `int`), unless you use C compiler option **--integer-enumeration** (always use 16-bit integers for enumeration).

### *Bit data type*

You can use the `__bit` type to define scalars in the bit-addressable area and for the return type of functions. A struct containing bit-fields cannot be used for this purpose, for example because the struct is aligned at a byte boundary. Unlike the `_Bool` type the `__bit` type is aligned on a bit boundary.

The following rules apply to `__bit` type variables:

- A `__bit` type variable is always unsigned.
- A `__bit` type variable can be exchanged with all other type-variables. The compiler generates the correct conversion.

  A `__bit` type variable is like a boolean. Therefore, if you convert an `int` type variable to a `__bit` type variable, it becomes 1 (true) if the integer is not equal to 0, and 0 (false) if the integer is 0. The next two C source lines have the same effect:

```
bit_variable = int_variable;
bit_variable = int_variable ? 1 : 0;
```

- Pointer to `__bit` is allowed, but you cannot take the address of a bit on the stack.
- The `__bit` type is allowed as a structure member. However, a bit structure can only contain members of type `__bit`, and you cannot push a bit structure on the stack or return a bit structure via a function.
- A union of a `__bit` structure and another type is not allowed.
- A `__bit` type variable is allowed as a parameter of a function.
- A `__bit` type variable is allowed as a return type of a function.
- A `__bit` typed expression is allowed as switch expression.
- The `sizeof` of a `__bit` type is 1.
- A global or static `__bit` type variable can be initialized.
- A `__bit` type variable can be declared volatile.

## 1.3 Memory Qualifiers

You can use static memory qualifiers to allocate static objects in a particular part of the addressing space of the processor or to use a specific addressing mode.

In addition, you can place variables at absolute addresses with the keyword `__at()`.

### 1.3.1 Memory Type Qualifiers

In the C language you can specify that a variable must lie in a specific part of memory. You can do this with a *memory type qualifier*.

You can specify the following memory types:

| Qualifier | Description |
|---|---|
| `__data` | Direct addressable on-chip RAM |
| `__sfr` | Defines a special function register. Special optimizations are performed on this type of variables. |
| `__bsfr` | Bit-addressable special function register |
| `__idata` | Indirect addressable on-chip RAM |
| `__bdata` | Bit-addressable on-chip RAM |
| `__xdata` | External RAM |
| `__pdata` | One 256 bytes page within external RAM |
| `__rom` | Data defined with this qualifier is placed in ROM. This section is excluded from automatic initialization by the startup code. `__rom` always implies the type qualifier `const`. |

*Table 1-2: Memory Type Qualifiers for the TSK51x/TSK52x*

If you do not specify a memory type qualifier for the TSK51x/TSK52x, the memory type for the variable depends on the default of the selected TSK51x/TSK52x memory model (see section 1.4, *Memory Models for the TSK51x/TSK52x*).

See also the assembler directive **.SECTION** (Start or continue section), in section 3.8.2, *Assembler Directives*, in Chapter *Assembly Language*.

Examples using explicit memory types:

```
__data   char  c;
__rom    char  text[] = "No smoking";
__xdata  int   array[10][4];
__idata  long  l;
```

The memory type qualifiers are treated like any other data type specifier (such as `unsigned`). This means the examples above can also be declared as:

```
char __data   c;
char __rom    text[] = ”No smoking”;
int  __xdata  array[10][4];
long __idata  l;
```

#### Pointers with memory type qualifiers

Pointers for the TSK51x/TSK52x can have two types: a 'logical' type and a memory type. For example, a function is residing in ROM (memory type), but the logical type is the return type of this function.

Example using memory types with pointers:

```
__rom char *__data p;  /* pointer residing in data, pointing to ROM */
```

means `p` has memory type data (allocated in on-chip RAM), but has logical type 'character in target memory space ROM'. The memory type qualifier used left to the '*', specifies the target memory of the pointer, the memory type qualifier used right to the '*', specifies the storage memory of the pointer.

The memory type qualifiers are treated like any other data type specifier (like unsigned). This means the pointer above can also be declared (exactly the same) using:

```
char __rom *__data p;  /* pointer residing in data, pointing to ROM */
```

The TSK51x/TSK52x C compiler is very efficient in allocating pointers, because it recognizes far (2 byte) and near (1 byte) pointers. Pointers to `__data`, `__idata` and `__pdata` have a size of 1 byte, whereas pointers to `__rom`, `__xdata` and functions (in ROM) have a size of 2 bytes.

#### Structure tags with memory type qualifiers

A tag declaration is intended to specify the layout of a structure or union. If a memory type is specified, it is considered to be part of the declarator. A tag name itself, nor its members can be bound to any storage area, although members having type "... pointer to" do require one. A tag may then be used to declare objects of that type, and may allocate them in different memories (if that declaration is in the same scope). The following example illustrates this constraint.

```
struct S {
  __xdata int i;   /* referring to storage: not correct      */
  __idata char *p; /* used to specify target memory: correct */
};
```

In the example above the TSK51x/TSK52x compiler ignores the erroneous `__xdata` memory type qualifier (without displaying a warning message).

#### Typedef with memory type qualifiers

Typedef declarations follow the same scope rules as any declared object. Typedef names may be (re-)declared in inner blocks but not at the parameter level. However, in `typedef` declarations, memory type qualifiers are allowed. A `typedef` declaration should at least contain one type qualifier.

Example using memory types with typedefs:

```
typedef __idata int IDATINT;   /* memory type __idata: OK */
typedef int __data *DATAPTR;   /* logical type __data,
                                  memory type 'default'   */
```

## 1.3.2 Accessing Hardware from C: __sfr, __bsfr

#### Using Special Function Registers

It is easy to access Special Function Registers (SFRs) that relate to peripherals from C. The SFRs are defined in a special function register file (`*.sfr`) as symbol names for use with the compiler. An SFR file contains the names of the SFRs and the bits in the SFRs.

Example use in C:

```
P0 = 0x88;  // use port name
P1_3 = 1;   // use of bit name
if (P1_4 == 1)
{
  P1_3 = 0;
}
IE1 = 1;    // use of bit name
```

The compiler generates (TSK51A):

```
mov  128,#136
setb 144.3
gjnb 144.4,_2
clr  144.3
_2:
setb 136.3
```

You can find a list of defined SFRs and defined bits by inspecting the SFR file for a specific core. The files are named `regcore.sfr`, for example `regtks51a.sfr` in the `Altium Designer 6\System\ Tasking\c51\include` directory.

### *Defining Special Function Registers*

With the `__sfr` memory type qualifier you can define a symbol as an SFR. The compiler may assume that special SFR operations can be performed on such symbols. The TSK51x/TSK52x compiler can decide to use bit instructions for those special function registers that are bit accessible, in this case use `__bsfr` instead of `__sfr`. For example, if bits are defined in the SFR definition, these bits can be accessed using bit instructions.

For the TSK51x/TSK52x only the SFRs at addresses 0x80, 0x88, 0x90, 0x98, 0xa0, 0xa8, 0xb0, 0xb8, 0xc0, 0xc8, 0xd0, 0xd8, 0xe0, 0xe8, 0xf0 and 0xf8 are bit addressable.

A typical definition of a special function register looks as follows:

```
typedef struct
    _Bool __b0:1;
    _Bool __b1:1;
    _Bool __b2:1;
    _Bool __b3:1;
    _Bool __b4:1;
    _Bool __b5:1;
    _Bool __b6:1;
    _Bool __b7:1;
} __bitstruct_t;

#define P0 (*(__bsfr unsigned char *)0x80)
#define P0_0 ((*(__bsfr __bitstruct_t *)0x80).__b0)
#define P0_1 ((*(__bsfr __bitstruct_t *)0x80).__b1)

#define SP (*(__sfr unsigned char *)0x81)

#define TCON (*(__bsfr unsigned char *)0x88)
#define IT0  ((*(__bsfr __bitstruct_t *)0x88).__b0)
#define IE0  ((*(__bsfr __bitstruct_t *)0x88).__b1)
```

Example of access to the SFR:

```
P0 = 0x56;
P0_0 = IE0;
```

Because the special function registers are dealing with I/O, it is incorrect to optimize away the access to them. Therefore, the compiler deals with the special function registers as if they were declared with the `volatile` qualifier.

Non-initialized global SFR variables are not cleared at startup. For example:

```
__sfr int i;      // global SFR not cleared
```

It is not allowed to initialize global SFR variables. SFR variables are not initialized at startup. For example:

```
__sfr int j=10;  // not allowed to initialize global SFR
```

See also C compiler option **--cpu** (Use SFR definitions for CPU) in section *C Compiler Options* in Chapter *Tool Options*.

### 1.3.3 Placing an Object at an Absolute Address: __at()

Just like you can declare a variable in a specific *part* of memory (using memory type qualifiers), you can also place an object at an *absolute address* in memory. This may be useful to interface with other programs using fixed memory schemes, or to access special function registers.

With the attribute `__at()` you can specify an absolute address.

#### Examples

```
unsigned char Display[80*24] __at( 0x2000 );
```

The array `Display` is placed at address 0x2000. In the generated assembly, an absolute section is created. On this position space is reserved for the variable `Display`.

```
int i __at(0x1000) = 1;
```

The variable `i` is placed at address 0x1000 and is initialized at 1.

```
void f(void) __at( 0xf0ff + 1 ) { }
```

The function `f` is placed at address 0xf100.

#### Restrictions

Take note of the following restrictions if you place a variable at an absolute address:

- The argument of the `__at()` attribute must be a constant address expression.
- You can place only global variables at absolute addresses. Parameters of functions, or automatic variables within functions cannot be placed at absolute addresses.
- A variable that is declared `extern`, is not allocated by the compiler in the current module. Hence it is not possible to use the keyword `__at()` on an external variable. Use `__at()` at the definition of the variable.
- You cannot place structure members at an absolute address.
- Absolute variables cannot overlap each other. If you declare two absolute variables at the same address, the assembler and / or linker issues an error. The compiler does not check this.

## 1.4 Memory Models for the TSK51x/TSK52x

The TASKING C compiler for the TSK51x/TSK52x architecture (**c51**) supports the following memory models:

| Memory Model | Description | Max RAM size | Default memory type |
|---|---|---|---|
| small | direct addressable internal RAM | 128 bytes | __data |
| auxiliary page | one page of external RAM | 256 bytes | __pdata |
| large | external RAM | 64 kB | __xdata |

*Table 1-3: Memory models and default memory types*

The small memory model is the default memory model. Per memory model you can choose to use reentrancy which enables you to call functions recursively.

Each memory model has a default memory type. You can overrule the default memory type with one of the memory type qualifiers (see section 1.3.1, *Memory Type Qualifiers.* This allows you to exceed the default maximum RAM size.

### 1.4.1 Compiling for the Small, Auxiliary, Large or Reentrant Memory Model

By default the TSK51x/TSK52x compiler uses the *small memory* model. In the *small memory model* all data objects with the default memory type and the stack (used for function parameter passing) must fit in the internal RAM. Objects with an explicit memory type qualifier can exceed this limitation (for example an object qualified as `__xdata` or `__pdata`). Note that the stack length depends upon the nesting depth of the various functions. Accessing data in internal RAM is considerably faster than accessing data in external RAM. Therefore, it is useful to place often used variables in internal data memory and less often referenced data elements in external data memory.

When the compiler uses the *large memory* model to access data, the produced code is larger and in some cases slower than the code for a similar operation in one of the other memory models.

The *auxiliary page memory model* is especially interesting for derivatives with 256 bytes of 'external' RAM on chip. All data objects with the default memory type must fit in one 256 bytes page.

Optionally you can choose to enable *reentrancy*. If you select reentrancy, a (less efficient) virtual dynamic stack is used which allows you to call functions recursively. With reentrancy, you can call functions at any time, even from interrupt functions.

To select the memory model to compile for:

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog appears.*

2. Make sure you have selected the **TASKING TSK51x/TSK52x** processor class.
3. Expand the **C Compiler** entry and select **Memory Model**.
4. Select the **Aux**, **Large** or **Small** memory model.
5. Optionally enable the **Allow reentrant functions** check box.

#### *Using predefined macro __MODEL__ to write conditional code*

With the predfined macro __MODEL__ you can write conditional C code in one source for different memory models. Depending on the memory model for which you compile, the macro __MODEL__ expands to:

'a' (auxiliary memory model)
'l' (large memory model)
's' (small memory model)

#### *Example*

```
#if __MODEL__ == 's'
/* this part is only for the small memory model */
...

#endif
```

## 1.5 Using Assembly in the C Source: __asm()

With the `__asm` keyword you can use assembly instructions in the C source and pass C variables as operands to the assembly code. Be aware that C modules that contain assembly are not portable and harder to compile in other environments.

Furthermore, assembly blocks are not interpreted by the compiler: they are regarded as a black box. So, it is your responsibility to make sure that the assembly block is syntactically correct.

#### *General syntax of the `__asm` keyword*

```
__asm( "instruction_template"
       [ : output_param_list
       [ : input_param_list
       [ : register_save_list]]] );
```

| | |
|---|---|
| *instruction_template* | Assembly instructions that may contain parameters from the input list or output list in the form: **%***parm_nr* |
| **%***parm_nr*[**.***regnum*] | Parameter number in the range 0 .. 9. With the optional **.***regnum* you can access an individual register from a register pair. For example, with the word register `R12`, `.0` selects register `R1`. |
| *output_param_list* | [[ **"=**[**&**]*constraint_char***"(**C_expression**)**],...] |
| *input_param_list* | [[ **"***constraint_char***"(**C_expression**)**],...] |
| **&** | Says that an output operand is written to before the inputs are read, so this output must not be the same register as any input. |
| *constraint _char* | Constraint character: the type of register to be used for the *C_expression*. |
| *C_expression* | Any C expression. For output parameters it must be an *lvalue*, that is, something that is legal to have on the left side of an assignment. |
| *register_save_list* | [[**"***register_name***"**],...] |
| *register_name:q* | Name of the register you want to reserve. |

### *Typical example: adding two C variables using assembly*

```
__data char a, b;
__data int result;

void add2( void )
{
    __asm( "MOV A, %1\n\t"
           "ADD A, %2\n\t"
           "MOV %0, A": "=m"(result): "r"(a), "r"(b) );
}
```

`%0` corresponds with the first C variable, `%1` with the second and so on.

Generated assembly code:

```
mov   R0,_b
mov   R1,_a
MOV A, R0
ADD A, R1
MOV _result, A
```

### *Specifying registers for C variables*

With a *constraint character* you specify the register type for a parameter. In the example above, the `r` is used to force the use of registers (Rn) for the parameters `a` and `b`.

You can reserve the registers that are already used in the assembly instructions, either in the parameter lists or in the reserved register list (*register_save_list*, also called "clobber list"). The compiler takes account of these lists, so no unnecessary register saving and restoring instructions are placed around the inline assembly instructions.

| Constraint character | Type | Operand | Remark |
|---|---|---|---|
| a | accumulator | A | |
| b | bit | ACC.[0..7], B.[0..7], C, AC, F0, RS1, RS0, OV, F1, P, _bitvar | bit registers/variables |
| d | direct register | PSW, SP, B, ACC, DPH, DPL, AR[0..7] | direct address of registers |
| i | immediate value | *#data*, *#data16* | |
| m | memory | *direct*, *label*, *addr11*, *addr16*, *rel* | memory variable or function address |
| p | data page pointer | DPTR | |
| r | register | R[0..7] | |
| R | registers | R01, R12, R23, R34, R45, R56, R67 | word registers |
| s | register indirect | @R0, @R1 | register indirect addressing |
| *number* | other operand | same as %*number* | Input constraint only. The *number* must refer to an output parameter. Indicates that %*number* and *number* are the same register. |

*Table 1-4: Available input/output operand constraints TSK51x/TSK52x*

### Loops and conditional jumps

The compiler does not detect loops that are coded with multiple `__asm` statements or (conditional) jumps across `__asm` statements and will generate incorrect code for the registers involved.

If you want to create a loop with `__asm`, the whole loop must be contained in a single `__asm` statement. The same counts for (conditional) jumps. As a rule of thumb, all references to a label in an `__asm` statement must be contained in the same statement.

### Example 1: no input or output

A simple example without input or output parameters. You can use any instruction or label. Note that you can use standard C escape sequences.

```
__asm( "nop\n\t"
       "nop" );
```

Generated code:

```
    nop
    nop
```

### Example 2: using output parameters

Assign the result of inline assembly to a variable. A register is chosen for the parameter because of the constraint `r`; the compiler decides which register is best to use. The `%0` in the instruction template is replaced with the name of this register. Finally, the compiler generates code to assign the result to the output variable.

```
__data char out;

void main(void)
{
    __asm( "mov %0,#0xff" : "=r"(out));
}
```

Generated assembly code:

```
mov R0,#0xff
mov    _out,R0
```

### Example 3: using input and output parameters

Add two C variables and assign the result to a third C variable. Registers are used for the input parameters (constraint `r`, `%1` for `a` and `%2` for `b` in the instruction template) and memory is used for the output parameter (constraint `m`, `%0` for `result` in the instruction template). The compiler generates code to move the input expressions into the input registers and to assign the result to the output variable.

```
__data char a, b;
__data int result;

void add( void )
{
    __asm( "MR A, %1\n\t"
           "ADD A, %2\n\t"
           "MR %0, a": "=m"(result): "r"(a), "r"(b) );
}

void main(void)
{
    a = 3;
    b = 4;
    add2( );
}
```

Generated assembly code:

```
_add2:
    mov   R0,_b
    mov   R1,_a
    MOV A, R0
    ADD A, R1
    MOV _result, A
_main:
    mov   _a,#3
    movx  _b,#4
    gjmp  _add2
```

### Example 4: reserve registers

Sometimes an instruction knocks out certain specific registers. The most common example of this is a function call, where the called function is allowed to do whatever it likes with some registers. If this is the case, you can list specific registers that get clobbered by an operation after the inputs.

Same as *Example 3*, but now register `R0` is a reserved register. You can do this by adding a reserved register list (`: "R0"`). As you can see in the generated assembly code, register `R0` is not used (the first register used is `R1`).

```
__data char a, b;
__data int result;

void add2( void )

{
    __asm( "MOV A, %1\n\t"
           "ADD A, %2\n\t"
           "MOV %0, A": "=m"(result): "r"(a), "r"(b) : "R0" );
}
```

Generated assembly code:

```
_add2:
    mov   R1,_b
    mov   R2,_a
    MOV A, R1
    ADD A, R2
    MOV _result, A
```

### *Example 5: input and output are the same*

If the input and output must be the same you can use a number constraint. The following example adds two values. Input variable `a` has to go in the same place as the output variable `a`, so `%2` and `%0` are the same thing. That is why the constraint of the argument 2 is "0", which means it has to be the same as argument 0. Note also that the `.0` and `.1` select a kid register from a register pair. Register `A` is reserved.

```
int _ADDI( int a, int b )
{
  __asm("MOV  A, %1.1\n\t"
        "ADD  A, %0.1\n\t"
        "MOV  %0.1, A\n\t"
        "MOV  A, %1.0\n\t"
        "ADDC A, %0.0\n\t"
        "MOV  %0.0, A" : "=R"(a) : "R"(b), "0"(a)  : "A" );
  return a;
}

void main(void)
{
    int ovar;
    ovar = _ADDI(2,3);
}
```

Generated assembly:

```
__ADDI:
        MOV  A, R5
        ADD  A, R7
        MOV  R7, A
        MOV  A, R4
        ADDC A, R6
        MOV  R6, A
        ret
_main:
        mov   R6,#0
        mov   R7,#2
        mov   R4,#0
        mov   R5,#3
        gcall __ADDI
        ret
```

## 1.6 Pragmas to Control the Compiler

*Pragmas* are keywords in the C source that control the behavior of the compiler. Pragmas overrule compiler options.

For example, you can set a compiler option to specify which optimizations the compiler should perform. With the `#pragma optimize` *`flags`* you can set an optimization level for a specific part of the C source. This overrules the general optimization level that is set in the C compiler Optimization page in the Project Options dialog (command line option **--optimize** (**-O**)).

The general syntax for pragmas is:

**#pragma** *pragma-spec* [**ON** | **OFF** | **DEFAULT** | **RESTORE**] or:

**_Pragma(** *"pragma-spec* [**ON** | **OFF** | **DEFAULT** | **RESTORE**]" **)**

Pragmas marked with (*) accept the following special arguments:

`default`  set the pragma to the initial value

`restore`  restore the previous value of the pragma

Pragmas marked with (+) are boolean flags, and accept the following arguments:

`on`  switch the flag on (same as without argument)

`off`  switch the flag off

The compiler recognizes the following pragmas, other pragmas are ignored.

***alias*** *symbol=defined_symbol*

Define *symbol* as an alias for *definined_symbol*. It corresponds to an equate directive (**.equ**) at assembly level. The *symbol* should not be defined elsewhere, and *defined_symbol* should be defined with static storage duration (not extern or automatic).

See assembler directive **.EQU** in section 3.8.2, *Assembler Directives*, in Chapter *Assembly Language*.

***clear***
***noclear***

By default, uninitialized global or static variables are cleared to zero on startup. With pragma noclear, this step is skipped. Pragma clear resumes normal behavior.

See C compiler option **--noclear** in section 4.1, *C Compiler Options,* in Chapter *Tool Options*.

***compactmaxmatch*** *value*

Control the maximum size of a match.

See C compiler option **--compact-max-size** in section 4.1, *C Compiler Options,* in Chapter *Tool Options*.

***extend*** *size*

Specify the maximum amount of internal RAM to be used for 'automatic variables' to be made 'register variables'.

See section 1.8.1, *Automatic Variables* in Chapter *C Language*.
See C compiler option **--extend** (**-x**) in section 4.1, *C Compiler Options,* in Chapter *Tool Options*.

***extension isuffix*** (*) (+)

Enables a language extension to specify imaginary floating-point constants. With this extension, you can use an "i" suffix on a floating-point constant, to make the type `_Imaginary`.

***extern*** *symbol*

Force an external reference (**.extern** assembler directive), even when the symbol is not used in the module.

See assember directive **.EXTERN** in section 3.8.2, *Assembler Directives*, in Chapter *Assembly Language*.

***inline***
***noinline***
***smartinline***

Instead of the qualifier `inline`, you can also use `pragma inline` and `pragma noinline` to inline a function body:

```
int  w,x,y,z;
```

```
#pragma inline
int add( int a, int b )
{
      int i=4;
      return( a + b );
}
#pragma noinline

void main( void )
{
      w = add( 1, 2 );
      z = add( x, y );
}
```

If a function has an `inline` or `__noinline` function qualifier, then this qualifier will overrule the current pragma setting.

See section 1.11.4, *Inlining Functions: inline / __noinline*.

By default, small fuctions that are not too often called (from different locations), are inlined. This reduces execution speed at the cost of code size (C compiler option **-Oi**). With the `pragma noinline / pragma smartinline` you can temporarily disable this optimization.

With the C compiler options **--inline-max-incr** and **--inline-max-size** you have more control over the automatic function inlining process of the compiler.

See for more information the C compiler options **--inline-max-incr** and **--inline-max-size** in section 4.1, *C Compiler Options* in Chapter *Tool Options*.

***macro***
***nomacro*** (*) (+)

Turns macro expansion on or off. By default, macro expansion is enabled.

***maxcalldepth*** *value*

Control the maximum call depth. By default, the maximum is infinite (-1).

See C compiler option **`--max-call-depth`** in section 4.1, *C Compiler Options,* in Chapter *Tool Options*.

***message*** *"message"* ***...***

Print the message string(s) on standard output.

***optimize*** *flags* (*)
***endoptimize***

You can overrule the compiler option **-O** for the code between the pragmas `optimize` and `endoptimize`. The pragma works the same as compiler option **-O**.

See section 2.6, *Compiler Optimizations* in Chapter *Using the Compiler* in the user's manual.
See C compiler option **--optimize** (**-O**) in section 4.1, *C Compiler Options,* in Chapter *Tool Options*.

***page***
***nopage***

Align or do not align code sections on a 256 page boundary.

***ramstring***

Allocate strings in ROM and RAM. The strings are copied to RAM at startup.

***romstring***

Same as compiler option **--source** (**-S**). Allocate strings in ROM only.

See C compiler option **--source** (-S) in section 4.1, *C Compiler Options,* in Chapter *Tool Options*.

***section*** *[type]={name* |**-*f***|**-*m***|**-*fm***} (*)
***endsection***

Rename sections of the specified *type* or restore default section naming.

See section 1.12, *Section Naming*.
See C compiler option **--rename-sections** in section 4.1, *C Compiler Options* in Chapter *Tool Options*.
See assembler directive **.SECTION** (Start or continue section), in section 3.8.2, *Assembler Directives*, in Chapter *Assembly Language*.

***source*** (*) (+)
***nosource***

With these pragmas you can choose which C source lines must be listed as comments in assembly output.

See also C compiler option **--source (-s)**

***linear_switch***
***jump_switch***
***binary_switch***
***smart_switch***

With these pragmas you can overrule the compiler chosen switch method:

| | |
|---|---|
| `linear_switch` | Force jump chain code. A jump chain is comparable with an if/else-if/else-if/else construction. |
| `jump_switch` | Force jump table code. A jump table is a table filled with jump instructions for each possible switch value. The switch argument is used as an index to jump within this table. |
| `binary_switch` | Force binary lookup table code. A binary search table is a table filled with a value to compare the switch argument with and a target address to jump to. |
| `smart_switch` | Let the compiler decide the switch method used |

See Section 1.10, *Switch Statement*.

***tradeoff*** *level* (*)

Specify tradeoff between speed (0) and size (4).

See also C compiler option **--tradeoff (-t)**

***vector_offset*** *offset* (*)

Specify base address for interrupt vectors.

See C compiler option **--vector-offset** in section 4.1, *C Compiler Options* in Chapter *Tool Options*.

***novector***

Do not generate interrupt vectors and reference to interrupt handler in run-time library.

See C compiler option **--novector** in section 4.1, *C Compiler Options* in Chapter *Tool Options*.

***warning*** *[number,...]* (*)

With this pragma you can disable warning messages. If you do not specify a warning number, all warnings will be suppressed.

See also C compiler option **--no-warnings (-w)**

***weak*** *symbol*

Mark a symbol as "weak" (**.weak** assembler directive). The symbol must have external linkage, which means a global or external object or function. A static symbol cannot be declared weak.

A weak external reference is resolved by the linker when a global (or weak) definition is found in one of the object files. However, a weak reference will not cause the extraction of a module from a library to resolve the reference. When a weak external reference cannot be resolved, the null pointer is substituted.

A weak definition can be overruled by a normal global definition. The linker will not complain about the duplicate definition, and ignore the weak definition.

See assembler directive **.WEAK** in Section 3.8.2, *Assembler Directives*, in Chapter *Assembly Language*.

## 1.7 Predefined Preprocessor Macros

In addition to the predefined macros required by the ISO C standard, such as `__DATE__` and `__FILE__`, the TASKING C compiler supports the predefined macros as defined in the table below. The macros are useful to create conditional C code.

| Macro | Description |
|---|---|
| `__BIG_ENDIAN__` | Expands to 1, indicating the processor accesses data in big-endian. |
| `__BUILD__` | Identifies the build number of the compiler, composed of decimal digits for the build number, three digits for the major branch number and three digits for the minor branch number. For example, if you use build 1.22.1 of the compiler, __BUILD__ expands to 1022001. If there is no branch number, the branch digits expand to zero. For example, build 127 results in 127000000. |
| `__C51__` | Expands to 1 for the TSK51x/TSK52x toolset, otherwise unrecognized as macro. |
| `__CPU__` | Expands to the CPU core name (option **--cpu**=*cpu* ). |
| `__MODEL__` | Identifies the memory model for which the current module is compiled. For example, if you compile for the small memory model, the macro expands to s. |
| `__REVISION__` | Identifies the revision number of the compiler. For example, if you use version 1.0r2 of the compiler, __REVISION__ expands to 2. |
| `__SINGLE_FP__` | Expands to 1 for single precision floating-point. |
| `__TASKING__` | Identifies the compiler as a TASKING compiler. Expands to 1 if a TASKING compiler is used. |
| `__VERSION__` | Identifies the version number of the compiler. For example, if you use version 1.0r2 of the compiler, __VERSION__ expands to 1000 (dot and revision number are omitted, minor version number in 3 digits). |

*Table 1-5: Predefined preprocessor macros*

### *Example*

```
#ifdef __C51__
/* this part is only compiled for the TSK51x/TSK52x target */
...

#endif
```

# 1.8 Variables

## 1.8.1 Automatic Variables

In non-reentrant functions recursion is not possible. In non-reentrant functions automatic variables are not allocated on a stack, but in a static area. In a reentrant function automatic variables are treated the conventional way: passed via the stack. The automatics in the static area are still overlayable with automatics of other functions. Automatics are subject to the memory model selected. In a static function this means static allocation in one of the RAM memory spaces. In a reentrant function this means dynamic allocation on the stack.

Although automatic variables are allocated in a static area with non-reentrant functions, they are not the same as local variables (within a function) which are declared to be static by means of the C keyword `static`. The difference is that it is not guaranteed that an automatic variable still has the same value as the previous time the function returned, because it may have been overlaid with another automatic variable of another module. Whereas the values of variables declared with the keyword `static` are the same as the previous time the function returned. `static` variables are new overlaid.

To generate code which is as fast as possible, the TSK51x/TSK52x compiler tries to place some automatic variables which are used the most into registers and internal RAM (extended virtual registers). You can change the maximum amount of internal RAM that may be used for such local variables with the compiler option **-x***size* or with the pragma **extend** *size*. The default size is 4 bytes. Note that these bytes can be allocated for each function. These bytes are overlaid by the linker.

The static versions of the TSK51x/TSK52x C library have been built with **-x0**.

C compiler option **-x** in section 4.1, *C Compiler Options* in Chapter *Tool Options*.

## 1.8.2 Initialized Variables

Non automatic initialized variables use the same amount of space in both ROM and RAM (for all possible RAM memory spaces). This is because the initializers are stored in ROM and copied to RAM at start-up. This is completely transparent to the user. The only exception is an initialized variable residing in ROM, by means of the `__rom` memory type qualifier.

The following examples are for the TSK51x/TSK52x compiler in the large memory model.

```
int         i = 100;       /* 2 bytes in ROM and
                              2 bytes in XDATA   */
__rom int   j = 3;         /* 2 bytes in ROM     */
char       *p = "TEXT";    /* 7 bytes in ROM and
                              7 bytes in XDATA:
                              2 bytes for p,
                              5 bytes for "TEXT" */
__rom  char[] = "HELP";    /* 5 bytes in ROM     */
__data char c = 'a';       /* 1 byte in ROM and
                              1 byte in DATA     */
```

Section 1.3.1, *Memory Type Qualifiers*.

# 1.9 Strings

In this context the word 'strings' means the separate occurrence of a string in a C program. So, array variables initialized with strings are just initialized character arrays, which can be allocated in any memory type, and are not considered as 'strings'.

The TSK51x/TSK52x compiler places strings in both ROM and RAM. Where strings in RAM are placed depends on the specified memory model. If you use the TSK51x/TSK52x compiler option **-S** (**--romstrings**) or `#pragma romstring`, the compiler places all strings in ROM only. This is useful for single chip applications when you want to allocate strings in ROM only.

Example without **-S** option:

```
__rom char hello[] = "Hello\n"; /* initialized array in ROM only */
char *world = "world\n";        /* initialized pointer
                                   to string in XDATA */
```

Example with compiler option **–S**:

```
__rom char hello[] = "Hello\n"; /* initialized array in ROM only */
__rom char *world = "world\n";  /* initialized pointer
                                   to string in ROM */
```

Example with `#pragma romstring`:

```
#pragma romstring
__rom char hello[] = "Hello\n"; /* initialized array in ROM only */
__rom char *world = "world\n";  /* initialized pointer
                                   to string in ROM */
#pragma ramstring
```

### *Strings in library routines*

Library routines containing pointer arguments always expect the target memory of these pointers to be the default RAM of the memory model used to make this library. For example:

```
int printf( const char *format, ... );
```

In large memory model, this means `printf()` expects the address of the format string (the first argument) to have memory type `__xdata`. Therefore, the C startup code of the large memory model copies all strings from ROM to XDATA. So, the statement:

```
printf( "Hello world\n" );
```

is executed correctly, because the TSK51x/TSK52x compiler passes the address of the allocated XDATA area (filled at C startup time) to `printf()`.

With the **–S** option specified, the string is put in ROM only and the standard printf/scanf like library routines will fail. You will need to create your own __rom qualified versions. All library sources are delivered. For example, you can use the source of `printf()` (in module `_printf.c`) to create a `__rom_printf()`. The prototype could be:

```
int __rom_printf( __rom char *format, ... );
```

### *Modifying string literals*

The TSK51x/TSK52x accepts that string literals are modifiable when strings are in both ROM and RAM. You can do this with pointers, or even with a construct like:

```
"st ing"[2] = 'r';
```

Of course, when you use the **–S** option this statement is not allowed.

## 1.10 Switch Statement

The TASKING C compiler supports three ways of code generation for a switch statement: a jump chain (linear switch), a jump table or a binary search table.

A *jump chain* is comparable with an if/else-if/else-if/else construction. A *jump table* is a table filled with jump instructions for each possible switch value. The switch argument is used as an index to jump within this table. A *binary search table* is a table filled with a value to compare the switch argument with and a target address to jump to.

`#pragma smart_switch` is the default of the compiler. The compiler tries to use the switch method which uses the least space in ROM (table size in ROMDATA plus code to do the indexing).

For a switch with a long type argument, only binary search table code is used.

For an int type argument, a jump table switch is only possible when all case values are in the same 256 value range (the high byte value of all programmed cases are the same).

Especially for large switch statements, the jump table approach executes faster than the binary search table approach. Also the jump table has a predictable behavior in execution speed: independent of the switch argument, every case is reached in the same execution time.

With a small number of cases, the jump chain method can be faster in execution and shorter in size.

You can overrule the compiler chosen switch method by using a pragma:

| | |
|---|---|
| `#pragma linear_switch` | force jump chain code |
| `#pragma jump_switch` | force jump table code |
| `#pragma binary_switch` | force binary search table code |
| `#pragma smart_switch` | let the compiler decide the switch method used |

Using a pragma cannot overrule the restrictions as described earlier.

The switch pragmas must be placed before the function body containing the `switch` statement. Nested `switch` statements use the same switch method, unless the nested `switch` is implemented in a separate function which is preceded by a different switch pragma.

### *Example*

```
/* place pragma before function body */

#pragma jump_switch

void test(unsigned char val)
{ /* function containing the switch */
    switch (val)
    {
        /* use jump table */
    }
}
```

# 1.11 Functions

## 1.11.1 Reentrant Functions

For the TSK51x/TSK52x functions in C can either be *static* or *reentrant*. In static functions parameters and automatic variables are not allocated on a stack, but in a static area. Reentrant functions use a less efficient virtual dynamic stack which allows you to call functions recursively. With reentrancy, you can call functions at any time, even from interrupt functions. The compiler can overlay parameters and automatics of static functions, but not of reentrant functions.

You can use the function qualifiers `__static` or `__reentrant` to specify a function as static or reentrant, respectively. If you do not specify a function qualifier, the TSK51x/TSK52x compiler assumes that those functions are static. If you specify the compiler option **--reentrant** the default for functions without a function qualifier is reentrant.

Although automatic variables are allocated in a static area with non-reentrant functions, they are not the same as local variables (within a function) which are declared to be static by means of the C keyword `static`. The difference is that it is not guaranteed that an automatic variable still has the same value as the previous time the function returned, because it may have been overlaid with another automatic variable of another module. Whereas the values of variables declared with the keyword `static` are the same as the previous time the function returned. `static` variables are never overlaid.

### *Example*

```
void f_static( void )
{
    /* this function is by default __static */
}

__reentrant int f_reentrant ( void )
{
    int i;
    /* variable i is placed on a virtual stack */
}
```

C compiler option **--reentrant** in section 4.1, *C Compiler Options* in Chapter *Tool Options* of the reference manual.

## 1.11.2 Parameter Passing

A lot of execution time of an application is spent transferring parameters between functions. The fastest parameter transport is via registers. Therefore, function parameters are first passed via registers. If no more registers are available for a parameter, the compiler pushes parameters on the stack (for the TSK51x/TSK52x compiler a static or reentrant stack depending on the `__reentrant` function qualifier). See the table below.

| **Parameter Type** | **Parameter Number** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| __bit / _Bool | B.0 | B.1 | B.2 | B.3 | B.4 | B.5 | B.6 | B.7 |
| char | R7 | R5 | R3 | R6 | R4 | R2 | | |
| 8-bit struct | R7 | R5 | R3 | R6 | R4 | R2 | | |
| 8-bit pointer (to data, bdata, idata, pdata, sfr, bsfr, bit) | R7 | R5 | R3 | R6 | R4 | R2 | | |
| short / int | R67 | R45 | R23 | | | | | |
| 16-bit struct | R67 | R45 | R23 | | | | | |
| 16-bit pointer (to xdata, rom, code) | R67 | R45 | R23 | | | | | |
| long | R4567 | | | | | | | |
| float | R4567 | | | | | | | |
| 32-bit struct | R4567 | | | | | | | |

*Table 1-6: Register usage for parameter passing*

If a register corresponding to a parameter number is already in use the next register is used.

***Example with three arguments***

```
func1( int a, int b, int *c )
```

- a (first parameter) is passed in registers R67.
- b (second parameter) is passed in registers R45.
- c (third parameter) is passed in registers R23.

***Example with two long/float arguments***

```
func2( long d, long e )
```

- d (first parameter) is passed in registers R4567.
- e (second parameter) cannot be passed through registers anymore, and is passed via the stack.

***Example with one long/float and one other argument***

```
func3( float f, char g )
```

- f (first parameter) is passed in registers R4567.
- g (second parameter) is passed in register R3.

## 1.11.3 Function Return Types

The C compiler uses registers to store C function return values, depending on the function return types.

| Return type | Register | Description |
|---|---|---|
| __bit / _Bool | C | carry |
| char | A | accumulator |
| short / int | R67 | R6 high byte, R7 low byte |
| long | R4567 | R45 high word, R67 low word |
| float | – | floating–point stack |
| 8–bit pointer | A | accumulator |
| 16–bit pointer | R67 | R6 high byte, R7 low byte |
| structure return buffer pointer16–bit | R67 | R6 high byte, R7 low byte |

*Table 1–7: Register usage for function return types*

## 1.11.4 Inlining Functions: inline / __noinline

With the C compiler option **--optimize=+inline**, the C compiler automatically inlines small functions in order to reduce execution time (smart inlining). The compiler inserts the function body at the place the function is called. The C compiler decides which functions will be inlined. You can overrule this behavior with the two keywords `inline` (ISO–C) and `__noinline`.

With the `inline` keyword you force the compiler to inline the specified function, regardless of the optimization strategy of the compiler itself:

```
inline unsigned int abs(int val)
{
    unsigned int abs_val = val;
    if (val < 0) abs_val = -val;
    return abs_val;
}
```

If a function with the keyword `inline` is not called at all, the compiler does not generate code for it.

You must define inline functions in the same source module as in which you call the function, because the compiler only inlines a function in the module that contains the function definition. When you need to call the inline function from several source modules, you must include the definition of the inline function in each module (for example using a header file).

With the `__noinline` keyword, you prevent a function from being inlined:

```
__noinline unsigned int abs(int val)
{
    unsigned int abs_val = val;
    if (val < 0) abs_val = -val;
    return abs_val;
}
```

#### *Using pragmas: inline, noinline, smartinline*

Instead of the `inline` qualifier, you can also use `#pragma inline` and `#pragma noinline` to inline a function body:

```
#pragma inline
unsigned int abs(int val)
{
    unsigned int abs_val = val;
    if (val < 0) abs_val = -val;
    return abs_val;
}
#pragma noinline
void main( void )
{
    int i;
    i = abs(-1);
}
```

If a function has an `inline/__noinline` function qualifier, then this qualifier will overrule the current pragma setting.

With the `#pragma noinline` / `#pragma smartinline` you can temporarily disable the default behavior that the C compiler automatically inlines small functions when you turn on the C compiler option **--optimize=+inline**.

## 1.11.5 Intrinsic Functions

Some specific assembly instructions have no equivalence in C. *Intrinsic functions* give the possibility to use these instructions. Intrinsic functions are predefined functions that are recognized by the compiler. The compiler generates the most efficient assembly code for these functions.

The compiler always inlines the corresponding assembly instructions in the assembly source (rather than calling it as a function). This avoids parameter passing and register saving instructions which are normally necessary during function calls.

Intrinsic functions produce very efficient assembly code. Though it is possible to inline assembly code by hand, intrinsic functions use registers even more efficiently. At the same time your C source remains very readable.

You can use intrinsic functions in C as if they were ordinary C (library) functions. All intrinsics begin with a double underscore character.

The TASKING TSK51x/TSK52x C compiler recognizes the following intrinsic functions:

#### *__alloc*

```
void * volatile __alloc( __size_t size );
```

Allocate memory. Same as library function malloc().

**Returns**: a pointer to space in external memory of `size` bytes length. NULL if there is not enough space left.

#### *__dotdotdot__*

```
char * __dotdotdot__( void );
```

Variable argument '**...**' operator. Used in library function `va_start()`.

**Returns**: the stack offset to the variable argument list.

### __free

```
void volatile __free( void *p );
```

Deallocates the memory pointed to by `p`. `p` must point to memory earlier allocated by a call to `__alloc()`. Same as library function free().

**Returns**: nothing.

### __getbit

```
__bit __getbit( bitaddressable, bitoffset );
```

Get the value of a bit. *bitoffset* must be an integral constant expression.

**Returns**: the bit at *bitoffset* (range 0-7 for a `char`, 0-15 for an `int` or 0-31 for a `long`) of the *bitaddressable* operand for use in bit expressions.

Example:

```
__bdata unsigned char byte;
int i;

if ( __getbit( byte, 3 ) )
    i = 1;
```

### __putbit

```
void __putbit( __bit value, bitaddressable, bitoffset );
```

Assign a *value* to the bit at *bitoffset* (range 0-7 for a `char`, 0-15 for an `int` or 0-31 for a `long`) of the *bitaddressable* operand. *bitoffset* must be an integral constant expression.

**Returns**: nothing.

Example:

```
__bdata unsigned int word;

__putbit( 1, word, 11 );
__putbit( 0, word, 10 );
```

For compatibiltity reasons, `__getbit()` and `__putbit()` are implemented as macros.

### __nop

```
void __nop( void );
```

Generate NOP instructions.

**Returns**: nothing.

Example:

```
__nop();  /* generate NOP instruction */
```

### __rol

```
unsigned char __rol( unsigned char operand, unsigned char count );
```

Use the RL instruction to rotate *operand* left *count* times.

**Returns**: the rotated value.

Example:

```
unsigned char c;
int i;

/* rotate left, using int variable */
c = __rol( c, i );
```

### __ror

```
unsigned char __ror( unsigned char operand, unsigned char count );
```

Use the RR instruction to rotate *operand* right *count* times.

**Returns**: the rotated value.

Example:

```
unsigned char c;
int i;

/* rotate right, using constant */
c = __ror( c, 2 );
c = __ror( c, 3 );
c = __ror( c, 7 );
```

### __testclear

```
__bit volatile __testclear( __bit *semaphore );
```

Read and clear *semaphore* using the JBC instruction.

**Returns**: 0 if *semaphore* was not cleared by the JBC instruction, 1 otherwise.

Example:

```
__bit b;
unsigned char c;

if ( __testclear( &b ) ) /* JBC instruction */
    c=1;
```

### __vsp__

```
__bit __vsp__( void );
```

Virtual stack pointer used. Used in library function `va_arg()`.

**Returns**: 1 if the virtual stack pointer is used, 0 otherwise.

### __get_return_address

```
__codeptr __get_return_address( void );
```

**Returns**: return address of a function.

## 1.11.6 Interrupt Functions

The TASKING C compiler supports a number of function qualifiers and keywords to program interrupt service routines (ISR). An *interrupt service routine* (or: interrupt function, interrupt handler, ) is called when an interrupt event (or: *service request*) occurs.

The different type of interrupts are explained in detail in the *Core Processor* reference manuals delivered with the product. You can find them in the Help system under **FPGA Design** » **Core References** » **Processors**.

### 1.11.6.1 Defining an Interrupt Service Routine: __interrupt()

With the function type qualifier `__interrupt()` you can declare a function as an interrupt service routine. The function type qualifier `__interrupt()` takes one or more vector addresses as argument(s). All supplied vector addresses will be initialized to point to the interrupt function.

Interrupt functions cannot return anything and must have a **void** argument type list:

```
void __interrupt(vector_address[, vector_address]...)
isr( void )
{
...
}
```

If you want to use interrupt numbers instead of vector addresses for the TSK51A core, you can use the `__INTNO` macro which is defined in the delivered special function register file (`regtsk51a.sfr`) as:

```
#define __INTNO(nr) ((8*nr)+3)
```

#### *Example*

```
#include <regtsk51a.sfr>

void __interrupt( 0x23 ) serial_receive( void )
{
  ...
}

void __interrupt( __INTNO(4) ) serial_transmit( void )
{
  ...
}
```

#### *Suppress generation of interrupt vectors*

When you define an interupt service routine, the compiler generates the appropriate interrupt vector, consisting of an instruction jumping to the interrupt function. You can suppress this with the compiler option **--novector** or the **#pragma novector**. The difference between a normal function and an interrupt function is that an interrupt function ends with a RETI instruction instead of a RET instruction, and that all registers that might possibly be corrupted during the execution of the interrupt function are saved on function entry (this is called the *interrupt frame*) and restored on function exit.

C compiler option **--novector** (Do not generate interrupt vectors) in section 4.1, *C Compiler Options* in Chapter *Tool Options* of the reference manual.

#### *Specify another vector offset*

For certain ROM monitors it is necessary to specify an offset for all interrupt vectors. For this you can use the command **--vector-offset=***value*. Suppose a ROM monitor has the interrupt table at offset 0x4000. When you compile with `--vector-offset=0x4000` interrupt vector 1 (vector address 11) is being located at address 0x400B instead of 0xB.

C compiler option **--vector-offset** (Specify a 16-bit offset address for interrupt vectors) in section 4.1, *C Compiler Options* in Chapter *Tool Options* of the reference manual.

### 1.11.6.2 Interrupt Frame: __frame()

With the function type qualifier `__frame()` can specify which registers and SFRs must be saved for a particular interrupt function. Only the specified registers will be pushed and popped from the stack. If you do not specify the function qualifier `__frame()`, the C compiler determines which registers must be pushed and popped. The syntax is:

```
void __interrupt(vector_address[, vector_address]...)
     __frame(reg[, reg]...) isr( void )
{
...
}
```

where, *reg* can be any register defined as an SFR. The compiler generates a warning if some registers are missing which are normally required to be pushed and popped in an interrupt function prolog and epilog to avoid run-time problems.

Refer to the special function register files (`.sfr`) in the `...\target\include` directory for an overview of all defined special function registers. See also section 1.3.2, *Accessing Hardware from C: __sfr*).

***Example***

```
__interrupt( 0x10 ) __frame(A,R0,R1) void alarm( void )
{
...
}
```

When you do not want the interrupt frame (saving/restoring registers) to be generated you can use the compiler option **--noframe**. In that case you will have to specify your own interrupt frame. For this you can use the inline capabilities of the compiler.

C compiler option **--noframe** (Do not generate frame for interrupt handler) in section 4.1, *C Compiler Options* in Chapter *Tool Options* of the reference manual.

Normally when an interrupt function is called, all registers in the default register bank that are (or could be) used in the interrupt function are saved on the stack so the registers are available for the interrupt routine. After returning from the interrupt routine, the original values are restored from the stack again.

### 1.11.6.3 Register Bank Switching: __registerbank()

For the TSK51x/TSK52x it is possible to assign a new register bank to an interrupt function, which can be used on the processor to minimize the interrupt latency because registers do not need to be pushed on stack. You can switch register banks with the `__registerbank()` function qualifier.

```
void __interrupt(vector_address[, vector_address]...)
     __registerbank(bank) isr( void )
{
...
}
```

When you specify the `__registerbank()` qualifier the registers R0-R7 are implicitly saved when the register bank is being switched (by using the predefined symbolic register addresses AR0-AR7).

The default register bank used is bank 0. You can change this default with the compiler option **-b** (**--bank-number**).

***Example***

```
#define __INTNO(nr) ((8*nr)+3)

__interrupt(__INTNO(1)) __registerbank(2) void timer(void);
```

The TSK51x/TSK52x compiler places a long-jump instruction on the vector address 11 of interrupt number 1, to the `timer()` routine, which switches the register bank to bank 2 and saves some more registers. When `timer()` is completed, the extra registers are popped, the bank is switched back to the original value and a RETI instruction is executed.

You can call another C function from the interrupt C function. However, this function must be compiled with the same `__registerbank(bank-nr)` qualifier, because the compiler generates code which uses the addresses of the registers R0-R7. Therefore, the `__registerbank()` qualifier is also possible with normal C functions (and their prototype declarations).

#### *Example*

Suppose `timer()`, from the previous example, is calling `get_number()`. The function prototype (and definition) of `get_number()` should contain the correct `__registerbank()`.

```
__registerbank( 2 ) int get_number( void );
```

The compiler checks if a function calls another function using another register bank, which is an error.

C compiler option **-b** (Specify default register bank number) in section 4.1, *C Compiler Options*, in Chapter *Tool Options*.

### 1.11.7 Register Bank Independent Code Generation

You can use compiler option **--noregaddr** or keyword `__noregaddr` to switch to register bank independent code generation. In order to generate very efficient code the compiler uses absolute register addresses in its code generation. For example a register to register 'move'. Since there is no 'MOV register, register' instruction, the compiler will generate a 'MOV register, direct' with the absolute address of the source register as the second operand.

The absolute address of a register depends on the register bank, but sometimes this dependency is undesired. For example when a function is called from both the main thread and an interrupt thread. If both threads use different register banks, they cannot call a function that uses absolute register addresses. To overcome this, you can instruct the compiler to generate a register bank independent function that can be called from both threads.

#### *Example*

```
__noregaddr int func( int x )
{
    /* this function can be called from any function
       independent of its register bank */
    return x+1;
}
__registerbank(1) void f1( void )
{
    func( 1 );
}
__registerbank(0) void main( void )
{
    func( 0 );
}
```

## 1.12 Section Naming

The compiler generates several types of sections depending on the attributes of a section. The compiler uses the following section naming convention:

[*name*][.*attribute*]...

The *name* is by default the section type (for example, code or data). Section attributes, such as "clear" and "init", can also be part of the section name. The section types and attributes are target dependent. See the assembler directive **.SECTION** for a complete list of section types and attributes.

#### *Example*

The following C code:

```
__data int i;
```

results in the following section declaration with name `data`:

```
.section data, data, clear
```

When you compile with **-Rdata=mysection** this results in:

```
.section mysection, data, clear
```

The following table lists the relation between C type qualifiers, assembly section types and the resulting memory spaces.

| Qualifier | Section Type / Space | Address Range |
|---|---|---|
| `__data` | `data` | 0 – 0x7f |
| `__sfr` | `sfr` | 0x80 – 0xff |
| `__idata` | `idata` | 0 – 0xff |
| `__bit` | `bit` | 0 – 0x7f |
| `__xdata` | `xdata` | 0 – 0xffff |
| `__pdata` | `pdata` | 0 – 0xff |
| `__rom` | `code` | 0 – 0xffff |
| `__bdata` | `bdata` | 0x20 – 0x2f |
| `__bsfr` | `bsfr` | 0x80, 0x88, 0x90, 0x98, 0xa0, 0xa8, 0xb0, 0xb8, 0xc0, 0xc8, 0xd0, 0xd8, 0xe0, 0xe8, 0xf0, 0xf8 |

*Table 1-8: C type qualifiers and section type relation for the TSK51x/TSK52x*

See also the assembler directive **.SECTION** (Start or continue section), in section 3.8.2, *Assembler Directives*, in Chapter *Assembly Language* of the reference manual.
See also C compiler option **--rename-sections** in section 4.1, *C Compiler Options* in Chapter *Tool Options*.

## 1.13 Libraries

The TASKING compilers come with standard C libraries (ISO/IEC 9899:1999) and header files with the appropriate prototypes for the library functions. All standard C libraries are available in object format and in C or assembly source code.

A number of standard operations within C are too complex to generate inline code for (too much code). These operations are implemented as *run-time* library functions to save code.

See section 2.2, *Library Functions*, in Chapter *Libraries*, for an extensive description of all standard C library functions.

### 1.13.1 Printf and Scanf Routines

The C library functions `printf()`, `fprintf()`, `vfprintf()`, `vsprintf()`, ... call one single function, `_doprint()`, that deals with the format string and arguments. The same applies to all `scanf` type functions, which call the function `_doscan()`, and also for the `wprintf` and `wscanf` type functions which call `_dowprint()` and `_dowscan()` respectively. The C library contains three versions of these routines: `int`, `long` and `long long` versions. If you use floating-point the formatter function for floating-point `_doflt()` or `_dowflt()` is called. Depending on the formatting arguments you use, the correct routine is used from the library. Of course the larger the version of the routine the larger your produced code will be.

Note that when you call any of the printf/scanf routines indirect, the arguments are not known and always the `long long` version with floating-point support is used from the library.

#### Example

```
#include <stdio.h>

long L;

void main(void)
{
    printf( "This is a long: %ld\n", L );
}
```

The linker extracts the `long` version without floating-point support from the library.

See also the description of `#pragma weak` in section 1.6, *Pragmas to Control the Compiler* in the user's manual.

# 2 Libraries

## Summary

This chapter lists all library functions that you can call in your C source.

## 2.1 Introduction

This chapter contains an overview of all library functions that you can call in your C source. This includes all functions of the standard C library (ISO C99) and some functions of the floating-point library.

A number of standard operations within C are too complex to generate inline code for (too much code). These operations are implemented as *run-time* library functions to save code.

Section 2.2, *Library Functions*, gives an overview of all library functions you can use, grouped per header file. A number of functions declared in `wchar.h` are parallel to functions in other header files. These are discussed together.

Each library is available in six variants: for the large (l), medium (m) and small memory (s) model and all three with all functions default reentrant (r) or static (s). The following libraries are available. Altium Designer automatically selects the appropriate libraries depending on the specified options.

| Libraries | Description |
|---|---|
| c51as.lib<br>c51ls.lib<br>c51ss.lib | Single precision C library, static functions<br>(some functions also need the floating-point library) |
| c51ar.lib<br>c51lr.lib<br>c51sr.lib | Single precision C library, reentrant functions<br>(some functions also need the floating-point library) |
| fp51as.lib<br>fp51ls.lib<br>fp51ss.lib | Floating-point library (non trapping) |
| fp51ar.lib<br>fp51lr.lib<br>fp51sr.lib | Floating-point library with reentrancy (non trapping) |
| fp51ast.lib<br>fp51lst.lib<br>fp51sst.lib | Floating-point library (trapping) |
| fp51art.lib<br>fp51lrt.lib<br>fp51srt.lib | Floating-point library with reentrancy (trapping) |
| rt51.lib | Run-time library |

*Table 2-1: Overview of libraries*

All libraries are compiled for the auxiliary page (a), large (l) and small (s) memory model.

## 2.2 Library Functions

The following sections list all library functions, grouped per header file in which they are declared. Some functions are not completely implemented because their implementation depends on the context where your application will run. These functions are for example all I/O related functions. Where possible, these functions are implemented using file system simulation (FSS). This system can be used by the debugger to simulate an I/O environment which enables you to debug your application.

A number of wide-character functions are available as C source code, but have not been compiled with the C library. To use complete wide-character functionality, you must recompile the libraries with the macro WCHAR_SUPPORT_ENABLED and keep this macro also defined when compiling your own sources. (See C compiler option **--define (-D)** in section 4.1, *C Compiler Options*, in Chapter 4, *Tool options*.)

### 2.2.1 assert.h

| | |
|---|---|
| `assert(`*`expr`*`)` | Prints a diagnostic message if NDEBUG is not defined.<br>(Implemented as macro) |

### 2.2.2 complex.h

The TSK51x/TSK52x does not support complex numbers.

### 2.2.3 ctype.h and wctype.h

The header file `ctype.h` declares the following functions which take a character *c* as an integer type argument. The header file `wctype.h` declares parallel wide-character functions which take a character *c* of the `wchar_t` type as argument.

| ctype.h | wctype.h | Description |
|---|---|---|
| `isalnum` | `iswalnum` | Returns a non-zero value when c is an alphabetic character or a number ([A-Z][a-z][0-9]). |
| `isalpha` | `iswalpha` | Returns a non-zero value when c is an alphabetic character ([A-Z][a-z]). |
| `isblank` | `iswblank` | Returns a non-zero value when c is a blank character (tab, space...) |
| `iscntrl` | `iswcntrl` | Returns a non-zero value when c is a control character. |
| `isdigit` | `iswditit` | Returns a non-zero value when c is a numeric character ([0-9]). |
| `isgraph` | `iswgraph` | Returns a non-zero value when c is printable, but not a space. |
| `islower` | `iswlower` | Returns a non-zero value when c is a lowercase character ([a-z]). |
| `isprint` | `iswprint` | Returns a non-zero value when c is printable, including spaces. |
| `ispunct` | `iswpunct` | Returns a non-zero value when c is a punctuation character<br>(such as '.', ',', '!'). |
| `isspace` | `iswspace` | Returns a non-zero value when c is a space type character (space, tab, vertical tab, formfeed, linefeed, carriage return). |
| `isupper` | `iswupper` | Returns a non-zero value when c is an uppercase character ([A-Z]). |
| `isxdigit` | `iswxdigit` | Returns a non-zero value when c is a hexadecimal digit ([0-9][A-F][a-f]). |
| `tolower` | `towlower` | Returns c converted to a lowercase character if it is an uppercase character, otherwise c is returned. |
| `toupper` | `towupper` | Returns c converted to an uppercase character if it is a lowercase character, otherwise c is returned. |
| `_tolower` | - | Converts c to a lowercase character, does not check if c really is an uppercase character. Implemented as macro. This macro function is not defined in ISO C99. |
| `_toupper` | - | Converts c to an uppercase character, does not check if c really is a lowercase character. Implemented as macro. This macro function is not defined in ISO C99. |
| `isascii` | | Returns a non-zero value when c is in the range of 0 and 127.<br>This function is not defined in ISO C99. |
| `toascii` | | Converts c to an ASCII value (strip highest bit).<br>This function is not defined in ISO C99. |

## 2.2.4 errno.h

| | |
|---|---|
| `int errno` | External variable that holds implementation defined error codes. |

The following error codes are defined as macros in `errno.h`:

| | | |
|---|---|---|
| EPERM | 1 | Not owner |
| ENOENT | 2 | No such file or directory |
| EINTR | 3 | Interrupted system call |
| EIO | 4 | I/O error |
| EBADF | 5 | Bad file number |
| EAGAIN | 6 | No more processes |
| ENOMEM | 7 | Not enough core |
| EACCES | 8 | Permission denied |
| EFAULT | 9 | Bad address |
| EEXIST | 10 | File exists |
| ENOTDIR | 11 | Not a directory |
| EISDIR | 12 | Is a directory |
| EINVAL | 13 | Invalid argument |
| ENFILE | 14 | File table overflow |
| EMFILE | 15 | Too many open files |
| ETXTBSY | 16 | Text file busy |
| ENOSPC | 17 | No space left on device |
| ESPIPE | 18 | Illegal seek |
| EROFS | 19 | Read-only file system |
| EPIPE | 20 | Broken pipe |
| ELOOP | 21 | Too many levels of symbolic links |
| ENAMETOOLONG | 22 | File name too long |

***Floating-point errors***

| | | |
|---|---|---|
| EDOM | 23 | Argument too large |
| ERANGE | 24 | Result too large |

***Errors returned by prinff/scanf***

| | | |
|---|---|---|
| ERR_FORMAT | 25 | Illegal format string for printf/scanf |
| ERR_NOFLOAT | 26 | Floating-point not supported |
| ERR_NOLONG | 27 | Long not supported |
| ERR_NOPOINT | 28 | Pointers not supported |

***Encoding error stored in errno by functions like fgetwc, getwc, mbrtowc, etc ...***

| | | |
|---|---|---|
| EILSEQ | 29 | Invalid or incomplete multibyte or wide character |

***Errors set by RTOS***

| | | |
|---|---|---|
| EILSEQ | 30 | Operation canceled |
| ENODEV | 31 | No such device |

## 2.2.5 fcntl.h

The file `fcntl.h` contains the function `open()`, which calls the low level function `_open()`, and definitions of flags used by the low level function `_open()`. This header file is not defined in ISO C99.

| | |
|---|---|
| `open` | Opens a file for reading or writing. Calls `_open`.<br>*(FSS implementation)* |

## 2.2.6 fenv.h

Contains mechanisms to control the floating-point environment. The functions in this header file are not implemented.

| | |
|---|---|
| `fegetenv` | Stores the current floating-point environment. (*Not implemented*) |
| `feholdexept` | Saves the current floating-point environment and installs an environment that ignores all floating-point exceptions. (*Not implemented*) |
| `fesetenv` | Restores a previously saved (fegetenv or feholdexcept) floating-point environment. (*Not implemented*) |
| `feupdateenv` | Saves the currently raised floating-point exceptions, restores a previously saved floating-point environment and finally raises the saved exceptions. (*Not implemented*) |

| | |
|---|---|
| `feclearexcept` | Clears the current exception status flags corresponding to the flags specified in the argument. (*Not implemented*) |
| `fegetexceptflag` | Stores the current setting of the floating-point status flags. (*Not implemented*) |
| `feraiseexcept` | Raises the exceptions represented in the argument. As a result, other exceptions may be raised as well. (*Not implemented*) |
| `fesetexceptflag` | Sets the current floating-point status flags. (*Not implemented*) |
| `fetestexcept` | Returns the bitwise-OR of the exception macros corresponding to the exception flags which are currently set *and* are specified in the argument. (*Not implemented*) |

For each supported exception, a macro is defined. The following exceptions are defined:

| | | |
|---|---|---|
| `FE_DIVBYZERO` | `FE_INEXACT` | `FE_INVALID` |
| `FE_OVERFLOW` | `FE_UNDERFLOW` | `FE_ALL_EXCEPT` |

| | |
|---|---|
| `fegetround` | Returns the current rounding direction, represented as one of the values of the rounding direction macros. (*Not implemented*) |
| `fesetround` | Sets the current rounding directions. (*Not implemented*) |

Currently no rounding mode macros are implemented.

## 2.2.7 float.h

The header file `float.h` defines the characteristics of the real floating-point types `float`, `double` and `long double`.

`Float.h` used to contain prototypes for the functions `copysign(f)`, `isinf(f)`, `isfinite(f)`, `isnan(f)` and `scalb(f)`. These functions have accordingly to the ISO C99 standard been moved to the header file `math.h`. See also section 2.2.15, *math.h and tgmath.h*.

## 2.2.8 fss.h

The header file `fss.h` contains definitions for the debugger's file system simulation (FSS). This header file is not defined in ISO C99.

| **fss.h** | **Description** |
|---|---|
| `_fss_break(`*`void`*`)` | Buffer and breakpoint functions for the debugger. |
| `_fss_init(`*`fd,is_close`*`)` | Opens file descriptors 0 (stdin), 1 (stdout) and 2 (stderr) and associates them with terminal window `FSS 0` of the debugger. |

## 2.2.9 inttypes.h and stdint.h

The header files `stdint.h` and `inttypes.h` provide additional declarations for integer types and have various characteristics. The `stdint.h` header file contains basic definitions of integer types of certain sizes, and corresponding sets of macros. This header file clearly refers to the corresponding sections in the ISO C99 standard.
The `inttypes.h` header file includes `stdint.h` and adds portable formatting and conversion functions. Below the conversion functions from `inttypes.h` are listed.

| | |
|---|---|
| `intmax_t` **`imaxabs`**`(intmax_t j);` | Returns the absolute value of j |
| `imaxdiv_t` **`imaxdiv`**`(intmax_t numer, intmax_t denom);` | Computes numer/denom and numer % denom. The result is stored in the quot and rem components of the imaxdiv_t structure type. |
| `intmax_t` **`strtoimax`**`(const char * restrict nptr, char ** restrict endptr, int base);` | Convert string to maximum sized integer. (Compare `strtol`) |
| `uintmax_t` **`strtoumax`**`(const char * restrict nptr, char ** restrict endptr, int base);` | Convert string to maximum sized unsigned integer. (Compare `strtoul`) |
| `intmax_t` **`wcstoimax`**`(const wchar_t * restrict nptr, wchar_t ** restrict endptr, int base);` | Convert wide string to maximum sized integer. (Compare `wctol`) |
| `uintmax_t` **`wcstoumax`**`(const wchar_t * restrict nptr, wchar_t ** restrict endptr, int base);` | Convert wide string to maximem sized unsigned integer. (Compare `wctoul`) |

## 2.2.10 io.h

The header file `io.h` contains definitions and prototypes for low level I/O functions. This header file is not defined in ISO/IEC9899.

| | |
|---|---|
| `_close(`*`fd`*`)` | Used by the functions close and fclose. (*FSS implementation)* |
| `_lseek(`*`fd,offset,whence`*`)` | Used by all file positioning functions: fgetpos, fseek, fsetpos, ftell, rewind. (*FSS implementation)* |
| `_open(`*`fd,flags`*`)` | Used by the functions `fopen` and `freopen`. (*FSS implementation)* |
| `_read(`*`fd,*buff,cnt`*`)` | Reads a sequence of characters from a file. (*FSS implementation)* |
| `_unlink(`*`*name`*`)` | Used by the function remove. (*FSS implementation)* |
| `_write(`*`fd,*buffer,cnt`*`)` | Writes a sequence of characters to a file. (*FSS implementation)* |

## 2.2.11 iso646.h

The header file iso646.h adds tokens that can be used instead of regular operator tokens.

```
#define and     &&
#define and_eq  &=
#define bitand  &
#define bitor   |
#define compl   ~
#define not     !
#define not_eq  !=
#define or      ||
#define or_eq   |=
#define xor     ^
#define xor_eq  ^=
```

## 2.2.12 limits.h

Contains the sizes of integral types, defined as macros.

## 2.2.13 locale.h

To keep C code reasonable portable accross different languages and cultures, a number of facilities are provided in the header file `local.h`.

`char *`**`setlocale`**`( int category, const char *locale )`

The function above changes locale-specific features of the run-time library as specified by the category to change and the name of the locale.

The following categories are defined and can be used as input for this function:

| | | | |
|---|---|---|---|
| LC_ALL | 0 | LC_NUMERIC | 3 |
| LC_COLLATE | 1 | LC_TIME | 4 |
| LC_CTYPE | 2 | LC_MONETARY | 5 |

`struct lconv *`**`localeconv`**`( void )`

Returns a pointer to type `stuct lconv` with values appropriate for the formatting of numeric quantities according to the rules of the current locale. The `struct lconv` in this header file is conforming the ISO standard.

## 2.2.14 malloc.h

The header file `malloc.h` contains prototypes for memory allocation functions. This include file is not defined in ISO C99, it is included for backwards compatibility with ISO C90. For ISO C99, the memory allocation functions are part of `stdlib.h`. See section 2.2.23, *stdlib.h and wchar.h*.

| | |
|---|---|
| `malloc(`*`size`*`)` | Allocates space for an object with size *size*. The allocated space is not initialized. Returns a pointer to the allocated space. |
| `calloc(`*`nobj`*`,`*`size`*`)` | Allocates space for n objects with size *size*. The allocated space is initialized with zeros. Returns a pointer to the allocated space. |
| `free(`*`*ptr`*`)` | Deallocates the memory space pointed to by *ptr* which should be a pointer earlier returned by the `malloc` or `calloc` function. |
| `realloc(`*`*ptr`*`,`*`size`*`)` | Deallocates the old object pointed to by ptr and returns a pointer to a niew object with size *size*. The new object cannot have a size larger than the previous object. |

## 2.2.15 math.h and tgmath.h

The header file `math.h` contains the prototypes for many mathematical functions. Before ISO C99, all functions were computed using the double type (the float was automatically converted to double, prior to calculation). In this ISO C99 version, parallel sets of functions are defined for double, float and long double. They are respectively named *function*, *function*`f`, *function*`l`. All `long` type functions, though declared in `math.h`, are implemented as the `double` type variant which nearly always meets the requirement in embedded applications.

The header file `tgmath.h` contains parallel type generic math macros whose expansion depends on the used type. `tgmath.h` includes `math.h` and the effect of expansion is that the correct `math.h` functions are called. The type generic macro, if available, is listed in the second column of the tables below.

### *Trigonometric and hyperbolic functions*

| math.h | | | tgmath.h | Description |
|---|---|---|---|---|
| sin | sinf | sinl | sin | Returns the sine of x. |
| cos | cosf | cosl | cos | Returns the cosine of x. |
| tan | tanf | tanl | tan | Returns the tangent of x. |
| asin | asinf | asinl | asin | Returns the arc sine $\sin^{-1}(x)$ of x. |
| acos | acosf | acosl | acos | Returns the arc cosine $\cos^{-1}(x)$ of x. |
| atan | atanf | atanl | atan | Returns the arc tangent $\tan^{-1}(x)$ of x. |

| math.h | | | tgmath.h | Description |
|---|---|---|---|---|
| atan2 | atan2f | atan2l | atan2 | Returns the result of: $\tan^{-1}$(y/x). |
| sinh | sinhf | sinhl | sinh | Returns the hyperbolic sine of x. |
| cosh | coshf | coshl | cosh | Returns the hyperbolic cosine of x. |
| tanh | tanhf | tanhl | tanh | Returns the hyperbolic tangent of x. |
| asinh | asinhf | asinhl | asinh | Returns the arc hyperbolic sinus of x. |
| acosh | acoshf | acoshl | acosh | Returns the non-negative arc hyperbolic cosinus of x. |
| atanh | atanhf | atanhl | atanh | Returns the arc hyperbolic tangent of x. |

### *Exponential and logarithmic functions*

All of these functions are new in ISO C99, except for `exp`, `log` and `log10`.

| math.h | | | tgmath.h | Description |
|---|---|---|---|---|
| exp | expf | expl | exp | Returns the result of the exponential function $e^x$. |
| exp2 | exp2f | exp2l | exp2 | Returns the result of the exponential function $2^x$. (*Not implemented*) |
| expm1 | expm1f | expm1l | expm1 | Returns the result of the exponential function $e^x$-1 (*Not implemented*) |
| log | logf | logl | log | Returns the natural logarithm ln(x), x>0. |
| log10 | log10f | log10l | log10 | Returns the base-10 logarithm of x, x>0. |
| log1p | log1pf | log1pl | log1p | Returns the base-e logarithm of (1+x). x <> -1. (*Not implemented*) |
| log2 | log2f | log2l | log2 | Returns the base-2 logarithm of x. x>0. (*Not implemented*) |
| ilogb | ilogbf | ilogbl | ilogb | Returns the signed exponent of x as an integer. x>0. (*Not implemented*) |
| logb | logbf | logbl | logb | Returns the exponent of x as a signed integer in value in floating-point notation. x > 0. (*Not implemented*) |

### *frexp, ldexp, modf, scalbn, scalbln*

| math.h | | | tgmath.h | Description |
|---|---|---|---|---|
| frexp | frexpl | frexpf | frexp | Splits a float x into fraction *f* and exponent *n*, so that: $f$ = 0.0 or 0.5 ≤ \| $f$ \| ≤ 1.0 and $f*2^n$ = x. Returns *f*, stores n. |
| ldexp | ldexpl | ldexpf | ldexp | Inverse of `frexp`. Returns the result of $x*2^n$. (x and n are both arguments). |
| modf | modfl | modff | - | Splits a float x into fraction *f* and integer *n*, so that: \| $f$ \| < 1.0 and $f+n$=x. Returns *f*, stores *n*. |
| scalbn | scalbnl | scalbnf | scalbn | Computes the result of x*FLT_RADIX$^n$. efficiently, not normally by computing FLT_RADIX$^n$ explicitly. |
| scalbln | scalblnl | scalblnf | scalbln | Same as `scalbn` but with argument n as `long int`. |

### Rounding functions

| math.h | | | tgmath.h | Description |
|---|---|---|---|---|
| ceil | ceilf | ceill | ceil | Returns the smallest integer not less than x, as a double. |
| floor | floorf | floorl | floor | Returns the largest integer not greater than x, as a double. |
| rint | rintl | rintf | rint | Returns the rounded integer value as an int according to the current rounding direction. See fenv.h. (*Not implemented*) |
| lrint | lrintf | lrintl | lrint | Returns the rounded integer value as a long int according to the current rounding direction. See fenv.h. (*Not implemented*) |
| llrint | lrintf | lrintl | llrint | Returns the rounded integer value as a long long int according to the current rounding direction. See fenv.h. (*Not implemented*) |
| nearbyint | nearbyintf nearbyintl | | nearbyint | Returns the rounded integer value as a floating-point according to the current rounding direction. See fenv.h. (*Not implemented*) |
| round | roundl | roundf | round | Returns the nearest integer value of x as int. (*Not implemented*) |
| lround | lroundl | lroundf | lround | Returns the nearest integer value of x as long int. (*Not implemented*) |
| llround | llroundl | llroundf | llround | Returns the nearest integer value of x as long long int. (*Not implemented*) |
| trunc | truncl | truncf | trunc | Returns the truncated integer value x. (*Not implemented*) |

### Remainder after devision

| math.h | | | tgmath.h | Description |
|---|---|---|---|---|
| fmod | fmodl | fmodf | fmod | Returns the remainder r of x-ny. n is chosen as trunc(*x/y*). r has the same sign as x. |
| remainder | remainderl remainderf | | remainder | Returns the remainder r of x-ny. n is chosen as trunc(*x/y*). r may not have the same sign as x. (*Not implemented*) |
| remquo | remquol | remquof | remquo | Same as remainder. In addition, the argument *quo is given a specific value (see ISO). (*Not implemented*) |

### Power and absolute-value functions

| math.h | | | tgmath.h | Description |
|---|---|---|---|---|
| cbrt | cbrtl | cbrtf | cbrt | Returns the real cube root of x ($=x^{1/3}$). (*Not implemented*) |
| fabs | fabsl | fabsf | fabs | Returns the absolute value of x (\|x\|). (abs, labs, llabs, div, ldiv, lldiv are defined in stdlib.h) |
| fma | fmal | fmaf | fma | Floating-point multiply add. Returns x*y+z. (*Not implemented*) |
| hypot | hypotl | hypotf | hypot | Returns the square root of $x^2+y^2$. |
| pow | powl | powf | power | Returns x raised to the power y ($x^y$). |
| sqrt | sqrtl | sqrtf | sqrt | Returns the non-negative square root of x. $x \neq 0$. |

### Manipulation functions: copysign, nan, nextafter, nexttoward

| math.h | | | tgmath.h | Description |
|---|---|---|---|---|
| copysign | copysignl copysignf | | copysign | Returns the value of x with the sign of y. |
| nan | nanl | nanf | – | Returns a quiet NaN, if available, with content indcated through tagp. (*Not implemented*) |
| nextafter | nextafterl nextafterf | | nextafter | Returns the next representable value in the specified format after x in the direction of y. Returns y is x=y. (*Not implemented*) |
| nexttoward | nexttowardl nexttowardf | | nexttoward | Same as nextafter, except that the second argument in all three variants is of type long double. Returns y if x=y. (*Not implemented*) |

### *Positive difference, maximum, minimum*

| math.h | | | tgmath.h | Description |
|---|---|---|---|---|
| fdim | fdiml | fdimf | fdim | Returns the positive difference between: \|x-y\|. (*Not implemented*) |
| fmax | fmaxl | fmaxf | fmax | Returns the maximum value of their arguments. (*Not implemented*) |
| fmin | fminl | fminf | fmin | Returns the minimum value of their arguments. (*Not implemented*) |

### *Error and gamma (Not implemented)*

| math.h | | | tgmath.h | Description |
|---|---|---|---|---|
| erf | erfl | erff | erf | Computes the error function of x. (*Not implemented*) |
| erfc | erfcl | erfcf | erc | Computes the complementary error function of x. (*Not implemented*) |
| lgamma | lgammal | lgammaf | lgamma | Computes the $*\log_e\|\Gamma(x)\|$ (*Not implemented*) |
| tgamma | tgammal | tgammaf | tgamma | Computes $\Gamma(x)$ (*Not implemented*) |

### *Comparison macros*

The next are implemented as macros. For any ordered pair of numeric values exactly one of the relationships – *less*, *greater*, and *equal* – is true. These macros are type generic and therefor do not have a parallel function in `tgmath.h`. All arguments must be expressions of real-floating type.

| math.h | tgmath.h | Description |
|---|---|---|
| isgreater | – | Returns the value of `(x) > (y)` |
| isgreaterequal | – | Returns the value of `(x) >= (y)` |
| isless | – | Returns the value of `(x) < (y)` |
| islessequal | – | Returns the value of `(x) <= (y)` |
| islessgreater | – | Returns the value of `(x) < (y) \|\| (x) > (y)` |
| isunordered | – | Returns 1 if its arguments are unordered, 0 otherwise. |

### *Classification macros*

The next are implemented as macros. These macros are type generic and therefor do not have a parallel function in `tgmath.h`. All arguments must be expressions of real-floating type.

| math.h | tgmath.h | Description |
|---|---|---|
| fpclassify | – | Returns the class of its argument: `FP_INFINITE`, `FP_NAN`, `FP_NORMAL`, `FP_SUBNORMAL` or `FP_ZERO` |
| isfinite | – | Returns a nonzero value if and only if its argument has a finite value |
| isinf | – | Returns a nonzero value if and only if its argument has an infinit value |
| isnan | – | Returns a nonzero value if and only if its argument has NaN value. |
| isnormal | – | Returns a nonzero value if an only if its argument has a normal value. |
| signbit | – | Returns a nonzero value if and only if its argument value is negative. |

## 2.2.16 setjmp.h

The `setjmp` and `longjmp` in this header file implement a primitive form of nonlocal jumps, which may be used to handle exceptional situations. This facility is traditionally considered more portable than `signal.h`.

| | |
|---|---|
| `int setjmp(jmp_buf env)` | Records its caller's environment in `env` and returns 0. |
| `void longjmp(jmp_buf env, int status)` | Restores the environment previously saved with a call to `setjmp()`. |

## 2.2.17 signal.h

Signals are possible asynchronous events that may require special processing. Each signal is named by a number. The following signals are defined:

| | | |
|---|---|---|
| `SIGINT` | 1 | Receipt of an interactive attention signal |
| `SIGILL` | 2 | Detection of an invalid function message |
| `SIGFPE` | 3 | An errouneous arithmetic operation (for example, zero devide, `overflow)` |
| `SIGSEGV` | 4 | An invalid access to storage |
| `SIGTERM` | 5 | A termination request sent to the program |
| `SIGABRT` | 6 | Abnormal terminiation, such as is initiated by the `abort` function. |

The next function sends the signal *sig* to the program:

```
int raise(int sig)
```

The next function determines how subsequent signals will be handled:

```
signalfunction *signal (int, signalfunction *);
```

The first argument specifies the signal, the second argument points to the signal-handler function or has one of the following values:

| | |
|---|---|
| `SIG_DFL` | Default behaviour is used |
| `SIG_IGN` | The signal is ignored |

The function returns the previous value of `signalfunction` for the specific signal, or `SIG_ERR` if an error occurs.

## 2.2.18 stdarg.h

The facilities in this header file gives you a portable way to access variable arguments lists, such as needed for as `fprintf` and `vfprintf`. `va_copy` is new in ISO C99. This header file contains the following macros:

| | |
|---|---|
| `va_arg(ap,type)` | Returns the value of the next argument in the variable argument list. It's return type has the type of the given argument `type`. A next call to this macro will return the value of the next argument. |
| `va_copy(va_list dest, va_list src)` | This macro duplicates the current state of `src` in `dest`, creating a second pointer into the argument list. After this call, `va_arg()` may be used on `src` and `dest` independently. |
| `va_end(va_list ap)` | This macro must be called after the arguments have been processed. It should be called before the function using the macro 'va_start' is terminated (ANSI specification). |
| `va_start( va_list ap, lastarg );` | This macro initializes `ap`. After this call, each call to va_arg() will return the value of the next argument. In our implementation, `va_list` cannot contain any bit type variables. Also the given argument `lastarg` must be the last non-bit type argument in the list. |

## 2.2.19 stdbool.h

This header file contains the following macro definitions. These names for boolean type and values are consistent with C++. You are allowed to `#undefine` or redefine the macros below.

```
#define bool                          _Bool
#define true                          1
#define false                         0
#define __bool_true_false_are_defined 1
```

## 2.2.20 stddef.h

This header file defines the types for common use:

| | |
|---|---|
| `ptrdiff_t` | signed integer type of the result of subtracting two pointers. |
| `size_t` | unsigned integral type of the result of the `sizeof` operator. |
| `wchar_t` | integer type to represent character codes in large character sets. |

Besides these types, the following macros are defined:

| | |
|---|---|
| `NULL` | expands to the null pointer constant |
| `offsetof(_type,_member)` | expands to an integer constant expression with type `size_t` that is the offset in bytes of `_member` within structure type `_type`. |

## 2.2.21 stdint.h

See section 2.2.9, *inttypes.h and stdint.h*

## 2.2.22 stdio.h and wchar.h

### *Types*

The header file `stdio.h` contains functions for performing input and output. A number of functions also have a parallel wide character function or macro, defined in `wchar.h`. The header file `wchar.h` also includes `stdio.h`.

In the C language, many I/O facilities are based on the concept of streams. The `stdio.h` header file defines the data type **`FILE`** which holds the information about a stream. An `FILE` object is created with the function `fopen`. The pointer to this object is used as an argument in many of the in this header file. The `FILE` object can contain the following information:

- the current position within the stream
- pointers to any associated buffers
- indications of for read/write errors
- end of file indication

The header file also defines type `fpos_t` as an `unsigned long`.

### Macros

| stdio.h / wchar.h | Description |
|---|---|
| NULL | expands to the null pointer constant |
| BUFSIZ | Size of the buffer used by the setbuf/setvbuf function: 512 |
| EOF | End of file indicator. Expands to -1. |
| WEOF | End of file indicator. Expands to UINT_MAX (defined in limits.h)<br>NOTE: WEOF need not to be a negative number as long as its value does not correspond to a member of the wide character set. (Defined in wchar.h). |
| FOPEN_MAX | Number of files that can be opened simultaneously: 4<br>NOTE: According to ISO C99 this value must be at least 8. |
| FILENAME_MAX | Maximum length of a filename: 100 |
| _IOFBF<br>_IOLBF<br>_IONBF | Expand to an integer expression, suitable for use as argument to the setvbuf function. |
| L_tmpnam | Size of the string used to hold temporary file names: 8 (tmp*xxxxx*) |
| TMP_MAX | Maximum number of unique temporary filenames that can be generated: 0x8000 |
| SEEK_CUR<br>SEEK_END<br>SEEK_SET | Expand to an integer expression, suitable for use as the third argument to the fseek function. |
| stderr<br>stdin<br>stdout | Expressions of type ”pointer to FILE” that point to the FILE objects associated with standard error, input and output streams. |

### File access

| stdio.h | Description |
|---|---|
| fopen(*name*,*mode*) | Opens a file for a given mode. Available modes are:<br>”r” read; open text file for reading<br>”w” write; create text file for writing; if the file already exists its contents is discarded<br>”a” append; open existing text file or create new text file for writing at end of file<br>”r+” open text file for update; reading and writing<br>”w+” create text file for update; previous contents if any is discarded<br>”a+” append; open or create text file for update, writes at end of file |
| fclose(*name*) | Flushes the data stream and closes the specified file that was previously opened with fopen. |
| fflush(*name*) | If stream is an output stream, any buffered but unwritten date is written. Else, the effect is undefined. |
| freopen(*name*,*mode*,*stream*) | Similar to fopen, but rather then generating a new value of type FILE *, the existing value is associated with a new stream. |
| setbuf(*stream*,*buffer*) | If buffer is NULL, buffering is turned off for the stream.<br>Otherwise, setbuf is equivalent to:<br>(void) setvbuf(*stream*,*buf*,_IOFBF, BUFSIZ). |
| setvbuf(*stream*,*buffer*, *mode*,*size*) | Controls buffering for the *stream*; this function must be called before reading or writing. *Mode* can have the following values:<br>_IOFBF causes full buffering<br>_IOLBF causes line buffering of text files<br>_IONBF causes no buffering<br>If *buffer* is not NULL, it will be used as a buffer; otherwise a buffer will be allocated. *size* determines the buffer size. |

### *Character input/output*

The format string of **printf** related functions can contain plain text mixed with conversion specifiers. Each conversion specifier should be preceded by a '%' character. The conversion specifier should be build in order:

- Flags (in any order):

| | |
|---|---|
| – | specifies left adjustment of the converted argument. |
| + | a number is always preceded with a sign character.<br>+ has higher precedence than space. |
| space | a negative number is preceded with a sign, positive numbers with a space. |
| 0 | specifies padding to the field width with zeros (only for numbers). |
| # | specifies an alternate output form. For o, the first digit will be zero. For x or X, "0x" and "0X" will be prefixed to the number. For e, E, f, g, G, the output always contains a decimal point, trailing zeros are not removed. |

- A number specifying a minimum field width. The converted argument is printed in a field with at least the length specified here. If the converted argument has fewer characters than specified, it will be padded at the left side (or at the right when the flag '–' was specified) with spaces. Padding to numeric fields will be done with zeros when the flag '0' is also specified (only when padding left). Instead of a numeric value, also '*' may be specified, the value is then taken from the next argument, which is assumed to be of type int.
- A period. This separates the minimum field width from the precision.
- A number specifying the maximum length of a string to be printed. Or the number of digits printed after the decimal point (only for floating-point conversions). Or the minimum number of digits to be printed for an integer conversion. Instead of a numeric value, also '*' may be specified, the value is then taken from the next argument, which is assumed to be of type int.
- A length modifier 'h', 'hh', 'l', 'll', 'L', 'j', 'z' or 't'. 'h' indicates that the argument is to be treated as a short or unsigned short. 'hh' indicates that the argument is to be treated as a char or unsigned char. 'l' should be used if the argument is a long integer, 'll' for a long long. 'L' indicates that the argument is a long double. 'j' indicates a pointer to intmax_t or uintmax_t, 'z' indicates a pointer to size_t and 't' indicates a pointer to ptrdiff_t.

Flags, length specifier, period, precision and length modifier are optional, the conversion character is not. The conversion character must be one of the following, if a character following '%' is not in the list, the behavior is undefined.

| Character | Printed as |
|---|---|
| d, i | int, signed decimal |
| o | int, unsigned octal |
| x, X | int, unsigned hexadecimal in lowercase or uppercase respectively |
| u | int, unsigned decimal |
| c | int, single character (converted to unsigned char) |
| s | char *, the characters from the string are printed until a NULL character is found. When the given precision is met before, printing will also stop |
| f | double |
| e, E | double |
| g, G | double |
| a, A | double |
| n | int *, the number of characters written so far is written into the argument. This should be a pointer to an integer in default memory. No value is printed. |
| p | pointer (hexadecimal 24-bit value) |
| % | No argument is converted, a '%' is printed. |

*Table 2-2: Printf conversion characters*

All arguments to the **scanf** related functions should be pointers to variables (in default memory) of the type which is specified in the format string.

The format string can contain :

- Blanks or tabs, which are skipped.
- Normal characters (not '%'), which should be matched exactly in the input stream.
- Conversion specifications, starting with a '%' character.

Conversion specifications should be built as follows (in order) :

- A '*', meaning that no assignment is done for this field.
- A number specifying the maximum field width.
- The conversion characters `d`, `i`, `n`, `o`, `u` and `x` may be preceded by 'h' if the argument is a pointer to `short` rather than `int`, or by 'hh' if the argument is a pointer to `char`, or by 'l' (letter ell) if the argument is a pointer to `long`, or by 'll' for a pointer to `long long`, 'j' for a pointer to `intmax_t` or `uintmax_t`, 'z' for a pointer to `size_t` or 't' for a pointer to `ptrdiff_t`. The conversion characters `e`, `f`, and `g` may be preceded by 'l' if the argument is a pointer to `double` rather than `float`, and by 'L' for a pointer to a `long double`.
- A conversion specifier. '*', maximum field width and length modifier are optional, the conversion character is not. The conversion character must be one of the following, if a character following '%' is not in the list, the behavior is undefined.

Length specifier and length modifier are optional, the conversion character is not. The conversion character must be one of the following, if a character following '%' is not in the list, the behavior is undefined.

| Character | Scanned as |
|---|---|
| d | int, signed decimal. |
| i | int, the integer may be given octal (i.e. a leading 0 is entered) or hexadecimal (leading "0x" or "0X"), or just decimal. |
| o | int, unsigned octal. |
| u | int, unsigned decimal. |
| x | int, unsigned hexadecimal in lowercase or uppercase. |
| c | single character (converted to unsigned char). |
| s | char *, a string of non white space characters. The argument should point to an array of characters, large enough to hold the string and a terminating NULL character. |
| f | float |
| e, E | float |
| g, G | float |
| a, A | float |
| n | int *, the number of characters written so far is written into the argument. No scanning is done. |
| p | pointer; hexadecimal 24-bit value which must be entered without 0x- prefix. |
| [...] | Matches a string of input characters from the set between the brackets. A NULL character is added to terminate the string. Specifying []...] includes the ']' character in the set of scanning characters. |
| [^...] | Matches a string of input characters not in the set between the brackets. A NULL character is added to terminate the string. Specifying [^]...] includes the ']' character in the set. |
| % | Literal '%', no assignment is done. |

*Table 2-3: Scanf conversion characters*

| stdio.h | wchar.h | Description |
|---|---|---|
| `fscanf(`*`stream`*`, `*`format`*`,...)` | `fwscanf(`*`stream`*`, `*`format`*`,...)` | Performs a formatted read from the given *stream*. Returns the number of items converted succesfully. (*FSS implementation*) |
| `scanf(`*`format`*`,...)` | `wscanf(`*`format`*`,...)` | Performs a formatted read from the `stdin` stream. Returns the number of items converted succesfully. (*FSS implementation*) |
| `sscanf(*`*`s`*`, `*`format`*`,...)` | `swscanf(*`*`s`*`, `*`format`*`,...)` | Performs a formatted read from the string *s*. Returns the number of items converted succesfully. |
| `vfscanf(`*`stream`*`, `*`format`*`,`*`arg`*`)` | `vfwscanf(`*`stream`*`, `*`format`*`,`*`arg`*`)` | Same as `fscanf`/`fwscanf`, but extra arguments are given as variable argument list *arg*.<br>(See section 2.2.18, *stdarg.h*) |
| `vscanf(`*`format`*`,`*`arg`*`)` | `vwscanf(`*`format`*`,`*`arg`*`)` | Same as `scanf`/`wscanf`, but extra arguments are given as variable argument list *arg*.<br>(See section 2.2.18, *stdarg.h*) |
| `vsscanf(`*`s`*`,`*`format`*`, `*`arg`*`)` | `vswscanf(`*`s`*`,`*`format`*`, `*`arg`*`)` | Same as `scanf`/`wscanf`, but extra arguments are given as variable argument list *arg*.<br>(See section 2.2.18, *stdarg.h*) |
| `fprintf(`*`stream`*`, `*`format`*`,...)` | `fwprintf(`*`stream`*`, `*`format`*`,...)` | Performs a formatted write to the given *stream*. Returns EOF/WEOF on error.<br>(*FSS implementation*) |
| `printf(`*`format`*`,...)` | `wprintf(`*`format`*`,...)` | Performs a formatted write to the stream `stdout`. Returns EOF/WEOF on error.<br>(*FSS implementation*) |
| `sprintf(*`*`s`*`, `*`format`*`,...)` | – | Performs a formatted write to string *s*. Returns EOF/WEOF on error. |
| `snprintf(*`*`s`*`,`*`n`*` `*`format`*`,...)` | `swprintf(*`*`s`*`,`*`n`*` `*`format`*`,...)` | Same as `sprintf`, but n specifies the maximum number of characters (including the terminating null character) to be written. |
| `vfprintf(`*`stream`*`, `*`format`*`,`*`arg`*`)` | `vfwprintf(`*`stream`*`, `*`format`*`,`*`arg`*`)` | Same as `fprintf`/`fwprintf`, but extra arguments are given as variable argument list *arg*. (See section 2.2.18, *stdarg.h*)<br>(*FSS implementation*) |
| `vprintf(`*`format`*`, `*`arg`*`)` | `vwprintf(`*`format`*`, `*`arg`*`)` | Same as `printf`/`wprintf`, but extra arguments are given as variable argument list *arg*. (See section 2.2.18, *stdarg.h*)<br>(*FSS implementation*) |
| `vsprintf(*`*`s`*`, `*`format`*`,`*`arg`*`)` | `vswprintf(*`*`s`*`, `*`format`*`,`*`arg`*`)` | Same as `sprintf`/`swprintf`, but extra arguments are given as variable argument list *arg*. (See section 2.2.18, *stdarg.h*)<br>(*FSS implementation*) |

### Character input/output

| stdio.h | wchar.h | Description |
|---|---|---|
| `fgetc(stream)` | `fgetwc(stream)` | Reads one character from *stream*. Returns the read character, or EOF/WEOF on error. (*FSS implementation*) |
| `getc(stream)` | `getwc(stream)` | Same as `fgetc/fgetwc` except that is implemented as a macro. (*FSS implementation*) NOTE: Currently #defined as `getchar()/getwchar()` because FILE I/O is not supported. Returns the read character, or EOF/WEOF on error. |
| `getchar(stdin)` | `getwchar(stdin)` | Reads one character from the `stdin` stream. Returns the character read or EOF/WEOF on error. Implemented as macro. (*FSS implementation*) |
| `fgets(*s,n, stream)` | `fgetws(*s,n, stream)` | Reads at most the next *n*-1 characters from the *stream* into array *s* until a newline is found. Returns s or NULL or EOF/WEOF on error. (*FSS implementation*) |
| `gets(*s,n,stdin)` | - | Reads at most the next *n*-1 characters from the `stdin` stream into array *s*. A newline is ignored. Returns *s* or NULL or EOF/WEOF on error. (*FSS implementation*) |
| `ungetc(c,stream)` | `ungetwc(c,stream)` | Pushes character *c* back onto the input *stream*. Returns EOF/WEOF on error. |
| `fputc(c,stream)` | `fputwc(c,stream)` | Put character *c* onto the given *stream*. Returns EOF/WEOF on error. (*FSS implementation*) |
| `putc(c,stream)` | `putwc(c,stream)` | Same as `fpuc/fputwc` except that is implemented as a macro. (*FSS implementation*) |
| `putchar(c,stdout)` | `putwchar(c,stdout)` | Put character *c* onto the `stdout` stream. Returns EOF/WEOF on error. Implemented as macro. (*FSS implementation*) |
| `fputs(*s,stream)` | `fputws(*s,stream)` | Writes string *s* to the given *stream*. Returns EOF/WEOF on error. |
| `puts(*s)` | - | Writes string *s* to the `stdout` stream. Returns EOF/WEOF on error. (*FSS implementation*) |

### Direct input/output

| stdio.h | Description |
|---|---|
| `fread(ptr,size,nobj,stream)` | Reads *nobj* members of *size* bytes from the given *stream* into the array pointed to by *ptr*. Returns the number of elements succesfully read. (*FSS implementation*) |
| `fwrite((ptr,size,nobj,stream)` | Writes *nobj* members of *size* bytes from to the array pointed to by *ptr* to the given *stream*. Returns the number of elements succesfully written. (*FSS implementation*) |

### Random access

| stdio.h | Description |
|---|---|
| `fseek(stream,offset, origin)` | Sets the position indicator for *stream*. (*FSS implementation*) |

When repositioning a binary file, the new position *origin* is given by the following macros:

| | |
|---|---|
| `SEEK_SET 0` | *offset* characters from the beginning of the file |
| `SEEK_CUR 1` | *offset* characters from the current position in the file |
| `SEEK_END 2` | *offset* characters from the end of the file |

| | |
|---|---|
| `ftell(stream)` | Returns the current file position for *stream*, or -1L on error. (*FSS implementation*) |
| `rewind(stream)` | Sets the file position indicator for the *stream* to the beginning of the file. This function is equivalent to: `(void) fseek( stream, 0L, SEEK_SET );` `clearerr( stream );` (*FSS implementation*) |
| `fgetpos(stream,pos)` | Stores the current value of the file position indicator for *stream* in the object pointed to by *pos*. (*FSS implementation*) |
| `fsetpos(stream,pos)` | Positions `stream` at the position recorded by `fgetpos` in **pos*. (*FSS implementation*) |

### *Operations on files*

| stdio.h | Description |
|---|---|
| `remove(file)` | Removes the named file, so that a subsequent attempt to open it fails. Returns a non-zero value if not succesful. |
| `rename(old,new)` | Changes the name of the file from old name to new name. Returns a non-zero value if not succesful. |
| `tmpfile()` | Creates a temporary file of the mode "`wb+`" that will be automatically removed when closed or when the program terminates normally. Returns a `file` pointer. |
| `tmpnam(buffer)` | Creates new file names that do not conflict with other file names currently in use. The new file name is stored in a *buffer* which must have room for L_tmpnam characters. Returns a pointer to the temporary name. The file names are created in the current directory and all start with "tmp". At most TMP_MAX unique file names can be generated. |

### *Error handling*

| stdio.h | Description |
|---|---|
| `clearerr(stream)` | Clears the end of file and error indicators for stream. |
| `ferror(stream)` | Returns a non-zero value if the error indicator for stream is set. |
| `feof(stream)` | Returns a non-zero value if the end of file indicator for stream is set. |
| `perror(*s)` | Prints *s* and the error message belonging to the integer `errno`. (See section 2.2.4, *errno.h*) |

## 2.2.23 stdlib.h and wchar.h

The header file `stdlib.h` contains general utility functions which fall into the following categories (Some have parallel wide-character, declared in `wchar.h`)

- Numeric conversions
- Random number generation
- Memory management
- Envirnoment communication
- Searching and sorting
- Integer arithmetic
- Multibyte/wide character and string conversions.

### *Macros*

| | |
|---|---|
| `EXIT_SUCCES 0` `EXIT_FAILURE 1` | Predefined exit codes that can be used in the `exit` function. |
| `RAND_MAX 32767` | Highest number that can be returned by the `rand`/`srand` function. |
| `MB_CUR_MAX 1` | Maximum number of bytes in a multibyte character for the extended character set specified by the current locale (category LC_CTYPE, see section 2.2.13, *locale.h*). |

### Numeric conversions

The following functions convert the intial portion of a string **s* to a `double`, `int`, `long int` and `long long int` value respectively.

```
double      atof(*s)
int         atoi(*s)
long        atol(*s)
long long   atoll(*s)
```

The following functions convert the initial portion of the string **s* to a float, double and long double value respectively. `*`*endp* will point to the first character not used by the conversion.

**stdlib.h**

```
float       strtof(*s,**endp)
double      strtod(*s,**endp)
long double strtold(*s,**endp)
```

**wchar.h**

```
float       wcstof(*s,**endp)
double      wcstod(*s,**endp)
long double wcstold(*s,**endp)
```

The following functions convert the initial portion of the string **s* to a `long`, `long long`, `unsigned long` and `unsigned long long` respectively. Base specifies the radix. `*`*endp* will point to the first character not used by the conversion.

**stdlib.h**

```
long          strtol(*s,**endp,base)
long long     strtoll(*s,**endp,base)
unsigned long strtoul(*s,**endp,base)
unsigned long long
              strtoull(*s,**endp,base)
```

**wchar.h**

```
long          wcstol(*s,**endp,base)
long long     wcstoll(*s,**endp,base)
unsigned long wcstoul(*s,**endp,base)
unsigned long long
              wcstoull(*s,**endp,base)
```

### Random number generation

| | |
|---|---|
| `rand` | Returns a pseudo random integer in the range 0 to RAND_MAX. |
| `srand(`*seed*`)` | Same as rand but uses *seed* for a new sequence of pseudo random numbers. |

### Memory management

| | |
|---|---|
| `malloc(`*size*`)` | Allocates space for an object with size *size*. The allocated space is not initialized. Returns a pointer to the allocated space. |
| `calloc(`*nobj*`,`*size*`)` | Allocates space for n objects with size *size*. The allocated space is initialized with zeros. Returns a pointer to the allocated space. |
| `free(*`*ptr*`)` | Deallocates the memory space pointed to by *ptr* which should be a pointer earlier returned by the `malloc` or `calloc` function. |
| `realloc(*`*ptr*`,`*size*`)` | Deallocates the old object pointed to by ptr and returns a pointer to a niew object with size *size*. The new object cannot have a size larger than the previous object. |

### Environment communication

| | |
|---|---|
| `abort()` | Causes abnormal program termination. If the signal SIGABRTis caught, the signal handler may take over control. (See section 2.2.17, *signal.h*). |
| `atexit(*`*func*`)` | *Func* points to a function that is called (without arguments) when the program normally terminates. |
| `exit(`*status*`)` | Causes normal program termination. Acts as if `main()` returns with status as the return value. Status can also be specified with the predefined macros EXIT_SUCCES or EXIT_FAILURE. |
| `_Exit(`*status*`)` | Same as `exit`, but no registered by the `atexit` function or signal handlers registerd by the `signal` function are called. |
| `getenv(*s)` | Searches an environment list for a string *s*. Returns a pointer to the contents of *s*. NOTE: this function is not implemented because there is no OS. |
| `system(*s)` | Passes the string *s* to the environment for execution. NOTE: this function is not implemented because there is no OS. |

### Searching and sorting

| | |
|---|---|
| bsearch(*key,*base, n,size,*cmp) | This function searches in an array of *n* members, for the object pointed to by *key*. The initial base of the array is given by *base*. The size of each member is specified by *size*. The given array must be sorted in ascending order, according to the results of the function pointed to by *cmp*. Returns a pointer to the matching member in the array, or NULL when not found. |
| qsort(*base,n, size,*cmp) | This function sorts an array of *n* members using the quick sort algorithm. The initial base of the array is given by *base*. The size of each member is specified by *size*. The array is sorted in ascending order, according to the results of the function pointed to by *cmp*. |

### Integer arithmetic

| | |
|---|---|
| int abs(*j*)<br>long labs(*j*)<br>long long llabs(*j*) | Compute the absolute value of an `int`, `long int`, and `long long int` *j* resepectively. |
| div_t div(*x*,*y*)<br>ldiv_t ldiv(*x*,*y*)<br>lldiv_t lldiv(*x*,*y*) | Compute *x/y* and *x%y* in a single operation. *X* and *y* have respectively type `int`, `long int` and `long long int`. The result is stored in the members `quot` and `rem` of `struct div_t`, `ldiv_t` and `lldiv_t` which have the same types. |

### Multibyte/wide character and string conversions

| | |
|---|---|
| mblen(*s,n) | Determines the number of bytes in the multi-byte character pointed to by *s*. At most *n* characters will be examined. (See also `mbrlen` in section 2.2.27, *wchar.h*) |
| mbtowc(*pwc,*s,n) | Converts the multi-byte character in *s* to a wide-character code and stores it in pwc. At most *n* characters will be examined. |
| wctomb(*s,wc) | Converts the wide-character *wc* into a multi-byte representation and stores it in the string pointed to by *s*. At most MB_CUR_MAX characters are stored. |
| mbstowcs(*pwcs,*s,n) | Converts a sequence of multi-byte characters in the string pointed to by *s* into a sequence of wide characters and stores at most *n* wide characters into the array pointed to by *pwcs*. (See also `mbsrtowcs` in section 2.2.27, *wchar.h*) |
| wcstombs(*s,*pwcs,n) | Converts a sequence of wide characters in the array pointed to by *pwcs* into multi-byte characters and stores at most *n* multi-byte characters into the string pointed to by *s*. (See also `wcsrtowmb` in section 2.2.27, *wchar.h*) |

## 2.2.24 string.h and wchar.h

This header file provides numerous functions for manipulating strings. By convention, strings in C are arrays of characters with a terminating null character. Most functions therefore take arguments of type `*char`. However, many functions have also parallel wide-character functions which take arguments of type `*wchar_t`. These functions are declared in `wchar.h`.

### Copying and concatenation functions

| stdio.h | wchar.h | Description |
|---|---|---|
| memcpy(*s1,*s2,n) | wmemcpy(*s1,*s2,n) | Copies *n* characters from **s2* into **s1* and returns *s1. If *s1 and *s2 overlap the result is undefined. |
| memmove(*s1,*s2,n) | wmemmove(*s1,*s2,n) | Same as `memcpy`, but overlapping strings are handled correctly. Returns **s1*. |
| strcpy(*s1,*s2) | wcscpy(*s1,*s2) | Copies **s2* into **s1* and returns **s1*. If **s1* and **s2* overlap the result is undefined. |
| strncpy(*s1,*s2,n) | wcsncpy(*s1,*s2,n) | Copies not more than *n* characters from **s2* into **s1* and returns **s1*. If **s1* and **s2* overlap the result is undefined. |
| strcat(*s1,*s2) | wcscat(*s1,*s2) | Appends a copy of **s2* to **s1* and returns **s1*. If **s1* and **s2* overlap the result is undefined. |
| strncat(*s1,*s2,n) | wcsncat(*s1,*s2,n) | Appends not more than *n* characters from **s2* to **s1* and returns **s1*. If **s1* and **s2* overlap the result is undefined. |

### Comparison functions

| stdio.h | wchar.h | Description |
|---|---|---|
| `memcmp(*s1,*s2,n)` | `wmemcmp(*s1,*s2,n)` | Compares the first *n* characters of **s1* to the first *n* characters of **s2*. Returns < 0 if **s1* < **s2*, 0 if **s1* = = **s2*, or > 0 if **s1* > **s2*. |
| `strcmp(*s1,*s2)` | `wcscmp(*s1,*s2)` | Compares string **s1* to string **s2*. Returns < 0 if **s1* < **s2*, 0 if **s1* = = **s2*, or > 0 if **s1* > **s2*. |
| `strncmp(*s1,*s2,n)` | `wcsncmp(*s1,*s2,n)` | Compares the first *n* characters of **s1* to the first *n* characters of **s2*. Returns < 0 if **s1* < **s2*, 0 if **s1* = = **s2*, or > 0 if **s1* > **s2*. |
| `strcoll(*s1,*s2)` | `wcscoll(*s1,*s2)` | Performs a local-specific comparison between string **s1* and string **s2* according to the LC_COLLATE category of the current locale. Returns < 0 if **s1* < **s2*, 0 if **s1* = = **s2*, or > 0 if **s1* > **s2*. (See section 2.2.13, *locale.h*) |
| `strxfrm(*s1,*s2,n)` | `wcsxfrm(*s1,*s2,n)` | Transforms (a local) string **s2* so that a comparison between transformed strings with `strcmp` gives the same result as a comparison between non-transformed strings with `strcoll`. Returns the transformed string **s1*. |

### Search functions

| stdio.h | wchar.h | Description |
|---|---|---|
| `memchr(*s,c,n)` | `wmemchr(*s,c,n)` | Checks the first *n* characters of **s* on the occurence of character *c*. Returns a pointer to the found character. |
| `strchr(*s,c)` | `wcschr(*s,c)` | Returns a pointer to the first occurence of character *c* in string **s* or the null pointer if not found. |
| `strrchr(*s,c)` | `wcsrchr(*s,c)` | Returns a pointer to the last occurence of character *c* in string **s* or the null pointer if not found. |
| `strspn(*s,*set)` | `wcsspn(*s,*set)` | Searches **s* for a sequence of characters specified in **set*. Returns the length of the first sequence found. |
| `strcspn(*s,*set)` | `wcscspn(*s,*set)` | Searches **s* for a sequence of characters *not* specified in **set*. Returns the length of the first sequence found. |
| `strpbrk(*s,*set)` | `wcspbrk(*s,*set)` | Same as `strspn`/`wcsspn` but returns a pointer to the first character in **s* that also is specified in **set*. |
| `strstr(*s,*sub)` | `wcsstr(*s,*sub)` | Searches for a substring **sub* in **s*. Returns a pointer to the first occurence of **sub* in **s*. |
| `strtok(*s,*delim)` | `wcstok(*s,*delim)` | A sequence of calls to this function breaks the string **s* into a sequence of tokens delimited by a character specified in **delim*. The token found in *s is terminated with a null character. The function returns a pointer to the first position in **s* of the token. |

### Miscellaneous functions

| stdio.h | wchar.h | Description |
|---|---|---|
| `memset(*s,c,n)` | `wmemset(*s,c,n)` | Fills the first *n* bytes of **s* with character *c* and returns **s*. |
| `strerror(errno)` | - | Typically, the values for errno come from `int errno`. This function returns a pointer to the associated error message. (See also section 2.2.4, *errno.h*) |
| `strlen(*s)` | `wcslen(*s)` | Returns the length of string **s*. |

## 2.2.25 time.h and wchar.h

The header file `time.h` provides facilities to retrieve and use the (calendar) date and time, and the process time. Time can be represented as an integer value, or can be broken-down in components. Two arithmetic data types are defined which are capable of holding the integer representation of times:

```
clock_t    unsigned long long
time_t     unsigned long
```

The type `struct tm` below is defined according to ISO/IEC9899 with one exception: this implementation does not support leap seconds. The `struct tm` type is defines as follows:

```
struct tm
{
  int   tm_sec;         /* seconds after the minute - [0, 59]   */
  int   tm_min;         /* minutes after the hour - [0, 59]     */
  int   tm_hour;        /* hours since midnight - [0, 23]       */
  int   tm_mday;        /* day of the month - [1, 31]           */
  int   tm_mon;         /* months since January - [0, 11]       */
  int   tm_year;        /* year since 1900                      */
  int   tm_wday;        /* days since Sunday - [0, 6]           */
  int   tm_yday;        /* days since January 1 - [0, 365]      */
  int   tm_isdst;       /* Daylight Saving Time flag            */
};
```

### *Time manipulation*

| | |
|---|---|
| `clock` | Returns the application's best approximation to the processor time used by the program since it was started. This low-level routine is not implemented because it strongly depends on the hardware. To determine the time in seconds, the result of clock should be divided by the value defined as<br>`CLOCKS_PER_SEC    12000000` |
| `difftime(`*`t1`*`,`*`t0`*`)` | Returns the difference *t1-t0* in seconds. |
| `mktime(tm *`*`tp`*`)` | Converts the broken-down time in the structure pointed to by *tp*, to a value of type `time_t`. The return value has the same encoding as the return value of the `time` function. |
| `time(*`*`timer`*`)` | Returns the current calendar time. This value is also assigned to *`timer`. |

### *Time conversion*

| | |
|---|---|
| `asctime(tm *`*`tp`*`)` | Converts the broken-down time in the structure pointed to by *tp* into a string in the form `Mon Jan 21 16:15:14 2004\n\0`. Returns a pointer to this string. |
| `ctime(*`*`timer`*`)` | Converts the calender time pointed to by *timer* to local time in the form of a string. This is equivalent to: `asctime(localtime(timer))` |
| `gmtime(*`*`timer`*`)` | Converts the calender time pointed to by *timer* to the broken-down time, expressed as UTC. Returns a pointer to the broken-down time. |
| `localtime(*`*`timer`*`)` | Converts the calendar time pointed to by *timer* to the broken-down time, expressed as local time. Returns a pointer to the broken-down time. |

### *Formatted time*

The next function has a parallel function defined in `wchar.h`:

| **stdio.h** | **wchar.h** |
|---|---|
| `strftime(*`*`s`*`,`*`smax`*`,*`*`fmt`*`,tm *`*`tp`*`)` | `wstrftime(*`*`s`*`,`*`smax`*`,*`*`fmt`*`,tm *`*`tp`*`)` |

Formats date and time information from `struct tm` **tp* into **s* according to the specified format **fmt*. No more than *smax* characters are placed into **s*. The formatting of `strftime` is locale-specific using the `LC_TIME` category (see section 2.2.13, *locale.h*). You can use the next conversion specifiers:

| | |
|---|---|
| %a | abbreviated weekday name |
| %A | full weekday name |
| %b | abbreviated month name |
| %B | full month name |
| %c | local date and time representation (same as %a %b %e %T %Y) |
| %C | last two of the year |
| %d | day of the month (01-31) |

| | |
|---|---|
| %D | same as %m/%d/%y |
| %e | day of the month (1-31), with single digits preceded by a space |
| %F | ISO 8601 date format: %Y-%m-%d |
| %g | last two digits of the week based year (00-99) |
| %G | week based year (0000–9999) |
| %h | same as %b |
| %H | hour, 24-hour clock (00-23) |
| %I | hour, 12-hour clock (01-12) |
| %j | day of the year (001-366) |
| %m | month (01-12) |
| %M | minute (00-59) |
| %n | replaced by the newline character |
| %p | local equivalent of AM or PM |
| %r | locale's 12-hour clock time; same as %I:%M:%S %p |
| %R | same as %H:%M |
| %S | second (00-59) |
| %t | replaced by horizontal tab character |
| %T | ISO 8601 time format: %H:%M:%S |
| %u | ISO 8601 weekday number (1-7), Monday as first day of the week |
| %U | week number of the year, Sunday as first day of the week (00-53) |
| %V | ISO 8601 week number (01-53) in the week-based year |
| %w | weekday (0-6, Sunday is 0) |
| %W | week number of the year (00-53), week 1 has the first Monday |
| %x | local date representation |
| %X | local time representation |
| %y | year without century (00-99) |
| %Y | year with century |
| %z | ISO 8601 offset of time zone from UTC, or nothing |
| %Z | time zone name, if any |
| %% | % |

## 2.2.26 unistd.h

The file `unistd.h` contains standard UNIX I/O functions. These functions are all implemented using the debugger's file system simulation. Except for `lstat` and `fstat` which are not implemented. This header file is not defined in ISO C99.

`access(*name,mode)` — Use the file system simulation of the debugger to check the permissions of a file on the host. *mode* specifies the type of access and is a bit pattern constructed by a logical OR of the following values:

- `R_OK` Checks read permission.
- `W_OK` Checks write permission.
- `X_OK` Checks execute (search) permission.
- `F_OK` Checks to see if the file exists.

(*FSS implementation)*

`chdir(*path)` — Use the file system simulation feature of the debugger to change the current directory on the host to the directory indicated by *path*.
(*FSS implementation)*

`close(fd)` — File close function. The given file descriptor should be properly closed. This function calls `_close()`.
(*FSS implementation)*

`getcwd(*buf,size)` — Use the file system simulation feature of the debugger to retrieve the current directory on the host. Returns the directory name.
(*FSS implementation)*

`lseek(fd,offset,whence)` — Moves read-write file offset. Calls `_lseek()`.
(*FSS implementation)*

`read(fd,*buff,cnt)` — Reads a sequence of characters from a file. This function calls `_read()`. (*FSS implementation)*

`stat(*name,*buff)` — Use the file system simulation feature of the debugger to stat() a file on the host platform.
(*FSS implementation)*

| | |
|---|---|
| `lstat(*name,*buff)` | This function is identical to `stat()`, except in the case of a symbolic link, where the link itself is 'stat'-ed, not the file that it refers to. (*Not implemented*) |
| `fstat(fd,*buff)` | This function is identical to `stat()`, except that it uses a file descriptor instead of a name. (*Not implemented*) |
| `unlink(*name)` | Removes the named file, so that a subsequent attempt to open it fails. Calls `_unlink()`. (*FSS implementation)* |
| `write(fd,*buff,cnt)` | Write a sequence of characters to a file. Calls `_write()`. (*FSS implementation)* |

## 2.2.27 wchar.h

Many in `wchar.h` represent the wide-character variant of other so these are discussed together. (See sections 2.2.22, *stdio.h and wchar.h*, 2.2.23, *stdlib.h and wchar.h*, 2.2.24, *string.h and wchar.h* and 2.2.25, *time.h and wchar.h*).

The remaining are described below. They perform conversions between multi-byte characters and wide characters. In these, *ps* points to struct `mbstate_t` which holds the conversion state information necessary to convert between sequences of multibyte characters and wide characters:

```
typedef struct
{
     wchar_t         wc_value;  /* wide character value solved so far */
     unsigned short  n_bytes;   /* number of bytes of solved multibyte */
     unsigned short  encoding;  /* encoding rule for wide character <=>
                                   multibyte conversion */
} mbstate_t;
```

When multibyte characters larger than 1 byte are used, this struct will be used to store the conversion information when not all the bytes of a particular multibyte character have been read from the source. In this implementation, multi-byte characters are 1 byte long (MB_CUR_MAX and MB_LEN_MAX are defined as 1) and this will never occur.

| | |
|---|---|
| `mbsinit(*ps)` | Determines whether the object pointed to by *ps*, is an initial conversion state. Returns a non-zero value if so. |
| `mbsrtowcs(*pwcs,**src,n,*ps)` | Restartable version of `mbstowcs`. See section 2.2.23, *stdlib.h and wchar.h*. The initial conversion state is specified by *ps*. The input sequence of multibyte charactersis specified indirectly by *src*. |
| `wcsrtombs(*s,**src,n,*ps)` | Restartable version of `wcstombs`. See section 2.2.23, *stdlib.h and wchar.h*. The initial conversion state is specified by *ps*. The input wide string is specified indirectly by *src*. |
| `mbrtowc(*pwc,*s,n,*ps)` | Converts a multibyte character **s* to a wide character **pwc* according to conversion state *ps*. See also `mbtowc` in section 2.2.23, *stdlib.h and wchar.h*. |
| `wcrtomb(*s,wc,*ps)` | Converts a wide character wc to a multi-byte character according to conversion state *ps* and stores the multi-byte character in **s*. |
| `btowc(c)` | Returns the wide character corresponding to character *c*. Returns WEOF on error. |
| `wctob(c)` | Returns the multi-byte character corresponding to the wide character *c*. The returned multi-byte character is represented as one byte. Returns EOF on error. |
| `mbrlen(*s,n,*ps)` | Inspects up to *n* bytes from the string **s* to see if those characters represent valid multibyte characters, relative to the conversion state held in **ps*. |

## 2.2.28 wctype.h

Most in `wctype.h` represent the wide-character variant of declared in `ctype.h` and are discussed in section 2.2.3, *ctype.h and wctype.h*. In addition, this header file provides extensible, locale specific, wide character classification.

`wctype(*property)` Constructs a value of type `wctype_t` that describes a class of wide characters identified by the string **property*. If property identifies a valid class of wide characters according to the LC_TYPE category (see section 2.2.13, *locale.h*) of the current locale, a non-zero value is returned that can be used as an argument in the `iswctype` function.

`iswctype(wc,desc)` Tests whether the wide character *wc* is a member of the class represented by `wctype_t` *desc*. Returns a non-zero value if tested true.

| Function | Equivalent to locale specific test |
|---|---|
| `iswalnum(wc)` | `iswctype(wc,wctype("alnum"))` |
| `iswalpha(wc)` | `iswctype(wc,wctype("alpha"))` |
| `iswcntrl(wc)` | `iswctype(wc,wctype("cntrl"))` |
| `iswdigit(wc)` | `iswctype(wc,wctype("digit"))` |
| `iswgraph(wc)` | `iswctype(wc,wctype("graph"))` |
| `iswlower(wc)` | `iswctype(wc,wctype("lower"))` |
| `iswprint(wc)` | `iswctype(wc,wctype("print"))` |
| `iswpunct(wc)` | `iswctype(wc,wctype("punct"))` |
| `iswspace(wc)` | `iswctype(wc,wctype("space"))` |
| `iswupper(wc)` | `iswctype(wc,wctype("upper"))` |
| `iswxditig(wc)` | `iswctype(wc,wctype("xdigit"))` |

`wctrans(*property)` Constructs a value of type `wctype_t` that describes a mapping between wide characters identified by the string **property*. If property identifies a valid mapping of wide characters according to the LC_TYPE category (see section 2.2.13, *locale.h*) of the current locale, a non-zero value is returned that can be used as an argument in the `towctrans` function.

`towctrans(wc,desc)` Transforms wide character *wc* into another wide-character, described by *desc*.

| Function | Equivalent to locale specific transformation |
|---|---|
| `towlower(wc)` | `towctrans(wc,wctrans("tolower")` |
| `towupper(wc)` | `towctrans(wc,wctrans("toupper")` |

# 3 Assembly Language

## Summary

This chapter describes the most important aspects of the TASKING assembly language and contains a detailed description of all built-in assembly functions and assembler directives. For a complete overview of the architecture you are using and a description of the assembly instruction set, refer to the target's *Core Reference Manual*.

## 3.1 Assembly Syntax

An assembly program consists of zero or more statements. A statement may optionally be followed by a comment. Any source statement can be extended to more lines by including the line continuation character (\) as the last character on the line. The length of a source statement (first line and continuation lines) is only limited by the amount of available memory.

Mnemonics and directives are case insensitive. Labels, symbols, directive arguments, and literal strings are case sensitive.

The syntax of an assembly *statement* is:

[*label*[**:**]] [*instruction* | *directive* | *macro_call*] [**;***comment*]

*label* A label is a special symbol which is assigned the value and type of the current program location counter. A label can consist of letters, digits and underscore characters (_). The first character cannot be a digit. A label which is prefixed by whitespace (spaces or tabs) has to be followed by a colon (:). The size of an identifier is only limited by the amount of available memory.

Examples:

```
    LAB1:  ; This label is followed by a colon and
           ; can be prefixed by whitespace
LAB1       ; This label has to start at the beginning
           ; of a line
```

*instruction* An instruction consists of a mnemonic and zero, one or more operands. It must not start in the first column.

Operands are described in section 3.3, *Operands of an Assembly Instruction*. The instructions are described in the target's *Core Reference Manual*.

The instruction can also be a so-called 'generic instruction'. Generic instructions are pseudo instructions (no instructions from the instruction set). Depending on the situation in which a generic instruction is used, the assembler replaces the generic instruction with appropriate real assembly instruction(s). For a complete list, see section 3.10, *Generic Instructions*.

*directive* With directives you can control the assembler from within the assembly source. Except for preprocessing directives, these must not start in the first column. Directives are described in section 3.8, *Assembler Directives*.

*macro_call* A call to a previously defined macro. It must not start in the first column. See section 3.9 *Macro Operations*.

*comment* Comment, preceded by a ; (semicolon).

You can use empty lines or lines with only comments.

## 3.2 Assembler Significant Characters

You can use all ASCII characters in the assembly source both in strings and in comments. Also the extended characters from the ISO 8859-1 (Latin-1) set are allowed.

Some characters have a special meaning to the assembler. Special characters associated with expression evaluation are described in section 3.6.3, *Expression Operators*. Other special assembler characters are:

| Character | Description |
|---|---|
| ; | Start of a comment |
| \ | Line continuation character or<br>Macro operator: argument concatenation |
| ? | Macro operator: return decimal value of a symbol |
| % | Macro operator: return hex value of a symbol |
| ^ | Macro operator: override local label |
| " | Macro string delimiter or<br>Quoted string **.DEFINE** expansion character |
| ' | String constants delimiter |
| @ | Start of a built-in assembly function |
| $ | Location counter substitution |
| [ ] | Substring delimiter |
| # | Immediate addressing (TSK51x/TSK52x) |

Note that macro operators have a higher precedence than expression operators.

## 3.3 Operands of an Assembly Instruction

In an instruction, the mnemonic is followed by zero, one or more operands. An operand has one of the following types:

| Operand | Description |
|---|---|
| *symbol* | A symbolic name as described in section 3.4, *Symbol Names*. Symbols can also occur in expressions. |
| *register* | Any valid register as listed in section 3.5, *Registers*. |
| *expression* | Any valid expression as described in section 3.6, *Assembly Expressions*. |
| *address* | A combination of *expression*, *register* and *symbol*. |

## 3.4 Symbol Names

### *User-defined symbols*

A user-defined *symbol* can consist of letters, digits and underscore characters (_). The first character cannot be a digit. The size of an identifier is only limited by the amount of available memory. The case of these characters is significant. You can define a symbol by means of a label declaration or an equate or set directive.

### *Labels*

Symbols used for memory locations are referred to as labels.

### *Reserved symbols*

Symbol names and other identifiers beginning with a period (.) are reserved for the system (for example for directives or section names). Instructions and names of core processor registers are also reserved. The case of these built-in symbols is insignificant.

#### Examples

Valid symbol names:

```
loop_1
ENTRY
a_B_c
_aBC
```

Invalid symbol names:

| | |
|---|---|
| `1_loop` | (starts with a number) |
| `.DEFINE` | (reserved directive name) |
| `R0` | (reserved register name) |

## 3.5 Registers

The following register names, either upper or lower case, should not be used for user-defined symbol names in an assembly language source file:

#### TSK51x/TSK52x registers

```
A    C    DPTR R0   R1   R2   R3   R4   R5   R6   R7
```

The following special function registers should also not be used as symbol names in an assembly language source file. However it is allowed to redefine them.

#### TSK51x/TSK52x special function registers

```
AR0  AR1  AR2  AR3  AR4  AR5  AR6  AR7

ACC  B    DPH  DPL  PSW  SP

AC   CY   F0   F1   P    OV   RS0  RS1
```

## 3.6 Assembly Expressions

An expression is a combination of symbols, constants, operators, and parentheses which represent a value that is used as an operand of an assembler instruction (or directive).

Expressions may contain user-defined labels (and their associated integer values), and any combination of integers or ASCII literal strings.

Expressions follow the conventional rules of algebra and boolean arithmetic.

Expressions that can be evaluated at assembly time are called *absolute expressions*. Expressions where the result is unknown until all sections have been combined and located, are called *relocatable* or *relative expressions*.

When any operand of an expression is relocatable, the entire expression is relocatable. Relocatable expressions are emitted in the object file and evaluated by the linker.

The assembler evaluates expressions with 64-bit precision in two's complement.

The syntax of an *expression* can be any of the following:

- *numeric contant*
- *string*
- *symbol*
- *expression binary_operator expression*
- *unary_operator expression*
- **(** *expression* **)**
- *function call*

All types of expressions are explained in separate sections.

### 3.6.1 Numeric Constants

Numeric constants can be used in expressions. If there is no prefix, by default the assembler assumes the number is a decimal number.

| Base | Description | Example |
|---|---|---|
| Binary | A **0b** prefix followed by binary digits (0,1). Or use a **b** suffix | `0b1101`<br>`11001010b` |
| Hexadecimal | A **0x** prefix followed by a hexadecimal digits (0–9, A–F, a–f). Or use a **h** suffix | `0x12FF`<br>`0x45`<br>`0fa10h` |
| Decimal, integer | Decimal digits (0–9). | `12`<br>`1245` |

*Table 3–1: Numeric constants*

### 3.6.2 Strings

ASCII characters, enclosed in single (') or double (") quotes constitue an ASCII string. Strings between double quotes allow symbol substitution by a `.DEFINE` directive, whereas strings between single quotes are always literal strings. Both types of strings can contain escape characters.

Strings constants in expressions are evaluated to a number (each character is replaced by its ASCII value). Strings in expressions can have a size of up to 4 characters or less depending on the operand of an instruction or directive; any subsequent characters in the string are ignored. In this case the assembler issues a warning. An exception to this rule is when a string is used in a `.DB`, `.DH`, `.DW` or `.DL` assembler directive; in that case all characters result in a constant value of the specified size. Null strings have a value of 0.

Square brackets (**[ ]**) delimit a substring operation in the form:

**[***string*,*offset*,*length***]**

*offset* is the start position within *string*. *length* is the length of the desired substring. Both values may not exceed the size of *string*.

#### Examples

```
'ABCD'              ; (0x41424344)
'''79'              ; to enclose a quote double it
"A\"BC"             ; or to enclose a quote escape it
'AB'+1              ; (0x4143) string used in expression
''                  ; null string
['TASKING',0,4]     ; results in the substring 'TASK'
```

### 3.6.3 Expression Operators

The next table shows the assembler operators. They are ordered according to their precedence. Operators of the same precedence are evaluated left to right. Parenthetical expressions have the highest priority (innermost first).

Valid operands include numeric constants, literal ASCII strings and symbols.

| Type | Operator | Name | Description |
|---|---|---|---|
| | ( ) | parenthesis | Expressions enclosed by parenthesis are evaluated first. |
| Unary | + | plus | Returns the value of its operand. |
| | – | minus | Returns the negative of its operand. |
| | ~ | complement | Returns complement, integer only |
| | ! | logical negate | Returns 1 if the operands' value is 0; otherwise 0. For example, if `buf` is 0 then `!buf` is 1. |

| Type | Operator | Name | Description |
|---|---|---|---|
| Arithmetic | * | multiplication | Yields the product of two operands. |
| | / | division | Yields the quotient of the division of the first operand by the second. With integers, the divide operation produces a truncated integer. |
| | % | modulo | Integer only: yields the remainder from a division of the first operand by the second. |
| | + | addition | Yields the sum of its operands. |
| | – | subtraction | Yields the difference of its operands. |
| Shift | << | shift left | Integer only: shifts the left operand to the left (zero-filled) by the number of bits specified by the right operand. |
| | >> | shift right | Integer only: shifts the left operand to the right (sign bit extended) by the number of bits specified by the right operand. |
| Relational | < | less than | Returns: an integer 1 if the indicated condition is TRUE. an integer 0 if the indicated condition is FALSE. |
| | <= | less or equal | |
| | > | greater than | |
| | >= | greater or equal | |
| | == | equal | |
| | != | not equal | |
| Bitwise | & | AND | Integer only: yields bitwise AND |
| | \| | OR | Integer only: yields bitwise OR |
| | ^ | exclusive OR | Integer only: yields bitwise exlusive OR |
| Logical | && | logical AND | Returns an integer 1 if both operands are non-zero; otherwise, it returns an integer 0. |
| | \|\| | logical OR | Returns an integer 1 if either of the operands is non-zero; otherwise, it returns an integer 1 |
| Dot | . | Dot | Singles out a bit number using the syntax: *byte*.*bitpos* |

*Table 3-2: Assembly expression operators*

## 3.7 Built-in Assembly Functions

The TASKING assemblers have several built-in functions to support data conversion, string comparison, and math computations. You can use functions as terms in any expression.

### *Syntax of an assembly function*

*@function_name*(**[***argument*[,*argument*]...]**)**

Functions start with '@' character and have zero or more arguments, and are always followed by opening and closing parentheses. White space (a blank or tab) is not allowed between the function name and the opening parenthesis and between the (comma-separated) arguments.

### 3.7.1 Overview of Built-in Assembly Functions

The following table provides an overview of all built-in assembly functions. Next all functions are described into more detail. *expr* can be any assembly expression resulting in an integer value. Expressions are explained in section 3.6, *Assembly Expressions*.

### *Overview of assembly functions*

| Function | Description |
|---|---|
| `@ARG('symbol'|expr)` | Test whether macro argument is present |
| `@CAST(type,expr)` | Cast result of *expr* to *type* |
| `@CNT()` | Return number of macro arguments |

| Function | Description |
|---|---|
| `@CPU(`*`string`*`)` | Test if current CPU matches *string* |
| `@DEFINED('`*`symbol`*`'`\|*`symbol`*`)` | Test whether *symbol* exists |
| `@LSB(`*`expr`*`)` | Least significant byte of the expression |
| `@LSW(`*`expr`*`)` | Least significant word of the expression |
| `@MSB(`*`expr`*`)` | Most significant byte of the expression |
| `@MSW(`*`expr`*`)` | Most significant word of the expression |
| `@STRCAT(`*`str1`*`,`*`str2`*`)` | Concatenate *str1* and *str2* |
| `@STRCMP(`*`str1`*`,`*`str2`*`)` | Compare *str1* with *str2* |
| `@STRLEN(`*`str`*`)` | Return length of string |
| `@STRPOS(`*`str1`*`,`*`str2`*`[,`*`start`*`])` | Return position of *str1* in *str2* |

## 3.7.2 Detailed Description of Built-in Assembly Functions

### @ARG('symbol' | expression)

Returns integer 1 if the macro argument represented by *symbol* or *expression* is present, 0 otherwise.

You can specify the argument with a *symbol* name (the name of a macro argument enclosed in single quotes) or with *expression* (the ordinal number of the argument in the macro formal argument list).

If you use this function when macro expansion is not active, the assembler issues a warning.

Example:

```
.IF @ARG('TWIDDLE') ;is argument twiddle present?
.IF @ARG(1)         ;is first argument present?
```

### @CAST(type,expression)

Returns the result of *expression*, but with the specified *type*.

This function can be useful when you assemble with expression type-checking enabled (option **--type-checking**), and the assembler reports a type conflict. You can then cast the expression to the correct type.

The following types are allowed:

data, sfr, idata, bit, bdata, xdata, pdata, code, sfrbit, bsfr, byte, word, dword

### @CNT()

Returns the number of macro arguments of the current macro expansion as an integer.

If you use this function when macro expansion is not active, the assembler issues a warning.

Example:

```
ARGCOUNT .SET @CNT() ; reserve argument count
```

### @CPU('processor_type')

With the `@CPU` function you can check whether the source code is being assembled for a certain processor type. The function evaluates to TRUE when the specified *processor_type* matches the processor type that was specified with the option **--cpu**=*cpu*.

This function is useful to create conditional code for several targets as shown in the example.

Example:

```
.IF @CPU('tsk51a')    ; true if you specified option --cpu=tsk51a
 ... ; code for the TSK51A
.ELIF @CPU('tsk52a')  ; true if you specified option --cpu=tsk52a
 ... ; code for the TSK52A
.ELSE
 ... ; code for other processor types
.ENDIF
```

C compiler option **--cpu** (Select CPU) in section 4.1, *C Compiler Options*, of Chapter *Tool Options*.

### *@DEFINED('symbol' | symbol)*

Returns 1 if *symbol* has been defined, 0 otherwise. If *symbol* is quoted, it is looked up as a `.DEFINE` symbol; if it is not quoted, it is looked up as an ordinary symbol, macro or label.

Example:

```
.IF @DEFINED('ANGLE')            ;is symbol ANGLE defined?
.IF @DEFINED(ANGLE)              ;does label ANGLE exist?
```

### *@LSB(expression)*

Returns the *least* significant byte of the result of the *expression*.
The result of the expression is calculated as 16 bits.

### *@LSW(expression)*

Returns the *least* significant word (bits 0..15) of the result of the *expression*.
The result of the expression is calculated as a long (32 bits).

### *@MSB(expression)*

Returns the *most* significant byte of the result of the *expression*.
The result of the expression is calculated as16 bits.

### *@MSW(expression)*

Returns the *most* significant word (bits 16..31) of the result of the *expression*.
The result of the expression is calculated as a long (32 bits).

### *@STRCAT(string1,string2)*

Concatenates *string1* and *string2* and returns them as a single string.
You must enclose *string1* and *string2* either with single quotes or with double quotes.

Example:

```
.DEFINE ID "@STRCAT('TAS','KING')"  ; ID = 'TASKING'
```

### *@STRCMP(string1,string2)*

Compares *string1* with *string2* by comparing the characters in the string. The function returns the difference between the characters at the first position where they disagree, or zero when the strings are equal:

- <0 if *string1* < *string2*
- 0 if *string1* == *string2*
- >0 if *string1* > *string2*

Example:

```
.IF (@STRCMP(STR,'MAIN'))==0  ; does STR equal 'MAIN'?
```

### @STRLEN(*string*)

Returns the length of *string* as an integer.

Example:

```
SLEN SET @STRLEN('string')    ; SLEN = 6
```

### @STRPOS(*string1*,*string2*[,*start*])

Returns the position of *string2* in *string1* as an integer. If *string2* does not occur in *string1*, the last string postition + 1 is returned.

With *start* you can specify the starting position of the search. If you do not specify start, the search is started from the beginning of *string1*.

Example:

```
ID .set @STRPOS('TASKING','ASK')  ; ID = 1
ID .set @STRPOS('TASKING','BUG')  ; ID = 7
```

# 3.8 Assembler Directives

An assembler directive is simply a message to the assembler. Assembler directives are not translated into machine instructions, but can produce data. There are three types of assembler directives.

- Assembler directives that tell the assembler how to go about translating instructions into machine code. This is the most typical form of assembly directives. Typically they tell the assembler where to put a program in memory, what space to allocate for variables, and allow you to initialize memory with data. When the assembly source is assembled, a location counter in the assembler keeps track of where the code and data is to go in memory.

  The following directives fall under this group:

  - Assembly control directives
  - Symbol definition directives
  - Data definition / Storage allocation directives
  - HLL directives
- Directives that are interpreted by the macro preprocessor. These directives tell the macro preprocessor how to manipulate your assembly code before it is actually being assembled. You can use these directives to write macros and to write conditional source code. Parts of the code that do not match the condition, will not be assembled at all. Unlike other directives, preprocesssor directives can start in the first column.
- Some directives act as assembler options and most of them indeed do have an equivalent assembler (command line) option. The advantage of using a directive is that with such a directive you can overrule the assembler option for a particular part of the code. A typical example is to tell the assembler with an option to generate a list file while with the directives `.NOLIST` and `.LIST` you overrule this option for a part of the code that you do *not* want to appear in the list file. Directives of this kind sometimes are called *controls*.

Each assembler directive has its own syntax. Some assembler directives can be preceded with a label. If you do not precede an assembler directive with a label, you must use white space instead (spaces or tabs). You can use assembler directives in the assembly code as pseudo instructions.

## 3.8.1 Overview of Assembler Directives

The following tables provide an overview of all assembler directives. For a detailed description of these directives, refer to section 3.8.2, *Detailed Description of Assembler Directives*.

### *Overview of assembly control directives*

| Directive | Description |
|---|---|
| .END | Indicates the end of an assembly module |
| .INCLUDE | Include file |
| .MESSAGE | Programmer generated message |

### *Overview of symbol definition directives*

| Directive | Description |
|---|---|
| .EQU | Set permanent value to a symbol |
| .EXTERN | Import global section symbol |
| .GLOBAL | Declare global section symbol |
| .LABEL | Define a label of specified type |
| .RESUME | Resume a previously defined section |
| .SECTION | Start a new section |
| .SET | Set temporary value to a symbol |
| .WEAK | Mark a symbol as 'weak' |

### *Overview of data definition / storage allocation directives*

| Directive | Description |
|---|---|
| .ALIGN | Align location counter |
| .BS/.BSBIT/.BSB/ .BSW/.BSL | Define block storage (initialized) |
| .DBIT | Define bit |
| .DB | Define byte |
| .DH | Define half word |
| .DW | Define word |
| .DL | Define long word |
| .DS/.DSBIT/.DSB/ .DSW/.DSL | Define storage |
| .OFFSET | Move location counter forwards |

### *Overview of macro and conditional assembly directives*

| Directive | Description |
|---|---|
| .DEFINE | Define substitution string |
| .BREAK | Break out of current macro expansion |
| .REPEAT/.ENDREP | Repeat sequence of source lines |
| .FOR/.ENDFOR | Repeat sequence of source lines *n* times |
| .IF/.ELIF/.ELSE | Conditional assembly directive |
| .ENDIF | End of conditional assembly directive |
| .MACRO/.ENDM | Define macro |
| .UNDEF | Undefine .DEFINE symbol or macro |

### *Overview of listing control assembly directives*

| Directive | Description |
|---|---|
| .LIST/.NOLIST | Print / do not print source lines to list file |
| .PAGE | Set top of page/size of page |
| .TITLE | Set program title in header of assembly list file |

### *Overview of HLL directives*

| Directive | Description |
|---|---|
| `.CALLS` | Pass call tree information |
| `.SYMB` | Generate symbolic debug information |

### *TSK51x/TSK52x specific directive*

| Directive | Description |
|---|---|
| `.REGISTERBANK` | Use register bank |

## 3.8.2 Detailed Description of Assembler Directives

## .ALIGN

#### Syntax

**.ALIGN** *expression*

#### Description

With the `.ALIGN` directive you tell the assembler to align the location counter.

When the assembler encounters the `.ALIGN` directive, it moves the location counter forwards to an address that is aligned as specified by *expression* and places the next instruction or directive on that address. The alignment is in minimal addressable units (MAUs). The assembler fills the 'gap' with NOP instructions. If the location counter is already aligned on the specified alignment, it remains unchanged. The location of absolute sections will not be changed.

The *expression* must be a power of two: 2, 4, 8, 16, ... If you specify another value, the assembler changes the alignment to the next higher power of two and issues a warning.

In bit-type sections *expression* is in number of bits.

#### Examples

```
.SECTION code, code
.ALIGN 16      ; the assembler aligns
instruction    ; this instruction at 16 MAUs and
               ; fills the 'gap' with NOP instructions.

.SECTION code, code
.ALIGN 12      ; WRONG: not a power of two, the
instruction    ; assembler aligns this instruction at
               ; 16 MAUs and issues a warning.
```

## .BREAK

### Syntax

**.BREAK**

### Description

The .BREAK directive causes immediate termination of a macro expansion, a .FOR loop exansion or a .REPEAT loop expansion. In case of nested loops or macros, the .BREAK directive returns to the previous level of expansion.

The .BREAK directive is, for example, useful in combination with the .IF directive to terminate expansion when error conditions are detected.

### Example

```
.FOR MYVAR IN 10 TO 20
  ...   ;
  ...   ; assembly source lines
  ...   ;
  .IF MYVAR > 15
    .BREAK
  .ENDIF
.ENDREP
```

## .BS/.BSBIT/.BSB/.BSH/.BSW/.BSL

### Syntax

[*label*] .**BS** *expression1* [,*expression2*]

[*label*] .**BSBIT** *expression1* [,*expression2*]

[*label*] .**BSB** *expression1* [,*expression2*]

[*label*] .**BSH** *expression1* [,*expression2*]

[*label*] .**BSW** *expression1* [,*expression2*]

[*label*] .**BSL** *expression1* [,*expression2*]

### Description

With the `.BS` directive (Block Storage) the assembler reserves a block of memory. The reserved block of memory is initialized to the value of *expression2*, or zero if omitted.

With *expression1* you specify the number of minimum addressable units (MAUs) you want to reserve, and how much the location counter will advance. The expression must be an integer greater than zero and cannot contain any forward references to address labels (labels that have not yet been defined).

In a bit-type section, the MAU size is 1, the `.BS` directive initializes a number of bits equal to the result of the expression.

With *expression2* you can specify a value to initialize the block with. Only the least significant MAU of *expression2* is used. If you omit *expression2*, the default is zero.

If you specify *label*, it gets the value of the location counter at the start of the directive processing.

Initialization of a block of memory only happens in sections with section attribute `init` or `romdata`. In other sections, the assembler issues a warning and only reserves space, just as with `.DS`.

The `.BSBIT`, `.BSB`, `.BSH`, `.BSW` and `.BSL` directives are variants of the `.BS` directive:

**.BSBIT** The *expression1* argument specifies the number of bits to reserve. You can only use this directive in sections of type `bit`.

**.BSB** The *expression1* argument specifies the number of bytes to reserve. In a bit-type section, the `.BSB` directive still initializes 8 bits.

**.BSH** Same as the `.BSB` directive.

**.BSW** The *expression1* argument specifies the number of words to reserve (one word is 16 bits). In a bit-type section, the `.BSW` directive still initializes 16 bits.

**.BSL** The *expression1* argument specifies the number of longs to reserve (one long is 32 bits). In a bit-type section, the `.BSL` directive still initializes 32 bits.

### Example

The `.BSB` directive is for example useful to define and initialize an array that is only partially filled:

```
.section data, data, init
.DB 84,101,115,116   ; initialize 4 bytes
.BSB 96,0xFF         ; reserve another 96 bytes, initialized with 0xFF
```

### Related information

**.DS** (Define Storage)

# .CALLS

### Syntax

**.CALLS** '*caller*', '*callee*'

### Description

With this directive you indicate that a function *caller* calls another function *callee*.

Normally `.CALLS` directives are automatically generated by the compiler. Use the `.CALLS` directive in hand coded assembly when the assembly code calls a C function. If you manually add `.CALLS` directives, make sure they connect to the compiler generated `.CALLS` directives: the name of the caller must also be named as a callee in another directive.

The linker uses the `.CALLS` information to build a call graph. The call graph then is used to create a static stack overlay.

### Example

```
.SECTION _func, data, overlay('stack_data')
.SECTION _main, data, overlay('stack_data')

.CALLS '_main','_nfunc'
```

Indicates that the function `_main` calls the function `_nfunc`

# .DB

### Syntax

[*label*] .**DB** *argument*[,*argument*]...

### Description

With the `.DB` directive (Define Byte) the assembler allocates and initializes one byte of memory for each *argument*.

An *argument* can be:

- a single or multiple character string constant
- an integer expression
- NULL (indicated by two adjacent commas: ,,)

If you specify *label*, it gets the value of the location counter at the start of the directive processing.

Multiple arguments are stored in successive address locations. If an argument is NULL, its corresponding address location is flled with zeros.

Integer arguments are stored as is, but must be byte values (within the range 0–255); floating–point numbers are not allowed. If the evaluated expression is out of the range [–256, +255] the assembler issues an error. For negative values within that range, the assembler adds 256 to the specified value (for example, –254 is stored as 2).

In case of single and multiple character strings, each character is stored in consecutive bytes whose lower seven bits represent the ASCII value of the character. The standard C escape sequences are allowed:

```
.DB 'R'         ; = 0x52
.DB 'AB',,'D'   ; = 0x41420043  (second argument is empty)
```

When you use the `.DB` directive in a bit–type section, each argument initializes 8 bits, and the location counter of the current section is incremented with 8 bits.

### Example

```
TABLE:  .DB 14,253,0x62,'ABCD'
CHARS:  .DB 'A','B',,'C','D'
```

### Related information

**.BS** (Block Storage)
**.DS** (Define Storage)
**.DBIT** (Define Bit)
**.DH** (Define Half Word)
**.DW** (Define Word)
**.DL** (Define Long)

# .DBIT

### Syntax

[*label*] .**DBIT** *argument*[,*argument*]...

### Description

With the `.DBIT` directive (Define Bit) you allocate and initialize memory in bit units for each *argument*.

You can use the `.DBIT` directive only within sections of the type `bit`.

An *argument* is 0 or 1.

If you specify *label*, it gets the value of the location counter at the start of the directive processing.

### Example

```
NBITS:  .DBIT 1,0,1,1    ; allocate and initialize four bits
```

### Related information

**.BS** (Block Storage)
**.DS** (Define Storage)
**.DB** (Define Byte)
**.DH** (Define Half Word)
**.DW** (Define Word)
**.DL** (Define Long)
**.SECTION** (Start a new section)

## .DEFINE

**Syntax**

.**DEFINE** *symbol string*

**Description**

With the `.DEFINE` directive you define a substitution string that you can use on all following source lines. The assembler searches all succeeding lines for an occurrence of *symbol*, and replaces it with *string*. If the *symbol* occurs in a double quoted string it is also replaced. Strings between single quotes are not expanded.

This directive is useful for providing better documentation in the source program. A *symbol* can consist of letters, digits and underscore characters (_), and the first character cannot be a digit.

The assembler issues a warning if you redefine an existing symbol.

**Example**

Suppose you defined the symbol `LEN` with the substitution string ”32”:

```
.DEFINE LEN ”32”
```

Then you can use the symbol `LEN` for example as follows:

```
.DS LEN
.MESSAGE I ”The length is: LEN”
```

The assembler preprocessor replaces `LEN` with “32” and assembles the following lines:

```
.DS 32
.MESSAGE I ”The length is: 32”
```

**Related information**

**.UNDEF** (Undefine a .DEFINE symbol or macro)
**.MACRO/.ENDM** (Define a macro)

# .DH

### Syntax

[*label*] .**DH** *argument*[,*argument*]...

### Description

With the `.DH` directive (Define Half Word) you allocate and initialize a half word of memory for each *argument*.

A half word is 8 bits (byte), so the `.DH` directive is the same as the `.DB` directive.

An *argument* is:

- a single or multiple character string constant
- an expression
- NULL (indicated by two adjacent commas: ,,)

If you specify *label*, it gets the value of the location counter at the start of the directive processing.

Multiple arguments are stored in successive half word address locations. If an argument is NULL, its corresponding address location is filled with zeros.

Integer arguments are stored as is, but must be byte values (within the range 0–255); floating-point numbers are not allowed. If the evaluated expression is out of the range [-256, +255] the assembler issues an error. For negative values within that range, the assembler adds 256 to the specified value (for example, -254 is stored as 2).

In case of single and multiple character strings, each character is stored in consecutive bytes whose lower seven bits represent the ASCII value of the character. The standard C escape sequences are allowed:

```
.DH 'AB',,'D' => 0x41
                 0x42
                 0x00 (second argument is empty)
                 0x44
```

When you use the `.DH` directive in a bit-type section, each argument initializes 8 bits, and the location counter of the current section is incremented with the same number of bits.

### Example

```
TABLE:  .DH 14,253,0x62,'ABCD'
CHARS:  .DH 'A','B',,'C','D'
```

### Related information

**.BS** (Block Storage)
**.DS** (Define Storage)
**.DBIT** (Define Bit)
**.DB** (Define Byte)
**.DW** (Define Word)
**.DL** (Define Long)

# .DL

### Syntax

[*label*] .**DL** *argument*[,*argument*]...

### Description

With the `.DL` directive (Define Long) you allocate and initialize four bytes of memory for each *argument*.

An *argument* is:

- a single or multiple character string constant
- an expression
- NULL (indicated by two adjacent commas: ,,)

If you specify *label*, it gets the value of the location counter at the start of the directive processing.

Multiple arguments are stored in sets of four bytes. If an argument is NULL, its corresponding address locations are flled with zeros.

Long arguments are stored as is. Floating-point values are not allowed.

If the evaluated argument is too large to be represented in a long, the assembler issues an error and truncates the value.

In case of character strings, each character is stored in the least significant byte of a long whose lower seven bits represent the ASCII value of the character:

```
.DL 'AB',,'D' => 0x00000041
                 0x00000042
                 0x00000000  (second argument is empty)
                 0x00000044
```

When you use the `.DL` directive in a bit-type section, each argument initializes 32 bits, and the location counter of the current section is incremented with the same number of bits.

### Example

```
TABLE:  .DL 14,253,0x62,'ABCD'
CHARS:  .DL 'A','B',,'C','D'
```

### Related information

**.BS** (Block Storage)
**.DS** (Define Storage)
**.DBIT** (Define Bit)
**.DB** (Define Byte)
**.DH** (Define Half Word)
**.DW** (Define Word)

## .DS/.DSBIT/.DSB/.DSH/.DSW/.DSL

### Syntax

[*label*] **.DS** *expression*

[*label*] **.DSBIT** *expression*

[*label*] **.DSB** *expression*

[*label*] **.DSH** *expression*

[*label*] **.DSW** *expression*

[*label*] **.DSL** *expression*

### Description

With the `.DS` directive (Define Storage) the assembler reserves a block of memory. The reserved block of memory is not initialized to any value.

With the *expression* you specify the number of minimum addressable units (MAUs) that you want to reserve. The expression must evaluate to an integer larger than zero and cannot contain references to symbols that are not yet defined in the assembly source.

In a bit-type section, the MAU size is 1, the `.DS` directive reserves a number of bits equal to the result of the expression.

If you specify *label*, it gets the value of the location counter at the start of the directive processing.

You cannot use the `.DS` directive in sections with attribute `init`. If you need to reserve *initialized* space in an init section, use the `.BS` directive instead.

The `.DSBIT`, `.DSB`, `.DSH`, `.DSW` and `.DSL` directives are variants of the `.DS` directive:

**.DSBIT** The *expression* argument specifies the number of bits to reserve.

**.DSB** The *expression* argument specifies the number of bytes to reserve. In a bit-type section, the `.DSB` directive still reserves 8 bits.

**.DSH** Same as the `.DSB` directive.

**.DSW** The *expression* argument specifies the number of words to reserve (one word is 16 bits). In a bit-type section, the `.DSW` directive still reserves16 bits.

**.DSL** The *expression* argument specifies the number of longs to reserve (one long is 32 bits). In a bit-type section, the `.DSL` directive still reserves 32 bits.

### Example

```
RES:  .DS 5+3   ; allocate 8 bytes
```

### Related information

**.BS** (Block Storage)
**.DBIT** (Define Bit)
**.DB** (Define Byte)
**.DH** (Define Half Word)
**.DW** (Define Word)
**.DL** (Define Long)

# .DW

### Syntax

[*label*] .**DW** *argument*[,*argument*]...

### Description

With the `.DW` directive (Define Word) you allocate and initialize one word of memory for each *argument*.

One word is 16 bits.

An *argument* is:

- a single or multiple character string constant
- an expression
- NULL (indicated by two adjacent commas: ,,)

If you specify *label*, it gets the value of the location counter at the start of the directive processing.

Multiple arguments are stored in sets of two bytes. If an argument is NULL, its corresponding address locations are flled with zeros.

Word arguments are stored as is. Floating-point values are not allowed. If the evaluated argument is too large to be represented in a word, the assembler issues a warning and truncates the value.

In case of character strings, each character is stored in the least significant byte of a word which represents the ASCII value of the character:

```
.DW 'AB',,'D' => 0x0041
                 0x0042
                 0x0000  (second argument is empty)
                 0x0044
```

When you use the `.DW` directive in a bit-type section, each argument initializes 16 bits, and the location counter of the current section is incremented with the same number of bits.

### Example

```
TABLE:  .DW 14,253,0x62,'ABCD'
CHARS:  .DW 'A','B',,'C','D'
```

### Related information

**.BS** (Block Storage)
**.DS** (Define Storage)
**.DBIT** (Define Bit)
**.DB** (Define Byte)
**.DH** (Define Half Word)
**.DL** (Define Long)

## .END

**Syntax**

**.END**

**Description**

With the `.END` directive you tell the assembler that the end of the module is reached. If the assembler finds assembly source lines beyond the `.END` directive, it ignores those lines and issues a warning.

**Example**

```
.section code, code
   ; source lines
.END                  ; End of assembly module
```

## .EQU

**Syntax**

*symbol* **.EQU** *expression*

**Description**

With the `.EQU` directive you assign the value of *expression* to *symbol* permanently. Once defined, you cannot redefine the *symbol*. With the `.GLOBAL` directive you can define the symbol global.

The *expression* can either be absolute or relocatable and cannot contain forward references. Normally, the defined symbol gets the same type as the result of the expression. However, when the resulting expression has type “none” the symbol gets no type when the `.EQU` is used outside a section and it gets the type of the section when it is defined inside a section.

**Example**

```
MYSYMBOL1 .EQU  0x4000 ; gets no type

          .SECTION code, code
_START:
          .SECTION data, data
MYSYMBOL2 .EQU  0x4100 ; gets type data

MYSYMBOL3 .EQU _START  ; gets type of the expression:
                       ; because _START is defined in
                       ; a section with type CODE, the
                       ; symbol gets type CODE.
          .END
```

You cannot redefine the used symbols.

**Related information**

**.SET** (Set temporary value to a symbol)

# .EXTERN

### Syntax

**.EXTERN** *symbol* [:*type*] [,*symbol* [:*type*]]...

### Description

With the `.EXTERN` directive you define an *external* symbol. It means that the symbol is referenced in the current module while it is defined outside the current module.

You must define the symbols either outside any module or declare it as globally accessible within another module with the `.GLOBAL` directive.

The type of the global symbol which is referenced with the `.EXTERN` directive is determined from its definition. The assembler then uses the *type* information of the `.EXTERN` directive to check the symbol's use: if the symbol does not fit the instruction's operand, the assembler issues a warning.

If you do not specify *type*, the assembler does not check the use of the specified symbol.

Each target has a specific set of types as described in the **.SECTION** (Start a new section) directive.

If you do not use the `.EXTERN` directive and the symbol is not defined within the current module, the assembler issues a warning and inserts the `.EXTERN` directive.

### Example

```
.EXTERN  AA,CC,DD  ; defined elsewhere

.EXTERN  AA:DATA   ; assembler checks for type
```

### Related information

**.GLOBAL** (Declare global section symbol)

## .FOR/.ENDFOR

**Syntax**

[*label*] **.FOR** *var* **IN** *expression*[,*expression*]...
....
**.ENDFOR**

or:

[*label*] **.FOR** *var* **IN** *start* **TO** *end* [**STEP** *step*]
....
**.ENDFOR**

**Description**

With the `.FOR/.ENDFOR` directive you can repeat a sequence of assembly source lines with an iterator. As shown by the syntax, you can use the `.FOR/.ENDFOR` in two ways.

1. In the first mehod, the loop is repeated as many times as the number of arguments following `IN`. If you use the symbol *var* in the assembly lines between `.FOR` and `.ENDFOR`, for each repetition the symbol *var* is substituted by a subsequent *expression* from the argument list. If the argument is a null, then the loop is repeated with each occurrence of the symbol *var* removed.
2. In the second method, the loop is repeated using the symbol *var* as a counter. The counter passes all integer values from *start* to *end* with a *step*. If you do not specify *step*, the counter is increased by one for every repetition.

If you specify *label*, it gets the value of the location counter at the start of the directive processing.

**Example**

In the following example the loop is repeated 4 times (there are four arguments). With the `.DB` directive you allocate and initialize a byte of memory for each repetition of the loop (a word for the `.DW` directive). Effectively, the preprocessor duplicates the `.DB` and `.DW` directives four times in the assembly source.

```
.FOR VAR1 IN 1,2+3,4,12
     .DB VAR1
     .DW (VAR1*VAR1)
.ENDFOR
```

In the following example the loop is repeated 16 times. With the `.DL` directive you allocate and initialize four bytes of memory for each repetition of the loop. Effectively, the preprocessor duplicates the `.DL` directive16 times in the assembled file, and substitutes `VAR2` with the subsequent numbers.

```
.FOR VAR2 IN 1 to 0x10
     .DL (VAR1*VAR1)
.ENDFOR
```

**Related information**

**.REPEAT/.ENDREP** (Repeat sequence of source lines)

# .GLOBAL

### Syntax

**.GLOBAL** *symbol*[,*symbol*]...

### Description

All symbols or labels defined in the current section or module are local to the module by default. You can change this default behavior with assembler option **–ig**.

With the `.GLOBAL` directive you declare one of more symbols as global. It means that the specified symbols are defined within the current section or module, and that those definitions should be accessible by all modules.

The type of the global defined symbol is determined by its definition.

To access a symbol, defined with `.GLOBAL`, from another module, use the `.EXTERN` directive.

Only program labels and symbols defined with `.EQU` can be made global.

### Example

```
LOOPA .EQU 1          ; definition of symbol LOOPA
      .GLOBAL  LOOPA  ; LOOPA will be globally
                      ; accessible by other modules
```

### Related information

**.EXTERN** (Import global section symbol)

# .IF/.ELIF/.ELSE/.ENDIF

### Syntax

**.IF** *expression*
.
.
[**.ELIF** *expression*] (the `.ELIF` directive is optional)
.
.
[**.ELSE**] (the `.ELSE` directive is optional)
.
.
**.ENDIF**

### Description

With the `.IF/.ENDIF` directives you can create a part of conditional assembly code. The assembler assembles only the code that matches a specified condition.

The *expression* must evaluate to an integer and cannot contain forward references. If *expression* evaluates to zero, the IF-condition is considered FALSE, any non-zero result of *expression* is considered as TRUE.

You can nest `.IF` directives to any level. The `.ELSE` and `.ELIF` directive always refer to the nearest previous `.IF` directive.

### Example

Suppose you have an assemble source file with specific code for a test version, for a demo version and for the final version. Within the assembly source you define this code conditionally as follows:

```
.IF   TEST
... ; code for the test version
.ELIF DEMO
... ; code for the demo version
.ELSE
... ; code for the final version
.ENDIF
```

Before assembling the file you can set the values of the symbols `TEST` and `DEMO` in the assembly source before the `.IF` directive is reached. For example, to assemble the demo version:

```
TEST .SET 0
DEMO .SET 1
```

You can also define the symbols in Altium Designer as preprocessor macros in dialog **Project** » **Project Options** » **Assembler** » **Preprocessing** (assembler option **--define**).

### Related information

Assembler option **--define** (Define preprocessor macro) in Section 4.2, *Assembler Options*, of Chapter *Tool Options*.

# .INCLUDE

### Syntax

**.INCLUDE** "*filename*" | <*filename*>

### Description

With the `.INCLUDE` directive you include another file at the exact location where the `.INCLUDE` occurs. This happens before the resulting file is assembled. The `.INCLUDE` directive works similarly to the `#include` statement in C. The source from the include file is assembled as if it followed the point of the `.INCLUDE` directive. When the end of the included file is reached, assembly of the original file continues.

The string specifies the filename of the file to be included. The filename must be compatible with the operating system (forward/backward slashes) and can contain a directory specification. If you omit a filename extension, the assembler assumes the extension `.asm`.

If an absolute pathname is specified, the assembler searches for that file. If a relative path is specified or just a filename, the order in which the assembler searches for include files is:

1. The current directory if you use the "*filename*" construction.

   The current directory is not searched if you use the <*filename*> syntax.

2. The path that is specified with the assembler option **--include-directory** (**-I**).
3. The path that is specified in the environment variable AS*target*INC when the product was installed.
4. The default directory `...\`*`ctarget`*`\include`.

### Example

Suppose that your assembly source file `test.src` contains the following line:

```
.INCLUDE "c:\myincludes\myinc.inc"
```

The assembler issues an error if it cannot find the file at the specified location.

```
.INCLUDE "myinc.inc"
```

The assembler searches the file `myinc.inc` according to the rules described above.

### Related information

Assembler option **--include-directory** (Add directory to include file search path) in Section 4.2, *Assembler Options*, of Chapter *Tool Options*.

## .LABEL

### Syntax

*label* **.LABEL** *type*

### Description

With the `.LABEL` directive you define a *label* of a specified *type*.

Use this directive if the label that you define, must have another type than it receives by default. By default, a label inherits its type from the type of the section in which you define the label.

### Example

In the next example, the first label receives the type of the section. The second label is defined with the `.LABEL` directive and receives the type `data`.

```
          .SECTION code, code
mylabel1  .EQU 2
mylabel2  .LABEL data
```

## .LIST/.NOLIST

### Syntax

**.NOLIST**
.
. ; assembly source lines
.
**.LIST**

### Description

If you generate a list file (see assembler option **--list-file**), you can use the `.LIST` and `.NOLIST` directives to specify which source lines the assembler must write to the list file.

The assembler prints all source lines to the list file, untill it encounters a `.NOLIST` directive. The assembler does not print the `.NOLIST` directive and subsequent source lines. When the assembler encounters the `.LIST` directive, it resumes printing to the list file, starting with the `.LIST` directive itself.

It is possible to nest the `.LIST/.NOLIST` directives.

### Example

Suppose you assemble the following assembly code with the assembler option **--list-file**:

```
.SECTION code, code
...  ; source line 1
.NOLIST
...  ; source line 2
.LIST
...  ; source line 3
.END
```

The assembler generates a list file with the following lines:

```
.SECTION code, code
...  ; source line 1
.LIST
...  ; source line 3
.END
```

### Related information

Assembler option **--list-file** (Generate list file) in Section 4.2, *Assembler Options*, of Chapter *Tool Options*.

## .MACRO/.ENDM

#### Syntax

*macro_name* **.MACRO** [*argument*[,*argument*]...]
...
*macro_definition_statements*
...
**.ENDM**

#### Description

With the `.MACRO` directive you define a macro. Macros provide a shorthand method for handling a repeated pattern of code or group of instructions. You can define the pattern as a macro, and then call the macro at the points in the program where the pattern would repeat.

The definition of a macro consists of three parts:

- *Header*, which assigns a name to the macro and defines the arguments.
- *Body*, which contains the code or instructions to be inserted when the macro is called.
- *Terminator*, which indicates the end of the macro definition (`.ENDM` directive).

The arguments are symbolic names that the macro processor replaces with the literal arguments when the macro is expanded (called). Each formal *argument* must follow the same rules as symbol names: the name can consist of letters, digits and underscore characters (_). The first character cannot be a digit. Argument names cannot start with a percent sign (**%**).

Macro definitions can be nested but the nested macro will not be defined until the primary macro is expanded.

You can use the following operators in macro definition statements:

| Operator | Name | Description |
|---|---|---|
| \ | Macro argument concatenation | Concatenates a macro argument with adjacent alphanumeric characters. |
| ? | Return decimal value of symbol | Substitutes the **?***symbol* sequence with a character string that represents the decimal value of the symbol. |
| % | Return hex value of symbol | Substitutes the **%***symbol* sequence with a character string that represents the hexadecimal value of the symbol. |
| " | Macro string delimiter | Allows the use of macro arguments as literal strings. |
| ^ | Macro local label override | Prevents name mangling on labels in macros. |

#### Example

The macro definition:

```
macro_a   .MACRO   arg1,arg2                    ;header
    .db arg1                                    ;body
    .dw (arg1*arg2)
    .ENDM                                       ;terminator
```

The macro call:

```
  .section  macro_data,data,init
  macro_a 2,3
```

The macro expands as follows:

```
  .db 2
  .dw (2*3)
```

**Related information**

**.DEFINE** (Define a substitution string)
Section 3.9, *Macro Operations*.

# .MESSAGE

### Syntax

**.MESSAGE** *type* [{*str*|*exp*|*symbol*}[,{*str*|*exp*|*symbol*}]...]

### Description

With the `.MESSAGE` directive you tell the assembler to print a message to `stdout` during the assembling process.

With *type* you can specify the following types of messages:

**I** Information message. Error and warning counts are not affected and the assembler continues the assembling process.

**W** Warning message. Increments the warning count and the assembler continues the assembling process.

**E** Error message. Increments the error count and the assembler continues the assembling process.

**F** Fatal error message. The assembler immediately aborts the assembling process and generates no object file or list file.

The `.MESSAGE` directive is for example useful in combination with conditional assembly to indicate which part is assembled.

### Example

```
   .MESSAGE I 'Generating tables'

ID .EQU 4
   .MESSAGE E 'The value of ID is ',ID

   .DEFINE LONG "SHORT"
   .MESSAGE I 'This is a LONG string'
   .MESSAGE I "This is a LONG string"
```

Within single quotes, the defined symbol `LONG` is not expanded. Within double quotes the symbol `LONG` is expanded so the actual message is printed as:

```
This is a LONG string
This is a SHORT string
```

## .OFFSET

### Syntax

**.OFFSET** *expression*

### Description

With the `.OFFSET` directive you tell the assembler to give the location counter a new offset relative to the start of the section.

When the assembler encounters the `.OFFSET` directive, it moves the location counter forwards to the specified address, relative to the start of the section, and places the next instruction on that address. If you specify an address equal to or lower than the current position of the location counter, the assembler issues an error.

### Example

```
.SECTION code, code
nop
nop
nop
.OFFSET 0x20    ; the assembler places
nop             ; this instruction at address 0x20
                ; relative to the start of the section.

.SECTION code, code
nop
nop
nop
.OFFSET 0x02    ; WRONG: the current position of the
nop             ; location counter is 0x03.
```

# .PAGE

### Syntax

**.PAGE** [*width*,*length*,*blanktop*,*blankbtm*,*blankleft*]

### Description

If you generate a list file (see assembler option **--list-file**), you can use the `.PAGE` directive to format the generated list file.

*width* Number of characters on a line (1-255). Default is 132.

*length* Number of lines per page (10-255). Default is 66.

*blanktop* Number of blank lines at the top of the page. Default = 0.
Specify a value so that *blanktop* + *blankbtm* ≤ *length* - 10.

*blankbtm* Number of blank lines at the bottom of the page. Default = 0.
Specify a value so that *blanktop* + *blankbtm* ≤ *length* - 10.

*blankleft* Number of blank columns at the left of the page. Default = 0. Specify a value smaller than *width*.

If you use the `.PAGE` directive without arguments, it causes a 'formfeed': the next source line is printed on the next page in the list file.

You can omit an argument by using two adjacent commas. If the remaining arguments after an argument are all empty, you can omit them.

A label is not allowed with this directive.

### Example

```
.PAGE      ; formfeed, the next source line is printed
           ; on the next page in the list file.

.PAGE 96   ; set pagewidth to 96. Note that you can
           ; omit the last four arguments

.PAGE ,,5  ; insert five blank lines at the top. Note
           ; that you can omit the last two arguments.
```

### Related information

**.TITLE** (Set program title in header of assembler list file)
Assembler option **--list-file** (Generate list file) in Section 4.2, *Assembler Options*, of Chapter *Tool Options*.

# .REGISTERBANK

### Syntax

**.REGISTERBANK** *expression*

### Description

This directive notifies the assembler of the register bank that is used by the subsequent code.

The *expression* is the number (0, 1, 2 or 3) which refers to one of four register banks. With the `.REGISTERBANK` directive you can predefine symbolic register addresses (AR0 through AR7) instead of their absolute addresses. In addition, this directive causes the assembler to generate an external `bank(nr)`. The run-time library will contain modules resolving this external and reserving the required data space.

If you equate a symbol (for example with the `.EQU` directive) to an AR*i* symbol, the user-defined symbol will not change its value as a result of the subsequent `.REGISTERBANK` directive.

### Example

```
.REGISTERBANK 3
PUSH AR2 ;Push register 2 of bank 3

.REGISTERBANK 1
PUSH AR2 ;Push register 2 of bank 1
```

## .REPEAT/.ENDREP

### Syntax

[*label*] **.REPEAT** *expression*
....
**.ENDREP**

### Description

With the `.REPEAT/.ENDREP` directive you can repeat a sequence of assembly source lines. With *expression* you specify the number of times the loop is repeated.

If you specify *label*, it gets the value of the location counter at the start of the directive processing.

### Example

In this example the loop is repeated 3 times. Effectively, the preprocessor repeats the source lines (`.DB 10`) three times, then the assembler assembles the result:

```
.REPEAT 3
.DB 10   ; assembly source lines
.ENDREP
```

### Related information

**.FOR/.ENDFOR** (Repeat sequence of source lines *n* times)

## .RESUME

### Syntax

**.RESUME** *name* [, *type*[, *attribute*]...]

### Description

With the `.SECTION` directive you always start a new section. With the `.RESUME` directive you can reactivate a previously defined section. See the `.SECTION` directive for a list of available section types and attributes. If you omit the type and attribute, the previously defined section with the same name is reactivated (ignoring the type and attribute(s)). If you specify a type and attribute you reactivate the section with that same type and attribute.

You cannot resume sections that have the group or overlay attribute. In this case the assembler issues a warning.

### Example

```
.SECTION code, code          ; First code section
 ...
.SECTION data, data          ; First data section
 ...
.SECTION code, code          ; Second code section
 ...
.SECTION data, data, init    ; Second data section
 ...
.RESUME code                 ; Resume in the second code section
 ...
.RESUME data, data           ; Resume in the first data section
 ...
.RESUME data, data, init     ; Resume in the second data section
```

### Related information

**.SECTION** (Start a new section)

## .SECTION

**Syntax**

**.SECTION** *name*, *type*[, *attribute*]...

**Description**

With the `.SECTION` directive you define a new section. Each time you use the `.SECTION` directive, a new section is created. It is possible to create multiple sections with exactly the same name.

To resume a previously defined section, use the `.RESUME` directive.

If you define a section, you must always specify the section *name* and *type*. Names starting with a dot '.' are reserved for the system. Optionally, you can specify one or more attributes.

You can specify the following section types:

| Section Type | Description |
|---|---|
| data | Direct addressable data (on-chip) |
| sfr | Special Function Registers, part of DATA |
| idata | Indirect addressable space (on-chip) |
| bit | Bit data space |
| xdata | External address space |
| pdata | Paged data, mapped in one 256 bytes page |
| code | Code address space |
| sfrbit | SFR bits (part of SFR space) |
| bdata | Bit-addressable data (on-chip RAM) |
| bsfr | Bit-addressable SFR space |

*Table 3-3: TSK51x/TSK52x section types*

Sections of a specified type are located by the linker in a memory space that has the same name as the section type. The space names are defined in a so-called 'linker script file' (files with the extension `.lsl`) delivered with the product in the directory `\Program Files\Altium Designer\System\Tasking \include.lsl`.

You can specify the following section attributes:

| Attribute | Description | Allowed on |
|---|---|---|
| at(*address*) | Locate the section at the specified address | all |
| clear | Clear the DATA section at program startup | all except: code, sfr, sfrbit, bsfr |
| noclear | Do not clear the DATA section at program startup (default) | all |
| init | Copies the data from the section from ROM to RAM at program setup. | all except: code, sfr, sfrbit, bsfr |
| noinit | Do not initialize section (default) | all |
| inpage | Indicates that the section must fit within a 256 byte page. | xdata, pdata |
| inblock | Indicates that the section must fit within a 2K page. | code |
| max | When sections with the same name occur in different object modules, with the MAX attribute, the linker generates a section of which the size is the maximum of the sizes in the individual object modules. | all except: code |
| romdata | Indicates that the section contains data to be placed in ROM | code, xdata, pdata |

| Attribute | Description | Allowed on |
|---|---|---|
| overlay('*overlay*') | Generated by the C compiler to create overlaid sections in the static model (TSK51x/TSK52x only) | all except:<br>sfr, sfrbit, bsfr |
| group('*group*') | Used to group sections, for example for placing in the same page. | all except:<br>sfr, sfrbit, bsfr |

*Table 3-4: TSK51x/TSK52x section attributes*

**Example**

```
.SECTION data, data, init     ; Declare section of type 'data' and
                              ; initialize it by copying
                              ; its data from ROM

.SECTION data, data, clear    ; Declare a data section,
                              ; cleared at program startup

.SECTION data, data, init     ; Declare a second data init section
```

**.RESUME** (Resume a previously defined section)

## .SET

### Syntax

*symbol* **.SET** *expression*

**.SET** *symbol expression*

### Description

With the `.SET` directive you assign the value of *expression* to *symbol* temporarily. If a symbol was defined with the `.SET` directive, you can redefine that symbol in another part of the assembly source, using the `.SET` directive again. Symbols that you define with the `.SET` directive are always local: you cannot define the symbol global with the `.GLOBAL` directive.

The `.SET` directive is useful in establishing temporary or reusable counters within macros. *expression* must be absolute and cannot include a symbol that is not yet defined (no forward references are allowed).

Normally, the defined symbol gets the same type as the result of the expression. However, when the resulting expression has type ”none”, the symbol gets no type.

### Example

```
COUNT   .SET   0    ; Initialize count. Later on you can
                    ; assign other values to the symbol
```

### Related information

**.EQU** (Set a permanent value to a symbol)

## .SYMB (read–only)

#### Syntax

**.SYMB** *string* [, *abs_expr*] [, *abs_expr*]

#### Description

With the `.SYMB` directive high–level language symbolic debug information is passed via the assembler (and linker) to the debugger.

The `.SYMB` is not meant for 'hand coded' assembly files but is generated internally by the C compiler.

# .TITLE

### Syntax

**.TITLE** [*title*]

### Description

If you generate a list file (see assembler option **--list-file**), you can use the `.TITLE` directive to specify the program title which is printed at the top of each page in the assembler list file.

If you use the `.TITLE` directive without the argument, the title becomes empty. This is also the default. The specified title is valid until the assembler encouters a new `.TITLE` directive.

### Example

```
.TITLE "The best program"
```

In the header of each page in the assembler list file, the title of the progam is printed. In this case: `The best program`

### Related information

**.PAGE** (Format the assembler list file)
Assembler option **--list-file** (Generate list file) in Section 4.2, *Assembler Options*, of Chapter *Tool Options*.

# .UNDEF

### Syntax

**.UNDEF** *symbol*

### Description

With the `.UNDEF` directive you can undefine a substitution string that was previously defined with the `.DEFINE` directive. The substitution string associated with *symbol* is released, and *symbol* will no longer represent a valid `.DEFINE` substitution.

The assembler issues a warning if you redefine an existing symbol.

### Example

```
.UNDEF LEN
```

Undefines the `LEN` substitution string that was previously defined with the `.DEFINE` directive.

### Related information

**.DEFINE** (Define substitution string)

# .WEAK

### Syntax

**.WEAK** *symbol*[,*symbol*]...

### Description

With the `.WEAK` directive you mark one or more symbols as 'weak'. The *symbol* can be defined in the same module with the `.GLOBAL` directive or the `.EXTERN` directive. If the symbol does not already exist, it will be created.

A 'weak' external reference is resolved by the linker when a global (or weak) definition is found in one of the object files. However, a weak reference will not cause the extraction of a module from a library to resolve the reference.

You can overrule a weak definition with a `.GLOBAL` definition in another module. The linker will not complain about the duplicate definition, and ignore the weak definition.

Only program labels and symbols defined with `.EQU` can be made weak.

### Example

```
LOOPA .EQU 1          ; definition of symbol LOOPA
      .GLOBAL  LOOPA  ; LOOPA will be globally
                      ; accessible by other modules
      .WEAK LOOPA     ; mark symbol LOOPA as weak
```

### Related information

**.EXTERN** (Import global section symbol)
**.GLOBAL** (Declare global section symbol)

## 3.9 Macro Operations

Macros provide a shorthand method for inserting a repeated pattern of code or group of instructions. You can define the pattern as a macro, and then call the macro at the points in the program where the pattern would repeat.

Some patterns contain variable entries which change for each repetition of the pattern. Others are subject to conditional assembly.

When a macro is called, the assembler executes the macro and replaces the call by the resulting in-line source statements. 'In-line' means that all replacements act as if they are on the same line as the macro call. The generated statements may contain substitutable arguments. The statements produced by a macro can be any processor instruction, almost any assembler directive, or any previously-defined macro. Source statements resulting from a macro call are subject to the same conditions and restrictions as any other statements.

Macros can be *nested*. The assembler processes nested macros when the outer macro is expanded.

### 3.9.1 Defining a Macro

The first step in using a macro is to define it.

The definition of a macro consists of three parts:

- *Header*, which assigns a name to the macro and defines the arguments.
- *Body*, which contains the code or instructions to be inserted when the macro is called.
- *Terminator*, which indicates the end of the macro definition (`.ENDM` directive).

A macro definition takes the following form:

*macro_name* **.MACRO** [*arg*[,*arg*]...] [; *comment*]
.
*source statements*
.
**.ENDM**

If the macro name is the same as an existing assembler directive or mnemonic opcode, the assembler replaces the directive or mnemonic opcode with the macro and issues a warning.

The arguments are symbolic names that the macro preprocessor replaces with the literal arguments when the macro is expanded (called). Each argument must follow the same rules as global symbol names. Argument names cannot start with a percent sign (**%**).

#### *Example*

Consider the following macro definition:

```
RESERV  .MACRO  val   ; reserve space
        .DS val
        .ENDM
```

After the following macro call:

```
.section code, code
RESERV 8
```

The macro expands to:

```
.DS 8
```

### 3.9.2 Calling a Macro

To invoke a macro, construct a source statement with the following format:

`[label] macro_name [arg[,arg...]]          [; comment]`

where:

*label* An optional label that corresponds to the value of the location counter at the start of the macro expansion.

*macro_name* The name of the macro. This may not start in the first column.

*arg* One or more optional, substitutable arguments. Multiple arguments must be separated by commas.

*comment* An optional comment.

The following applies to macro arguments:

- Each argument must correspond one-to-one with the formal arguments of the macro definition. If the macro call does not contain the same number of arguments as the macro definition, the assembler issues a warning.
- If an argument has an embedded comma or space, you must surround the argument by single quotes (').
- You can declare a macro call argument as null in three ways:
  - enter delimiting commas in succession with no intervening spaces

    ```
    macroname ARG1,,ARG3 ; the second argument is a null argument
    ```
  - terminate the argument list with a comma, the arguments that normally would follow, are now considered null

    ```
    macroname ARG1,      ; the second and all following arguments are null
    ```
  - declare the argument as a null string
- No character is substituted in the generated statements that reference a null argument.

### 3.9.3 Using Operators for Macro Arguments

The assembler recognizes certain text operators within macro definitions which allow text substitution of arguments during macro expansion. You can use these operators for text concatenation, numeric conversion, and string handling.

| Operator | Name | Description |
|---|---|---|
| \ | Macro argument concatenation | Concatenates a macro argument with adjacent alphanumeric characters. |
| ? | Return decimal value of symbol | Substitutes the **?***symbol* sequence with a character string that represents the decimal value of the symbol. |
| % | Return hex value of symbol | Substitutes the **%***symbol* sequence with a character string that represents the hexadecimal value of the symbol. |
| " | Macro string delimiter | Allows the use of macro arguments as literal strings. |
| ^ | Macro local label override | Prevents name mangling on labels in macros. |

***Example: Argument Concatenation Operator –*** \

Consider the following macro definition:

```
SWAP_REG  .MACRO  REG1,REG2  ; swap registers
    XCH  A, R\REG1
    XCH  A, R\REG2
    XCH  A, R\REG1
    .ENDM
```

The macro is called as follows:

```
SWAP_REG  0,1
```

The macro expands as follows:

```
XCH  A, R0
XCH  A, R1
XCH  A, R0
```

The macro preprocessor substitutes the character '0' for the argument `REG1`, and the character '1' for the argument `REG2`. The concatenation operator (\) indicates to the macro preprocessor that the substitution characters for the arguments are to be concatenated with the character 'R'.

Without the '\' operator the macro would expand as:

```
XCH   A, RREG1
XCH   A, RREG2
XCH   A, RREG1
```

which results in an assembler error (invalid operand).

### *Example: Decimal Value Operator – ?*

Instead of substituting the formal arguments with the actual macro call arguments, you can also use the *value* of the macro call arguments.

Consider the following source code that calls the macro `SWAP_SYM` after the argument `AREG` has been set to 0 and `BREG` has been set to 1.

```
AREG .SET       0
BREG .SET       1
     SWAP_SYM   AREG,BREG
```

If you want to replace the arguments with the value of `AREG` and `BREG` rather than with the literal strings `'AREG'` and `'BREG'`, you can use the **?** operator and modify the macro as follows:

```
SWAP_SYM   .MACRO  REG1,REG2    ;swap REG1,REG2
     XCH   A,R\?REG1
     XCH   A,R\?REG2
     XCH   A,R\?REG1
     .ENDM
```

The macro first expands as follows:

```
XCH   A, R\0
XCH   A, R\1
XCH   A, R\2
```

Because of the concatenation operator '\' the strings are concatenated:

```
XCH   A, R0
XCH   A, R1
XCH   A, R2
```

### *Example: Hex Value Operator – %*

The percent sign (**%**) is similar to the standard decimal value operator (**?**) except that it returns the hexadecimal value of a symbol.

Consider the following macro definition:

```
GEN_LAB    .MACRO   LAB,VAL,STMT
LAB\%VAL   STMT
     .ENDM
```

The macro is called after `NUM` has been set to 10:

```
NUM .SET        10
    GEN_LAB    HEX,NUM,NOP
```

The macro expands as follows:

```
HEXA NOP
```

The `%VAL` argument is replaced by the character 'A' which represents the hexadecimal value 10 of the argument `VAL`.

### *Example: Argument String Operator – "*

To generate a literal string, enclosed by single quotes ('), you must use the argument string operator (") in the macro definition.

Consider the following macro definition:

```
STR_MAC     .MACRO   STRING
     .DB      "STRING"
     .ENDM
```

The macro is called as follows:

```
   STR_MAC   ABCD
```

The macro expands as follows:

```
    .DB      'ABCD'
```

Within double quotes `.DEFINE` directive definitions can be expanded. Take care when using constructions with quotes and double quotes to avoid inappropriate expansions. Since `.DEFINE` expansion occurs before macro substitution, any `.DEFINE` symbols are replaced first within a macro argument string:

```
     .DEFINE LONG  'short'
STR_MAC     .MACRO   STRING
     .MESSAGE I 'This is a LONG STRING'
     .MESSAGE I "This is a LONG STRING"
     .ENDM
```

If the macro is called as follows:

```
    STR_MAC   sentence
```

it expands as:

```
   .MESSAGE I 'This is a LONG STRING'
   .MESSAGE I 'This is a short sentence'
```

### *Macro Local Label Override Operator – ^*

If you use labels in macros, the assembler normally generates another unique name for the labels (such as `LOCAL__M_L000001`).

The macro `^`-operator prevents name mangling on macro local labels.

Consider the following macro definition:

```
INIT   .MACRO   addr
LOCAL:   mov    A,^addr
       .ENDM
```

The macro is called as follows:

```
LOCAL:
       INIT LOCAL
```

The macro expands as:

```
LOCAL__M_L000001: mov    A,LOCAL
```

If you would not have used the ^ operator, the macro preprocessor would choose another name for `LOCAL` because the label already exists. The macro would expand like:

```
LOCAL__M_L000001: mov    A,LOCAL__M_L000001
```

## 3.9.4 Using the .FOR and .REPEAT Directives as Macros

The `.FOR` and `.REPEAT` directives are specialized macro forms to repeat a block of source statements. You can think of them as a simultaneous definition and call of an unnamed macro. The source statements between the `.FOR` and `.ENDFOR` directives and `.REPEAT` and `.ENDREP` directives follow the same rules as macro definitions.

For a detailed description of these directives, see section 3.8, *Assembler Directives*.

### 3.9.5 Conditional Assembly

With the conditional assembly directives you can instruct the macro preprocessor to use a part of the code that matches a certain condition.

You can specify assembly conditions with arguments in the case of macros, or through definition of symbols via the `.DEFINE`, `.SET`, and `.EQU` directives.

The built-in functions of the assembler provide a versatile means of testing many conditions of the assembly environment.

You can use conditional directives also within a macro definition to check at expansion time if arguments fall within a range of allowable values. In this way macros become self-checking and can generate error messages to any desired level of detail.

The conditional assembly directive `.IF/.ENDIF` has the following form:

```
.IF   expression
 .
 .
[.ELIF   expression]     ;(the .ELIF directive is optional)
 .
 .
[.ELSE]     ;(the .ELSE directive is optional)
 .
 .
.ENDIF
```

A section of a program that is to be conditionally assembled must be bounded by an `.IF-.ENDIF` directive pair. If the optional `.ELSE` and/or `.ELIF` directives are not present, then the source statements following the `.IF` directive and up to the next `.ENDIF` directive will be included as part of the source file being assembled only if the *expression* had a non-zero result.

If the *expression* has a value of zero, the source file will be assembled as if those statements between the `.IF` and the `.ENDIF` directives were never encountered.

If the `.ELSE` directive is present and *expression* has a nonzero result, then the statements between the `.IF` and `.ELSE` directives will be assembled, and the statement between the `.ELSE` and `.ENDIF` directives will be skipped. Alternatively, if *expression* has a value of zero, then the statements between the `.IF` and `.ELSE` directives will be skipped, and the statements between the `.ELSE` and `.ENDIF` directives will be assembled.

## 3.10 Generic Instructions

The assembler supports so-called 'generic instructions'. Generic instructions are pseudo instructions (no instructions from the instruction set). Depending on the situation in which a generic instruction is used, the assembler replaces the generic instruction with appropriate real assembly instruction(s).

The TSK51x/TSK52x assembler recognizes the following generic instructions:

| Instruction | Replacement 1 | Replacement 2 | Replacement 3 |
|---|---|---|---|
| GCALL *label* | ACALL *label* | LCALL *label* | |
| GJMP *label* | SJMP *label* | AJMP *label* | LJMP *label* |
| GJC *label* | JC *label* | JNC ~1<br>AJMP *label*<br>~1: | JNC ~1<br>LJMP *label*<br>~1: |
| GJNC *label* | JNC *label* | JC ~1<br>AJMP *label*<br>~1: | JC ~1<br>LJMP *label*<br>~1: |
| GJZ *label* | JZ *label* | JNZ ~1<br>AJMP *label*<br>~1: | JNZ ~1<br>LJMP *label*<br>~1: |
| GJNZ *label* | JNZ *label* | JZ ~1<br>AJMP *label*<br>~1: | JZ ~1<br>LJMP *label*<br>~1: |
| GJB *bit*,*label* | JB *bit*,*label* | JNB *bit*,~1<br>AJMP *label*<br>~1: | JNB *bit*,~1<br>LJMP *label*<br>~1: |
| GJNB *bit*,*label* | JNB *bit*,*label* | JB *bit*,~1<br>AJMP *label*<br>~1: | JNB *bit*,~1<br>LJMP *label*<br>~1: |
| GJBC *bit*,*label* | JBC *bit*,*label* | JBC *bit*,~1<br>SJMP ~2<br>~1: AJMP *label*<br>~2: | JBC *bit*,~1<br>SJMP ~2<br>~1: LJMP *label*<br>~2: |
| GCJNE A,*direct*,*label* | CJNE A,*direct*,*label* | CJNE A,*direct*,~1<br>SJMP ~2<br>~1: AJMP *label*<br>~2: | CJNE A,*direct*,~1<br>SJMP ~2<br>~1: LJMP *label*<br>~2: |
| GCJNE A,#*imm8*,*label* | CJNE A,#*imm8*,*label* | CJNE A,#*imm8*,~1<br>SJMP ~2<br>~1: AJMP *label*<br>~2: | CJNE A,#*imm8*,~1<br>SJMP ~2<br>~1: LJMP *label*<br>~2: |
| GCJNE R*n*,#*imm8*,*label* | CJNE R*n*,#*imm8*,*label* | CJNE R*n*,#*imm8*,~1<br>SJMP ~2<br>~1: AJMP *label*<br>~2: | CJNE R*n*,#*imm8*,~1<br>SJMP ~2<br>~1: LJMP *label*<br>~2: |
| GCJNE @R*i*,#*imm8*,*label* | CJNE @R*i*,#*imm8*,*label* | CJNE @R*i*,#*imm8*,~1<br>SJMP ~2<br>~1: AJMP *label*<br>~2: | CJNE @R*i*,#*imm8*,~1<br>SJMP ~2<br>~1: LJMP *label*<br>~2: |
| GDJNZ *direct*,*label* | DJNZ *direct*,*label* | DJNZ *direct*,~1<br>SJMP ~2<br>~1: AJMP *label*<br>~2: | DJNZ *direct*,~1<br>SJMP ~2<br>~1: LJMP *label*<br>~2: |
| GDJNZ R*n*,*label* | DJNZ R*n*,*label* | DJNZ R*n*,~1<br>SJMP ~2<br>~1: AJMP *label*<br>~2: | DJNZ R*n*,~1<br>SJMP ~2<br>~1: LJMP *label*<br>~2: |

# 4 Tool Options

**Summary**

This chapter provides a detailed description of the options for the compiler, assembler, linker, control program, make program and the librarian.

## 4.1 C Compiler Options

Altium Designer uses a makefile to build your entire project. This means that in Altium Designer you cannot run the compiler separately. If you compile a single C source file from within Altium Designer, the file is also assembled. However, you can set options specific for the compiler.

### *Options in Altium Designer versus options on the command line*

Most command line options have an equivalent option in Altium Designer but some options are only available on the command line (for example in a Windows Command Prompt). If there is no equivalent option in Altium Designer, you can specify a command line option in Altium Designer as follows:

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **Miscellaneous**.
3. Enter one or more command line options in the **Additional C compiler options** field.

### *Invocation syntax on the command line (Windows Command Prompt)*

To call the compiler from the command line, use the following syntax:

```
c51 [ [option]... [file]... ]...
```

The input *file* must be a C source file (`.c` or `.ic`).

### *Short and long option names*

Options can have both short and long names. Short option names always begin with a single minus (**-**) character, long option names always begin with double minus (**--**) characters. You can abbreviate long option names as long as the name is unique. You can mix short and long option names on the command line.

Options can have flags or sub-options. To switch a flag 'on', use a lowercase letter or a **+***longflag*. To switch a flag off, use an uppercase letter or a **-***longflag*. Separate *longflags* with commas. The following two invocations are equivalent:

```
c51 -Oac test.c
```

```
c51 --optimize=+coalesce,+cse test.c
```

When you do not specify an option, a default value may become active.

# C Compiler: --bank-number (-b)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **Miscellaneous**.

3. Add the option **--bank-number**=*number* to the **Additional C compiler options** field.

### *Command line syntax*

**--bank-number**=*number*
**-b***number*

### *Description*

Select the default register bank number for all functions of the module. You can specify register bank 0, 1, 2 or 3. Notice that no code is generated to switch to this register bank.
The default register bank is 0.

### *Related information*

See section 1.11.6.3, *Register Bank Switching: __registerbank()*, in chapter *C Language*.

# C Compiler: --bypass

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **Miscellaneous**.

3. Add the option **--bypass=***value* to the **Additional C compiler options** field.

### *Command line syntax*

**--bypass=***value*

You can specify the following values:

**0** No bypasses (default)
**1** Bypass chip erratum for Dallas DS80C390

### *Description*

With **--bypass=1** you can bypass the erratum regarding the `DIV AB` instruction for the Dallas DS80C390. The `DIV AB` instruction can return erroneous results if the A register is accessed immediately preceding the `DIV AB` instruction. With this option you tell the compiler to insert a `NOP` instruction between the `MOV` and `DIV` instruction.

### *Related information*

Dallas reference: *Dallas DS80C390 erratum #6, revision B3 01/19/00*

## C Compiler: --check

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **Miscellaneous**.
3. Add the option **--check** to the **Additional C compiler options** field.

### *Command line syntax*

**--check**

### *Description*

With this option you can check the source code for syntax errors, without generating code. This saves time in developing your application because the code will not actually be compiled.

The compiler reports any warnings and/or errors.

### *Related information*

Assembler option **--check** (Check syntax)

# C Compiler: --cpu (–C)

### Menu entry

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **Processor** entry and select **Processor Definition**.
3. Select a processor from the **Select processor** box.

### Command line syntax

**–cpu**=[**tsk51a**|**tsk52a**|**tsk52b**]
**--C**[**tsk51a**|**tsk52a**|**tsk52b**]

### Description

With this option you define the CPU core for which you create your application. The TSK51x/TSK52x target has more than one processor type and therefore you need to specify for which processor type the compiler should compile.

The effect of this option is that the compiler includes the appropriate special function register file: `reg`*`cpu`*`.sfr`. You choose one of the following CPU's: `TSK51A`, `TSK52A` or `TSK52B`.

### Example

To compile the file `test.c` for the TSK51x/TSK52x processor and use the SFR file for the TSK51A processor type, enter the following on the command line:

```
c51 --cpu=tsk51a test.c
```

The compiler includes the SFR file `regtsk51a.sfr` and compiles for the chosen processor type.

When you call the compiler from the command line, make sure you specify the same core type to the assembler to avoid conflicts!

### Related information

–

# C Compiler: --compact-max-size

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **Miscellaneous**.
3. Add the option **--compact-max-size** to the **Additional C compiler options** field.

### *Command line syntax*

**--compact-max-size**=*value* (Default: 200)

### *Description*

This option is related to the compiler optimization **--optimize=+compact** (Code compaction or reverse inlining). Code compaction is the opposite of inlining functions: large sequences of code that occur more than once, are transformed into a function. This reduces code size (possibly at the cost of execution speed).

However, in the process of finding sequences of matching instructions, compile time and compiler memory usage increase quadratically with the number of instructions considered for code compaction. With this option you tell the compiler to limit the number of matching instructions it considers for code compaction.

### *Example*

To limit the maximum number of instructions in functions that the compiler generates during code compaction:

```
c51 --optimize=+compact --compact-max-size=100 test.c
```

### *Related information*

C compiler option **--optimize=+compact** (Optimization: code compaction)
C compiler option **--max-call-depth** (Maximum call depth for code compaction)

# C Compiler: --debug-info (-g)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **Debug Information**.

3. Enable the option **Generate symbolic debug information**.

4. Enable or disable the suboptions.

### *Command line syntax*

**--debug-info**[=*suboption*]

**-g**[**d**|**a**]

You can set the following suboptions (when you specify **-g** without suboption, the default is **-gd**):

| | | |
|---|---|---|
| **default** | (**d**) | Generate default debug information. |
| **all** | (**a**) | Generate all debug information. |

### *Description*

With this option you tell the compiler to add directives to the output file for including symbolic information. This facilitates high level debugging but increases the size of the resulting assembler file (and thus the size of the object file). For the final application, compile your C files without debug information.

When you specify a high optimization level, debug comfort may decrease. Therefore, the compiler issues a warning if the chosen optimizations expect to affect ease of debugging.

**default debug information**

This provides all debug information you need to debug your application. It meets the debugging requirements in most cases without resulting in over-sized assembler/object files.

**all debug information**

With this information extra debug information is generated. In extra-ordinary cases you may use this debug information (for instance, if you use your own debugger which makes use of this information). With this suboption, the resulting assembler/object file increases significantly.

### *Related information*

–

## C Compiler: --define (-D)

### Menu entry

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **Preprocessing**.
3. Select **User macro** and click on the down arrow in the right pane to expand macro input.
4. Click on an empty **Macro** field and enter a macro name. (Then click an empty cell to confirm)
5. Optionally, click in the **Value** field and enter a definition. (Then click an empty cell to confirm)

### Command line syntax

**--define**=*macro_name*[=macro_definition]
**-D***macro_name*[=*macro_definition*]

### Description

With this option you can define a macro and specify it to the preprocessor. If you only specify a macro name (no macro definition), the macro expands as '1'. You can specify as many macros as you like.

On the command line, you can use the option **--define** (**-D**) multiple times. If the command line exceeds the length limit of the operating system, you can define the macros in an *option file* which you then must specify to the compiler with the option **--option-file**=*file* (**-f**).

Defining macros with this option (instead of in the C source) is, for example, useful to compile conditional C source as shown in the example below.

### Example

Consider the following C program with conditional code to compile a demo program and a real program:

```
void main( void )
{
#if DEMO == 1
    demo_func();   /* compile for the demo program */
#else
    real_func();   /* compile for the real program */
#endif
}
```

You can now use a macro definition to set the DEMO flag:

| Macro | Value |
|---|---|
| DEMO | 1 (or empty) |

On the command line, use the option as follows:

```
c51 --define=DEMO test.c
c51 --define=DEMO=1 test.c
```

Note that both invocations have the same effect.

The next example shows how to specify a macro with arguments. Macro definitions follow exactly the same rules as the `#define` statement in the C language.

| Macro | Value |
|---|---|
| MAX(A,B) | ((A) > (B) ? (A) : (B)) |

On the command line, use the option **-D** as follows:

```
c51 -D"MAX(A,B)=((A) > (B) ? (A) : (B))" test.c
```

Note that the macro name and definition are placed between double quotes because otherwise the spaces would indicate a new option.

### Related information

C compiler option **--undefine** (Undefine preprocessor macro)
C compiler option **--option-file** (Read options from file)

## C Compiler: --diag

### *Menu entry*

1. From the **View** menu, select **Workspace** » **Panels** » **System Messages**.

   *The Message pannel appears.*

2. In the **Message** panel, right-click on the message you want more information on.

   *A popup menu appears.*

3. Select **More Info**.

   *A Message Info box appears with additional information.*

### *Command line syntax*

**--diag**=[*format*:]{**all**|*nr*,...}

### *Description*

With this option you can ask for an extended description of error messages in the format you choose. The output is directed to `stdout` (normally your screen) and in the format you specify. You can specify the following formats: **html**, **rtf** or **text** (default). To create a file with the descriptions, you must redirect the output.

With the suboption **all**, the descriptions of all error messages are given. If you want the description of one or more selected error messages, you can specify the error message numbers, separated by commas.

With this option the compiler does not compile any files.

### *Example*

To display an explanation of message number 282, enter:

```
c51 --diag=282
```

This results in the following message and explanation:

```
E282: unterminated comment

Make sure that every comment starting with /* has a matching */. Nested comments are not
possible.
```

To write an explanation of all errors and warnings in HTML format to file `cerrors.html`, use redirection and enter:

```
c51 --diag=html:all > cerrors.html
```

### *Related information*

-

# C Compiler: --error-file

### *Menu entry*

*Command line only.*

### *Command line syntax*

**--error-file**[=*file*]

### *Description*

With this option the compiler redirects error messages to a file.

If you do not specify a filename, the error file will be named after the input file with extension `.err`.

### *Example*

To write errors to `errors.err` instead of `stderr`, enter:

```
c51 --error-file=errors.err test.c
```

### *Related information*

-

## C Compiler: --extend (-x)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **Miscellaneous**.

3. Add the option **-x** to the **Additional C compiler options** field.

### *Command line syntax*

**--extend**=*size*
**-x***size*

### *Description*

By default the compiler uses a maximum of four bytes of internal RAM for automatic registers. With this option you can change the number of bytes the compiler uses as a maximum.

### *Related information*

Section 1.8.1, *Automatic Variables*, in the chapter *C Language*.

## C Compiler: --help (-?)

### Menu entry

*Command line only.*

### Command line syntax

**--help**[=*item*,...]
**-?**

You can specify the following arguments:

| | | |
|---|---|---|
| **intrinsics** | (**i**) | Show the list of intrinsic functions |
| **options** | (**o**) | Show extended option descriptions |
| **pragmas** | (**p**) | Show the list of supported pragmas |
| **typedefs** | (**t**) | Show the list of predefined typedefs |

### Description

Displays an overview of all command line options. With an argument you can specify which extended information is shown.

### Example

The following invocations all display a list of the available command line options:

```
c51 -?
c51 --help
c51
```

The following invocation displays a list of the available pragmas:

```
c51 --help=pragmas
```

## C Compiler: --include-directory (-I)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Select **Build Options**.
3. Add a pathname in the **Include files path** field.

   If you enter multiple paths, separate them with a semicolon (;).

### *Command line syntax*

**--include-directory**=*path*,...
**-I***path*,...

### *Description*

With this option you can specify the path where your include files are located. A relative path will be relative to the current directory.

The order in which the compiler searches for include files is:

1. The pathname in the C source file and the directory of the C source (only for #include files that are enclosed in "").
2. The path that is specified with this option.
3. The path that is specified in the environment variable `C51INC` when the product was installed.
4. The default `include` directory relative to the installation directory (unless you specified option **--nostdinc**).

### *Example*

Suppose that the C source file `test.c` contains the following lines:

```
#include <stdio.h>
#include "myinc.h"
```

You can specify the include directory `myinclude` to the C compiler:

```
c51 --include-directory=myinclude test.c
```

First the compiler looks for the file `stdio.h` in the directory `myinclude` relative to the current directory. If it was not found, the compiler searches in the environment variable and then in the default `include` directory.

The compiler now looks for the file `myinc.h`, in the directory where `test.c` is located. If the file is not there the compiler searches in the directory `myinclude`. If it was still not found, the compiler searches in the environment variable and then in the default `include` directory.

### *Related information*

C compiler option **--include-file** (Include file at the start of a compilation)
C compiler option **--nostdinc** (Skip standard include files directory)

# C Compiler: --include-file (-H)

### Menu entry

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **Preprocessing**.

3. Enter the name of the file in the **Include this file before source** field or click **...** and select a file.

### Command line syntax

**--include-file**=*file*,...
**-H***file*,...

### Description

With this option (set at project level) you include one extra file at the beginning of each C source file in your project. On a document level (**Project** » **Document Options**), you can overrule this option with another file or no file at all.

The specified include file is included before all other includes. This is the same as specifying `#include "file"` at the very beginning of (each of) your C source files.

### Example

```
c51 --include-file=stdio.h test1.c test2.c
```

The file `stdio.h` is included at the beginning of both `test1.c` and `test2.c`.

### Related information

C compiler option **--include-directory** (Add directory to include file search path)

Section 2.4, *How the Compiler Searches Include Files*, in chapter *Using the Compiler* of the user's manual.

## C Compiler: --inline

### Menu entry

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **Miscellaneous**.
3. Add the option **--inline** to the **Additional C compiler options** field.

### Command line syntax

**--inline**

### Description

With this option you instruct the compiler to inline calls to functions without the `__noinline` function qualifier whenever possible. This option has the same effect as a `#pragma inline` at the start of the source file.

This option can be useful to increase the possibilities for code compaction (compiler option **--optimize=+compact**).

### Related information

C compiler option **--optimize=+compact** (Code compaction)

# C Compiler: --inline-max-incr / --inline-max-size

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **Optimization**.
3. Set the option **Maximum code size increasse caused by** to a value (default: 25)
4. Set the option **Maximum size for functions to always inline** to a value (default: 10)

### *Command line syntax*

**--inline-max-incr**=*percentage* (Default: 25)
**--inline-max-size**=*threshold* (Default: 10)

### *Description*

With these options you can control the function inlining optimization process of the compiler. These options have only effect when you have enabled the inlining optimization (option **-Oi**).

Regardless of the optimization process, the compiler always inlines all functions that have the function qualifier `inline`.

With the option **--inline-max-size** you can specify the maximum size of functions that the compiler inlines as part of the optimization process. The compiler always inlines all functions that are smaller than the specified threshold. The threshold is measured in compiler internal units and the compiler uses this measure to decide which functions are small enough to inline. The default threshold is 10.

After the compiler has inlined all functions that have the function qualifier inline and all functions that are smaller than the specified threshold, the compiler looks whether it can inline more functions without increasing the code size too much. With the option **--inline-max-incr** you can specify how much the code size is allowed to increase. Default, this is 25% which means that the compiler continues inlining functions until the resulting code size is 25% larger than the original size.

### *Example*

```
c51 --inline-max-incr=40 --inline-max-size=15 test.c
```

The compiler first inlines all functions with the function qualifier inline and all functions that are smaller than the specified threshold of 15. If the code size has still not increased with 40%, the compiler decides which other functions it can inline.

### *Related information*

C compiler option **--optimize** (Specify optimization level)

Section 1.11.4, *Inlining Functions*, in chapter *C Language*.

## C Compiler: --integer-enumeration

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **Language**.
3. Enable the option **Treat enumerated types always as integer**.

### *Command line syntax*

**--integer-enumeration**

### *Description*

Normally the compiler treats enumerated types as the smallest data type possible (`char` or even as `__bit` instead of `int`). This reduces code size. With this option the compiler always treats enum-types as `int` as defined in the ISO C99 standard.

### *Related information*

–

# C Compiler: --iso (-c)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **Language**.
3. Select the ISO C standard **C90** or **C99**.

### *Command line syntax*

**--iso**={**90**|**99**}
**-c**{**90**|**99**}

### *Description*

With this option you select the ISO C standard. The compiler checks the C source against this standard and may generate warnings or errors if you use C language that is not defined in the standard.

C90 is also referred to as the "ANSI C standard". C99 refers to the newer ISO/IEC 9899:1999 (E) standard. C99 is the default.

```
c51 --iso=90 test.c
```

### *Related information*

C compiler option **--language** (Language extensions)

## C Compiler: --keep-output-files (-k)

### *Menu entry*

Altium Designer *always* removes the `.src` file when errors occur during compilation.

### *Command line syntax*

**--keep-output-files**
**-k**

### *Description*

If an error occurs during compilation, the resulting `.src` file may be incomplete or incorrect. With this option you keep the generated output file (`.src`) when an error occurs.

By default the compiler removes the generated output file (`.src`) when an error occurs. This is useful when you use the make utility. If the erroneous files are not removed, the make utility may process corrupt files on a subsequent invocation.

Use this option when you still want to inspect the generated assembly source. Even if it is incomplete or incorrect.

### *Related information*

–

## C Compiler: --language (-A)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **Language**.

3. Enable or disable the following options:

   - **Allow C++ style comments in C source code** (only available when **ISO C 90** is selected)
   - **Relax const check for string literals**

### *Command line syntax*

**--language=**[*flags*]
**-A**[*flags*]

You can set the following flags:

| | | |
|---|---|---|
| **+/-gcc** | **(g/G)** | Enable a number of gcc extensions |
| **+/-comments** | **(p/P)** | Allow C++ style comments in C source code |
| **+/-strings** | **(x/X)** | Relaxed const check for string literals |

The option **--language** (**-A**) is the equivalent of **-AGPX** which disables all language extensions.
The default is **-Agpx**.

### *Description*

With this option you control the language extensions the compiler accepts. Default the C compiler allows all language extensions.

With **Allow C++ style comments in C source code** (**-Ap**) you tell the compiler to allow C++ style comments (//) in ISO C90 mode (option **-c90**). In ISO C99 mode this style of comments is always accepted.

With **Relax const check for string literals** (**-Ax**) you tell the compiler not to check for assignments of a constant string to a non-constant string pointer. With this option the following example produces no warning:

```
char *p;
void main( void ) { p = "hello"; }
```

With option **--language=+gcc** (**-Ag**, command line only) you tell the compiler to enable the following gcc languages extensions:

- The identifier __FUNCTION__ expands to the current function name
- Alternative syntax for variadic macros
- Alternative syntax for designated initializers
- Allow zero sized arrays
- Allow empty struct/union
- Allow empty initializer list
- Allow initialization of static objects by compound literals
- The middle operand of a ? : operator may be omitted
- Allow a compound statement inside braces as expression
- Allow arithmetic on void pointers and function pointers
- Allow a range of values after a single case label
- Additional preprocessor directive #warning
- Allow comma operator, conditional operator and cast as lvalue
- An inline function without "static" or "extern" will be global
- An "extern inline" function will not be compiled on its own
- An __attribute__ directly following a struct/union definition relates to that tag instead of to the objects in the declaration.

For an exact description of these gcc extensions, please refer to the gcc info pages (**info gcc**).

### *Example*

```
c51 -AGPx -c90 test.c
c51 --language=-gcc,-comments,+strings --iso=90 test.c
```

C compiler option **--iso** (ISO C standard)

# C Compiler: --max-call-depth

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **Miscellaneous**.

3. Add the option **--max-call-depth** to the **Additional C compiler options** field.

### *Command line syntax*

**--max-call-depth**=*value*   (Default: -1)

### *Description*

This option is related to the compiler optimization **--optimize=+compact** (Code compaction or reverse inlining). Code compaction is the opposite of inlining functions: large sequences of code that occur more than once, are transformed into a function. This reduces code size (possibly at the cost of execution speed).

During code compaction the compiler generates nested calls. This may cause the program to run out of its stack. To prevent stack overflow caused by too deeply nested function calls, you can use this option to limit the call depth. This option can have the following values:

**-1** Poses no limit to the call depth (default)

**0** The compiler will not generate any function calls. (Effectively the same as if you turned of code compaction with option **--optimize=-compact**)

**>0** Code sequences are only reversed if this will not lead to code at a call depth larger than specified with *value*. Function calls will be placed at a call depth no larger than *value*-1. (Note that if you specified a *value* of 1, the option **--optimize=+compact** may remain without effect when code sequences for reversing contain function calls.)

This option does not influence the call depth of user written functions.

If you use this option with various C modules, the call depth is valid for each individual module. The call depth after linking may differ, depending on the nature of the modules.

### *Related information*

C compiler option **--optimize=+compact** (Optimization: code compaction)
C compiler option **--compact-max-size** (Maximum size of a match for code compaction)

# C Compiler: ––mdptr (–m)

### Menu entry

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **Miscellaneous**.
3. Add the option **––mdptr** to the **Additional C compiler options** field.

### Command line syntax

**––mdptr**={**Amtel**|**Dallas**|**Infineon**|**Philips**}
**–m**{**a**|**d**|**i**|**p**}

### Description

The standard TSK51x/TSK52x architecture provides just one 16–bit pointer for indirect addressing of external memory (DPTR). At this moment however, there are several architectures supporting more than just one data pointer. You can use the following suboptions to use multiple data pointers:

**a** **Amtel** AT8x53/AT89S53/AT89S4D12/AT89S8252 supports *two* 16–bit data pointers

**d** **Dallas** 80C320/520/530 and AMD 80C521 supports *eight* 16–bit data pointers

**i** **Infineon** Technologies C500/C800 family supports *two* 16–bit data pointers

**p** **Philips** 51 family supports *eight* 16–bit data pointers

By default this option is not set and just *one* data pointer is supported.

### Related information

–

## C Compiler: --misrac

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **MISRA-C**.

3. Select a MISRA-C Standard.

   If you select Custom MISRA-C configuration:

4. In the left pane, expand the **MISRA-C** entry and select **MISRA-C Rules**.

5. Enable or disable the individual rules.

### *Command line syntax*

**--misrac**={**all**|*number*[**-***number*],... }

### *Description*

With this option you specify to the compiler which MISRA-C rules must be checked. With the option **--misrac=all** the compiler checks for all supported MISRA-C rules.

### *Example*

```
c51 --misrac=9-13 test.c
```

The compiler generates an error for each MISRA-C rule 9, 10, 11, 12 or 13 violation in file `test.c`.

### *Related information*

C compiler option **--misrac-advisory-warnings**
C compiler option **--misrac-required-warnings**

Linker option **--misrac-report**

## C Compiler: --misrac-advisory-warnings / --misrac-required-warnings

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **MISRA-C**.

3. Enable one or both options **Turn advisory rule violation into warning** and **Turn required rule violation into warning.**

### *Command line syntax*

**--misrac-advisory-warnings**

**--misrac-required-warnings**

### *Description*

Normally, if an advisory rule or required rule is violated, the compiler generates an error. As a consequence, no output file is generated. With this option, the compiler generates a warning instead of an error.

### *Related information*

C compiler option **--misrac**

Linker option **--misrac-report**

## C Compiler: --misrac-version

### Menu entry

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog appears.*

2. Expand the **C Compiler** entry and select **MISRA-C**.
3. Select the MISRA-C standard: **MISRA-C:1998** or **MISRA-C:2004**.

### Command line syntax

**--misrac-version**={**1998**|**2004**}

### Description

MISRA-C rules exist in two versions: MISRA-C:1998 and MISRA-C:2004. By default, the C source is checked against the MISRA-C:2004 rules. With this option you can specify to check against the MISRA-C:1998 rules.

### Related information

See Chapter 8, *MISRA-C Rules*, for a list of all supported MISRA-C rules.

C compiler option **--misrac**

## C Compiler: --model (-M)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **Memory Model**.
3. Select the **Small**, **Aux** or **Large** memory model.
4. Optionally enable the **Allow reentrant functions** check box.

### *Command line syntax*

**--model**={**aux**|**large**|**small**}
**-M**{**a**|**l**|**s**}

### *Description*

By default the TSK51x/TSK52x compiler uses the *small memory* model. When the compiler uses the small memory model to access data, all data objects and the stack (used for function parameter passing) must fit in the internal RAM. Note that the stack length depends upon the nesting depth of the various functions. Accessing data in internal RAM is considerably faster than accessing data in external RAM.

In the *large memory* model the produced code is larger and in some cases slower than the code for a similar operation in one of the other memory models.

The *auxiliary page memory* model is especially interesting for derivatives with 256 bytes of 'external' RAM on chip. All data must fit in one 256 bytes page.

### *Related information*

Optionally you can choose to enable reentrancy with C compiler option **--reentrant**.

Section 1.4, *Memory Models*, in chapter *C Language*.

# C Compiler: --noclear

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **Miscellaneous**.
3. Add the option **--noclear** to the **Additional C compiler options** field.

### *Command line syntax*

**--noclear**

### *Description*

Normally variables are cleared at program startup. With this option you tell the compiler to generate code to prevent non-initialized global variables from being cleared at program startup.

### *Related information*

–

## C Compiler: --noframe

### Menu entry

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **Code Generation**.
3. *Disable* the option **Generate frame for interrupt handler**.

### Command line syntax

**--noframe**

### Description

With this option you can specify whether the compiler should generate an interrupt frame (saving/restoring registers) for interrupt handlers or not.

### Related information

C compiler option **--vector-offset** (Reset/interrupt vector offset)
C compiler option **--novector** (Generate code for interrupt vector)

Section 1.11.6, *Interrupt Functions*, in chapter *C Language*.

## C Compiler: −−noregaddr

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **Code Generation**.

3. *Disable* the option **Allow absolute register addresses (AR0−AR7) in generated code**.

### *Command line syntax*

**−−noregaddr**

### *Description*

With this option you tell the compiler to generate register bank independent code. This creates the possibility to generate functions that can be called from any function, independent of its register bank.

### *Related information*

Section 1.11.7, *Register Bank Independent Code Generation*, in chapter *C Language*.

## C Compiler: --nostdinc

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **Miscellaneous**.
3. Add the option **--nostdinc** to the **Additional C compiler options** field.

### *Command line syntax*

**--nostdinc**

### *Description*

With this option you tell the compiler not to look in the default `include` directory relative to the installation directory, when searching for include files. This way the compiler only searches in the include file search paths you specified.

### *Related information*

C compiler option **--include-directory** (Add directory to include file search path)

## C Compiler: --novector

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **Code Generation**.
3. *Disable* the option **Generate code for interrupt vector**.

### *Command line syntax*

**--novector**

### *Description*

With this option you tell the compiler not to generate code for interrupt vectors and references to the interrupt handler in the run-time library. Use this option if you do not use interrupts in your application, or if you want to write your own interrupt vectors.

### *Related information*

C compiler option **--vector-offset** (Specify a base address for interrupt vectors)
C compiler option **--noframe** (Do not generate frame for interrupt handler)

Section 1.11.6, *Interrupt Functions*, in chapter *C Language*.

## C Compiler: --no-warnings (-w)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **Diagnostics**.
3. In the Warnings field, select one of the following options:
   - **Report all warnings**
   - **Suppress all warnings**
   - **Suppress specific warningsn**

   *If you select **Suppress specific warnings**:*

4. Enter the numbers, separated by commas, of the warnings you want to suppress.

### *Command line syntax*

**--no-warnings**[=*number*,...]
**-w**[*number*,...]

### *Description*

With this option you can suppress all warning messages or specific warning messages.

On the command line this option works as follows:

- If you do not specify this option, all warnings are reported.
- If you specify this option but without numbers, all warnings are suppressed.
- If you specify this option with a number, only the specified warning is suppressed.
  You can specify the option **--no-warnings**=*number* multiple times.

### *Example*

To suppress warnings 135 and 136, enter `135,136` in the **Specific warnings to suppress** field, or enter the following on the command line:

```
c51 test.c --no-warnings=135,136
```

### *Related information*

C compiler option **--warnings-as-errors** (Treat warnings as errors)

# C Compiler: --optimize (-O)

### Menu entry

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **Optimization**.
3. Select an optimization level in the **Optimization level** box.
4. If you select **Custom Optimization**, enable or disable the optimizations you want.
5. In addition, in the **Size/speed trade-off** field, select a level between **fully optimize for size** or **fully optimize for speed**.

### Command line syntax

**--optimize**[=*flags*]
**-O**[*flags*]

Use the following options for predefined sets of flags:

| | | |
|---|---|---|
| **--optimize=0** | (**-O0**) | **No optimization**<br>Alias for: **-OABCEFGILOPRSY** |
| **--optimize=1** | (**-O1**) | **Few optimizations**<br>Alias for: **-OabcefgILOPRSy** |
| **--optimize=2** | (**-O2**) | **Medium optimization** (default)<br>Alias for: **-Oabcefglloprsy** |
| **--optimize=3** | (**-O3**) | **Full optimization**<br>Alias for: **-Oabcefgiloprsy** |

You can enable the following individual optimizations:

| | | |
|---|---|---|
| **+/-coalesce** | (**a**/**A**) | **Coalescer** (remove unnecessary moves) |
| **+/-ipro** | (**b**/**B**) | **Interprocedural Register Optimization** |
| **+/-cse** | (**c**/**C**) | **Common subexpression elimination (CSE)** |
| **+/-expression** | (**e**/**E**) | **Expression simplification** |
| **+/-flow** | (**f**/**F**) | **Control flow simplification** (optimization and code reordering) |
| **+/-glo** | (**g**/**G**) | **Generic assembly code optimizations** |
| **+/-inline** | (**i**/**I**) | **Function inlining** |
| **+/-loop** | (**l**/**L**) | **Loop transformations** |
| **+/-forward** | (**o**/**O**) | **Forward store** |
| **+/-propagate** | (**p**/**P**) | **Constant propagation** |
| **+/-compact** | (**r**/**R**) | **Code compaction (reverse inlining)** |
| **+/-subscript** | (**s**/**S**) | **Subscript strength reduction** |
| **+/-peephole** | (**y**/**Y**) | **Peephole optimizations** |

For an extensive description of these optimizations, please refer to section 2.6, *Compiler Optimizations* in chapter *Using the Compiler* of the user's manual.

### Description

The TASKING C compilers offer four optimization levels and a custom level, at each level a specific set of optimizations is enabled.

- **No optimization** (**-O0**): No optimizations are performed. The compiler tries to achieve a 1-to-1 resemblance between source code and produced code. Expressions are evaluated in the order written in the source code, associative and commutative properties are not used.
- **Few optimizations** (**-O1**): Enables optimizations that do not affect the debug-ability of the source code. Use this level when you encounter problems during debugging your source code with optimization level 2.
- **Medium optimization** (**-O2**): Enables more optimizations to reduce code size and/or execution time. This is the default optimization level.

- **Full optimization** (**–O3**): This is the highest optimization level. Use this level to decrease execution time to meet your real–time requirements.
- **Custom optimization** (**–O***x*/*X*): you can enable/disable specific optimizations.

With these options you can control the level of optimization. The default optimization level is **Medium optimization** (option **–O2** or **–O** or **–OabcefgIloprsy**).

You can overrule these settings in your C source file with the pragma pair `#pragma optimize` *`flag`* and `#pragma endoptimize`.

In addition to the command line option **––optimize** (**–O**), you can specify the option **––tradeoff** (**–t**). With this option you specify whether the used optimizations should optimize for more speed (regardless of code size) or for smaller code size (regardless of speed).

### *Example*

The following invocations are equivalent and result all in the default optimization set:

```
c51 test.c
c51 -O2 test.c
c51 --optimize=2 test.c
c51 -O test.c
c51 --optimize test.c
c51 -OabcefgIloprsy test.c
c51 --optimize=+coalesce,+ipro,+cse,+expression,+flow,+glo,
  -inline,+loop,+forward,+propagate,+compact,+subscript,+peephole
  test.c
```

### *Related information*

Section 2.6, *Compiler Optimizations*, in chapter *Using the Compiler* of the user's manual.

C compiler option **––tradeoff** (**–t**) (Trade off between speed (**–t0**) and size (**–t4**))

# C Compiler: --option-file (-f)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **Miscellaneous**.
3. Add the option **--option-file** to the **Additional C compiler options** field.

Be aware that the options in the option file are added to the C compiler options you have set in the other dialogs. Only in extraordinary cases you may want to use them in combination. Altium Designer automatically saves the options with your project.

### *Command line syntax*

**--option-file=***file*,...
**-f** *file*,...

### *Description*

This option is primarily intended for command line use. Instead of typing all options on the command line, you can create an option file which contains all options and flags you want to specify. With this option you specify the option file to the compiler.

Use an option file when the command line would exceed the limits of the operating system, or just to store options and save typing.

You can specify the option **--option-file** multiple times.

**Format of an option file**

- Multiple arguments on one line in the option file are allowed.
- To include whitespace in an argument, surround the argument with single or double quotes.
- If you want to use single quotes as part of the argument, surround the argument by double quotes and vise versa:

```
"This has a single quote ' embedded"

'This has a double quote " embedded'

'This has a double quote " and a single quote '"' embedded"
```

- When a text line reaches its length limit, use a \ to continue the line. Whitespace between quotes is preserved.

```
"This is a continuation \
line"

    -> "This is a continuation line"
```

- It is possible to nest command line files up to 25 levels.

### *Example*

Suppose the file `myoptions` contains the following lines:

```
-g
-DDEMO=1
test.c
```

Specify the option file to the C compiler:

```
c51 --option-file=myoptions
```

This is equivalent to the following command line:

```
c51 -g -DDEMO=1 test.c
```

### *Related information*

-

## C Compiler: --output (-o)

### *Menu entry*

Altium Designer names the output file always after the C source file.

### *Command line syntax*

**--output**=*file*
**-o** *file*

### *Description*

With this option you can specify another filename for the output file of the compiler. Without this option the basename of the C source file is used with extension `.src`.

### *Example*

To create the file `output.src` instead of `test.src`, enter:

```
c51 --output=output.src test.c
```

### *Related information*

-

## C Compiler: --preprocess (-E)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **Preprocessing**.
3. Enable the option **Store the C Compiler preprocess output (<file>.pre)**.

### *Command line syntax*

**--preprocess**[=*flags*]
**-E**[*flags*]

You can set the following flags (when you specify **-E** without flags, the default is **-ECMP**):

| | | |
|---|---|---|
| **+/-comments** | (**c**/**C**) | Keep comments from the C source in the preprocessed output |
| **+/-make** | (**m**/**M**) | Generate dependency lines that can be used for the makefile |
| **+/-noline** | (**p**/**P**) | Strip #line source position info (lines starting with `#line`) |

The compiler sends the preprocessed file to stdout. To capture the information in a file, specify an output file with the option **--output**.

### *Description*

When compiling, each file is preprocessed first. With this option you can store the result of preprocessed C files. Altium Designer stores the preprocessed file in a file called *name*.pre (where *name* is the name of the C source file being compiled). C comments are not preserved (similar to **-ECMP**)

### *Related information*

## C Compiler: --rename-sections (-R)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **Miscellaneous**.
3. Add the option **--rename-sections** to the **Additional C compiler options** field.

### *Command line syntax*

**--rename-sections**=[*type*]={*name*|**-f**|**-m**|**-fm**}
**-R**[*type*]={*name*|**-f**|**-m**|**-fm**}

### *Description*

In case a module must be loaded at a fixed address, or a data section needs a special place in memory, you can use this option to generate different section names. You can then use this unique section name in the linker script file for locating.

With the section *type* you select which sections are renamed. With *name* you specify a new name for these sections. The following name values have special meaning:

With the suboption **-f**, the compiler uses the function name (only for code).

With the suboption **-m**, the compiler uses the name of the current module.

With the suboption **-fm** (or **-mf**), the compiler uses the name of the current module for data sections and the function name for code sections.

If you do not specify a section *type*, all sections are renamed.

It is not possible to rename overlay sections.

Instead of the option **-R** you can use the pragma pair `#pragma section` / `endsection` in the source:

```
#pragma section type=name  /* rename section */

....

#pragma endsection   /* restore default naming convention */
```

See the assembler directive **.SECTION** for a list of section types and attributes.

### *Example*

The following C code:

```
__data int i;
```

results after compilation in the following section declaration with name `data` and type `data`:

```
.section data, data, clear
```

To change the name of all sections with type `data`, enter:

```
c51 --rename-sections=data=NEW test.c
```

This results in:

```
.section NEW, data, clear
```

To use the name of the current module name (`test`) for all `data` sections:

```
c51 --rename-sections=data=-m test.c
```

### *Example*

To change all sections named `.data` into `.data.NEW`:

***Related information***

*Section 1.12, Section Naming*, in chapter *C Language*.

Assembler directive **.SECTION**

## C Compiler: --reentrant

### Menu entry

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **Memory Model**.
3. Enable the **Allow reentrant functions** check box.

### Command line syntax

**--reentrant**

### Description

If you select reentrancy, a (less efficient) virtual dynamic stack is used which allows you to call functions recursively. With reentrancy, you can call functions at any time, even from interrupt functions.

### Related information

C compiler option **--model** (Memory model)

Section 1.4, *Memory Models*, in chapter *C Language*.
Section 1.11.1, *Reentrant Functions*, in chapter *C Language*.

# C Compiler: --romstrings (-S)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **Code Generation**.
3. Enable the option **Put strings in ROM only**.

### *Command line syntax*

**--romstrings**
**-S**

### *Description*

By default, constant strings are copied from ROM to RAM at program startup. With this option you tell the compiler to keep constant strings in ROM. If you use this option, you can access these strings only with the `__rom` keyword.

With this option enabled, strings are *not* copied to RAM at startup to save RAM memory. Strings in ROM cannot be modified and access is slower than access to strings in RAM.

### *Related information*

-

## C Compiler: --signed-bitfields

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **Language**.

3. Enable the option **Treat 'int' bit-fields as signed**.

### *Command line syntax*

**--signed-bitfields**

### *Description*

For bit-fields it depends on the implementation whether a plain `int` is treated as `signed int` or `unsigned int`. By default an `int` bit-field is treated as `unsigned int`. This offers the best performance. With this option you tell the compiler to treat `int` bit-fields as `signed int`. In this case, you can still add the keyword `unsigned` to treat a particular `int` bit-field as `unsigned`.

### *Related information*

–

## C Compiler: −−source (−s)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **Miscellaneous**.

3. Enable the option **Merge C source code with assembly in output file (.src)**.

### *Command line syntax*

**−−source**
**−s**

### *Description*

With this option you tell the compiler to merge C source code with generated assembly code in the output file. The C source lines are included as comments.

### *Related information*

−

## C Compiler: --static

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **Miscellaneous**.
3. Add the option **--static** to the **Additional C compiler options** field.

### *Command line syntax*

**--static**

### *Description*

With this option, the compiler treats external definitions at file scope (except for `main`) as if they were declared `static`. As a result, unused functions will be eliminated, and the alias checking algorithm assumes that objects with static storage cannot be referenced from functions outside the current module.

On the command line this option only makes sense when you specify all modules of an application on the command line.

### *Example*

```
c51 --static module1.c module2.c module3.c ...
```

### *Related information*

–

# C Compiler: −−stdout (−n)

### Menu entry

*Command line only.*

### Command line syntax

**−−stdout**
**−n**

### Description

With this option you tell the compiler to send the output to stdout (usually your screen). No files are created. This option is for example useful to quickly inspect the output or to redirect the output to other tools.

### Related information

–

# C Compiler: ––tradeoff (–t)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **Optimization**.

3. In the **Size**/**speed trade–off** field, select a level between **fully optimize for size** or **fully optimize for speed**.

### *Command line syntax*

**––tradeoff**={**0**|**1**|**2**|**3**|**4**}
**–t**{**0**|**1**|**2**|**3**|**4**}

### *Description*

If the compiler uses certain optimizations (option **––optimize**), you can use this option to specify whether the used optimizations should optimize for more speed (regardless of code size) or for smaller code size (regardless of speed).

By default the compiler optimizes for more speed (**––tradeoff=0**).

If you have not used the option **––optimize**, the compiler uses the default optimization. In this case it is still useful to specify a trade–off level.

### *Related information*

C compiler option **––optimize** (Specify optimization level)

# C Compiler: --uchar (-u)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **Language**.
3. Enable the option **Treat 'char' variables as unsigned**.

### *Command line syntax*

**--uchar**
**-u**

### *Description*

By default `char` is the same as specifying `signed char`. With this option `char` is the same as `unsigned char`.

### *Related information*

–

## C Compiler: --undefine (–U)

### Menu entry

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **Miscellaneous**.
3. Add the option **--undefine** to the **Additional C compiler options** field.

### Command line syntax

**--undefine**=*macro_name*
**-U***macro_name*

### Description

With this option you can undefine an earlier defined macro as with `#undef`.

This option is for example useful to undefine predefined macros.

However, the following predefined ISO C standard macros cannot be undefined:

| | |
|---|---|
| __FILE__ | current source filename |
| __LINE__ | current source line number (int type) |
| __TIME__ | hh:mm:ss |
| __DATE__ | mmm dd yyyy |
| __STDC__ | level of ANSI standard |

### Example

To undefine the predefined macro __TASKING__:

```
c51 --undefine=__TASKING__ test.c
```

### Related information

C compiler option **--define** (Define preprocessor macro)

# C Compiler: --vector-offset

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **Code Generation**.
3. Enable the option **Generate code for interrupt vector**.
4. In the **Reset/interrupt vector offset** field, enter an offset address in the range 0x0000-0xFFFF.

### *Command line syntax*

**--vector-offset**=*address*

### *Description*

With this option you can specify a 16-bit offset address for the interrupt vector table. The default offset address is 0x0000.

This option is for example useful to place the vector table in RAM.

### *Example*

Type 0x4000 as the base address of the interrupt vector table in the **Reset/interrupt vector offset** field, or enter the following on the command line:

```
c51 --vector-offset=0x4000 test.c
```

Suppose your C source contains the following interrupt function:

```
__interrupt(0x0013) void isr( void )
```

The compiler adds the offset address to the vector address in the C source so the actual vector address becomes 0x4013.

### *Related information*

C compiler option **--novector** (Do not generate interrupt vectors)
C compiler option **--noframe** (Do not generate frame for interrupt handler)

Section 1.11.6, *Interrupt Functions*, in chapter *C Language*.

## C Compiler: --version (-V)

***Menu entry***

*Command line only.*

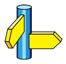
***Command line syntax***

**--version**
**-V**

***Description***

Displays version information of the compiler. The compiler ignores all other options or input files.

***Related information***

 –

# C Compiler: --warnings-as-errors

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **Diagnostics**.

3. Enable the option **Treat warnings as errors**.

### *Command line syntax*

**--warnings-as-errors**

### *Description*

If the compiler encounters an error, it stops compiling. When you use this option without arguments, you tell the compiler to treat all warnings as errors. This means that the exit status of the compiler will be non-zero after one or more compiler warnings. As a consequence, the compiler now also stops after encountering a warning.

### *Related information*

C compiler option **--no-warnings** (Suppress some or all warnings)

## 4.2 Assembler Options

Altium Designer uses a makefile to build your entire project. This means that in Altium Designer you cannot run the assembler separately. If you want assembly results, you must compile a single C source file from within Altium Designer, the file is then also assembled. However, you can set options specific for the assembler.

### *Options in Altium Designer versus options on the command line*

Most command line options have an equivalent option in Altium Designer but some options are only available on the command line (for example in a Windows Command Prompt). If there is no equivalent option in Altium Designer, you can specify a command line option in Altium Designer as follows:

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **Assembler** entry and select **Miscellaneous**.

3. Enter one or more command line options in the **Additional assembler options** field.

### *Invocation syntax on the command line (Windows Command Prompt)*

To call the assembler from the command line, use the following syntax:

```
as51 [ [option]... [file]... ]...
```

The input *file* must be an assembly source file (`.asm` or `.src`).

### *Short and long option names*

Options can have both short and long names. Short option names always begin with a single minus (**-**) character, long option names always begin with double minus (**--**) characters. You can abbreviate long option names as long as the name is unique. You can mix short and long option names on the command line.

Options can have flags or sub-options. To switch a flag 'on', use a lowercase letter or a **+***longflag*. To switch a flag off, use an uppercase letter or a **-***longflag*. Separate *longflags* with commas. The following two invocations are equivalent:

```
as51 -Ogs test.src

as51 --optimize=+generics,+instr-size test.src
```

When you do not specify an option, a default value may become active.

# Assembler: --case-insensitive (-c)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **Assembler** entry and select **Miscellaneous**.
3. Disable the option **Assemble case sensitive**.

### *Command line syntax*

**--case-insensitive**
**-c**

### *Description*

With this option you tell the assembler not to distinguish between upper and lower case characters. By default the assembler considers upper and lower case characters as different characters.

Disabling the option **Assemble case sensitive** in Altium Designer is the same as specifying the option **--case-insensitive** on the command line.

Assembly source files that are generated by the compiler must always be assembled case sensitive. When you are writing your own assembly code, you may want to specify the case insensitive mode.

### *Example*

When assembling case insensitive, the label `LabelName` is the same label as `labelname`.

### *Related information*

–

## Assembler: --check

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **Assembler** entry and select **Miscellaneous**.
3. Add the option **--check** to the **Additional assembler options** field.

### *Command line syntax*

**--check**

### *Description*

With this option you can check the source code for syntax errors, without generating code. This saves time in developing your application.

The assembler reports any warnings and/or errors.

### *Related information*

C compiler option **--check** (Check syntax)

# Assembler: --cpu (-C)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **Processor** entry and select **Processor Definition**.

3. Select a processor from the **Select processor** box.

### *Command line syntax*

**--cpu**=*cpu*
**-C***cpu*

### *Description*

With this option you define the CPU core for which you create your application. The TSK51x/TSK52x target has more than one processor type and therefore you need to specify for which processor type the assembler should assemble.

The effect of this option is that the assembler includes the appropriate special function register file: `reg`*`cpu`*`.sfr`. You choose one of the following CPU's: `TSK51A`, `TSK52A` or `TSK52B`.

Assembly code can check the value of the option by means of the built-in function `@CPU()`.

### *Example*

To assemble the file `test.src` for the TSK51x/TSK52x processor and use the SFR file for the TSK51A processor type, enter the following on command line:

```
as51 --cpu=tsk51a test.src
```

The assembler includes the SFR file `regtsk51a.sfr` and assembles for the chosen processor type.

When you call the assembler from the command line, make sure you specify the same core type to the compiler to avoid conflicts!

### *Related information*

Assembly function `@CPU()`

# Assembler: --debug-info (-g)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **Assembler** entry and select **Debug Information**.
3. Select which debug information to include: **Automatic HLL or assembly level debug information**, **Custom debug information** or **No debug information**.

   *If you select **Custom debug information**:*

4. Select which Custom debug information to include: **Assembler source line information**, **Pass HLL debug information**, or **None**.
5. Enable or disable the option **Assembler local symbols information**.

### *Command line syntax*

**--debug-info**[=*flag*]
**-g**[*flag*]

You can set the following flags:

| | | |
|---|---|---|
| +/**-asm** | (**a**/**A**) | Assembly source line information |
| +/**-hll** | (**h**/**H**) | Pass high level language debug information (HLL) |
| +/**-local** | (**l**/**L**) | Assembler local symbols debug information |
| +/**-smart** | (**s**/**S**) | Smart debug information |

### *Description*

With this option you tell the assembler which kind of debug information to emit in the object file.

If you do not use this option, the default is **--debug-info**=+**hll**. If you specify **--debug-info** without any flags, the default is **--debug-info**=+**smart**.

You cannot specify **--debug-info=+asm,+hll**. Either the assembler generates assembly source line information, or it passes HLL debug information.

When you specify **--debug-info=+smart**, the assembler selects which flags to use. If high level language information is available in the source file, the assembler passes this information (same as **--debug-info=-asm,+hll,-local**). If not, the assembler generates assembly source line information (same as **--debug-info=+asm,-hll,+local**).

With **--debug-info=AHLS** the assembler does not generate any debug information.

### *Related information*

–

# Assembler: --define (-D)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **Assembler** entry and select **Preprocessing**.
3. Click on **User macro**, click on the down arrow in the right pane to expand macro input.
4. Click on an empty **Macro** field and enter a macro name. (Then click outside the cell to confirm)
5. Optionally, click in the **Value** field and enter a definition. (Then click outside the cell to confirm)

### *Command line syntax*

**--define**=*macro_name*[=*macro_definition*]
**-D***macro_name*[=*macro_definition*]

### *Description*

With this option you can define a macro and specify it to the assembler preprocessor. If you only specify a macro name (no macro definition), the macro expands as '1'.

You can specify as many macros as you like. On the command line you can use the option **--define** (**-D**) multiple times. If the command line exceeds the limit of the operating system, you can define the macros in an *option file* which you then must specify to the assembler with the option **--option-file**=*file* (**-f**).

Defining macros with this option (instead of in the assembly source) is, for example, useful in combination with conditional assembly as shown in the example below.

This option has the same effect as defining symbols via the `.DEFINE`, `.SET`, and `.EQU` directives. (similar to `#define` in the C language). With the `.MACRO` directive you can define more complex macros.

### *Example*

Consider the following assembly program with conditional code to assemble a demo program and a real program:

```
.IF DEMO == 1
...          ; instructions for demo application
.ELSE
...          ; instructions for the real application
.ENDIF
```

You can now use a macro definition to set the DEMO flag:

| Macro | Value |
|---|---|
| DEMO | 1 (or empty) |

```
as51 --define=DEMO test.src
as51 --define=DEMO=1 test.src
```

Note that both invocations have the same effect.

### *Related information*

Assembler option **--option-file** (Read options from file)

## Assembler: --diag

### *Menu entry*

1. From the **View** menu, select **Workspace Panels** » **System** » **Messages**.

   *The Messages panel appears.*

2. In the **Messages** panel, right-click on the message you want more information on.

   *A popup menu appears.*

3. Select **More Info**.

   *A Message Info box appears with additional information.*

### *Command line syntax*

**--diag**=[*format*:]{**all**|**nr**,...}

### *Description*

With this option you can ask for an extended description of error messages in the format you choose. The output is directed to `stdout` (normally your screen) and in the format you specify. You can specify the following formats: **html**, **rtf** or **text** (default). To create a file with the descriptions, you must redirect the output.

With the suboption **all**, the descriptions of all error messages are given. If you want the description of one or more selected error messages, you can specify the error message numbers, separated by commas.

With this option the assembler does not assemble any files.

### *Example*

To display an explanation of message number 241, enter:

```
as51 --diag=241
```

This results in the following message and explanation:

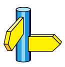
```
W241: additional input files will be ignored

The assembler supports only a single input file. All other input files are ignored.
```

To write an explanation of all errors and warnings in HTML format to file `aserrors.html`, use redirection and enter:

```
as51 --diag=html:all > aserrors.html
```

### *Related information*

 -

## Assembler: --emit-locals

### *Menu entry*

*Command line only.*

### *Command line syntax*

**--emit-locals**

### *Description*

With this option the assembler also emits local symbols to the object file. Normally, only global symbols are emitted. Having local symbols in the object file can be useful for debugging.

### *Related information*

–

## Assembler: --error-file

### *Menu entry*

*Command line only.*

### *Command line syntax*

**--error-file**[=*file*]

### *Description*

With this option the assembler redirects error messages to a file.

If you do not specify a filename, the error file will be named after the input file with extension `.ers`.

### *Example*

To write errors to `errors.err` instead of `stderr`, enter:

```
as51 --error-file=errors.err test.src
```

### *Related information*

–

## Assembler: --help (-?)

### *Menu entry*

*Command line only.*

### *Command line syntax*

**--help**[=**options**]
**-?**

### *Description*

Displays an overview of all command line options. When you specify the argument **options** you can list detailed option descriptions.

### *Example*

The following invocations all display a list of the available command line options:

```
as51 -?
as51 --help
as51
```

To see a detailed description of the available options, enter:

```
as51 --help=options
```

## Assembler: --include-directory (-I)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Select **Build Options**.

3. Add a pathname in the **Include Files Path** field.

   If you enter multiple paths, separate them with a semicolon (;).

### *Command line syntax*

**--include-directory**=*path*,...
**-I***path*,...

### *Description*

With this option you can specify the path where your include files are located. A relative path will be relative to the current directory.

The order in which the assembler searches for include files is:

1. The pathname in the assembly file and the directory of the assembly source.
2. The path that is specified with this option.
3. The path that is specified in the environment variable `AS51INC` when the product was installed.
4. The default `include` directory relative to the installation directory.

### *Example*

Suppose that your assembly source file `test.src` contains the following line:

```
.INCLUDE 'myinc.inc'
```

You can call the assembler as follows:

```
as51 --include-directory=c:\proj\include test.src
```

First the assembler looks in the directory where `test.src` is located for the file `myinc.inc`. If it does not find the file, it looks in the directory `c:\proj\include` for the file `myinc.inc` (this option). If the file is still not found, the assembler searches in the environment variable and then in the default `include` directory.

### *Related information*

Assembler option **--include-file** (**-H**) (Include file before source)

## Assembler: --include-file (-H)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **Assembler** entry and select **Preprocessing**.
3. Enter the name of the file in the **Include this file before source** field or click **...** and select a file.

### *Command line syntax*

**--include-file**=*file*,...
**-H***file*,...

### *Description*

With this option (set at project level) you include one extra file at the beginning of the assembly source file. The specified include file is included before all other includes. This is the same as specifying `.INCLUDE 'file'` at the beginning of your assembly source.

### *Example*

```
as51 --include-file=myinc.inc test1.src
```

The file `myinc.inc` is included at the beginning of `test1.src` before it is assembled.

### *Related information*

Assembler option **--include-directory** (Include files path)

Section 3.4, *How the Assembler Searches Include Files*, in chapter *Using the Assembler* of the user's manual.

## Assembler: --keep-output-files (-k)

### *Menu entry*

Altium Designer *always* removes the object file when errors occur during assembling.

### *Command line syntax*

**--keep-output-files**
**-k**

### *Description*

If an error occurs during assembling, the resulting object file (`.obj`) may be incomplete or incorrect. With this option you keep the generated object file when an error occurs.

By default the assembler removes the generated object file when an error occurs. This is useful when you use the make utility. If the erroneous files are not removed, the make utility may process corrupt files on a subsequent invocation.

Use this option when you still want to use the generated object. For example when you know that a particular error does not result in a corrupt object file.

### *Related information*

–

# Assembler: --list-file (-l)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **Assembler** entry and select **List File**.
3. Enable **Generate list file**.
4. In the **List file format** section, enable or disable the types of information to be included.

### *Command line syntax*

**--list-file**[=*file*]
**-l**[*file*]

### *Description*

With this option you tell the assembler to generate a list file. A list file shows the generated object code and the relative addresses. Note that the assembler generates a relocatable object file with relative addresses.

With the optional *file* you can specify an alternative name for the list file. By default, the name of the list file is the basename of the source file with the extension `.lst`.

### *Related information*

On the command line you can use the option **--list-format** (**-L**) to specify which types of information should be included in the list file.

## Assembler: --list-format (-L)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **Assembler** entry and select **List File**.
3. Enable **Generate list file**.
4. In the **List file format** section, enable or disable the types of information to be included.

### *Command line syntax*

**--list-format=***flags*
**-L***flags*

You can set the following flags:

| | |
|---|---|
| **0** | Same as **-LDEGILMNPQRSVWXY** (all options disabled) |
| **1** | Same as **-Ldegilmnpqrsvwxy** (all options enabled) |

| | | |
|---|---|---|
| **+/-section** | **(d/D)** | **Section directives (.SECTION)** |
| **+/-symbol** | **(e/E)** | **Symbol definition directives** |
| **+/-generic-expansion** | **(g/G)** | **Generic instruction expansion** |
| **+/-generic** | **(i/I)** | **Generic instructions** |
| **+/-line** | **(l/L)** | **C preprocessor #line directives** |
| **+/-macro** | **(m/M)** | **Macro/dup definitions (e.g. .MACRO)** |
| **+/-empty-line** | **(n/N)** | **Empty source lines (newline)** |
| **+/-conditional** | **(p/P)** | **Conditional assembly (.IF, .ELSE, .ENDIF)** |
| **+/-equate** | **(q/Q)** | **Assembler .EQU and .SET directives** |
| **+/-relocations** | **(r/R)** | **Relocation characters ('r')** |
| **+/-hll** | **(s/S)** | **HLL symbolic debug information (.SYMB)** |
| **+/-equate-values** | **(v/V)** | **Assembler .EQU and .SET values** |
| **+/-wrap-lines** | **(w/W)** | **Wrapped source lines** |
| **+/-macro-expansion** | **(x/X)** | **Macro expansions** |
| **+/-cycle-count** | **(y/Y)** | **Cycle counts** |

Default: **-LDEGilMnPqrsVWXy**

### *Description*

With this option you specify which information you want to include in the list file.

On the command line you must use this option in combination with the option **--list-file** (**-l**).

### *Related information*

Assembler option **--list-file** (Generate list file)
Assembler option **--section-info=+list** (Display section information in list file)

## Assembler: --no-warnings (-w)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **Assembler** entry and select **Diagnostics**.

3. Enable one of the options:
   - **Report all warnings**
   - **Suppress all warnings**
   - **Suppress specific warnings**

   *If you select* ***Suppress specific warnings****:*

4. Enter the numbers, separated by commas, of the warnings you want to suppress.

### *Command line syntax*

**--no-warnings**[=*number*,...]
**-w**[*number*,...]

### *Description*

With this option you can suppresses all warning messages or specific warning messages.

- If you do not specify this option, all warnings are reported.
- If you specify this option but without numbers, all warnings are suppressed.
- If you specify this option with a number, only the specified warning is suppressed.
  You can specify the option **--no-warnings**=*number* multiple times.

### *Example*

To suppress warnings 135 and 136, enter **135, 136** in the **Specific warnings to suppress** field, or enter the following on the command line:

```
as51 test.src --no-warnings=135,136
```

### *Related information*

Assembler option **--warnings-as-errors** (Treat warnings as errors)

## Assembler: --optimize (-O)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **Assembler** entry and select **Optimization**.

3. Enable or disable the optimization options:

   - **Generic instructions**
   - **Jump chains**
   - **Instruction size**

### *Command line syntax*

**-O***flags*
**--optimize=***flags*

You can set the following flags:

| | | |
|---|---|---|
| **+/-generics** | **(g/G)** | Allow **generic instructions** |
| **+/-jumpchains** | **(j/J)** | **Jump chains** |
| **+/-instr-size** | **(s/S)** | Optimize **instruction size** |

Default**: --optimize=gJs**

### *Description*

#### Allow generic instructions

If you use generic instructions in your assembly source, the assembler can optimize them by replacing it with the fastest or shortest possible variant of that instruction. By default this option is enabled. If you turn off this optimization, the assembler generates an error on generic instructions. Be aware that the compiler also generates generic instructions!

#### Jump chains

With this optimization, the assembler replaces chained jumps by a single jump instruction. For example, a jump from *a* to *b* immediately followed by a jump from *b* to *c*, is replaced by a jump from *a* to *c*.

#### Optimize instruction size

With this optimization the assembler tries to find the shortest possible operand encoding for instructions.

### *Related information*

Section 3.5, *Assembler Optimizations* in chapter *Using the Assembler* of the user's manual.

# Assembler: --option-file (-f)

### Menu entry

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **Assembler** entry and select **Miscellaneous**.

3. Add the option **--option-file** to the **Additional assembler options** field.

Be aware that the options in the option file are added to the assembler options you have set in the other dialogs. Only in extraordinary cases you may want to use them in combination.

### Command line syntax

**--option-file**=*file*,...
**-f** *file*,...

### Description

This option is primarily intended for command line use. Instead of typing all options on the command line, you can create an option file which contains all options and flags you want to specify. With this option you specify the option file to the assembler.

Use an option file when the command line would exceed the limits of the operating system, or just to store options and save typing.

Option files can also be generated on the fly, for example by the make utility. You can specify the option **--option-file** multiple times.

**Format of an option file**

- Multiple arguments on one line in the option file are allowed.
- To include whitespace in an argument, surround the argument with single or double quotes.
- If you want to use single quotes as part of the argument, surround the argument by double quotes and vise versa:

```
"This has a single quote ' embedded"

'This has a double quote " embedded'

'This has a double quote " and a single quote '"' embedded"
```

- When a text line reaches its length limit, use a ’to continue the line. Whitespace between quotes is preserved.

```
"This is a continuation \
line"

    -> "This is a continuation line"
```

- It is possible to nest command line files up to 25 levels.

### Example

Suppose the file `myoptions` contains the following lines:

```
-gaL
test.src
```

Specify the option file to the assembler:

```
as51 --option-file=myoptions
```

This is equivalent to the following command line:

```
as51 -gaL test.src
```

### Related information

-

## Assembler: −−output (−o)

### *Menu entry*

Altium Designer names the output file always after the source file.

### *Command line syntax*

**−−output**=*file*
**−o** *file*

### *Description*

With this option you can specify another filename for the output file of the assembler. Without this option, the basename of the assembly source file is used with extension `.obj`.

### *Example*

To create the file `relobj.obj` instead of `asm.obj`, enter:

```
as51 --output=relobj.obj asm.src
```

### *Related information*

–

# Assembler: --preprocessor-type (-m)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **Assembler** entry and select **Miscellaneous**.
3. Add the option **--preprocessor-type** to the **Additional assembler options** field.

### *Command line syntax*

**--preprocessor-type**={**none**|**tasking**}
**-m**{**n**|**t**} Default: **-mt**

### *Description*

With this option you select the preprocessor that the assembler will use. By default, the assembler uses the TASKING preprocessor.

When the assembly source file does not contain any preprocessor symbols, you can specify to the assembler not to use a preprocessor.

### *Related information*

–

## Assembler: --rom-monitor-nops

### *Menu entry*

*Command line only.*

### *Command line syntax*

**--rom-monitor-nops**

### *Description*

With this option you generate 2 extra NOP instructions before any code label for TSK51x/TSK52x ROM monitor support. This is to prevent errors when breakpoints are set just before a label.

### *Related information*

–

# Assembler: --section-info (-t)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **Assembler** entry and select **List File**.
3. Enable **Generate list file**.
4. Enable the option **Display section information**.

### *Command line syntax*

**--section-info**[=*flags*]
**-t**[*flags*]

You can set the following flags:

| | | |
|---|---|---|
| +/**-console** | (**c**/**C**) | Display section information on `stdout`. |
| +/**-list** | (**l**/**L**) | Write section information to the list file. |

### *Description*

With this option you tell the assembler to display section information. For each section its memory space, size, total cycle counts and name is listed on stdout and/or in the list file.

The cycle count consists of two parts: the total accumulated count for the section and the total accumulated count for all repeated instructions. In the case of nested loops it is possible that the total supersedes the section total.

Without arguments this option is the same as **--section-info=cl**.

With **--section-info=l**, the assembler writes the section information to the list file. You must specify this option in combination with the option **--list-file** (generate list file).

### *Example*

```
as51 --list-file --section-info=+console,+list test.src
```

The assembler generates a list file and writes the section information to this file. The section information is also displayed on stdout.

### *Related information*

Assembler option **--list-file** (generate list file)

## Assembler: --symbol-scope (-i)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **Assembler** entry and select **Miscellaneous**.
3. Select the default label mode: **Local** or **Global**.

### *Command line syntax*

**--symbol-scope**={**global**|**local**}
**-i**{**g**|**l**} (Default: **-il**)

### *Description*

With this option you tell the assembler how to treat symbols that you have not specified explicitly as global or local. By default the assembler treats all symbols as local symbols unless you have defined them explicitly as global.

### *Related information*

–

## Assembler: --version (-V)

### *Menu entry*

*Command line only.*

### *Command line syntax*

**--version**
**-V**

### *Description*

Displays version information of the assembler. The assembler ignores all other options or input files.

### *Related information*

–

## Assembler: ––verbose (–v)

### *Menu entry*

*Command line only.*

### *Command line syntax*

**––verbose**
**–v**

### *Description*

With this option you put the assembler in verbose mode. The assembler prints the filenames and the assembly passes while it processes the files so you can monitor the current status of the assembler.

### *Related information*

–

# Assembler: --warnings-as-errors

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **Assembler** entry and select **Diagnostics**.

3. Enable the option **Treat warnings as errors**.

### *Command line syntax*

**--warnings-as-errors**

### *Description*

If the assembler encounters an error, it stops assembling. When you use this option without arguments, you tell the assembler to treat all warnings as errors. This means that the exit status of the assembler will be non-zero after one or more compiler warnings. As a consequence, the assembler now also stops after encountering a warning.

### *Related information*

Assembler option **--no-warnings** (Suppress some or all warnings)

## 4.3 Linker Options

Altium Designer uses a *makefile* to build your entire project. This means that you cannot run the linker separately. However, you can set options specific for the linker.

### *Options in Altium Designer versus options on the command line*

Most command line options have an equivalent option in Altium Designer but some options are only available on the command line (for example in a Windows Command Prompt). If there is no equivalent option in Altium Designer, you can specify a command line option in Altium Designer as follows:

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **Linker** entry and select **Miscellaneous**.
3. Enter one or more command line options in the **Additional Linker options** field.

### *Invocation syntax on the command line (Windows Command Prompt)*

The invocation syntax on the command line is:

```
lk51 [ [option]... [file]... ]...
```

When you are linking multiple files (either relocatable object files (`.obj`) or libraries (`.lib`), it is important to specify the files in the right order.

### *Short and long option names*

Options can have both short and long names. Short option names always begin with a single minus (**-**) character, long option names always begin with double minus (**--**) characters. You can abbreviate long option names as long as the name is unique. You can mix short and long option names on the command line.

Options can have flags or sub-options. To switch a flag 'on', use a lowercase letter or a +*longflag*. To switch a flag off, use an uppercase letter or a -*longflag*. Separate *longflags* with commas. The following two invocations are equivalent:

```
lk51 -mfk test.obj
lk51 --map-file-format=+files,+link test.obj
```

When you do not specify an option, a default value may become active.

## Linker: --case-insensitive

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **Linker** entry and select **Miscellaneous**.

3. *Disable* the option **Link case sensitive**.

### *Command line syntax*

**--case-insensitive**

### *Description*

With this option you tell the linker not to distinguish between upper and lower case characters in symbols. By default the linker considers upper and lower case characters as different characters.

*Disabling* the option **Link case sensitive** in Altium Designer is the same as specifying the option **--case-insensitive** on the command line.

Assembly source files that are generated by the compiler must *always* be assembled and thus linked case sensitive. When you have written your own assembly code and specified to assemble it case insensitive, you must also link the `.obj` file case insensitive.

### *Related information*

-

## Linker: --chip-output (-c)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **Linker** entry and select **Output Format**.
3. Enable the options **Intel HEX records** and/or **Motorola S-records**.

### *Command line syntax*

**--chip-output**=[*basename*]**:***format*[**:***addr_size*],...
**-c**[*basename*]**:***format*[**:***addr_size*],...

You can specify the following formats:

| | |
|---|---|
| **IHEX** | Intel Hex |
| **SREC** | Motorola S-records |

The *addr_size* specifies the size of the addresses in bytes (record length). For Intel Hex you can use the values **1**, **2** or **4** bytes (default). For Motorola-S you can specify: **2** (S1 records), **3** (S2 records) or **4** bytes (S3 records, default). In Altium Designer you cannot specify the address size because Altium Designer always uses the default values.

### *Description*

With this option you specify the Intel Hex or Motorola S-record output format for loading into a PROM-programmer. The linker generates a file for each ROM memory defined in the LSL file, where sections are located:

```
memory memname
{  type=rom;  }
```

The name of the file is the name of the Altium Designer project or, on the command line, the name of the memory device that was emitted with extension `.hex` or `.sre`. Optionally, you can specify a *basename* which prepends the generated file name.

The linker always outputs a debugging file in IEEE-695 format and optionally an absolute object file in Intel Hex-format and/or Motorola S-record format.

### *Example*

To generate Intel Hex output files for each defined memory, enter the following on the command line:

```
lk51 --chip-output=myfile:IHEX test1.obj
```

In this case, this generates the file `myfile_memname.hex`

### *Related information*

Linker option **--output** (Output file)

Section 6.2, *Motorola S-Record Format*,
Section 6.3, *Intel Hex Record Format*, in Chapter *Object File Formats*.

## Linker: --define (-D)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **Linker** entry and select **Miscellaneous**.
3. Add the option **--define** to the **Additional linker options** field.

### *Command line syntax*

**--define**=*macro_name*[=*macro_definition*]
**-D***macro_name*[=*macro_definition*]

### *Description*

With this option you can define a macro and specify it to the linker LSL file preprocessor. If you only specify a macro name (no macro definition), the macro expands as '1'.

You can specify as many macros as you like; just use the option **--define** multiple times. If the command line exceeds the limit of the operating system, you can define the macros in an *option file* which you then must specify to the linker with the option **--option-file**=*file* (**-f**).

The definition can be tested by the preprocessor with `#if`, `#ifdef` and `#ifndef`, for conditional locating.

### *Example*

To define the stack size which is used in the linker script file `51.lsl`, enter:

```
lk51 test.obj -otest.abs -d51.lsl -D__STACK=32
```

or using the long option names:

```
lk51 test.obj -otest.abs -lsl-file=51.lsl --define=__STACK=32
```

### *Related information*

Linker option **--option-file** (Read options from file)

## Linker: --diag

### *Menu entry*

1. From the **View** menu, select **Workspace Panels** » **System** » **Messages**.

   *The Messages panel appears.*

2. In the **Messages** panel, right-click on the message you want more information on.

   *A popup menu appears.*

3. Select **More Info**.

   *A Message Info box appears with additional information.*

### *Command line syntax*

**--diag**=[*format*:]{**all**|**nr**,...]

### *Description*

With this option you can ask for an extended description of error messages in the format you choose. The output is directed to `stdout` (normally your screen) and in the format you specify. You can specify the following formats: **html**, **rtf** or **text** (default). To create a file with the descriptions, you must redirect the output.

With the suboption **all**, the descriptions of all error messages are given. If you want the description of one or more selected error messages, you can specify the error message numbers, separated by commas.

With this option the linker does not link/locate any files.

### *Example*

To display an explanation of message number 106, enter:

```
lk51 --diag=106
```

This results in the following message and explanation:

```
E106: unresolved external: <message>

The linker could not resolve all external symbols. This is an error when the incremental
linking option is disabled. The <message> indicates the symbol that is unresolved.
```

To write an explanation of all errors and warnings in HTML format to file `lerrors.html`, enter:

```
lk51 --diag=html:all > lerrors.html
```

### *Related information*

–

## Linker: --error-file

### Menu entry

–

### Command line syntax

**--error-file**[=*file*]

### Description

With this option the linker redirects error messages to a file.

If you do not specify a filename, the error file is `lk51.elk`.

### Example

To write errors to `errors.elk` instead of `stderr`, enter:

```
lk51 --error-file=errors.elk test.obj
```

### Related information

–

## Linker: --error-limit

### *Menu entry*

–

### *Command line syntax*

**--error-limit**=*number*

### *Description*

With this option you tell the linker to only emit the specified maximum number of errors. When 0 (null) is specified, the linker emits all errors. Without this option the maximum number of errors is 42.

### *Related information*

–

## Linker: --extern (-e)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **Linker** entry and select **Miscellaneous**.

3. Add the option **--extern** to the **Additional linker options** field.

### *Command line syntax*

**--extern**=*symbol*
**-e** *symbol*

### *Description*

With this option you force the linker to consider the given symbol as an undefined reference. The linker tries to resolve this symbol, either the symbol is defined in an object file or the linker extracts the corresponding symbol definition from a library.

This option is, for example, useful if the startup code is part of a library. Because your own application does not refer to the startup code, you can force the startup code to be extracted by specifying the symbol `__start` as an unresolved external.

### *Example*

Consider the following invocation:

```
lk51 mylib.lib
```

Nothing is linked and no output file will be produced, because there are no unresolved symbols when the linker searches through `mylib.lib`.

```
lk51 --extern=__start mylib.lib
```

In this case the linker searches for the symbol `__start` in the library and (if found) extracts the object that contains `__start`, the startup code. If this module contains new unresolved symbols, the linker looks again in `mylib.lib`. This process repeats until no new unresolved symbols are found.

### *Related information*

Section 4.4, *Linking with Libraries*, in chapter *Using the Linker* of the user's manual.

## Linker: --first-library first

### Menu entry

–

### Command line syntax

**--first-library-first**

### Description

When the linker processes a library it searches for symbols that are referenced by the objects and libraries processed so far. If the library contains a definition for an unresolved reference the linker extracts the object that contains the definition from the library.

By default the linker processes object files and libraries in the order in which they appear on the command line. If you specify the option **--first-library-first** the linker always tries to take the symbol definition from the library that appears first on the command line before scanning subsequent libraries.

This is for example useful when you are working with a newer version of a library that partially overlaps the older version. Because they do not contain exactly the same functions, you have to link them both. However, when a function is present in both libraries, you may want the linker to extract the most recent function.

### Example

Consider the following example:

```
lk51 --first-library-first a.lib test.obj b.lib
```

If the file `test.obj` calls a function which is both present in `a.lib` and `b.lib`, normally the function in `b.lib` would be extracted. With this option the linker first tries to extract the symbol from the first library `a.lib`.

Note that routines in `b.lib` that call other routines that are present in both `a.lib` and `b.lib` are now also resolved from `a.lib`.

### Related information

Linker option **--no-rescan** (Rescan libraries to solve unresolved externals)

## Linker: --help (-?)

### Menu entry

-

### Command line syntax

**--help**[=**options**]
**-?**

### Description

Displays an overview of all command line options. When you specify the argument **options** you can list detailed option descriptions.

### Example

The following invocations all display a list of the available command line options:

```
lk51 -?
lk51 --help
lk51
```

To see a detailed description of the available options, enter:

```
lk51 --help=options
```

## Linker: --include-directory (-I)

### Menu entry

–

### Command line syntax

**--include-directory**=*path*,...
**-I***path*,...

### Description

With this option you can specify the path where your LSL include files are located. A relative path will be relative to the current directory.

The order in which the linker searches for LSL include files is:

1. The pathname in the LSL file and the directory where the LSL file is located (only for #include files that are enclosed in "")
2. The path that is specified with this option.
3. The default directory `$(PRODDIR)\include.lsl`.

### Example

Suppose that your linker script file `mylsl.lsl` contains the following line:

```
#include "myinc.inc"
```

You can call the linker as follows:

```
lk51 --include-directory=c:\proj\include --lsl-file=mylsl.lsl test.obj
```

First the linker looks in the directory where `mylsl.lsl` is located for the file `myinc.inc`. If it does not find the file, it looks in the directory `c:\proj\include` for the file `myinc.inc` (this option). Finally it looks in the directory `$(PRODDIR)\include.lsl`.

### Related information

–

## Linker: --incremental (-r)

### *Menu entry*

–

### *Command line syntax*

**--incremental**
**-r**

### *Description*

Normally the linker links and locates the specified object files. With this option you tell the linker only to link the specified files. The linker creates a linker output file `.out`. You then can link this file again with other object files until you have reached the final linker output file that is ready for locating.

In the last pass, you call the linker without this option with the final linker output file `.out`. The linker will now locate the file.

### *Example*

In this example, the files `test1.obj`, `test2.obj` and `test3.obj` are incrementally linked:

1. `lk51 --incremental test1.obj test2.obj -otest.out`

   *`test1.obj` and `test2.obj` are linked*

2. `lk51 --incremental test3.obj test.out`

   *`test3.obj` and `test.out` are linked, `task1.out` is created*

3. `lk51 task1.out`

   *`task1.out` is located*

### *Related information*

Section 4.5, *Incremental Linking* in chapter *Using the Linker* of the user's manual.

## Linker: --keep-output-files (-k)

### *Menu entry*

Altium Designer *always* removes the output files when errors occurred.

### *Command line syntax*

**--keep-output-files**
**-k**

### *Description*

If an error occurs during linking, the resulting output file may be incomplete or incorrect. With this option you keep the generated output files when an error occurs.

By default the linker removes the generated output file when an error occurs. This is useful when you use the make utility. If the erroneous files are not removed, the make utility may process corrupt files on a subsequent invocation.

Use this option when you still want to use the generated file. For example when you know that a particular error does not result in a corrupt object file, or when you want to inspect the output file, or send it to Altium support.

### *Related information*

–

## Linker: --library (-l)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **Linker** entry and select **Libraries**.
3. Enable the option **Link default C libraries**.

### *Command line syntax*

**--library**=*name*
**-l***name*

### *Description*

With this option you tell the linker to use system library `name.lib`, where *name* is a string. The linker first searches for system libraries in any directories specified with **--library-directory**, then in the directories specified with the environment variable `LIBC51`, unless you used the option **--ignore-default-library-path**.

### *Example*

To search in the system library `c51ls.lib` (C library):

```
lk51 test.obj mylib.lib --library=c51ls
```

The linker links the file `test.obj` and first looks in `mylib.lib` (in the current directory only), then in the system library `c51ls.lib` to resolve unresolved symbols.

### *Related information*

Linker option **--library-directory** (Additional search path for system libraries)

Section 4.4, *Linking with Libraries*, in chapter *Using the Linker* of the user's manual.

## Linker: --library-directory (-L) / --ignore-default-library-path

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Open the **Build Options** page.
3. Add a pathname in the **Library files path** field.

   *If you enter multiple paths, separate them with a semicolon (;).*

### *Command line syntax*

**--library-directory**=*dir*
**-L***dir*

**--ignore-default-library-path**
**-L**

### *Description*

With this option you can specify the path(s) where your system libraries, specified with the **--library** option, are located. If you want to specify multiple paths, use the option **--library-directory** for each separate path.

The default path is `$(PRODDIR)\c51\lib`.

If you specify only **-L** (without a pathname) or the long option **--ignore-default-library-path**, the linker will not search the default path and also not in the paths specified in the environment variable `LIBC51`. So, the linker ignores steps 2 and 3 as listed below.

The priority order in which the linker searches for system libraries specified with the **--library** option is:

1. The path that is specified with the **--library-directory** option.
2. The path that is specified in the environment variable `LIBC51`.
3. The default directory `$(PRODDIR)\c51\lib` (or a processor specific sub-directory).

### *Example*

Suppose you call the linker as follows:

```
lk51 test.obj --library-directory=c:\mylibs --library=c51ls
```

First the linker looks in the directory `c:\mylibs` for library `c51ls.lib` (this option).

If it does not find the requested libraries, it looks in the directory that is set with the environment variable `LIBC51`.

Then the linker looks in the default directory `$(PRODDIR)\c51\lib` for libraries.

### *Related information*

Linker option **--library** (Link system library)

Section 4.4.1, *How the linker searches libraries* in chapter *Using the Linker* of the user's manual.

## Linker: --link-only

### *Menu entry*

–

### *Command line syntax*

**--link-only**

### *Description*

With this option you suppress the locating phase. The linker stops after linking and informs you about unresolved references.

### *Related information*

Control program option **-cl** (Stop after linking)

## Linker: --lsl-check

### *Menu entry*

–

### *Command line syntax*

**--lsl-check**

### *Description*

With this option the linker just checks the syntax of the LSL file(s) and exits. No linking or locating is performed. Use the option **--lsl-file**=*file* to specify the name of the Linker Script File you want to test.

### *Related information*

Linker option **--lsl-file** (Linker script file)
Linker option **--lsl-dump** (Dump LSL info)

Section 4.8, *Controlling the Linker with a Script*, in chapter *Using the Linker* of the user's manual.

## Linker: --lsl-dump

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **Linker** entry and select **Miscellaneous**.

3. Enable the option **Dump processor and memory info from LSL file**.

### *Command line syntax*

**--lsl-dump**[=*file*]

### *Description*

With this option you tell the linker to dump the LSL part of the map file in a separate file, independent of the option **--map-file** (generate map file). If you do not specify a filename, the file `lktarget.ldf` is used.

### *Related information*

Linker option **--map-file-format** (Map file formatting)

## Linker: --lsl-file (-d)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **Linker** entry and select **Miscellaneous**.
3. Enable the option **Use project specific LSL file**.
4. In the **LSL file** field, type a name or click **...** and select an LSL file.

### *Command line syntax*

**--lsl-file**=*file*
**-d***file*

### *Description*

A linker script file contains vital information about the core for the locating phase of the linker. A linker script file is coded in LSL and contains the following types of information:

- the architecture definition describes the core's hardware architecture.
- the memory definition describes the physical memory available in the system.
- the section layout definition describes how to locate sections in memory.

With this option you specify a linker script file to the linker. If you do not specify this option, the linker uses a default script file. You can specify the existing file `51.lsl` or the name of a manually written linker script file. You can use this option multiple times. The linker processes the LSL files in the order in which they appear on the command line.

### *Related information*

Linker option **--lsl-check** (Check LSL file(s) and exit)

Section 4.8, *Controlling the Linker with a Script*, in chapter *Using the Linker* of the user's manual.

## Linker: --map-file (-M)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **Linker** entry and select **Map File**.
3. Enable the option **Generate a memory map file (.map)**.
4. In the **Map file format** section, enable or disable the information you want to be included in the map file.

### *Command line syntax*

**--map-file**[=*file*]
**-M**[*file*]

### *Description*

With this option you tell the linker to generate a linker map file. If you do not specify a filename and you specfied the **-o** option, the linker uses the same basename as the output file with the extension `.map`. If you did not specify the **-o** option, the linker uses the file `task1.map`. Altium Designer names the `.map` file after the project.

A linker map file is a text file that shows how the linker has mapped the sections and symbols from the various object files (`.obj`) to the linked object file. A locate part shows the absolute position of each section. External symbols are listed per space with their absolute address, both sorted on symbol and sorted on address.

### *Related information*

With the option **--map-file-format** (map file formatting) you can specify which parts you want to place in the map file.

Section 5.2, *Linker Map File Format*, in Chapter *List File Formats*.

## Linker: --map-file-format (-m)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **Linker** entry and select **Map File**.
3. Enable the option **Generate a map file (.map)**.
4. In the **Map file format** section, enable or disable the information you want to be included in the map file.

### *Command line syntax*

**--map-file-format=***flags*
**-m***flags*

You can specify the following formats:

| | | |
|---|---|---|
| 0 | | Same as **-mcfikLMNoQrSU** (link information) |
| 1 | | Same as **-mCfiKlMNoQRSU** (locate information) |
| 2 | | Same as **-mcfiklmNoQrSu** (most information) |
| **+/-callgraph** | (**c**/**C**) | Call graph information |
| **+/-files** | (**f**/**F**) | Processed files information |
| **+/-invocation** | (**i**/**I**) | Invocation and tool information |
| **+/-link** | (**k**/**K**) | Link result information |
| **+/-locate** | (**l**/**L**) | Locate result information |
| **+/-memory** | (**m**/**M**) | Memory usage information |
| **+/-nonalloc** | (**n**/**N**) | Non alloc information |
| **+/-overlay** | (**o**/**O**) | Overlay information |
| **+/-statics** | (**q**/**Q**) | Module local symbols |
| **+/-crossref** | (**r**/**R**) | Cross references information |
| **+/-lsl** | (**s**/**S**) | Processor and memory information |
| **+/-rules** | (**u**/**U**) | Locate rules |

### *Description*

With this option you specify which information you want to include in the map file. Use this option in combination with the option **--map-file** (**-M**).

If you do not specify this option, the linker uses the default: **--map-file-format=2**.

### *Related information*

Linker option **--map-file** (Generate map file)

# Linker: --misra-c-report

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **C Compiler** entry and select **MISRA-C**.
3. Select a MISRA-C configuration.
4. Enable the option **Produce a MISRA-C report**.

### *Command line syntax*

**--misra-c-report**[=*file*]

### *Description*

With this option you tell the linker to create a MISRA-C Quality Assurance report. This report lists the various modules in the project with the respective MISRA-C settings at the time of compilation. If you do not specify a filename, the file *name*`.mcr` is used.

### *Related information*

Compiler option **--misrac**

## Linker: --non-romable

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **Linker** entry and select **Miscellaneous**.
3. Add the option **--non-romable** to the **Additional linker options** field.

### *Command line syntax*

**--non-romable**

### *Description*

With this option, the linker will locate all ROM sections in RAM. A copy table is generated and is located in RAM. When the application is started, that data and BSS sections are re-initialized.

### *Related information*

–

# Linker: --no-rescan

### Menu entry

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **Linker** entry and select **Libraries**.
3. *Disable* the option **Rescan libraries to solve unresolved externals**.

### Command line syntax

**--no-rescan**

### Description

When the linker processes a library it searches for symbol definitions that are referenced by the objects and libraries processed so far. If the library contains a definition for an unresolved reference the linker extracts the object that contains the definition from the library. The linker processes object files and libraries in the order in which they appear on the command line.

When all objects and libraries are processed the linker checks if there are unresolved symbols left. If so, the default behavior of the linker is to rescan all libraries in the order given at the command line. The linker stops rescanning the libraries when all symbols are resolved, or when the linker could not resolve any symbol(s) during the rescan of all libraries. Notice that resolving one symbol may introduce new unresolved symbols.

With this option, you tell the linker to scan the object files and libraries only once. When the linker has not resolved all symbols after the first scan, it reports which symbols are still unresolved. This option is useful if you are building your own libraries. The libraries are most efficiently organized if the linker needs only one pass to resolve all symbols.

### Related information

Linker option **--first-library-first** (Scan libraries in given order)

## Linker: --no-rom-copy (-N)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **Linker** entry and select **Miscellaneous**.
3. Add the option **--no-rom-copy** to the **Additional linker options** field.

### *Command line syntax*

**--no-rom-copy**
**-N**

### *Description*

With this option the linker will not generate a ROM copy for data sections. A copy table is generated and contains entries to clear BSS section. However, no entries to copy data sections from ROM to RAM are placed in the copy table.

The data sections are initialized when the application is downloaded. The data sections are not re-initialized when the application is restarted.

### *Related information*

–

## Linker: --no-warnings (-w)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **Linker** entry and select **Diagnostics**.

3. Set **Error reporting** to one of the following values:

   - **Report all warnings**
   - **Suppress all warnings**
   - **Suppress specific warnings**.

   *If you select **Suppress specific warnings**:*

4. Enter the numbers, separated by commas, of the warnings you want to suppress.

### *Command line syntax*

**--no-warnings**[=*number*,...]
**-w**[*number*,...]

### *Description*

With this option you can suppresses all warning messages or specific warning messages.

- If you do not specify this option, all warnings are reported.
- If you specify this option but without numbers, all warnings are suppressed.
- If you specify this option with a number, only the specified warning is suppressed. You can specify the option **--no-warnings**=*number* multiple times.

### *Example*

To suppress warnings 135 and 136, enter **135, 136** in the **Specific warnings to suppress** field, or enter the following on the command line:

```
lk51 --no-warnings=135,136 test.obj
```

### *Related information*

Linker option **--warnings-as-errors** (Treat warnings as errors)

## Linker: --optimize (-O)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **Linker** entry and select **Optimization**.
3. Select an optimization level in the **Optimization level** box.

   *If you select **Custom Optimization:***

4. Enable the optimizations you want.

### *Command line syntax*

**--optimize**[=*flags*]
**-O**[*flags*]

Use the following options for predefined sets of flags:

| | | |
|---|---|---|
| **--optimize=0** | (**-O0**) | **No optimization**<br>Alias for: **-OCLTXY** |
| **--optimize=1** | (**-O1**) | **Default optimization**<br>Alias for: **-OCLtxy** |
| **--optimize=2** | (**-O2**) | All optimizations<br>Alias for: **-Ocltxy** |

You can set the following flags:

| | | |
|---|---|---|
| +/**-delete-unreferenced-sections** | (**c**/**C**) | Delete unreferenced sections from the output file |
| +/**-first-fit-decreasing** | (**l**/**L**) | Use a 'first fit decreasing' algorithm to locate unrestricted sections in memory. |
| +/**-copytable-compression** | (**t**/**T**) | Emit smart restrictions to reduce copy table size |
| +/**-delete-duplicate-code** | (**x**/**X**) | Delete duplicate code sections from the output file |
| +/**-delete-duplicate-data** | (**y**/**Y**) | Delete duplicate constant data from the output file |

### *Description*

With this option you can control the level of optimization the linker performs. If you do not use this option, **--optimize=1** is the default.

### *Related information*

Section 4.7, *Linker Optimizations*, in chapter *Using the Linker* of the user's manual.

## Linker: --option-file (-f)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **Linker** entry and select **Miscellaneous**.
3. Add the option **--option-file** to the **Additional linker options** field.

Be aware that the options in the option file are added to the linker options you have set in the other dialogs. Only in extraordinary cases you may want to use them in combination. Altium Designer automatically saves the options with your project.

### *Command line syntax*

**--option-file=***file*
**-f** *file*

### *Description*

This option is primarily intended for command line use. Instead of typing all options on the command line, you can create an option file which contains all options and flags you want to specify. With this option you specify the option file to the linker.

Use an option file when the length of the command line would exceed the limits of the operating system, or just to store options and save typing.

You can specify the option **--option-file** multiple times.

**Format of an option file**

- Multiple arguments on one line in the option file are allowed.
- To include whitespace in an argument, surround the argument with single or double quotes.
- If you want to use single quotes as part of the argument, surround the argument by double quotes and vise versa:

```
"This has a single quote ' embedded"

'This has a double quote " embedded'

'This has a double quote " and a single quote '"' embedded"
```

- When a text line reaches its length limit, use a \ to continue the line. Whitespace between quotes is preserved.

```
"This is a continuation \
line"

    -> "This is a continuation line"
```

- It is possible to nest command line files up to 25 levels.

### *Example*

Suppose the file `myoptions` contains the following lines:

| | |
|---|---|
| `-Mmymap` | (generate a map file) |
| `test.obj` | (input file) |
| `-Lc:\mylibs` | (additional search path for system libraries) |

Specify the option file to the linker:

```
lk51 --option-file=myoptions
```

This is equivalent to the following command line:

```
lk51 -Mmymap test.obj -Lc:\mylibs
```

### *Related information*

-

## Linker: --output (-o)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **Linker** entry and select **Output Format**.
3. Enable one or more output formats

### *Command line syntax*

**--output**=[*filename*][**:***format*[**:***addr_size*]]...
**-o**[*filename*][**:***format*[**:***addr_size*]]...

You can specify the following formats:

**IEEE** IEEE-695
**ELF** ELF/DWARF
**IHEX** Intel Hex
**SREC** Motorola S-records

### *Description*

By default, the linker generates an output file in IEEE-695 format, named after the first input file with extension `.abs`.

With this option you can specify an alternative *filename*, and an alternative *output* format. The default output format is the format of the first input file.

You can use the **--output** option multiple times. This is useful to generate multiple output formats. With the first occurrence of the **--output** option you specify the basename (the filename without extension), which is used for subsequent **--output** options with no filename specified. If you do not specify a filename, or you do not specify the **--output** option at all, the linker uses the default basename `task`*`n`*.

#### IHEX and SREC formats

If you specify the Intel Hex format or the Motorola S-records format, you can use the argument *addr_size* to specify the size of addresses in bytes (record length). For Intel Hex you can use the values: **1**, **2**, and **4** (default). For Motorola S-records you can specify: **2** (S1 records), **3** (S2 records) or **4** bytes (S3 records, default).

The name of the output file will be *filename* with the extension `.hex` or `.sre` and contains the code and data allocated in the default address space. If they exist, any other address spaces are also emitted whereas their output files are named *`filename_spacename`*`.hex` (`.sre`).

Use option **--chip-output** (**-c**) to create Intel Hex or Motorola S-record output files for each chip defined in the LSL file (suitable for loading into a PROM-programmer).

### *Example*

To create the output file `myfile.hex` of the default address space:

```
lk51 test.obj --output=myfile.hex:IHEX
```

If they exist, any other address spaces are emitted as well and are named `myfile_`*`spacename`*`.hex`.

### *Related information*

Linker option **--chip-output** (Generate an output file for each chip)

## Linker: --strip-debug (-S)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **Linker** entry and select **Miscellaneous**.

3. *Disable* the option **Include symbolic debug information**.

### *Command line syntax*

**--strip-debug**
**-S**

### *Description*

With this option you specify not to include symbolic debug information in the resulting output file.

### *Related information*

–

## Linker: --user-provided-initialization-code (-i)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **Linker** entry and select **Miscellaneous**.
3. Add the option **--user-provided-initialization-code** to the **Additional linker options** field.

### *Command line syntax*

**--user-provided-initialization-code**
**-i**

### *Description*

It is possible to use your own initialization code, for example, to save ROM space. With this option you tell the linker not to generate a copy table for initialize/clear sections. Use linker labels in your source code to access the positions of the sections when located.

If the linker detects references to the TASKING initialization code, an error is emitted: it is either the TASKING initialization routine or your own, not both.

Note that the options **--no-rom-copy** and **--non-romable**, may vary independently. The 'copytable-compression' optimization (**--optimize=t**) is automatically disabled when you enable this option.

### *Related information*

–

## Linker: --verbose (-v) / --extra-verbose (-vv)

### *Menu entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **Linker** entry and select **Miscellaneous**.

3. Add the option **--verbose** or**--extra-verbose** to the **Additional linker options** field.

### *Command line syntax*

**--verbose** / **--extra-verbose**
**-v** / **-vv**

### *Description*

With this option you put the linker in *verbose* mode. The linker prints the link phases while it processes the files. In the *extra verbose* mode, the linker also prints the filenames and it shows which objects are extracted from libraries. With this option you can monitor the current status of the linker.

### *Related information*

–

## Linker: --version (-V)

***Menu entry***

–

***Command line syntax***

**--version**
**-V**

***Description***

Display version information. The linker ignores all other options or input files.

***Related information***

–

## Linker: --warnings-as-errors

### Menu entry

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Expand the **Linker** entry and select **Diagnostics**.
3. Enable the option **Treat warnings as errors**.

### Command line syntax

**--warnings-as-errors**

### Description

When the linker detects an error or warning, it tries to continue the link process and reports other errors and warnings. When you use this option without arguments, you tell the linker to treat all warnings as errors. This means that the exit status of the linker will be non-zero after the detection of one or more linker warnings. As a consequence, the linker will not produce any output files.

You can also limit this option to specific warnings by specifying a comma-separated list of warning numbers.

### Related information

Linker option **--no-warnings** (Suppress some or all warnings)

## 4.4 Control Program Options

The control program is a tool to facilitate use of the toolset from the command line. Therefore you can only call the control program from the command line. The invocation syntax is:

**cc51** [*option*]... [*file*]...

### *Options*

The control program processes command line options either by itself, or, when the option is unknown to the control program, it looks whether it can pass the option to one of the other tools. However, for directly passing an option to the C compiler, assembler or linker, it is recommended to use the control program options **--pass-c**, **--pass-assembler**, **--pass-linker**.

### *Short and long option names*

Options can have both short and long names. Short option names always begin with a single minus (**-**) character, long option names always begin with double minus (**--**) characters. You can abbreviate long option names as long as the name is unique. You can mix short and long option names on the command line.

Options can have flags or sub-options. To switch a flag 'on', use a lowercase letter or a **+***longflag*. To switch a flag off, use an uppercase letter or a **-***longflag*. Separate *longflags* with commas. The following two invocations are equivalent:

```
cc51 -Wc-Oac test.c
cc51 --pass-c=--optimize=+coalescer,+cse test.c
```

When you do not specify an option, a default value may become active.

## Control Program: --address-size

### *Command line syntax*

**--address-size**=*addr_size*

### *Description*

If you specify IHEX or SREC with the control option **--format**, you can additionally specify the record length to be emitted in the output files.

With this option you can specify the size of addresses in bytes (record length). For Intel Hex you can use the values: **1**, **2**, and **4** (default). For Motorola S-records you can specify: **2** (S1 records), **3** (S2 records) or **4** bytes (S3 records, default).

If you do not specify *addr_size*, the default address size is generated.

### *Example*

To create the SREC file `test.sre` with S1 records, type:

```
cc51 --format=SREC --address-size=2 test.c
```

### *Related information*

Control program option **--format** (Set linker output format)

Linker option **--output** (Specify an output object file)

## Control Program: --check

### Command line syntax

**--check**

### Description

With this option you can check the source code for syntax errors, without generating code. This saves time in developing your application.

The compiler/assembler reports any warnings and/or errors.

### Related information

C compiler option **--check** (Check syntax)

Assembler option **--check** (Check syntax)

# Control Program: --cpu (-C)

### *Command line syntax*

**--cpu**=*cpu*
**-C***cpu*

### *Description*

With this option you define the CPU core for which you create your application. The TSK51x/TSK52x target has more than one processor type and therefore you need to specify for which processor type you want to create your application.

The effect of this option is that the compiler includes the appropriate special function register file: `reg`*`cpu`*`.sfr`. You choose one of the following CPU's: `TSK51A`, `TSK52A` or `TSK52B`.

Assembly code can check the value of the option by means of the built-in function `@CPU()`.

### *Example*

To build the file `test.c` for the TSK51x/TSK52x processor and use SFR file `regtsk51a.sfr`:

```
cc51 --cpu=tsk51a test.c
```

### *Related information*

C compiler option **--cpu** (Select CPU core type)
Assembler option **--cpu** (Select CPU core type)

## Control Program: --create (-cl/-cm/-co/-cs)

### *Command line syntax*

**--create**[=*stage*]
**-c**[*stage*]

You can specify the following stages (if you omit the *stage*, the default is **--create=object**):

| | | |
|---|---|---|
| **relocatable** | (**l**) | Stop after the files are linked to a linker object file (`.out`) |
| **mil** | (**m**) | Stop after C files are compiled to MIL (`.mil`) |
| **object** | (**o**) | Stop after the files are assembled to objects (`.obj`) |
| **assembly** | (**s**) | Stop after C files are compiled to assembly (`.src`) |

### *Description*

Normally the control program generates an absolute object file of the specified output format from the file you supplied as input.

With this option you tell the control program to stop after a certain number of phases.

### *Related information*

Linker option **--link-only** (Link only, no locating)

## Control Program: −−debug−info (−g)

### *Command line syntax*

**−−debug−info**
**−g**

### *Description*

With this option you tell the control program to include debug information in the generated object file.

### *Related information*

−

## Control Program: --define (-D)

### *Command line syntax*

**--define**=*macro_name*[=*macro_definition*]
**-D***macro_name*[=*macro_definition*]

### *Description*

With this option you can define a macro and specify it to the preprocessor. If you only specify a macro name (no macro definition), the macro expands as '1'.

You can specify as many macros as you like. On the command line, use the option **--define** multiple times. If the command line exceeds the length limit of the operating system, you can define the macros in an *option file* which you then must specify to the control program with the option **--option-file**=*file* (**-f**).

Defining macros with this option (instead of in the C source) is, for example, useful to compile or assemble conditional source as shown in the example below.

The control program passes the option **--define** (**-D**) to the compiler and the assembler.

### *Example*

Consider the following C program with conditional code to compile a demo program and a real program:

```
void main( void )
{
#if DEMO == 1
    demo_func();   /* compile for the demo program */
#else
    real_func();   /* compile for the real program */
#endif
}
```

You can now use a macro definition to set the DEMO flag. With the control program this looks as follows:

```
cc51 --define=DEMO test.c
cc51 --define=DEMO=1 test.c
```

Note that both invocations have the same effect.

The next example shows how to define a macro with arguments. Note that the macro name and definition are placed between double quotes because otherwise the spaces would indicate a new option.

```
cc51 -D"MAX(A,B)=((A) > (B) ? (A) : (B))" test.c
```

### *Related information*

Control Program option **--undefine** (Undefine preprocessor macro)
Control Program option **--option-file** (Read options from file)

## Control Program: --diag

### *Command line syntax*

**--diag**=[*format*:]{**all**|**nr**,...}

### *Description*

With this option you can ask for an extended description of error messages in the format you choose. The output is directed to `stdout` (normally your screen) and in the format you specify. You can specify the following formats: **html**, **rtf** or **text** (default). To create a file with the descriptions, you must redirect the output.

With the suboption **all**, the descriptions of all error messages are given. If you want the description of one or more selected error messages, you can specify the error message numbers, separated by commas.

With this option the control program does not process any files.

### *Example*

To display an explanation of message number 103, enter:

```
cc51 --diag=103
```

This results in message 103 with explanation.

To write an explanation of all errors and warnings in HTML format to file `ccerrors.html`, enter:

```
cc51 --diag=html:all > ccerrors.html
```

### *Related information*

-

# Control Program: ––dry–run (–n)

### *Command line syntax*

**––dry–run**
**–n**

### *Description*

With this option you put the control program *verbose* mode. The control program prints the invocations of the tools it would use to process the files without actually performing the steps.

### *Related information*

Control Program option **––verbose** (**–v**) (Verbose output)

# Control Program: --error-file

### *Command line syntax*

**--error-file**

### *Description*

With this option the control program tells the compiler, assembler and linker to redirect error messages to a file.

The error file will be named after the input file with extension `.err` (for compiler) or `.ers` (for assembler). For the linker, the error file is `lk51.elk`.

### *Example*

To write errors to error files instead of `stderr`, enter:

```
cc51 --error-file -t test.c
```

### *Related information*

Control Program option **--warnings-as-errors** (Treat warnings as errors)

## Control Program: --format

### *Command line syntax*

**--format**=*format*

You can specify the following formats:

**IEEE** IEEE-695
**ELF** ELF/DWARF
**IHEX** Intel Hex
**SREC** Motorola S-records

### *Description*

With this option you specify the output format for the resulting (absolute) object file. The default output format is IEEE-695, which can directly be used by the debugger.

If you choose IHEX or SREC, you can additionally specify the address size of the chosen format (option **--address-size**).

### *Example*

To generate an Motorola S-record output file:

```
cc51 --format=SREC test1.c test2.c --output=test.sre
```

### *Related information*

Control program option **--address-size** (Set address size for linker IHEX/SREC files)

Linker option **--output** (Specify an output object file)
Linker option **--chip-output** (Generate hex file for each chip)

# Control Program: --fp-trap

### *Command line syntax*

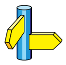
**--fp-trap**

### *Description*

By default the control program uses the non-trapping floating-point library (`fp51ls.lib` for the large model). With this option you tell the control program to use the trapping floating-point library (`fp51lst.lib`).

If you use the trapping floating-point library, exceptional floating-point cases are intercepted and can be handled separately by an application defined exception handler. Using this library decreases the execution speed of your application.

### *Related information*



## Control Program: --help (-?)

### *Command line syntax*

**--help**[=**options**]
**-?**

### *Description*

Displays an overview of all command line options. When you specify the argument **options** you can list detailed option descriptions.

### *Example*

The following invocations all display a list of the available command line options:

```
cc51 -?
cc51 --help
cc51
```

To see a detailed description of the available options, enter:

```
cc51 --help=options
```

## Control Program: --include-directory (-I)

### *Command line syntax*

**--include-directory**=*path*,...
**-I***path*,...

### *Description*

With this option you can specify the path where your include files are located. A relative path will be relative to the current directory.

### *Example*

Suppose that the C source file `test.c` contains the following lines:

```
#include <stdio.h>
#include "myinc.h"
```

You can call the control program as follows:

```
cc51 --include-directory=myinclude test.c
```

First the compiler looks for the file `stdio.h` in the directory `myinclude` relative to the current directory. If it was not found, the compiler searches in the environment variable and then in the default `include` directory.

The compiler now looks for the file `myinc.h`, in the directory where `test.c` is located. If the file is not there the compiler searches in the directory `myinclude`. If it was still not found, the compiler searches in the environment variable and then in the default `include` directory.

### *Related information*

C compiler option **--include-directory** (Add directory to include file search path)
C compiler option **--include-file** (Include file at the start of a compilation)

Section 2.4, *How the Compiler Searches Include Files*, in chapter *Using the Compiler* of the user's manual.

# Control Program: --iso

### *Command line syntax*

**--iso**={**90**|**99**}

### *Description*

With this option you specify to the control program against which ISO standard it should check your C source. C90 is also referred to as the "ANSI C standard". C99 refers to the newer ISO/IEC 9899:1999 (E) standard and is the default.

Independant of the chosen ISO standard, the control program always links libraries with C99 support.

### *Example*

To compile the file `test.c` conform the ISO C90 standard:

```
cc51 --iso=90 test.c
```

### *Related information*

C compiler option **--iso** (ISO C standard)

## Control Program: --keep-output-files (-k)

### *Command line syntax*

**--keep-output-files**
**-k**

### *Description*

If an error occurs during the compilation, assembling or linking process, the resulting output file may be incomplete or incorrect. With this option you keep the generated output files when an error occurs.

By default the control program removes generated output files when an error occurs. This is useful when you use the make utility. If the erroneous files are not removed, the make utility may process corrupt files on a subsequent invocation.

Use this option when you still want to use the generated files. For example when you know that a particular error does not result in a corrupt file, or when you want to inspect the output file, or send it to Altium support.

### *Related information*

-

## Control Program: --keep-temporary-files (-t)

### *Menu Entry*

1. From the **Project** menu, select **Project Options...**

   *The Project Options dialog box appears.*

2. Select **Build Options**.
3. Enable the option **Keep temporary files that are generated during a compile**.

### *Command line syntax*

**--keep-temporary-files**
**-t**

### *Description*

By default, the control program removes intermediate files like the `.src` file (result of the compiler phase) and the `.obj` file (result of the assembler phase).

With this option you tell the control program to keep temporary files it generates during the creation of the absolute object file.

### *Related information*

–

# Control Program: --library (-l)

### *Command line syntax*

**--library**=*name*
**-l***name*

### *Description*

With this option you tell the linker via the control program to use system library `name.lib`, where *name* is a string. The linker first searches for system libraries in any directories specified with **--library-directory**, then in the directories specified with the environment variable `LIBC51`, unless you used the option **--ignore-default-library-path**.

### *Example*

To search in the system library `c51ls.lib` (C library):

```
cc51 test.obj mylib.lib --library=c51ls
```

The linker links the file `test.obj` and first looks in `mylib.lib` (in the current directory only), then in the system library `c51ls.lib` to resolve unresolved symbols.

### *Related information*

Linker option **--library-directory** (Additional search path for system libraries)

Section 4.4, *Linking with Libraries*, in chapter *Using the Linker* of the user's manual.

## Control Program:--library-directory (-L) / --ignore-default-library-path

### *Command line syntax*

**--library-directory**=*dir*
**-L***dir*

**--ignore-default-library-path**
**-L**

### *Description*

With this option you can specify the path(s) where your system libraries, specified with the **--library** option, are located. If you want to specify multiple paths, use the option **--library-directory** for each separate path.

By default path this is `$(PRODDIR)\c51\lib` directory.

If you specify only **-L** (without a pathname) or the long option **--ignore-default-library-path**, the linker will not search the default path and also not in the paths specified in the environment variable `LIBC51`. So, the linker ignores steps 2 and 3 as listed below.

The priority order in which the linker searches for system libraries specified with the **--library** option is:

1. The path that is specified with the **--library-directory** option.
2. The path that is specified in the environment variable `LIBC51`.
3. The default directory `$(PRODDIR)\c51\lib` (or a processor specific sub-directory).

### *Example*

Suppose you call the control program as follows:

```
cc51 test.c --library-directory=c:\mylibs --library=c51ls
```

First the linker looks in the directory `c:\mylibs` for library `c51ls.lib` (this option).

If it does not find the requested libraries, it looks in the directory that is set with the environment variable `LIBC51`.

Then the linker looks in the default directory `$(PRODDIR)\c51\lib` for libraries.

### *Related information*

Linker option **--library** (Link system library)

# Control Program: --list-files

### Command line syntax

**--list-files**[=*name*]

### Description

With this option you tell the assembler via the control programma to generate a list file for each specified input file. A list file shows the generated object code and the relative addresses. Note that the assembler generates a relocatable object file with relative addresses.

With *name* you can specify a name for the list file. This is only possible if you specify only one input file to the control program. If you do not specify *name*, or you specify more than one input files, the control program names the generated list file(s) after the specified input file(s) with extension `.lst`.

### Example

This example generates the list files `1.lst` and `2.lst` for `1.c` and `2.c`. If in this example also a *name* had been specified, it would be ignored because two input files are specified.

```
cc51 1.c 2.c --list-files
```

### Related information

Assembler option **--list-file** (Generate list file)

Assembler option **--list-format** (List file formatting options)

## Control Program: --lsl-file (-d)

### *Command line syntax*

**--lsl-file**=*file*
**-d***file*

### *Description*

A linker script file contains vital information about the core for the locating phase of the linker. A linker script file is coded in LSL and contains the following types of information:

- the architecture and derivative definition describe the core's hardware architecture and its internal memory.
- the board specification describes the physical memory available in the system.
- the section layout definition describes how to locate sections in memory.

With this option you specify a linker script file via the control program to the linker. If you do not specify this option, the linker does not use a script file. You can specify the existing file `51.lsl` or the name of a manually written linker script file. You can use this option multiple times. The linker processes the LSL files in the order in which they appear on the command line.

### *Related information*

Section 4.8, *Controlling the Linker with a Script*, in chapter *Using the Linker* of the user's manual.

## Control Program: --model (-M)

### Command line syntax

**--model**={**aux**|**large**|**small**}
**-M**{**a**|**l**|**s**}

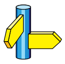
### Description

By default the TSK51x/TSK52x compiler uses the *small memory* model. When the compiler uses the small memory model to access data, all data objects and the stack (used for function parameter passing) must fit in the internal RAM. Note that the stack length depends upon the nesting depth of the various functions. Accessing data in internal RAM is considerably faster than accessing data in external RAM.

In the *large memory* model the produced code is larger and in some cases slower than the code for a similar operation in one of the other memory models.

The *auxiliary page memory* model is especially interesting for derivatives with 256 bytes of 'external' RAM on chip. All data must fit in one 256 bytes page.

### Related information



Optionally you can choose to enable reentrancy with control program option **--reentrant**.

Section 1.4, *Memory Models*, in chapter *C Language*.

## Control Program: --no-default-libraries

### *Command line syntax*

**--no-default-libraries**

### *Description*

By default the control program specifies the standard C libraries (C99) and run-time library to the linker. With this option you tell the control program *not* to specify the standard C libraries and run-time library to the linker.

In this case you must specify the libraries you want to link to the linker with the option **-l***library_name*. The control program recognizes the option **-l** as an option for the linker and passes it as such.

### *Example*

```
cc51 --no-default-libraries test.c
```

The control program does not specify any libraries to the linker. In normal cases this would result in unresoved externals.

To specify your own libraries (`libmy.a`) and avoid unresolved externals:

```
cc51 --no-default-libraries -lmy test.c
```

### *Related information*

Linker option **--library** (**-l**) (Add library)

## Control Program: --no-map-file

### *Command line syntax*

**--no-map-file**

### *Description*

By default the control program tells the linker to generate a linker map file.

A linker map file is a text file that shows how the linker has mapped the sections and symbols from the various object files (`.obj`) to the linked object file. A locate part shows the absolute position of each section. External symbols are listed per space with their absolute address, both sorted on symbol and sorted on address.

With this option you prevent the generation of a map file.

### *Related information*

-

## Control Program: --no-preprocessing-only

### *Command line syntax*

**--no-preprocessing-only**

### *Description*

On the command line, the control program stops after preprocessing. If you also want to compile the C source you can specify the option **--no-preprocessing-only**. In this case the control program calls the compiler twice, once with option **--preprocess** and once for a regular compilation.

### *Related information*

Control program option **--preprocess** / **-E**

## Control Program: --no-warnings (-w)

### *Command line syntax*

**--no-warnings**[=*number*]
**-w**[*number*]

### *Description*

With this option you can suppress all warning messages or specific C compiler warning messages:

- If you do not specify this option, all warnings are reported.
- If you specify this option but without numbers, all warnings are suppressed.
- If you specify this option with a number, only the specified C compiler warning is suppressed.
  You can specify the option **--no-warnings=***number* multiple times.

### *Related information*

–

## Control Program: --option-file (-f)

### *Command line syntax*

**--option-file**=*file*
**-f** *file*

### *Description*

Instead of typing all options on the command line, you can create an option file which contains all options and flags you want to specify. With this option you specify the option file to the control program.

Use an option file when the command line would exceed the limits of the operating system, or just to store options and save typing.

You can specify the option **--option-file** multiple times.

**Format of an option file**

- Multiple arguments on one line in the option file are allowed.
- To include whitespace in an argument, surround the argument with single or double quotes.
- If you want to use single quotes as part of the argument, surround the argument by double quotes and vise versa:

```
"This has a single quote ' embedded"

'This has a double quote " embedded'

'This has a double quote " and a single quote '"' embedded"
```

- When a text line reaches its length limit, use a 'to continue the line. Whitespace between quotes is preserved.

```
"This is a continuation \
line"

    -> "This is a continuation line"
```

- It is possible to nest command line files up to 25 levels.

### *Example*

Suppose the file `myoptions` contains the following lines:

```
-DDEMO=1
test.c
```

Specify the option file to the control program:

```
cc51 --option-file=myoptions
```

This is equivalent to the following command line:

```
cc51 -DDEMO=1 test.c
```

### *Related information*

-

## Control Program: ––output (–o)

### *Command line syntax*

**––output**=*file*
**–o** *file*

### *Description*

Default, the control program generates a file with the same basename as the first specified input file. With this option you specify another name for the resulting absolute object file.

### *Example*

```
cc51 test.c prog.c
```

The control program generates an IEEE–695 object file (default) with the name `test.abs`.

To generate the file `result.abs`:

```
cc51 --output=result.abs test.c prog.c
```

### *Related information*

–

## Control Program: --pass (-W)

### *Command line syntax*

| | | |
|---|---|---|
| **--pass-assembler**=*option* | (**-Wa***option*) | Pass option directly to the assembler |
| **--pass-c**=*option* | (**-Wc***option*) | Pass option directly to the C compiler |
| **--pass-linker**=*option* | (**-Wl***option*) | Pass option directly to the linker |

### *Description*

With this option you tell the control program to call a tool with the specified option. The control program does not use or interpret the option itself, but specifies it directly to the tool which it calls.

### *Related information*

–

# Control Program: --preprocess (-E)

### *Command line syntax*

**--preprocess**[=*flags*]
**-E**[*flags*]

You can set the following flags (when you specify **-E** without flags, the default is **-ECMP**):

| | | |
|---|---|---|
| +/**-comments** | (**c**/**C**) | Keep comments from the C source in the preprocessed output |
| +/**-make** | (**m**/**M**) | Generate dependency lines that can be used for the makefile |
| +/**-noline** | (**p**/**P**) | Strip #line source position info (lines starting with `#line`) |

### *Description*

With this option you tell the control program to preprocess the C source.

The C compiler sends the preprocessed output to the file *name*.pre (where *name* is the name of the C source file being compiled). Altium Designer also compiles the C source.

On the command line, the control program stops after preprocessing. If you also want to compile the C source you can specify the option **--no-preprocessing-only**. In this case the control program calls the compiler twice, once with option **--preprocess** and once for a regular compilation.

### *Example*

```
cc51 --preprocess=+comments,-make,-noline --no-preprocessing-only test.c
```

The compiler preprocesses the file `test.c` and sends the output to the file `test.pre`. Comments are included but no dependencies are generated and the line source position information is not stripped from the output file. Next, the control program calls the compiler, assembler and linker to create the final object file `test.abs`.

### *Related information*

Control program option **--no-preprocessing-only**

## Control Program: --reentrant

### *Command line syntax*

**--reentrant**

### *Description*

If you select reentrancy, a (less efficient) virtual dynamic stack is used which allows you to call functions recursively. With reentrancy, you can call functions at any time, even from interrupt functions.

### *Related information*

Control Program option **--model** (Memory model)

Section 1.4, *Memory Models*, in chapter *C Language*.
Section 1.11.1, *Reentrant Functions*, in chapter *C Language*.

# Control Program: --static

### *Command line syntax*

**--static**

### *Description*

This option is directly passed to the compiler.

With this option, the compiler treats external definitions at file scope (except for `main`) as if they were declared `static`. As a result, unused functions will be eliminated, and the alias checking algorithm assumes that objects with static storage cannot be referenced from functions outside the current module.

This option only makes sense when you specify all modules of an application on the command line.

### *Example*

```
cc51 --static module1.c module2.c module3.c
```

### *Related information*

-

## Control Program: --undefine (-U)

### *Command line syntax*

**--undefine**=*macro_name*
**-U***macro_name*

### *Description*

With this option you can undefine an earlier defined macro as with `#undef`.

This option is for example useful to undefine predefined macros. However, you cannot undefine predefined ISO C standard macros.

The control program passes the option **--undefine** (**-U**) to the compiler.

### *Example*

To undefine the predefined macro __TASKING__:

```
cc51 --undefine=__TASKING__ test.c
```

### *Related information*

Control Pogram option **--define** (Define preprocessor macro)

## Control Program: −−verbose (−v)

### *Command line syntax*

**−−verbose**
**−v**

### *Description*

With this option you put the control program in verbose mode. With the option **−v** the control program performs it tasks while it prints the steps it performs to `stdout`.

### *Related information*

Control Program option **−n** (**−−dry−run**) (Verbose output and suppress execution)

## Control Program: ––version (–V)

### *Command line syntax*

**––version**
**–V**

### *Description*

Display version information. The control program ignores all other options or input files.

### *Related information*

–

## Control Program: --warnings-as-errors

### *Command line syntax*

**--warnings-as-errors**

### *Description*

If one of the tools encounters an error, it stops processing the file(s). With this option you tell the tools to treat warnings as errors. As a consequence, the tools now also stop after encountering a warning.

### *Related information*

Control Program option **--no-warnings** (Suppress all warnings)

## 4.5 Make Utility Options

When you build a project in Altium Designer, Altium Designer generates a makefile and uses the make utility **tmk** to build all your files. However, you can also use the make utility directly from the command line to build your project.

The invocation syntax is:

```
tmk [option...] [target...] [macro=def]
```

This section describes all options for the make utility. The make utility is a command line tool so there are no equivalent options in Altium Designer.

# Defining Macros

### Command line syntax

**macro**=*definition*

### Description

With this argument you can define a macro and specify it to the make utility.

A macro definition remains in existence during the execution of the makefile, even when the makefile recursively calls the make utility again. In the recursive call, the macro acts as an environment variable. This means that it is overruled by definitions in the recursive call. Use the option **-e** to prevent this.

You can specify as many macros as you like. If the command line exceeds the limit of the operating system, you can define the macros in an *option file* which you then must specify to the make utility with the option **-m** *file*.

Defining macros on the command line is, for example, useful in combination with conditional processing as shown in the example below.

### Example

Consider the following makefile with conditional rules to build a demo program and a real program:

```
ifdef DEMO      # the value of DEMO is of no importance
  real.abs : demo.obj main.obj
             lk51 demo.obj main.obj -d51.lsl -lc51ss -lfp51ss -lrt51
else
  real.abs : real.obj main.obj
             lk51 real.obj main.obj -d51.lsl -lc51ss -lfp51ss -lrt51
endif
```

You can now use a macro definition to set the `DEMO` flag:

```
tmk real.abs DEMO=1
```

In both cases the absolute object file `real.abs` is created but depending on the DEMO flag it is linked with `demo.obj` or with `real.obj`.

### Related information

Make utility option **-e** (Environment variables override macro definitions)
Make utility option **-m** (Name of invocation file)

## Make Utility: –?

### *Command line syntax*

**–?**

### *Description*

Displays an overview of all command line options.

### *Example*

The following invocation displays a list of the available command line options:

```
tmk -?
```

### *Related information*

–

## Make Utility: −a

### *Command line syntax*

**−a**

### *Description*

Normally the make utility rebuilds only those files that are out of date. With this option you tell the make utility to rebuild *all* files, without checking whether they are out of date.

### *Example*

```
tmk -a
```

Rebuilds all your files, regardless of whether they are out of date or not.

### *Related information*

-

## Make Utility: –c

### *Command line syntax*

**–c**

### *Description*

Altium Designer uses this option for the graphical version of the make utility when you create sub–projects. In this case the make utility calls another instance of the make utility for the sub–project. With the option **–c**, the make utility runs as a child process of the current make.

The option **–c** overrules the option **–err**.

### *Example*

```
tmk -c
```

The make utility runs its commands as a child processes.

### *Related information*

–

## Make Utility: –D/–DD

### *Command line syntax*

**–D**
**–DD**

### *Description*

With the option **–D** the make utility prints every line of the makefile to standard output as it is read by **tmk**.

With the option **–DD** not only the lines of the makefile are printed but also the lines of the `tmk.mk` file (implicit rules).

### *Example*

```
tmk -D
```

Each line of the makefile that is read by the make utility is printed to standard output (usually your screen).

### *Related information*

–

## Make Utility: –d/–dd

### *Command line syntax*

**–d**
**–dd**

### *Description*

With the option **–d** the make utility shows which files are out of date and thus need to be rebuild. The option **–dd** gives more detail than the option **–d**.

### *Example*

```
tmk -d
```

Shows which files are out of date and rebuilds them.

### *Related information*

–

## Make Utility: –e

### *Command line syntax*

**–e**

### *Description*

If you use macro definitions, they may overrule the settings of the environment variables.

With the option **–e**, the settings of the environment variables are used even if macros define otherwise.

### *Example*

```
tmk -e
```

The make utility uses the settings of the environment variables regardless of macro definitions.

### *Related information*

–

## Make Utility: –err

### *Command line syntax*

**–err** *file*

### *Description*

With this option the make utility redirects error messages and verbose messages to a specified file.

With the option **–s** the make utility only displays error messages.

### *Example*

```
tmk -err error.txt
```

The make utility writes messages to the file `error.txt`.

### *Related information*

Make utility option **–s** (Do not print commands before execution)

## Make Utility: –f

### *Command line syntax*

**–f** *my_makefile*

### *Description*

Default the make utility uses the file `makefile` to build your files.

With this option you tell the make utility to use the specified file instead of the file `makefile`. Multiple **–f** options act as if all the makefiles were concatenated in a left–to–right order.

### *Example*

```
tmk -f mymake
```

The make utility uses the file `mymake` to build your files.

### *Related information*

–

## Make Utility: –G

### *Command line syntax*

**–G** *path*

### *Description*

Normally you must call the make utility **tmk** from the directory where your makefile and other files are stored.

With the option **–G** you can call the make utility from within another directory. The *path* is the path to the directory where your makefile and other files are stored and can be absolute or relative to your current directory.

### *Example*

Suppose your makefile and other files are stored in the directory `..\myfiles`. You can call the make utility, for example, as follows:

```
tmk -G ..\myfiles
```

### *Related information*

–

## Make Utility: –i

### *Command line syntax*

**–i**

### *Description*

When an error occurs during the make process, the make utility exits with a certain exit code.

With the option **–i**, the make utility exits without an error code, even when errors occurred.

### *Example*

```
tmk -i
```

The make utility exits without an error code, even when an error occurs.

### *Related information*

–

## Make Utility: –K

### Command line syntax

**–K**

### Description

With this option the make utility keeps temporary files it creates during the make process. The make utility stores temporary files in the directory that you have specified with the environment variable TMPDIR or in the default 'temp' directory of your system when the TMPDIR environment variable is not specified.

### Example

```
tmk -K
```

The make utility preserves all temporary files.

### Related information

–

## Make Utility: –k

### *Command line syntax*

**–k**

### *Description*

When during the make process the make utility encounters an error, it stops rebuilding your files.

With the option **–k**, the make utility only stops building the target that produced the error. All other targets defined in the makefile are built.

### *Example*

```
tmk -k
```

If the make utility encounters an error, it stops building the current target but proceeds with the other targets that are defined in the makefile.

### *Related information*

Make utility option **–S** (Undo the effect of **–k**)

## Make Utility: –m

### *Command line syntax*

**–m** *file*

### *Description*

Instead of typing all options on the command line, you can create an option file which contains all options and flags you want to specify. With this option you specify the option file to the make utility.

Use an option file when the command line would exceed the limits of the operating system, or just to store options and save typing.

You can specify the option -**m** multiple times.

### *Format of an option file*

- Multiple arguments on one line in the option file are allowed.
- To include whitespace in an argument, surround the argument with single or double quotes.
- If you want to use single quotes as part of the argument, surround the argument by double quotes and vise versa:

```
”This has a single quote ’ embedded”

’This has a double quote ” embedded’

’This has a double quote ” and a single quote ’”’ embedded”
```

- When a text line reaches its length limit, use a '\' to continue the line. Whitespace between quotes is preserved.

```
”This is a continuation \
line”
     -> ”This is a continuation line”
```

- It is possible to nest command line files up to 25 levels.

### *Example*

Suppose the file `myoptions` contains the following lines:

```
-k
-err errors.txt
test.abs
```

Specify the option file to the make utility:

```
tmk -m myoptions
```

This is equivalent to the following command line:

```
tmk -k -err errors.txt test.abs
```

### *Related information*

-

# Make Utility: –n

### Command line syntax

**–n**

### Description

With this option you tell the make utility to perform a *dry run*. The make utility shows what it would do but does not actually perform these tasks.

This option is for example useful to quickly inspect what would happen if you call the make utility.

### Example

```
tmk -n
```

The make utility does not perform any tasks but displays what it would do if called without the option **–n**.

### Related information

Make utility option **–s** (Do not print commands before execution)

## Make Utility: –p

### *Command line syntax*

**–p**

### *Description*

Normally, if a command in a target rule in a makefile returns an error or when the target construction is interrupted, the make utility removes that target file. With this option you tell the make utility to make all target files precious. This means that dependency files are never removed.

### *Example*

```
tmk -p
```

The make utility never removes target dependency files.

### *Related information*

–

## Make Utility: –q

### *Command line syntax*

**–q**

### *Description*

With this option the make utility does not perform any tasks but only returns an exit code. A zero status indicates that all target files are up to date, a non-zero status indicates that some or all target files are out of date.

### *Example*

```
tmk -q
```

The make utility only returns an exit code that indicates whether all target files are up to date or not. It does not rebuild any files.

### *Related information*

-

## Make Utility: –r

### *Command line syntax*

**–r**

### *Description*

When you call the make utility, it first reads the implicit rules from the file `tmk.mk`, then it reads the makefile with the rules to build your files. (The file `tmk.mk` is located in the `\etc` directory of the toolset.)

With this option you tell the make utility *not* to read `tmk.mk` and to rely fully on the make rules in the makefile.

### *Example*

```
tmk -r
```

The make utility does not read the implicit make rules in `tmk.mk`.

### *Related information*

–

## Make Utility: –S

### *Command line syntax*

**–S**

### *Description*

With this option you cancel the effect of the option **–k**. This is only necessary in a recursive make where the option **–k** might be inherited from the top-level make via MAKEFLAGS or if you set the option **–k** in the environment variable MAKEFLAGS.

### *Example*

```
tmk -S
```

The effect of the option **–k** is cancelled so the make utility stops with the make process after it encounters an error.

The option **–k** in this example may have been set with the environment variable MAKEFLAGS or in a recursive call to **tmk** in the makefile.

### *Related information*

Make utility option **–k** (On error, abandon the work for the current target only)

## Make Utility: –s

### *Command line syntax*

**–s**

### *Description*

With this option you tell the make utility to perform its tasks without printing the commands it executes. Error messages are normally printed.

### *Example*

```
tmk -s
```

The make utility rebuilds your files but does not print the commands it executes during the make process.

### *Related information*

Make utility option **–n** (Perform a dry run)

## Make Utility: –t

### *Command line syntax*

**–t**

### *Description*

With this option you tell the make utility to *touch* the target files, bringing them up to date, rather than performing the rules to rebuild them.

### *Example*

```
tmk -t
```

The make utility updates out-of-date files by giving them a new date and time stamp. The files are not actually rebuild.

### *Related information*

-

## Make Utility: –time

### *Command line syntax*

**–time**

### *Description*

With this option you tell the make utility to display the current date and time on standard output.

### *Example*

```
tmk -time
```

The make utility displays the current date and time and updates out-of-date files.

### *Related information*

–

## Make Utility: –V

### *Command line syntax*

**–V**

### *Description*

Display version information. The make utility ignores all other options or input files.

### *Example*

```
tmk -V
```

The make utility displays the version information but does not perform any tasks.

### *Related information*

–

## Make Utility: –W

### *Command line syntax*

**–W** *target*

### *Description*

With this option the make utility considers the specified target file always as up to date and will not rebuild it.

### *Example*

```
tmk -W test.abs
```

The make utility rebuilds out of date targets in the makefile except the file `test.abs` which is considered now as up to date.

### *Related information*

-

## Make Utility: –x

### *Command line syntax*

**–x**

### *Description*

With this option the make utility shows extended error messages. Extended error messages give more detailed information about the exit status of the make utility after errors. Altium Designer uses this option for the graphical version of make.

### *Example*

```
tmk -x
```

If errors occur, the make utility gives extended information.

### *Related information*

-

## 4.6 Librarian Options

The librarian **tlb** is a tool to build library files and it offers the possibility to replace, extract and remove modules from an existing library.

You can only call the librarian from the command line. The invocation syntax is:

**tlb** *key_option* [*sub_option*...] *library* [*object_file*]

This section describes all options for the make utility. Suboptions can only be used in combination with certain key options. Keyoptions and their suboptions are therefor described together. The miscellaneous options can always be used and are also described separately.

The librarian is a command line tool so there are no equivalent options in Altium Designer.

| Description | Option | Suboption |
|---|---|---|
| **Main functions (key options)** | | |
| Replace or add an object module | **–r** | **–a –b –c –u –v** |
| Extract an object module from the library | **–x** | **–o –v** |
| Delete object module from library | **–d** | **–v** |
| Move object module to another position | **–m** | **–a –b –v** |
| Print a table of contents of the library | **–t** | **–s0 –s1** |
| Print object module to standard output | **–p** | |
| **Suboptions** | | |
| Append or move new modules after existing module *name* | **–a** *name* | |
| Append or move new modules before existing module *name* | **–b** *name* | |
| Create library without notification if library does not exist | **–c** | |
| Preserve last–modified date from the library | **–o** | |
| Print symbols in library modules | **–s**{**0**\|**1**} | |
| Replace only newer modules | **–u** | |
| Verbose | **–v** | |
| **Miscellaneous** | | |
| Display options | **–?** | |
| Display version header | **–V** | |
| Read options from *file* | **–f** *file* | |
| Suppress warnings above level *n* | **–w***n* | |

*Table 4–1: Overview of librarian options and suboptions*

## Librarian: –?

### *Command line syntax*

**–?**

### *Description*

Displays an overview of all command line options.

### *Example*

The following invocations display a list of the available command line options:

```
tlb -?
tlb
```

### *Related information*

–

## Librarian: –d

### *Command line syntax*

**–d** [**–v**]

### *Description*

Delete the specified object modules from a library. With the suboption **–v** the librarian shows which files are removed.

**–v** Verbose: the librarian shows which files are removed.

### *Example*

```
tlb -d mylib.lib obj1.obj obj2.obj
```

The librarian deletes `obj1.obj` and `obj2.obj` from the library `mylib.lib`.

```
tlb -d -v mylib.lib obj1.obj obj2.obj
```

The librarian deletes `obj1.obj` and `obj2.obj` from the library `mylib.lib` and displays which files are removed.

### *Related information*

–

# Librarian: –f

### Command line syntax

**–f** *file*

### Description

Instead of typing all options on the command line, you can create an option file which contains all options and flags you want to specify. With this option you specify the option file to the librarian **tlb**.

Use an option file when the command line would exceed the limits of the operating system, or just to store options and save typing.

Option files can also be generated on the fly, for example by the make utility. You can specify the option **–f** multiple times.

Format of an option file

- Multiple arguments on one line in the option file are allowed.
- To include whitespace in an argument, surround the argument with single or double quotes.
- If you want to use single quotes as part of the argument, surround the argument by double quotes and vise versa:

```
"This has a single quote ' embedded"
```

```
'This has a double quote " embedded'
```

```
'This has a double quote " and a single quote '"' embedded"
```

- When a text line reaches its length limit, use a 'to continue the line. Whitespace between quotes is preserved.

```
"This is a continuation \
line"
     -> "This is a continuation line"
```

- It is possible to nest command line files up to 25 levels.

### Example

Suppose the file `myoptions` contains the following lines:

```
-x mylib.lib obj1.obj
-w5
```

Specify the option file to the librarian:

```
tlb -f myoptions
```

This is equivalent to the following command line:

```
tlb -x mylib.lib obj1.obj -w5
```

# Librarian: –m

### Command line syntax

**–m** [**–a** *posname*] [**–b** *posname*]

### Description

Move the specified object modules to another position in the library.

The ordering of members in a library can make a difference in how programs are linked if a symbol is defined in more than one member.

Default, the specified members are moved to the end of the archive. Use the suboptions **–a** or **–b** to move them to a specified place instead.

| | |
|---|---|
| **–a** *posname* | Move the specified object module(s) after the existing module *posname*. |
| **–b** *posname* | Move the specified object module(s) before the existing module *posname*. |

### Example

Suppose the library `mylib.lib` contains the following objects (see option **–t**):

```
obj1.obj
obj2.obj
obj3.obj
```

To move `obj1.obj` to the end of `mylib.lib`:

```
tlb -m mylib.lib obj1.obj
```

To move `obj3.obj` just before `obj2.obj`:

```
tlb -m -b obj3.obj mylib.lib obj2.obj
```

The library `mylib.lib` after these two invocations now looks like:

```
obj3.obj
obj2.obj
obj1.obj
```

### Related information

Librarian option **–t** (Print library contents)

## Librarian: –p

### *Command line syntax*

**–p**

### *Description*

Print the specified object module(s) in the library to standard output.

This option is only useful when you redirect or pipe the output to other files or tools that serve your own purposes. Normally you do not need this option.

### *Example*

```
tlb -p mylib.lib obj1.obj > file.obj
```

The librarian prints the file `obj1.obj` to standard output where it is redirected to the file `file.obj`. The effect of this example is very similar to extracting a file from the library but in this case the 'extracted' file gets another name.

### *Related information*

–

## Librarian: –r

### *Command line syntax*

**–r** [**–a** *posname*] [**–b** *posname*] [**–c**] [**–u**] [**–v**]

### *Description*

You can use the option **–r** for several purposes:

- Adding new objects to the library
- Replacing objects in the library with the same object of a newer date
- Creating a new library

The option **–r** normally *adds* a new module to the library. However, if the library already contains a module with the specified name, the existing module is *replaced*. If you specify a library that does not exist, the librarian *creates* a new library with the specified name.

If you add a module to the library without specifying the suboption **–a** or **–b**, the specified module is added at the end of the archive. Use the suboptions **–a** or **–b** to insert them to a specified place instead.

| | |
|---|---|
| **–a** *posname* | Add the specified object module(s) after the existing module *posname*. |
| **–b** *posname* | Add the specified object module(s) before the existing module *posname*. |
| **–c** | Create a new library without checking whether it already exists. If the library already exists, it is overwritten. |
| **–u** | Insert the specified object module only if it is newer than the module in the library. |
| **–v** | Verbose: the librarian shows which files are removed. |

The suboptions **–a** or **–b** have no effect when an object is added to the library.

### *Examples*

Suppose the library `mylib.lib` contains the following objects (see option **–t**):

```
obj1.obj
```

To add `obj2.obj` to the end of `mylib.lib`:

```
tlb -r mylib.lib obj2.obj
```

To insert `obj3.obj` just before `obj2.obj`:

```
tlb -r -b obj2.obj mylib.lib obj3.obj
```

The library `mylib.lib` after these two invocations now looks like:

```
obj1.obj
obj3.obj
obj2.obj
```

### *Creating a new library*

To *create a new library file*, add an object file and specify a library that does not yet exist:

```
tlb -r obj1.obj newlib.lib
```

The librarian creates the library `newlib.lib` and adds the object `obj1.obj` to it.

To *create a new library file and overwrite an existing library*, add an object file and specify an existing library with the supoption **–c**:

```
tlb -r -c obj1.obj mylib.lib
```

The librarian overwrites the library `mylib.lib` and adds the object `obj1.obj` to it. The new library `mylib.lib` only contains `obj1.obj`.

### *Related information*

Librarian option **–t** (Print library contents)

## Librarian: –t

### *Command line syntax*

**–t** [**–s0**|**–s1**]

### *Description*

Print a table of contents of the library to standard out. With the suboption **-s** the librarian displays all symbols per object file.

**–s0** Displays per object the library in which it resides, the name of the object itself and all symbols in the object.

**–s1** Displays only the symbols of all object files in the library.

### *Example*

```
tlb -t mylib.lib
```

The librarian prints a list of all object modules in the libary `mylib.lib`.

```
tlb -t -s0 mylib.lib
```

The librarian prints per object all symbols in the library. This looks like:

```
prolog.obj
   symbols:
mylib.lib:prolog.obj:___Qabi_callee_save
mylib.lib:prolog.obj:___Qabi_callee_restore
div16.obj
   symbols:
mylib.lib:div16.obj:___udiv16
mylib.lib:div16.obj:___div16
mylib.lib:div16.obj:___urem16
mylib.lib:div16.obj:___rem16
```

### *Related information*

–

## Librarian: –V

### *Command line syntax*

**–V**

### *Description*

Display version information. The librarian ignores all other options or input files.

### *Example*

```
tlb -V
```

The librarian displays version information but does not perform any tasks.

### *Related information*

-

## Librarian: –w

### *Command line syntax*

**–w***level*

### *Description*

With this suboption you tell the librarian to suppress all warnings above the specified level. The level is a number between 0 – 9.

The level of a message is printed between parentheses after the warning number. If you do not use the **–w** option, the default warning level is 8.

### *Example*

To suppresses warnings above level 5:

```
tlb -x -w5 mylib.lib obj1.obj
```

### *Related information*

–

## Librarian: –x

### *Command line syntax*

**–x** [**–o**] [**–v**]

### *Description*

Extract an existing module from the library.

**–o** Give the extracted object module the same date as the last-modified date that was recorded in the library.

Without this suboption it receives the last-modified date of the moment it is extracted.

**–v** Verbose: the librarian shows which files are extracted.

### *Examples*

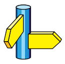
To extract the file `obj1.obj` from the library `mylib.lib`:

```
tlb -x mylib.lib obj1.obj
```

If you do not specify an object module, all object modules are extracted:

```
tlb -x mylib.lib
```

### *Related information*

 –

# 5 List File Formats

## Summary

This chapter describes the format of the assembler list file and the linker map file.

## 5.1 Assembler List File Format

The assembler list file is an additional output file of the assembler that contains information about the generated code.

The list file consists of a page header and a source listing.

### *Page header*

The page header is repeated on every page:

```
TASKING target Assembler vx.yrz Build nnn SN 00000000
Title                                                      Page 1

ADDR CODE      CYCLES  LINE SOURCE LINE
```

The first line contains version information.

The second line can contain a title which you can specify with the assembler directive `.TITLE` and always contains a page number. With the assembler directives `.LIST`/`.NOLIST` and `.PAGE`, and with the assembler option **-L***flag* (**--list-format**) you can format the list file.

See Section 3.8.2, *Assembler Directives* in Chapter *Assembly Language* and Section 4.2, *Assembler Options* in Chapter *Tools Options*.

The fourth line contains the headings of the columns for the source listing.

### *Source listing*

The following is a sample part of a listing. An explanation of the different columns follows below.

```
ADDR CODE      CYCLES  LINE SOURCE LINE
                          1         ; Module start
                          .
                          .
0010 7Err      2    24    32        mov     R6,#@msb(__2_ini)
0012 7Frr      2    26    33        mov     R7,#@lsb(__2_ini)
0014 12rrrr    6    32    34        gcall   _printf
                          .
                          .
0000                      38        .ds     2
  |  RESERVED
0001
```

The meaning of the different columns is:

`ADDR` This column contains the memory address. The address is a hexadecimal number that represents the offset from the beginning of a relocatable section or the absolute address for an absolute section. The address only appears on lines that generate object code.

| | |
|---|---|
| `CODE` | This is the object code generated by the assembler for this source line, displayed in hexadecimal format. The displayed code need not be the same as the generated code that is entered in the object module. The code can also be relocatable code. In this case the letter 'r' is printed for the relocatable code part in the listing. For lines that allocate space, the code field contains the text "RESERVED". For lines that initialize a buffer, the code field lists one value followed by the word "REPEATS". |
| `CYCLES` | The first number in this column is the number of instruction cycles needed to execute the instruction(s) as generated in the `CODE` field. The second number is the accumulated cycle count of this section. |
| `LINE` | This column contains the line number. This is a decimal number indicating each input line, starting from 1 and incrementing with each source line. |
| `SOURCE LINE` | This column contains the source text. This is a copy of the source line from the assembly source file. |

For the `.SET` and `.EQU` directives the `ADDR` and `CODE` columns do not apply. The symbol value is listed instead.

### *Related information*

See section 3.6, *Generating a List File*, in Chapter *Using the Assembler* of the user's manual for more information on how to generate a list file and specify the amount of list file information.

## 5.2 Linker Map File Format

The linker map file is an additional output file of the linker that shows how the linker has mapped the sections and symbols from the various object files (`.obj`) to output sections. The locate part shows the absolute position of each section. External symbols are listed per space with their absolute address, both sorted on symbol and sorted on address.

With the linker option **--map-file-format** (map file formatting) you can specify which parts of the map file you want to see.

### *Example (part of) linker map file*

```
**********************************************************  Processed Files Part  **********************************************************

+---------------------------------------------------------+
| File       | From archive | Symbol causing the extraction |
|=========================================================|
| cstart.obj | c51ls.lib    | __start                       |
| hello.obj  |              |                               |
| printf.obj | c51ls.lib    | __overlay__printf             |
+---------------------------------------------------------+


***************************************************************  Link Part  ***************************************************************
+-----------------------------------------------------------------------------------+
| [in] File  | [in] Section | [in] Size  | [out] Offset | [out] Section | [out] Size |
|===================================================================================|
| hello.obj  | code         | 0x00000028 | 0x00000000   | code          | 0x00000028 |
|-----------------------------------------------------------------------------------|
| cstart.obj | code         | 0x00000003 | 0x00000000   | code          | 0x00000003 |
|-----------------------------------------------------------------------------------|
| printf.obj | code         | 0x0000002d | 0x00000000   | code          | 0x0000002d |
+-----------------------------------------------------------------------------------+


*******************************************************  Module Local Symbols Part  *******************************************************

+ Scope ".\hello.obj"
+--------------------------------------------+
| Name        | Address    | Space           |
|============================================|
| __999001__1 | 0x00000008 | system:sw:data  |
| __1_ini     | 0x00000000 | system:sw:xdata |
| __2_ini     | 0x00000010 |                 |
| _2          | 0x00000522 | system:sw:code  |
+--------------------------------------------+


**********************************************************  Cross Reference Part  **********************************************************

+--------------------------------------------------------------------------------+
| Definition file | Definition section  | Symbol     | Referenced in             |
|================================================================================|
| cstart.obj      | _start              | __start    | hello.obj                 |
| hello.obj       | code                | _main      | cstart.obj                |
+--------------------------------------------------------------------------------+

* Undefined symbols
===================
+-------------------------+
| Symbol | Referenced in |
|=======================|
| __init | hello.obj     |
+-------------------------+
```

```
*************************************************************  Call Graph Part  **************************************************************

@__start
|
+-- @_main
    |
    +-- @_printloop
    |   |
    |   +-- @_printf *
    |
    +-- @_printf *

@_printf
|
+-- @__doprint
    |
    +-- @__emitchar *
    |
    +-- @__putstring *
    |
    +-- @__putnumber
    |   |
    |   +-- @__emitchar *
    |   |
    |   +-- @__putstring *
    |   |
    |   +-- @_strlen *
    |   |
    |   +-- @__ltoa
    |
    +-- @__doflt
***************************************************************  Overlay Part  **************************************************************

* Overlay: stack_xdata
=======================
+-------------------+
| size | 0x000000a1 |
+-------------------+

+ Paths
+-------------------------------------------------------------------------+
| [in] File         | [in] Section           | [in] Size  | [out] Offset |
|=========================================================================|
| cstart.obj        | stack_xdata@__start    | 0x00000000 | 0x0000001d   |
| hello.obj         | stack_xdata@_main      | 0x00000000 | 0x0000001d   |
| -                 | stack_xdata@_printf *  | 0x00000008 | 0x0000001d   |
+-------------------------------------------------------------------------+

***************************************************************  Locate Part  ***************************************************************

* Task entry address
====================
+------------------+
| symbol | __start |
+------------------+

* Section translation
=====================

+ Space system:sw:code

+-----------------------------------------------------------------------+
| Chip         | Group | Section | Size (MAU) | Space addr | Chip addr  |
|=======================================================================|
| system:xrom  |       | code    | 0x00000003 | 0x00000000 | 0x00000000 |
|              |       | _start  | 0x00000019 | 0x00000003 | 0x00000003 |
|              |       | [xdata] | 0x00000004 | 0x0000001c | 0x0000001c |
+-----------------------------------------------------------------------+

* Symbol translation (sorted on name)
=====================================
+---------------------------------------------+
| Name         | Address    | Space            |
|=============================================|
| __fss_buffer | 0x00000053 | system:sw:xdata |
| _errno       | 0x0000004c |                  |
| _main        | 0x000001e1 | system:sw:code   |
+---------------------------------------------+
```

```
* Symbol translation (sorted on address)
========================================
+---------------------------------------------+
| Address    | Name         | Space         |
|=============================================|
| 0x0000004c | _errno       | system:sw:xdata |
| 0x00000053 | __fss_buffer |                 |
| 0x000001e1 | _main        | system:sw:code  |
+---------------------------------------------+

**************************************************************  Memory Part  **************************************************************

* Address range usage at space level
====================================
+-------------------------------------------------------------------------------+
| Name            | Total      | Used       %  | Free       %  | > free gap  %  |
|===============================================================================|
| system:sw:code  | 0x00010000 | 0x00002008  13 | 0x0000dff8  87 | 0x0000dff8  87 |
| system:sw:data  | 0x00000080 | 0x0000002b  34 | 0x00000055  66 | 0x00000055  66 |
| system:sw:idata | 0x00000100 | 0x0000002b  17 | 0x000000d5  83 | 0x000000d5  83 |
| system:sw:pdata | 0x00000100 | 0x00000100 100 | 0x00000000   0 | 0x00000000   0 |
| system:sw:xdata | 0x00010000 | 0x0000010a   1 | 0x0000fef6  99 | 0x0000fef6  99 |
+-------------------------------------------------------------------------------+

* Address range usage at memory level
=====================================
+---------------------------------------------------------------------------+
| Name        | Total      | Used       %  | Free       %  | > free gap  %  |
|===========================================================================|
| system:iram | 0x00000100 | 0x0000002b  17 | 0x000000d5  83 | 0x000000d5  83 |
| system:xram | 0x00010000 | 0x0000010a   1 | 0x0000fef6  99 | 0x0000fef6  99 |
| system:xrom | 0x00010000 | 0x00002008  13 | 0x0000dff8  87 | 0x0000dff8  87 |
+---------------------------------------------------------------------------+

********************************************************  Linker Script File Part  ********************************************************


************************************************************  Locate Rule Part  ************************************************************
+-----------------------------------------------------------------------------------------------+
| Address space   | Type          | Properties             | Sections                          |
|===============================================================================================|
| system:sw:code  | absolute      | 0x00000000             | code                              |
| system:sw:code  | address range | 0x00000000..0x000000ff | _start                            |
| system:sw:xdata | clustered     |                        | xdata + xdata + xdata + xdata     |
| system:sw:code  | clustered     |                        | [xdata] + [xdata] + [xdata] + [xdata] |
| system:sw:idata | unrestricted  |                        | stack                             |
| system:sw:code  | unrestricted  |                        | _Exit   _fss_break   code         |
+-----------------------------------------------------------------------------------------------+
```

The meaning of the different parts is:

### *Processed Files Part*

This part of the map file shows all processed files. This also includes object files that are extracted from a library, with the symbol that led to the extraction.

### *Link Part*

This part of the map file shows per object file how the link phase has mapped the sections from the various object files (`.obj`) to output sections.

| | |
|---|---|
| `[in] File` | The name of an input object file. |
| `[in] Section` | A section name from the input object file. |
| `[in] Size` | The size of the input section. |
| `[out] Offset` | The offset relative to the start of the output section. |
| `[out] Section` | The resulting output section name. |
| `[out] Size` | The size of the output section. |

### Module Local Symbols Part

This part of the map file shows a table for each local scope within an object file. Each table has three columns, 1 the symbol name, 2 the address of the symbol and 3 the space where the symbol resides in. The table is sorted on symbol name within each space.

By default this part is not shown in the map file. You have to turn this part on manually with linker option **--map-file-format=+statics** (module local symbols).

### Cross Reference Part

This part of the map file lists all symbols defined in the object modules and for each symbol the object modules that contain a reference to the symbol are shown. Also, symbols that remain undefined are shown.

### Call Graph Part

This part of the map file contains a schematic overview that shows how (library) functions call each other.

### Overlay Part

This part of the map file shows how the static stack is organized. This part also shows the locate overlay information if you used overlay groups in the linker script file.

### Locate Part: Section translation

This part of the map file shows the absolute position of each section in the absolute object file. It is organized per address space, memory chip and group and sorted on space address.

| | |
|---|---|
| `+ Space` | The names of the address spaces as defined in the linker script file (`*.lsl`). The names are constructed of the `derivative` name followed by a colon ':', the `core` name, another colon ':' and the `space` name. |
| `Chip` | The names of the memory chips as defined in the linker script file (`*.lsl`) in the `memory` definitions. |
| `Group` | Sections can be ordered in groups. These are the names of the groups as defined in the linker script file (`*.lsl`) with the keyword `group` in the `section_layout` definition. The name that is displayed is the name of the deepest nested group. |
| `Section` | The name of the section. Names within square brackets **[ ]** will be copied during initialization from ROM to the corresponding section name in RAM. |
| `Size (MAU)` | The size of the section in minimum addressable units. |
| `Space addr` | The absolute address of the section in the address space. |
| `Chip addr` | The absolute offset of the section from the start of a memory chip. |

### Locate Part: Symbol translation

This part of the map file lists all external symbols per address space name, both sorted on address and sorted on symbol name.

| | |
|---|---|
| `Name` | The name of the symbol. |
| `Address` | The absolute address of the symbol in the address space. |
| `Space` | The names of the address spaces as defined in the linker script file (`*.lsl`). The names are constructed of the `derivative` name followed by a colon ':', the `core` name, another colon ':' and the `space` name. |

### Memory Part

This part of the map file shows the memory usage in totals and percentages for spaces and chips. The largest free block of memory per space and per chip is also shown.

### Linker Script File Part

This part of the map file shows the processor and memory information of the linker script file.

By default this part is not shown in the map file. You have to turn this part on manually with linker option **--map-file-format=+lsl** (processor and memory info). You can print this information to a separate file with linker option **--lsl-dump**.

### *Locate Rule Part*

This part of the map file shows the rules the linker uses to locate sections.

`Address space` The names of the address spaces as defined in the linker script file (`*.lsl`). The names are constructed of the `derivative` name followed by a colon ':', the `core` name, another colon ':' and the `space` name.

`Type` The rule type:

- `ordered/contiguous/clustered/unrestricted`
  Specifies how sections are grouped. By default, a group is 'unrestricted' which means that the linker has total freedom to place the sections of the group in the address space.
- `absolute` The section must be located at the address shown in the Properties column.
- `address range` The section must be located in the union of the address ranges shown in the Properties column; end addresses are not included in the range.
- `address range size` The sections must be located in some address range with size not larger than shown in the Properties column; the second number in that field is the alignment requirement for the address range.
- `ballooned` After locating all sections, the largest remaining gap in the space is used completely for the stack and/or heap.

`Properties` The contents depends on the Type column.

`Sections` The sections to which the rule applies;
restrictions between sections are shown in this column:

| | |
|---|---|
| < | ordered |
| \| | contiguous |
| + | clustered |

For contiguous sections, the linker uses the section order as shown here. Clustered sections can be located in any relative order.

### *Related information*

Section 4.10, *Generating a Map File*, in Chapter *Using the Linker* of the user's manual.
Linker option **--map-file** (Generate map file)

# 6 Object File Formats

**Summary**

This chapter describes the formats of several object files.

## 6.1 IEEE−695 Format

The IEEE−695 standard describes MUFOM: Microprocessor Universal Format for Object Modules. It defines a target independent storage standard for object files. However, this standard does not describe how symbolic debug information should be encoded according to that standard. Symbolic debug information can be a part of an object file. A debugger which reads an object file uses the symbolic debug information to obtain knowledge about the relation between the executable code and the origination high−level language source files. Since the IEEE−695 standard does not describe the representation of debug information, working implementations of this standard show vendor specific and microprocessor specific solutions for this area.

TIOF, which stands for Target Independent Object Format, is specified as a MUFOM based standard including the representation of symbolic debug information for high−level languages, without introducing the microprocessor dependent solutions.

Since TIOF and IEEE−695 both use the MUFOM concept as their basis both formats are very similar to each other.

### 6.1.1 Command Language Concept

Most object formats are record oriented: there are one or more section headers at a fixed position in the file which describe how many sections are present. A section header contains information like start address, file offset, etc. The contents of the section is in some data part, which can only be processed after the header has been read. So the tool that reads such an object uses implicit assumptions how to process such a file. Seeking through the file to get those records which are relevant is usual.

MUFOM ( IEEE−695 ) uses a different approach. It is designed as a command language which steers the linker and object reader in the debugger.

An assembler or compiler may create an object module where most of the data contained in it is relocatable. The next phase in the translation process is linking several object modules into one new object module. A relocatable object uses relocation expressions at places where the absolute values are not yet known. An expression evaluator in the linker transforms the relocation expressions into absolute values.

Finally the object is ready for loading into memory. Since an object file is transformed by several processes, MUFOM implements an object file as a sequence of commands which steers this transformation process.

These commands are created, executed or copied by one of five processes which act on a MUFOM object file:

1. Creation process
   Creation of the object file by an assembler or compiler. The assembler or compiler tells other MUFOM processes what to do, by emitting commands generated from assembly source text or a high−level language.

2. Linkage process
   Linking of several object modules into one module resolving external references by renaming X variables into I variables, and by generating new commands (assigning of R variables).

3. Relocation process
   Relocation, giving all sections an absolute address by assigning their L variable.

4. Expression evaluation process
   Evaluation of loader expressions, generated in one of the three previously mentioned MUFOM processes.

5. Loader process
   Loading the absolute memory image.

The last four processes are in fact command interpreters: the assembler writes an object file which is basically a large sequence of instructions for the linker. For example, instead of writing the contents of a section as a sequence of bytes at a specific position in the file, IEEE-695 defines a load command, LR, which instructs the linker to load a number of bytes. The LR command specifies the number of MAUs (minimum addressable unit) that will be relocated, followed by the actual data. This data can be a number of absolute bytes, or an expression which must be evaluated by the linker.

Transforming relocation expressions into new expressions or absolute data and combining sections is the actual linkage process.

It is possible that one or more of the above MUFOM processes are combined in one tool. For instance, the linker is built from process 2, 3 and 4 above.

## 6.1.2 Notational Conventions

The following conventions are used in this appendix:

| | |
|---|---|
| \| | select one of the items listed between '\|' |
| " " | literal characters are between " " |
| [ ]+ | optional item repeats one time or more |
| [ ]? | optional item repeats zero times or one time |
| [ ]* | optional item repeats zero times or more |
| ::= | can be read as "is defined as" |

## 6.1.3 Expressions

An expression in an IEEE-695 file is a combination of variables, operators and absolute data.

The variable name always starts with a non-hexadecimal letter (G...Z), immediately followed by an optional hexadecimal number. The first non-hexadecimal letter gives the class of the variable. Reading an object file you encounter the following variables:

**G** – Start address of a program. If not assigned this address defaults to the address of low-level symbol **_start**.

**I** – An I variable represents a global symbol in an object module.

The I variable is assigned an expression which is to be made available to other modules for the purpose of linkage edition. The name of an I variable is always composed of the letter 'I', followed by a hexadecimal number. An I variable is created only by an NI command.

**L** – Start address of a section. This variable is only used for absolute sections. The 'L' is followed by a section index, which is an hexadecimal number. L variables are created by an assignment command, but the section index must have been been defined by an ST command.

**N** – Name of internal symbol. This variable is used to assign values of local symbols, or, to build complex types for use by a high-level language debugger, or for inter-modular type checking during linkage. The N variable is created with a NN command.

**P** – Program pointer per section. This variable always contains the current address of the target memory location. The P variable is followed by a section index, which is a hexadecimal number. The section index must have been defined with an ST command (section type command). The variable is created after its first assignment.

**R** – The R type variable is a relocation reference for a particular section. All references to addresses in this section must be made relative to the R variable. Linking is accomplished by assigning a new value to R. The R variable consists of the letter 'R', followed by an section index, which is a hexadecimal number. The section index must have been defined with an ST command. The default value of an (unassigned) R variable is 0.

**S** – The S type variable is the section size (in MAUs) for a section. There is one S variable per section. The 'S' is followed by an section index. An S variable is created by its first assignment.

**W** – Work variable. This type of variable can be used to assign values to, which can be used in following MUFOM commands. They serve the purpose of maintaining values in a workspace without any additional meaning. A work variable consists of the letter 'W' followed by a hexadecimal number. W variables are created by their first assignment.

**X** – An X type variable refers to an external reference. X–variables cannot have a value assigned to it. An X variable consists of the letter ’X’ followed by a hexadecimal number.

The MUFOM language uses the following data types to form expressions:

digit ::= ”0” | ”1” | ”2” | ”3” | ”4” | ”5” | ”6” | ”7” | ”8” | ”9”

hex_letter ::= ”A” | ”B” | ”C” | ”D” | ”E” | ”F”

hex_digit ::= digit | hex_letter

hex_number ::= [ hex_digit ]+

nonhex_letter ::= ”G” | ”H” | ”I” | ”J” | ”K” | ”L” | ”M” | ”N” | ”O” | ”P” | ”Q” | ”R” | ”S” | ”T” | ”U” | ”V” | ”W” | ”X” | ”Y” | ”Z”

letter ::= hex_letter | nonhex_letter

alpha_num ::= letter | digit

identifier ::= letter [ alpha_num ]*

character ::= ’value valid within chosen character set’

char_string_length ::= hex_digit hex_digit

char_string ::= char_string_length [ character ]*

The numeric value specified in ’char_string_length’ should be followed by an equal number of characters.

Expressions may be formed out of immediate numbers and MUFOM variables. The MUFOM processes 2 to 4, which form the linker, contain expression evaluators which parse and calculate the values for the expressions. If a MUFOM process cannot calculate the absolute value of an expression, because the values of the variable are not yet known, it copies the expression (with modifications) into the output file.

Expression are coded in reverse Polish notation. (The operator follows the operands.)

expression ::=boolean_function | one_operand_function |
two_operand_function | three_operand_function |
four_operand_function | conditional_expr | hex_number |
MUFOM_variable

### 6.1.3.1 Functions without Operands

@F : false function

@T : true function

boolean_function ::= ”@F” | ”@T”

The false and true function produce a boolean result false or true which may be used in logical expressions. Both functions do not have operands.

### 6.1.3.2 Monadic Functions

Monadic functions have one operand which precedes the function.

one_operand_function ::= operand ”,” monop
operand ::= expression
monop ::= ”@ABS” | ”@NEG” | ”@NOT” | ”@ISDEF”

@ABS: returns the absolute value of an integer operand

@NEG: returns the negative value of an integer operand

@NOT: returns the negation of a boolean operand or the one’s complement value if the operand is an integer

@ISDEF: returns the logical true value if all variable in an expression are defined, return false otherwise.

### 6.1.3.3 Dyadic Functions and Operators

Dyadic functions and operators have two operands which precede the operator or function.

two_operand_function ::= operand1 "," operand2 "," dyadop

operand1 ::= expression

operand2 ::= expression

dyadop ::= "@AND" | "@MAX" | "@MIN" | "@MOD" | "@OR" |"@XOR" | "+" | "−" | "/" | "*" |
"<" | ">" | "=" | "#"

@AND: returns boolean true/false result of logical 'and' operation on operands, when both operands are logical values. When both operands are not logical values the bitwise and is performed.

@MAX: compares both operands arithmetically and returns the largest value.

@MIN: compares both operands arithmetically and returns the smallest value.

@MOD: returns the modulo result of the division of operand1 by operand2. The result is undefined if either operand is negative, or if operand2 is zero.

@OR: returns boolean true/false result of logical 'or' operation on operands, when both operands are logical values. When both operands are no logical values the bitwise and is performed.

+, −, *, /: These are the arithmetic operators for addition, subtraction, multiplication and division. The result is an integer. For division the result is undefined if operand2 equals zero. The result of a division rounds toward zero.

<, >, =, #: These are operators for the following logical relations: 'less than', 'greater than', 'equals', 'is unequal'. The result is true or false.

### 6.1.3.4 MUFOM Variables

The meaning of the MUFOM variable is explained in section 6.1.3. The following syntax rules apply for the MUFOM variables:

MUFOM_variable ::= MUFOM_var | MUFOM_var_num | MUFOM_var_optnum

MUFOM_var ::= "G"

MUFOM_var_num ::= "I" | "N" | "W" | "X" | hex_number

MUFOM_var_optnum ::= "L" | "P" | "R" | "S" | [ hex_number ]?

### 6.1.3.5 @INS and @EXT Operator

The @INS operator inserts a bit string.

four_operand_function ::= operand1 "," operand2 "," operand3"," operand4 "," @INS

operand2 is inserted in operand1 starting at position operand3, and ending at position operand4.

The @EXT operator extracts a bit string.

three_operand_function ::= operand1 "," operand2 "," operand3"," @EXT

A bit string is extracted from operand1 starting at position operand2 and ending at position operand3.

### 6.1.3.6 Conditional Expressions

conditional_expr ::= err_expr | if_else_expr

err_expr ::= value "," condition "," err_num "," "@ERR"

value ::= expression

condition ::= expression

err_num ::= expression

if_else_expr ::= condition "," "@IF" "," expression ","@ELSE" "," expression "," "@END"

### 6.1.4 MUFOM Commands

#### 6.1.4.1 Module Level Commands

At module level there are four commands: one command to start and one to end a module, one command to set the date and time of creation of the module, and one command to specify address formats.

***MB Command***

The MB command is the first command in a module. It specifies the target machine configuration and an optional command with the module name.

MB_command ::= ”MB” machine_identifier [ ”,” module_name ]? ”.”

Example: `MB c51.`

***ME Command***

The module end command is the last command in an object file. It defines the end of the object module.

ME_command ::= ”ME.”

***DT Command***

The DT command sets the date and time of creation of an object module.

DT_command ::= ”DT” [ digit ]* ”.”

Example: `DT19930120120432.`

The format of display of the date and time is ”YYYYMMDDHHMMSS”:

4 digits for the year, 2 digits for the month, 2 digits for the day, 2 digits for the hour, 2 digits for the minutes and 2 digits for the seconds.

***AD Command***

The AD command specifies the address format of the target execution environment.

| | | |
|---|---|---|
| AD_command | ::= | ”AD” bits_per_MAU [ ”,” MAU_per_address [ ”,” order ]? ]? |
| MAU_per_address | ::= | hex_number |
| bits_per_MAU | ::= | hex_number |
| order | ::= | ”L” \| ”M” |

MAU stands for minimum addressable unit. This is target processor dependant.

L means least significant byte at lowest address ( little endian )
M means most significant byte at lowest address ( big endian )

Example:

```
AD8,2,L.
```

Specifies a 2-byte addressable 8-bit processor running in little endian mode.

#### 6.1.4.2 Comment and Checksum Command

The comment command offers the possibility to store information in an object module about the object module and the translators that created it. The comment may be used to record the file name of the source file of the object module or the version number of the translator that created it. Because the standard supports several layers each of which has its own revision number an object module may contain several comment commands which specify which revision of the standard has been used to create the module. The contents of a comment is not prescribed by the standard and thus it is implementation defined how a MUFOM process handles a comment command.

CO_command ::= ”CO” [comment_level]? ”,” comment_text ”.”

comment_level ::= hex_number

comment_text::= char_string

The comment levels 0 – 6 are reserved to pass information about the revision number of the layers in this standard.

The checksum command starts and checks the checksum calculation of an object module.

### 6.1.4.3 Sections

A section is the smallest unit of code or data that can be controlled separately. Each section has a unique number which is introduced at the first section begin (SB) command. The contents of a section may follow its introduction. A section ends at the next SB command with a number different from the current number. A section resumes at an SB command with a number that has been introduced before.

#### *SB Command*

SB_command::= ”SB” hex_number ”.”

The maximum number of sections in an object module is implementation defined.

#### *ST Command*

The ST command specifies the type of a section.

ST_command::= ”ST” section_number [ ”,” section_type ]* [ ”,” section_name ]? ”.”

section_type ::= letter

section_name::= char_string

A section can be named or unnamed. If section_name is omitted a section is unnamed. A section can be relocatable or absolute. If the section start address is an absolute number the section is called absolute. If the section start address is not yet known, the section is called relocatable. In relocatable sections all addresses are specified relative to the relocation base of that section. The relocation phase of the linker may map the relocation base of a section onto a fixed address.

During linkage edition the section name and the section attributes identify a section and thus the actions to be taken. If a section is defined in several modules, the linkage editor must determine how to act on sections with the same name. This can be either one of the following strategies:

- several sections are to be joined into a single one
- several sections are to be overlapped
- sections are not to coexist

A section type gives additional information to the linkage editor about the section, which may be used to layout a section in memory. Section type information is encoded with letters, which may be combined in one ST command. Some combinations of letters are invalid or may be meaningless.

| letter | meaning | class | explanation |
|---|---|---|---|
| A | absolute | access | section has absolute address assigned to corresponding L–variable |
| R | read only | access | no write access to this section |
| W | writable | access | section may be read and written |
| X | executable | access | section contains executable code |
| Z | zero page | access | if target has zero page or short addressable page Z–section map into it |
| Y*num* | addressing mode | access | section must be located in addressing mode *num* |
| B | blank | access | section must be initialized to ’0’ (cleared) |
| F | not filled | access | section is not filled or cleared (scratch) |
| I | initialize | access | section must be initialized in rom |
| E | equal | overlap | if sections in two modules have different length an error must be raised |
| M | max | overlap | Use largest value as section size |
| U | unique | overlap | The section name must be unique |

| letter | meaning | class | explanation |
|---|---|---|---|
| C | cumulative | overlap | Concatenate sections if they appear in several modules. The section alignment for partial section must be preserved |
| O | overlay | overlap | sections with the name *name@func* must be combined to one section *name*, according to the rules for *func* obtained from the call graph |
| S | separate | overlap | multiple sections can have the same name and they may relocated at unrelated addresses |
| N | now | when | section is located before normal sections (without N or P) |
| P | postpone | when | section is located after normal sections (without N or P) |

*Table 6-1: Section types*

#### SA Command

SA_command ::= ”SA” section_number ”,” [MAU_boundary ]?[ ”,” page_size ]? ”.’

MAU_boundary ::= expression

page_size ::= expression

The MAU boundary value forces the relocator to align a section on the number of MAUs specified. If page_size is present the relocator checks that the section does not exceed a page boundary limit when it is relocated.

### 6.1.4.4 Symbolic Name Declaration and Type Definition

#### NI Command

The NI command defines an internal symbol. An internal symbol is visible outside the module. Thus it may resolve an undefined external in another module.

NI_command ::= ”N” I_variable ”,” char_string ”.”

The NI_command must precede any reference to the I_variable in a module. There may not be more than one I_variable with the same name or number.

#### NX Command

The NX command defines an external symbol which is undefined in the current module. The NX command must precede all occurrences of the corresponding X variable.

NX_command ::= ”N” X_variable ”,” char_string ”.”

The unresolved reference corresponding to an NX-command can be resolved by an internal symbol definition ( NI_command ) in another module.

#### NN Command

The NN command defines a local name which may be used for defining a name of a local symbol in a module or a name in a type definition.

A name defined with an NN command is not visible outside the scope of the module. The NN command must precede all occurrences of the corresponding N variable.

NN_command ::= ”N” N_variable ”,” char_string ”.”

#### AT Command

The attribute command may be used to define debugging related information of a symbol, such as the symbol type number. Level 2 of the standard does not prescribe the contents of the optional fields of the AT command. The language dependent layer (level 3) describes how these fields can be used to pass high-level symbol information with the AT command.

AT_command ::= ”AT” variable ”,” type_table_entry [ ”,” lex_level [ ”,” hex_number ]* ]? ”.”

variable ::= I_variable | N_variable | X_variable

type_table_entry ::= hex_number

lex_level ::= hex_number

The type_table entry is a type number introduced with a type command (TY). References to type numbers in the AT command may precede the definition of the type in the TY command.

The meaning of the lex_level field is defined at layer 3 or higher. The same applies to the optional hex_number fields.

#### TY Command

The TY-command defines a new type table entry. The type number introduced by the type command can be seen as a reference index to this type. The TY-command defines the relation between the newly introduced type and other types that are defined in other places in the object module. It also establishes a relation between a new type index and symbols (N_variable).

```
TY_command       ::= "TY" type_table_entry [ "," parameter ]+ "."
type_table_entry ::= hex_number
parameter        ::= hex_number | N_variable | "T" type_table_entry
```

Level 2 does not define the semantics of the parameters. These are defined at level 3, the language layer. A linkage editor which does not have knowledge of the semantics of the parameter in a type command can still perform type comparison: Two types are considered to compare equal when the following conditions hold:

- both types have an equal number of parameters.
- the numeric values in the types are equal
- N_variables in both types have the same name
- the type entries referenced from both types compare equal

Variable N0 is supposed to compare equal to any other name.

Type table entry T0 is supposed to compare equal to any other type.

### 6.1.4.5 Value Assignment

#### AS Command

The assignment command assigns a value to a variable.

```
AS_command ::= "AS" MUFOM_variable "," expression "."
```

### 6.1.4.6 Loading Commands

The contents of a section is either absolute data (code) or relocatable data (code). Absolute data can be loaded with the LD command. The address where loading takes place depends on the value of the P-variable belonging to the section. Data which is contiguous in a LD command is supposed to be loaded contiguously in memory.

If data is not absolute it contains expressions which must be evaluated by the expression evaluator. The LR command allows a relocation expression to be part of the loading command.

#### LD Command

```
LD_command ::= "LD" [ hex_digit ]+ "."
```

The constants loaded with the LD command are loaded with the most significant part first.

#### IR Command

A relocation base is an expression which can be associated with a relocation letter. This relocation letter can be used in subsequent load relocate commands.

```
IR_command        ::= "IR" relocation_letter "," relocation_base[ "," number_of_bits ]? "."
relocation_letter ::= nonhex_letter
relocation_base   ::= expression
number_of_bits    ::= expression
```

Example:

```
IRV,X20,16.
ITM,R2,40,+,8.
```

The number_of_bits must be less than or equal to the number of bits per address, which is the product of the number of MAUs per address and the number of bits per MAU, both of which are specified in the AD command. If the number_of_bits is not specified it equals the number of bits per address.

#### LR Command

| | | |
|---|---|---|
| LR_command | ::= | ”LR” [ load_item ]+ ”.” |
| load_item | ::= | relocation_letter offset ”,” \| load_constant \|<br>”(” expression [ ”,” number_of_MAUs ]? ”)” |
| load_constant | ::= | [ hex_digit ]+ |
| number_of_MAUs | ::= | expression |

Examples:

```
LR002000400060.
LRT80,0020.
LR(R2,100,+,4).
```

The first example shows immediate constants which may be loaded as a part of an LR command.

The second example shows the use of the relocation base defined in the previous paragraph, followed by a constant.

The third example shows how the value of the expression R2 + 100 is used to load 4 MAUs.

The three commands in this example may be combined into one LR command:

```
LR002000400060T80,0020(R2,100,+,4).
```

#### RE Command

The replicate command defines the number of times a LR command must be replicated:

RE_command ::= ”RE” expression ”.”

The LR command must immediately follow the RE command.

Example:

```
RE04.
LR(R2,200,+,4).
```

The commands above load 16 MAUs: 4 times the 4 MAU value of R2 + 200

### 6.1.4.7 Linkage Commands

#### RI Command

The retain internal symbol command indicates that the symbolic information of an NI command must be retained in the output file.

| | |
|---|---|
| RI_command | ::= ”R” I_variable [ ”,” level_number ]? ”.” |
| level_number | ::= hex_number |

#### WX Command

The weak external command flags a previously defined external (NX_command) as weak. This means that if the external remains unresolved, the value of the expression in the WX command is assigned to the X variable.

| | |
|---|---|
| WX_command | ::= ”W” X_variable [ ”,” default_value ]? ”.” |
| default_value | ::= expression |

### *LI Command*

The LI command specifies a default library search list. The library names specified in the LI_command are searched for unresolved references.

LI_command ::= ”LI” char_string [ ”,” char_string ]* ”.”

### *LX Command*

The LX command specifies a library to search for a named unresolved variable.

LX_command ::= ”L” X_variable [ ”,” char_string ]+ ”.”

The paragraphs above showed the commands and operators as ASCII strings. In an object file they are binary encoded. The following tables show the binary representation.

## 6.1.5 MUFOM Functions

The following table lists the first byte of MUFOM elements. Each value between 0 and 255 classifies the MUFOM language element that follows, or it is a language element itself. E.g. numbers outside the range 0–127 are preceded by a length field: 0x82 specifies that a 2 byte integer follows. 0xE4 is the function code for the LR command.

### *Overview of first byte of MUFOM language elements*

| Value | Description |
|---|---|
| 0x00 – 0x7F | Start of regular string, or one byte numbers ranging 0 – 127 |
| 0x80 | Code for omitted optional number field |
| 0x81 – 0x88 | Numbers outside the range 0 – 127 |
| 0x89 – 0x8F | Unused |
| 0x90 – 0xA0 | User defined function codes |
| 0xA0 – 0xBF | MUFOM function codes |
| 0xC0 | Unused |
| 0xC1 – 0xDA | MUFOM letters |
| 0xDB – 0xDF | Unused |
| 0xE0 – 0xF9 | MUFOM commands |
| 0xFA – 0xFF | Unused |

*Table 6–2: Overview of first byte of MUFOM language elements*

### *Binary encoding of MUFOM letters and function codes*

| Function code | | Identifiers | |
|---|---|---|---|
| **Function** | **code** | **Letter** | **code** |
| @F | 0xA0 | | |
| @T | 0xA1 | A | 0xC1 |
| @ABS | 0xA2 | B | 0xC2 |
| @NEG | 0xA3 | C | 0xC3 |
| @NOT | 0xA4 | D | 0xC4 |
| + | 0xA5 | E | 0xC5 |
| – | 0xA6 | F | 0xC6 |
| / | 0xA7 | G | 0xC7 |
| * | 0xA8 | H | 0xC8 |
| @MAX | 0xA9 | I | 0xC9 |

| Function code | | Identifiers | |
|---|---|---|---|
| **Function** | **code** | **Letter** | **code** |
| @MIN | 0xAA | J | 0xCA |
| @MOD | 0xAB | K | 0xCB |
| < | 0xAC | L | 0xCC |
| > | 0xAD | M | 0xCD |
| = | 0xAE | N | 0xCE |
| != <> | 0xAF | O | 0xCF |
| @AND | 0xB0 | P | 0xD0 |
| @OR | 0xB1 | Q | 0xD1 |
| @XOR | 0xB2 | R | 0xD2 |
| @EXT | 0xB3 | S | 0xD3 |
| @INS | 0xB4 | T | OxD4 |
| @ERR | 0xB5 | U | 0xD5 |
| @IF | 0xB6 | V | 0xD6 |
| @ELSE | 0xB7 | W | 0xD7 |
| @END | 0xB8 | X | 0xD8 |
| @ISDEF | 0xB9 | Y | 0xD9 |
| | | Z | 0xDA |

*Table 6-3: Binary encoding of MUFOM letters and function codes*

### MUFOM Command codes

| Command | Code | Description |
|---|---|---|
| MB | 0xE0 | Module begin |
| ME | 0xE1 | Module end |
| AS | 0xE2 | Assign |
| IR | 0xE3 | Inititialize relocation base |
| LR | 0xE4 | Load with relocation |
| SB | 0xE5 | Section begin |
| ST | 0xE6 | Section type |
| SA | 0xE7 | Section alignment |
| NI | 0xE8 | Internal name |
| NX | 0xE9 | External name |
| CO | 0xEA | Comment |
| DT | 0xEB | Date and time |
| AD | 0xEC | Address description |
| LD | 0xED | Load |
| CS (with sum) | 0xEE | Checksum followed by sum value |
| CS | 0xEF | Checksum (reset sum to 0 ) |
| NN | 0xF0 | Name |
| AT | 0xF1 | Attribute |
| TY | 0xF2 | Type |
| RI | 0xF3 | Retain internal symbol |

| Command | Code | Description |
|---|---|---|
| WX | 0xF4 | Weak external |
| LI | 0xF5 | Library search list |
| LX | 0xF6 | Library external |
| RE | 0xF7 | Replicate |
| SC | 0xF8 | Scope definition |
| LN | 0xF9 | Line number |
| | 0xFA | Undefined |
| | 0xFB | Undefined |
| | 0xFC | Undefined |
| | 0xFD | Undefined |
| | 0xFE | Undefined |
| | 0xFF | Undefined |

*Table 6-4: MUFOM Command codes*

## 6.2 Motorola S–Record Format

With the linker option **–o***filename***:SREC** option the linker produces output in Motorola S–record format with three types of S–records: S0, S3 and S7. With the options **–o***filename***:SREC:2** or **–o***filename***:SREC:3** option you can force other types of S–records. They have the following layout:

### *S0 – record*

'S' '0' <*length_byte*> <2 bytes 0> <*comment*> <*checksum_byte*>

A linker generated S–record file starts with a S0 record with the following contents:

length_byte : $07
comment : lk51
checksum : $BB

```
        l k 5 1
S00700006C6B3531BB
```

The S0 record is a comment record and does not contain relevant information for program execution.

The length_byte represents the number of bytes in the record, not including the record type and length byte.

The checksum is calculated by first adding the binary representation of the bytes following the record type (starting with the length_byte) to just before the checksum. Then the one's complement is calculated of this sum. The least significant byte of the result is the checksum. The sum of all bytes following the record type is 0FFH.

### *S1 – record*

With the linker option **–o***filename***:SREC:2**, the actual program code and data is supplied with S1 records, with the following layout:

'S' '1' <*length_byte*> <*address*> <*code bytes*> <*checksum_byte*>

This record is used for 2–byte addresses.

Example:

```
S1130250F03EF04DF0ACE8A408A2A013EDFCDB00E6
  | |   |                               |_ checksum
  | |   |_ code
  | |_ address
  |_ length
```

The linker has an option that controls the length of the output buffer for generating S1 records. The default buffer length is 32 code bytes.

The checksum calculation of S1 records is identical to S0.

### *S2 – record*

With the linker option **–o***filename***:SREC:3**, the actual program code and data is supplied with S2 records, with the following layout:

'S' '2' <*length_byte*> <*address*> <*code bytes*> <*checksum_byte*>

This record is used for 3–byte addresses.

Example:

```
S213FF002000232222754E00754F04AF4FAE4E22BF
  | |     |                             |_ checksum
  | |     |_ code
  | |_ address
  |_ length
```

The linker has an option that controls the length of the output buffer for generating S2 records. The default buffer length is 32 code bytes.

The checksum calculation of S2 records is identical to S0.

### *S3 – record*

With the linker option **–o***filename***:SREC:4**, which is the default, the actual program code and data is supplied with S3 records, with the following layout:

'S' '3' *<length_byte> <address> <code bytes> <checksum_byte>*

The linker generates 4-byte addresses by default.

Example:

```
S3070000FFFE6E6825
  | |       |   |_ checksum
  | |       |_ code
  | |_ address
  |_ length
```

The linker has an option that controls the length of the output buffer for generating S3 records.

The checksum calculation of S3 records is identical to S0.

### *S7 – record*

With the linker option **–o***filename***:SREC:4**, which is the default, at the end of an S-record file, the linker generates an S7 record, which contains the program start address. S7 is the corresponding termination record for S3 records.

Layout:

'S' '7' *<length_byte> <address> <checksum_byte>*

Example:

```
S70500000000FA
  | |       |_checksum
  | |_ address
  |_ length
```

The checksum calculation of S7 records is identical to S0.

### *S8 – record*

With the linker option **–o***filename***:SREC:3**, at the end of an S-record file, the linker generates an S8 record, which contains the program start address.

Layout:

'S' '8' *<length_byte> <address> <checksum_byte>*

Example:

```
S804FF0003F9
  | |     |_checksum
  | |_ address
  |_ length
```

The checksum calculation of S8 records is identical to S0.

### *S9 – record*

With the linker option **–o***filename***:SREC:2**, at the end of an S-record file, the linker generates an S9 record, which contains the program start address. S9 is the corresponding termination record for S1 records.

Layout:

'S' '9' *<length_byte> <address> <checksum_byte>*

Example:

```
S9030210EA
  | |    |_checksum
  | |_ address
  |_ length
```

The checksum calculation of S9 records is identical to S0.

## 6.3 Intel Hex Record Format

Intel Hex records describe the hexadecimal object file format for 8-bit, 16-bit and 32-bit microprocessors. The hexadecimal object file is an ASCII representation of an absolute binary object file. There are six different types of records:

- Data Record (8-, 16, or 32-bit formats)
- End of File Record (8-, 16, or 32-bit formats)
- Extended Segment Address Record (16, or 32-bit formats)
- Start Segment Address Record (16, or 32-bit formats)
- Extended Linear Address Record (32-bit format only)
- Start Linear Address Record (32-bit format only)

By default the linker generates records in the 32-bit format (4-byte addresses).

### *General Record Format*

In the output file, the record format is:

| : | *length* | *offset* | *type* | *content* | *checksum* |
|---|---|---|---|---|---|

Where:

: is the record header.

*length* is the record length which specifies the number of bytes of the *content* field. This value occupies one byte (two hexadecimal digits). The linker outputs records of 255 bytes (32 hexadecimal digits) or less; that is, *length* is never greater than FFH.

*offset* is the starting load offset specifying an absolute address in memory where the data is to be located when loaded by a tool. This field is two bytes long. This field is only used for Data Records. In other records this field is coded as four ASCII zero characters ('0000').

*type* is the record type. This value occupies one byte (two hexadecimal digits). The record types are:

| Byte Type | Record type |
|---|---|
| 00 | Data |
| 01 | End of File |
| 02 | Extended segment address (not used) |
| 03 | Start segment address (not used) |
| 04 | Extended linear address (32-bit) |
| 05 | Start linear address (32-bit) |

*content* is the information contained in the record. This depends on the record type.

*checksum* is the record checksum. The linker computes the checksum by first adding the binary representation of the previous bytes (from *length* to *content*). The linker then computes the result of sum modulo 256 and subtracts the remainder from 256 (two's complement). Therefore, the sum of all bytes following the header is zero.

### *Extended Linear Address Record*

The Extended Linear Address Record specifies the two most significant bytes (bits 16-31) of the absolute address of the first data byte in a subsequent Data Record:

| : | 02 | 0000 | 04 | *upper_address* | *checksum* |
|---|---|---|---|---|---|

The 32-bit absolute address of a byte in a Data Record is calculated as:

( *address* + *offset* + *index* ) modulo 4G

where:

*address* is the base address, where the two most significant bytes are the *upper_address* and the two least significant bytes are zero.

*offset* is the 16-bit offset from the Data Record.

*index* is the index of the data byte within the Data Record (0 for the first byte).

Example:

```
:0200000400FFFB
 | |   | |   |_ checksum
 | |   | |_ upper_address
 | |   |_ type
 | |_ offset
 |_ length
```

### Data Record

The Data Record specifies the actual program code and data.

| : | *length* | *offset* | 00 | *data* | *checksum* |
|---|---|---|---|---|---|

The *length* byte specifies the number of *data* bytes. The linker has an option that controls the length of the output buffer for generating Data records. The default buffer length is 32 bytes.

The *offset* is the 16-bit starting load offset. Together with the address specified in the Extended Address Record it specifies an absolute address in memory where the data is to be located when loaded by a tool.

Example:

```
:0F00200000232222754E00754F04AF4FAE4E22C3
 | |   | |                             |_ checksum
 | |   | |_ data
 | |   |_ type
 | |_ offset
 |_ length
```

### Start Linear Address Record

The Start Linear Address Record contains the 32-bit program execution start address.

Layout:

| : | 04 | 0000 | 05 | *address* | *checksum* |
|---|---|---|---|---|---|

Example:

```
:0400000500FF0003F5
 | |   | |       |_ checksum
 | |   | |_ address
 | |   |_ type
 | |_ offset
 |_ length
```

### End of File Record

The hexadecimal file always ends with the following end-of-file record:

```
:00000001FF
 | |   | |_ checksum
 | |   |_ type
 | |_ offset
 |_ length
```

# 7 Linker Script Language

**Summary**

This chapter describes the syntax of the linker script language (LSL)

## 7.1 Introduction

To make full use of the linker, you can write a script with information about the architecture of the target processor and locating information. The language for the script is called the *Linker Script Language* (LSL). This chapter first describes the structure of an LSL file. The next section contains a summary of the LSL syntax. Finally, in the remaining sections, the semantics of the Linker Script Language is explained.

The TASKING linker is a target independent linker/locator that can simultaneously link and locate all programs for all cores available on a target board. The target board may be of arbitrary complexity. A simple target board may contain one standard processor with some external memory that executes one task. A complex target board may contain multiple standard processors and DSPs combined with configurable IP-cores loaded in an FPGA. Each core may execute a different program, and external memory may be shared by multiple cores.

LSL serves two purposes. First it enables you to specify the characteristics (that are of interest to the linker) of your specific target board and of the cores installed on the board. Second it enables you to specify how sections should be located in memory.

## 7.2 Structure of a Linker Script File

A script file consists of several definitions. The definitions can appear in any order.

### *The architecture definition (required)*

In essence an *architecture definition* describes how the linker should convert logical addresses into physical addresses for a given type of core. If the core supports multiple address spaces, then for each space the linker must know how to perform this conversion. In this context a physical address is an offset on a given internal or external bus. Additionally the architecture definition contains information about items such as the (hardware) stack and the vector table.

This specification is normally written by Altium. The architecture definition of the LSL file should not be changed by you unless you also modify the core's hardware architecture. If the LSL file describes a multi-core system an architecture definition must be available for each different type of core.

See section 7.5, *Semantics of the Architecture Definition* for detailed descriptions of LSL in the architecture definition.

### *The derivative definition*

The *derivative definition* describes the configuration of the internal (on-chip) bus and memory system. Basically it tells the linker how to convert offsets on the buses specified in the architecture definition into offsets in internal memory. A derivative definition must be present in an LSL file. Microcontrollers and DSPs often have internal memory and I/O sub-systems apart from one or more cores. The design of such a chip is called a *derivative*.

When you design an FPGA together with a PCB, the components on the FPGA become part of the board design and there is no need to distinguish between internal and external memory. For this reason you probably do not need to work with derivative definitions at all. There are, however, two situations where derivative definitions are useful:

1. When you re-use an FPGA design for several board designs it may be practical to write a derivative definition for the FPGA design and include it in the project LSL file.

2. When you want to use multiple cores of the same type, you must instantiate the cores in a derivative definition, since the linker automatically instantiates only a single core for an unused architecture.

See section 7.6, *Semantics of the Derivative Definition* for a detailed description of LSL in the derivative definition.

### The processor definition

The *processor definition* describes an instance of a derivative. Typically the processor definition instantiates one derivative only (single-core processor). A processor that contains multiple cores having the same (homogeneous) or different (heterogeneous) architecture can also be described by instantiating multiple derivatives of the same or different types in separate processor definitions.

If for a derivative 'A' no processor is defined in the LSL file, the linker automatically creates a processor named 'A' of derivative 'A'. This is why for single-processor applications it is enough to specify the derivative in the LSL file.

See section 7.7, *Semantics of the Board Specification* for a detailed description of LSL in the processor definition.

### The memory and bus definitions (optional)

Memory and bus definition are used within the context of a derivative definition to specify internal memory and on-chip buses. In the context of a board specification the memory and bus definitions are used to define external (off-chip) memory and buses. Given the above definitions the linker can convert a logical address into an offset into an on-chip or off-chip memory device.

See section 7.7.3, *Defining External Memory and Buses,* for more information on how to specify the external physical memory layout. *Internal* memory for a processor should be defined in the derivative definition for that processor.

### The board specification

The processor definition and memory and bus definitions together form a *board specification*. LSL provides language constructs to easily describe single-core and heterogeneous or homogeneous multi-core systems. The board specification describes all characteristics of your target board's system buses, memory devices, I/O sub-systems, and cores that are of interest to the linker. Based on the information provided in the board specification the linker can for each core:

- convert a logical address to an offset within a memory device
- locate sections in physical memory
- maintain an overall view of the used and free physical memory within the whole system while locating

### The section layout definition (optional)

The optional *section layout definition* enables you to exactly control where input sections are located. Features are provided such as: the ability to place sections at a given load-address or run-time address, to place sections in a given order, and to overlay code and/or data sections.

Which object files (sections) constitute the task that will run on a given core is specified on the command line when you invoke the linker. The linker will link and locate all sections of all tasks simultaneously. From the section layout definition the linker can deduce where a given section may be located in memory, form the board specification the linker can deduce which physical memory is (still) available while locating the section.

See section 7.9, *Semantics of the Section Layout Definition*, for more information on how to locate a section at a specific place in memory.

### Skeleton of a Linker Script File

The skeleton of a linker script file now looks as follows:

```
architecture architecture_name
{
    architecture definition
}

derivative derivative_name
{
    derivative definition
}
```

```
processor processor_name
{
    processor definition
}

memory definitions and/or bus definitions

section_layout space_name
{
    section placement statements
}
```

## 7.3 Syntax of the Linker Script Language

### 7.3.1 Preprocessing

When the linker loads an LSL file, the linker processes it with a C-style prepocessor. As such, it strips C and C++ comments. You can use the standard ISO C preprocessor directives, such as `#include`, `#define`, `#if/#else/#endif`.

For example:

```
#include "arch.lsl"
```

Preprocess and include the file `arch.lsl` at this point in the LSL file.

### 7.3.2 Lexical Syntax

The following lexicon is used to describe the syntax of the Linker Script Language:

| | |
|---|---|
| *A* ::= *B* | = *A* is defined as *B* |
| *A* ::= *B C* | = *A* is defined as *B* and *C*; *B* is followed by *C* |
| *A* ::= *B* \| *C* | = *A* is defined as *B* or *C* |
| <*B*>0\|1 | = zero or one occurrence of *B* |
| <*B*>>=0 | = zero of more occurrences of *B* |
| <*B*>>=1 | = one of more occurrences of *B* |

| | |
|---|---|
| *IDENTIFIER* | = a character sequence starting with 'a'–'z', 'A'–'Z' or '_'. Following characters may also be digits and dots '.' |
| *STRING* | = sequence of characters not starting with \n, \r or \t |
| *DQSTRING* | = " *STRING* " (double quoted string) |
| *OCT_NUM* | = octal number, starting with a zero (06, 045) |
| *DEC_NUM* | = decimal number, not starting with a zero (14, 1024) |
| *HEX_NUM* | = hexadecimal number, starting with '0x' (0x0023, 0xFF00) |

*OCT_NUM*, *DEC_NUM* and *HEX_NUM* can be followed by a **k** (kilo), **M** (mega), or **G** (giga).

Characters in **bold** are characters that occur literally. Words in *italics* are higher order terms that are defined in the same or in one of the other sections.

To write comments in LSL file, you can use the C style '`/* */`' or C++ style '`//`'.

### 7.3.3 Identifiers

```
arch_name          ::= IDENTIFIER
bus_name           ::= IDENTIFIER
core_name          ::= IDENTIFIER
derivative_name    ::= IDENTIFIER
file_name          ::= DQSTRING
group_name         ::= IDENTIFIER
mem_name           ::= IDENTIFIER
proc_name          ::= IDENTIFIER
section_name       ::= DQSTRING
space_name         ::= IDENTIFIER
stack_name         ::= section_name
symbol_name        ::= DQSTRING
```

### 7.3.4 Expressions

The expressions and operators in this section work the same as in ISO C.

```
number             ::= OCT_NUM
                     | DEC_NUM
                     | HEX_NUM

expr               ::= number
                     | symbol_name
                     | unary_op expr
                     | expr binary_op expr
                     | expr ? expr : expr
                     | ( expr )
                     | function_call

unary_op           ::= !    // logical NOT
                     | ~    // bitwise complement
                     | -    // negative value

binary_op          ::= ^    // exclusive OR
                     | *    // multiplication
                     | /    // division
                     | %    // modulus
                     | +    // addition
                     | -    // subtraction
                     | >>   // right shift
                     | <<   // left shift
                     | ==   // equal to
                     | !=   // not equal to
                     | >    // greater than
                     | <    // less than
                     | >=   // greater than or equal to
                     | <=   // less than or equal to
                     | &    // bitwise AND
                     | |    // bitwise OR
                     | &&   // logical AND
                     | ||   // logical OR
```

## 7.3.5 Built-in Functions

```
function_call     ::= absolute ( expr )
                    | addressof ( addr_id )
                    | exists ( section_name )
                    | max ( expr , expr )
                    | min ( expr , expr )
                    | sizeof ( size_id )

addr_id           ::= sect : section_name
                    | group : group_name

size_id           ::= sect : section_name
                    | group : group_name
                    | mem : mem_name
```

- Every space, bus, memory, section or group your refer to, must be defined in the LSL file.
- The `addressof()` and `sizeof()` functions with the **`group`** or **`sect`** argument can only be used in the right hand side of an assignment. The `sizeof()` function with the **`mem`** argument can be used anywhere in section layouts.

You can use the following built-in functions in expressions. All functions return a numerical value. This value is a 64-bit signed integer.

### *absolute()*

```
int absolute( expr )
```

Converts the value of *expr* to a positive integer.

```
absolute( "labelA"-"labelB" )
```

### *addressof()*

```
int addressof( addr_id )
```

Returns the address of *addr_id*, which is a named section or group. To get the offset of the section with the name `asect`:

```
addressof( sect: "asect")
```

This function only works in assignments.

### *exists()*

```
int exists( section_name )
```

The function returns 1 if the section *section_name* exists in one or more object file, 0 otherwise. If the section is not present in input object files, but generated from LSL, the result of this function is undefined.

To check whether the section `mysection` exists in one of the object files that is specified to the linker:

```
exists( "mysection" )
```

### *max()*

```
int max( expr, expr )
```

Returns the value of the expression that has the largest value. To get the highest value of two symbols:

```
max( "sym1" , "sym2")
```

### *min()*

```
int min( expr, expr )
```

Returns the value of the expression hat has the smallest value. To get the lowest value of two symbols:

```
min( "sym1" , "sym2")
```

### *sizeof()*

```
int sizeof( size_id )
```

Returns the size of the object (group, section or memory) the identifier refers to. To get the size of the section "asection":

```
sizeof( sect: "asection" )
```

The **group** and **sect** arguments only works in assignments. The **mem** argument can be used anywhere in section layouts.

## 7.3.6 LSL Definitions in the Linker Script File

```
description        ::= <definition>>=1

definition          ::= architecture_definition
                      | derivative_definition
                      | board_spec
                      | section_definition
                      | section_setup
```

- At least one *architecture_definition* must be present in the LSL file.

## 7.3.7 Memory and Bus Definitions

```
mem_def            ::= memory mem_name { <mem_descr ;>>=0 }
```

- A *mem_def* defines a *memory* with the *mem_name* as a unique name.

```
mem_descr          ::= type = <reserved>0|1 mem_type
                      | mau = expr
                      | size = expr
                      | speed = number
                      | mapping
```

- A *mem_def* contains exactly one **type** statement.
- A *mem_def* contains exactly one **mau** statement (non-zero size).
- A *mem_def* contains exactly one **size** statement.
- A *mem_def* contains zero or one **speed** statement (default value is 1).
- A *mem_def* contains at least one *mapping*.

```
mem_type           ::= rom          // attrs = rx
                      | ram          // attrs = rw
                      | nvram        // attrs = rwx

bus_def            ::= bus bus_name { <bus_descr ;>>=0 }
```

- A *bus_def* statement defines a *bus* with the given *bus_name* as a unique name within a core architecture.

```
bus_descr          ::= mau = expr
                      | width = expr   // bus width, nr
                      |                // of data bits
                      | mapping        // legal destination
                                       // 'bus' only
```

- The **mau** and **width** statements appear exactly once in a *bus_descr*. The default value for **width** is the **mau** size.
- The bus width must be an integer times the bus MAU size.

- The MAU size must be non-zero.
- A bus can only have a *mapping* on a destination *bus* (through **dest = bus:** ).

```
mapping          ::= map ( map_descr <, map_descr>>=0 )

map_descr        ::= dest = destination
                   | dest_dbits = range
                   | dest_offset = expr
                   | size = expr
                   | src_dbits = range
                   | src_offset = expr
```

- A *mapping* requires at least the **size** and **dest** statements.
- Each *map_descr* can occur only once.
- You can define multiple mappings from a single source.
- Overlap between source ranges or destination ranges is not allowed.
- If the **src_dbits** or **dest_dbits** statement is not present, its value defaults to the **width** value if the source/destination is a bus, and to the **mau** size otherwise.

```
destination      ::= space : space_name
                   | bus : <proc_name |
                          core_name :>0|1 bus_name
```

- A *space_name* refers to a defined address space.
- A *proc_name* refers to a defined processor.
- A *core_name* refers to a defined core.
- A *bus_name* refers to a defined bus.
- The following mappings are allowed (source to destination)
  - space => space
  - space => bus
  - bus => bus
  - memory => bus

```
range            ::= expr .. expr
```

### 7.3.8 Architecture Definition

```
architecture_definition
                 ::= architecture arch_name
                     <( parameter_list )>0|1
                     <extends arch_name
                            <( argument_list )>0|1 >0|1
                     { arch_spec>=0 }
```

- An *architecture_definition* defines a core *architecture* with the given *arch_name* as a unique name.
- At least one *space_def* and at least one *bus_def* have to be present in an *architecture_definition*.
- An *architecture_definition* that uses the **extends** construct defines an architecture that *inherits* all elements of the architecture defined by the second *arch_name*. The *parent architecture* must be defined in the LSL file as well.

```
parameter_list   ::= parameter <, parameter>>=0

parameter        ::= IDENTIFIER <= expr>0|1

argument_list    ::= expr <, expr>>=0

arch_spec        ::= bus_def
                   | space_def
                   | endianness_def

space_def        ::= space space_name { <space_descr;>>=0 }
```

- A *space_def* defines an address space with the given *space_name* as a unique name within an architecture.

```
space_descr        ::= space_property ;
                     | section_definition  //no space ref
                     | vector_table_statement
                     | reserved_range

space_property     ::= id = number // as used in object
                     | mau = expr
                     | align = expr
                     | page_size = expr <[ range ] <| [ range ]>>=0 >0|1
                     | page
                     | direction = direction
                     | stack_def
                     | heap_def
                     | copy_table_def
                     | start_address
                     | mapping
```

- A *space_def* contains exactly one **id** and one **mau** statement.
- A *space_def* contains at most one **align** statement.
- A *space_def* contains at most one **page_size** statement.
- A *space_def* contains at least one mapping.

```
stack_def          ::= stack stack_name ( stack_heap_descr
                                          <, stack_heap_descr >>=0 )
```

- A *stack_def* defines a stack with the *stack_name* as a unique name.

```
heap_def           ::= heap heap_name ( stack_heap_descr
                                        <, stack_heap_descr >>=0 )
```

- A *heap_def* defines a heap with the *heap_name* as a unique name.

```
stack_heap_descr   ::= min_size = expr
                     | grows = direction
                     | align = expr
                     | fixed
                     | id = expr
```

- The **min_size** statement must be present.
- You can specify at most one **align** statement and one **grows** statement.
- Each stack definition has its own unique **id**, the number specified corresponds to the index in the `.CALLS` directive as generated by the compiler. If the **id** is omitted, the id is 0 (zero).

```
direction          ::= low_to_high
                     | high_to_low
```

- If you do not specify the **grows** statement, the stack and grow **low-to-high**.

```
copy_table_def     ::= copytable <( copy_table_descr
                                  <, copy_table_descr>>=0 )>0|1
```

- A *space_def* contains at most one **copytable** statement.
- If the architecture definition contains more than one address space, exactly one copy table must be defined in one of the spaces. If the architecture definition contains only one address space, a copy table definition is optional (it will be generated in the space).

```
copy_table_descr   ::= align = expr
                     | copy_unit = expr
                     | dest <space_name>0|1 = space_name
                     | page
```

- The **copy_unit** is defined by the size in MAUs in which the startup code moves data.
- The **dest** statement is only required when the startup code initializes memory used by another processor that has no access to ROM.
- A *space_name* refers to a defined address space.

```
start_addr        ::= start_address ( start_addr_descr
                             <, start_addr_descr>>=0 )

start_addr_descr  ::= run_addr = expr
                    | symbol = symbol_name
```

- A *symbol_name* refers to the section that contains the startup code.

```
vector_table_statement
                  ::= vector_table section_name
                      ( vecttab_spec <, vecttab_spec>>=0 )
                       { <vector_def>>=0 }

vecttab_spec      ::= vector_size = expr
                    | size = expr
                    | id_symbol_prefix = symbol_name
                    | run_addr = addr_absolute
                    | template = section_name
                    | template_symbol = symbol_name
                    | vector_prefix = section_name
                    | fill = vector_value
                    | no_inline
                    | copy

vector_def        ::= vector ( vector_spec <, vector_spec>>=0 )

vector_spec       ::= id = vector_id_spec
                    | fill = vector_value

vector_id_spec    ::= number
                    | [ range ] <, [ range ]>>=0

vector_value      ::= symbol_name
                    | [ number <, number>>=0 ]
                    | loop <[ expr ]>0|1

reserved_range    ::= reserved expr .. expr ;

endianness_def    ::= endianness { <endianness_type;>>=1 }

endianness_type   ::= big
                    | little
```

### 7.3.9 Derivative Definition

```
derivative_definition
                  ::= derivative derivative_name
                      <( parameter_list )>0|1
                      <extends derivative_name
                              <( argument_list )>0|1 >0|1
                      { <derivative_spec>>=0 }
```

- A *derivative_definition* defines a derivative with the given *derivative_name* as a unique name.

```
derivative_spec   ::= core_def
                    | bus_def
                    | mem_def
                    | section_definition // no processor name
                    | section_setup

core_def          ::= core core_name { <core_descr ;>>=0 }
```

- A *core_def* defines a *core* with the given *core_name* as a unique name.
- At least one *core_def* must be present in a *derivative_definition*.

```
core_descr          ::= architecture = arch_name
                        <( argument_list )>0|1
                      | endianness = ( endianness_type
                                  <, endianness_type>>=0 )
```

- An *arch_name* refers to a defined core architecture.
- Exactly one **architecture** statement must be present in a *core_def*.

## 7.3.10 Processor Definition and Board Specification

```
board_spec          ::= proc_def
                      | bus_def
                      | mem_def

proc_def            ::= processor proc_name
                        { proc_descr ; }

proc_descr          ::= derivative = derivative_name
                        <( argument_list )>0|1
```

- A *proc_def* defines a *processor* with the *proc_name* as a unique name.
- If you do not explicitly define a processor for a derivative in an LSL file, the linker defines a processor with the same name as that derivative.
- A *derivative_name* refers to a defined derivative.
- A *proc_def* contains exactly one **derivative** statement.

## 7.3.11 Section Layout Definition and Section Setup

```
section_definition ::= section_layout <space_ref>0|1
                         <( locate_direction )>0|1
                         { <section_statement>>=0 }
```

- A section definition inside a space definition does not have a *space_ref*.
- All global section definitions have a *space_ref*.

```
space_ref           ::= <proc_name>0|1 : <core_name>0|1
                          : space_name
```

- If more than one processor is present, the *proc_name* must be given for a global section layout.
- If the section layout refers to a processor that has more than one core, the *core_name* must be given in the *space_ref*.
- A *proc_name* refers to a defined processor.
- A *core_name* refers to a defined core.
- A *space_name* refers to a defined address space.

```
locate_direction    ::= direction = direction

direction           ::= low_to_high
                      | high_to_low
```

- A section layout contains at most one **direction** statement.
- If you do not specify the **direction** statement, the locate direction of the section layout is **low-to-high**.

```
section_statement
                    ::= simple_section_statement ;
                      | aggregate_section_statement

simple_section_statement
                    ::= assignment
                      | select_section_statement
                      | special_section_statement

assignment          ::= symbol_name assign_op expr

assign_op           ::= =
                      | :=
```

```
select_section_statement
                  ::= select <ref_tree>0|1 <section_name>0|1
                      <section_selections>0|1
```

- Either a *section_name* or at least one *section_selection* must be defined.

```
section_selections
                  ::= ( section_selection
                        <, section_selection>>=0 )

section_selection
                  ::= attributes = < <+|-> attribute>>0
```

- **+***attribute* means: select all sections that have this attribute.
- **-***attribute* means: select all sections that do not have this attribute.

```
special_section_statement
                  ::= heap stack_name <size_spec>0|1
                    | stack stack_name <size_spec>0|1
                    | copytable
                    | reserved section_name <reserved_specs>0|1
```

- Special sections cannot be selected in load-time groups.

```
size_spec         ::= ( size = expr )

reserved_specs    ::= ( reserved_spec <, reserved_spec>>=0 )

reserved_spec     ::= attributes
                    | fill_spec
                    | size = expr
                    | alloc_allowed = absolute
```

- If a **reserved** section has attributes **r**, **rw**, **x**, **rx** or **rwx**, and no fill pattern is defined, the section is filled with zeros. If no attributes are set, the section is created as a scratch section (attributes **ws**, no image).

```
fill_spec         ::= fill = fill_values

fill_values       ::= expr
                    | [ expr <, expr>>=0 ]

aggregate_section_statement
                  ::= { <section_statement>>=0 }
                    | group_descr
                    | if_statement
                    | section_creation_statement

group_descr       ::= group <group_name>0|1 <( group_specs )>0|1
                            section_statement
```

- No two groups for an address space can have the same *group_name*.

```
group_specs       ::= group_spec <, group_spec >>=0

group_spec        ::= group_alignment
                    | attributes
                    | copy
                    | nocopy
                    | group_load_address
                    | fill <= fill_values>0|1
                    | group_page
                    | group_run_address
                    | group_type
                    | allow_cross_references
                    | priority = number
```

- The **allow-cross-references** property is only allowed for *overlay* groups.
- Sub groups inherit all properties from a parent group.

```
group_alignment   ::= align = expr

attributes        ::= attributes = <attribute>>=1

attribute         ::= r    // readable sections
                    | w    // writable sections
                    | x    // executable code sections
                    | i    // initialized sections
                    | s    // scratch sections
                    | b    // blanked (cleared) sections

group_load_address
                  ::= load_addr <= load_or_run_addr>0|1

group_page        ::= page <= expr>0|1
                    | page_size = expr <[ range ] <| [ range ]>>=0 >0|1

group_run_address ::= run_addr <= load_or_run_addr>0|1

group_type        ::= clustered
                    | contiguous
                    | ordered
                    | overlay
```

- For *non-contiguous* groups, you can only specify *group_alignment* and *attributes*.
- The **overlay** keyword also sets the **contiguous** property.
- The **clustered** property cannot be set together with **contiguous** or **ordered** on a single group.

```
load_or_run_addr  ::= addr_absolute
                    | addr_range <| addr_range>>=0

addr_absolute     ::= expr
                    | memory_reference [ expr ]
```

- An absolute address can only be set on *ordered* groups.

```
addr_range        ::= [ expr .. expr ]
                    | memory_reference
                    | memory_reference [ expr .. expr ]
```

- The parent of a group with an *addr_range* or **page** restriction cannot be **ordered**, **contiguous** or **clustered**.

```
memory_reference  ::= mem : <proc_name :>0|1 <core_name :>0|1 mem_name
```

- A *proc_name* refers to a defined processor.
- A *core_name* refers to a defined core.
- A *mem_name* refers to a defined memory.

```
if_statement      ::= if ( expr ) section_statement
                      <else section_statement>0|1

section_creation_statement
                  ::= section section_name ( section_specs )
                      { <section_statement2>>=0 }

section_specs     ::= section_spec <, section_spec >>=0

section_spec      ::= attributes
                    | fill_spec
                    | size = expr
                    | blocksize = expr
                    | overflow = section_name

section_statement2
                  ::= select_section_statement ;
                    | group_descr2
                    | { <section_statement2>>=0 }
```

```
group_descr2       ::= group <group_name>0|1
                             ( group_specs2 )
                             section_statement2

group_specs2       ::= group_spec2 <, group_spec2 >>=0

group_spec2        ::= group_alignment
                     | attributes
                     | load_addr

section_setup      ::= section_setup space_ref
                       { <section_setup_item>>=0 }

section_setup_item
                   ::= vector_table_statement
                     | reserved_range
                     | stack_def ;
                     | heap_def ;
```

## 7.4 Expression Evaluation

Only *constant* expressions are allowed, including sizes, but not addresses, of sections in object files.

All expressions are evaluated with 64-bit precision integer arithmetic. The result of an expression can be absolute or relocatable. A symbol you assign is created as an absolute symbol.

## 7.5 Semantics of the Architecture Definition

***Keywords in the architecture definition***

```
architecture
   extends
endianness          big  little
bus
   mau
   width
   map
space
   id
   mau
   align
   page_size
   page
   direction        low_to_high  high_to_low
   stack
      min_size
      grows         low_to_high  high_to_low
      align
      fixed
      id
   heap
      min_size
      grows         low_to_high  high_to_low
      align
      fixed
      id
   copytable
      align
      copy_unit
      dest
      page
   vector_table
      vector_size
      size
      id_symbol_prefix
      run_addr
      template
      template_symbol
      vector_prefix
      fill
      no_inline
      copy
      vector
         id
         fill       loop
   reserved
   start_address
      run_addr
      symbol
   map
```

```
map
   dest          bus  space
   dest_dbits
   dest_offset
   size
   src_dbits
   src_offset
```

### 7.5.1 Defining an Architecture

With the keyword **architecture** you define an architecture and assign a unique name to it. The name is used to refer to it at other places in the LSL file:

```
architecture name
{
     definitions
}
```

If you are defining multiple core architectures that show great resemblance, you can define the common features in a parent core architecture and extend this with a child core architecture that contains specific features. The child inherits all features of the parent. With the keyword **extends** you create a child core architecture:

```
architecture name_child_arch extends name_parent_arch
{
     definitions
}
```

A core architecture can have any number of parameters. These are identifiers which get values assigned on instantiation or extension of the architecture. You can use them in any expression within the core architecture. Parameters can have default values, which are used when the core architecture is instantiated with less arguments than there are parameters defined for it. When you extend a core architecture you can pass arguments to the parent architecture. Arguments are expressions that set the value of the parameters of the sub-architecture.

```
architecture name_child_arch (parm1,parm2=1)
             extends name_parent_arch (arguments)
{
     definitions
}
```

### 7.5.2 Defining Internal Buses

With the **bus** keyword you define a bus (the combination of data and corresponding address bus). The bus name is used to identify a bus and does not conflict with other identifiers. Bus descriptions in an architecture definition or derivative definition define *internal* buses. Some internal buses are used to communicate with the components outside the core or processor. Such buses on a processor have physical pins reserved for the number of bits specified with the **width** statements.

- The **mau** field specifies the MAU size (Minimum Addressable Unit) of the data bus. This field is required.
- The **width** field specifies the width (number of address lines) of the data bus. The default value is the MAU size.
- The **map** keyword specifies how this bus maps onto another bus (if so). Mappings are described in section 7.5.4, *Mappings*.

```
bus bus_name
{
     mau = 8;
     width = 8;
     map ( map_description );
}
```

### 7.5.3 Defining Address Spaces

With the **space** keyword you define a logical address space. The space name is used to identify the address space and does not conflict with other identifiers.

- The **id** field defines how the addressing space is identified in object files. In general, each address space has a unique ID. The linker locates sections with a certain ID in the address space with the same ID. This field is required. In IEEE this ID is specified explicitly for sections and symbols, ELF sections map by default to the address space with ID 1. Sections with one of the special names defined in the ABI (Application Binary Interface) may map to different address spaces.
- The **mau** field specifies the MAU size (Minimum Addressable Unit) of the space. This field is required.
- The **align** value must be a power of two. The linker uses this value to compute the start addresses when sections are concatenated. An align value of *n* means that objects in the address space have to be aligned on *n* MAUs.
- The **page_size** field sets the page alignment and page size in MAUs for the address space. It must be a power of 2. The default value is 1. If one or more page ranges are supplied the supplied value only sets the page alignment. The ranges specify the available space in each page, as offsets to the page start, which is aligned at the page alignment.

  See also the **page** keyword in subsection *Locating a group* in section 7.9.2, *Creating and Locating Groups of Sections*.
- With the optional **direction** field you can specify how all sections in this space should be located. This can be either from **low_to_high** addresses (this is the default) or from **high_to_low** addresses.
- The **map** keyword specifies how this address space maps onto an internal bus or onto another address space. Mappings are described in section 7.5.4, *Mappings*.

### *Stacks and heaps*

- The **stack** keyword defines a stack in the address space and assigns a name to it. The architecture definition must contain at least one stack definition. Each stack of a core architecture must have a unique name. See also the **stack** keyword in section 7.9.3, *Creating or Modifying Special Sections*.

  The stack is described in terms of a minimum size (**min_size**) and the direction in which the stack grows (**grows**). This can be either from **low_to_high** addresses (stack grows upwards, this is the default) or from **high_to_low** addresses (stack grows downwards). The **min_size** is required.

  By default, the linker tries to maximize the size of the stacks and heaps. After locating all sections, the largest remaining gap in the space is used completely for the stacks and heaps. If you specify the keyword **fixed**, you can disable this so-called 'balloon behavior'. The size is also fixed if you used a stack or heap in the software layout definition in a restricted way. For example when you override a stack with another size or select a stack in an ordered group with other sections.

  The **id** keyword matches stack information generated by the compiler with a stack name specified in LSL. This value assigned to this keyword is strongly related to the compiler's output, so users are not supposed to change this configuration.

  Optionally you can specify an alignment for the stack with the argument **align**. This alignment must be equal or larger than the alignment that you specify for the address space itself.
- The **heap** keyword defines a heap in the address space and assigns a name to it. The definition of a heap is similar to the definition of a stack. See also the **heap** keyword in section 7.9.3, *Creating or Modifying Special Sections*.

See section 7.9, *Semantics of the Section Layout Definition*, for information on creating and placing stack sections.

### *Copy tables*

- The **copytable** keyword defines a copy table in the address space. The content of the copy table is created by the linker and contains the start address and size of all sections that should be initialized by the startup code. You must define exactly one copy table in one of the address spaces (for a core).

  Optionally you can specify an alignment for the copy table with the argument **align**. This alignment must be equal or larger than the alignment that you specify for the address space itself. If smaller, the alignment for the address space is used.

  The **copy_unit** argument specifies the size in MAUs of information chunks that are copied. If you do not specify the copy unit, the MAU size of the address space itself is used.

  The **dest** argument specifies the destination address space that the code uses for the copy table. The linker uses this information to generate the correct addresses in the copy table. The memory into where the sections must be copied at run-time, must be accessible from this destination space.

  Sections generated for the copy table may get a page restriction with the address space's page size, by adding the **page** argument.

### Vector table

- The **vector_table** keyword defines a vector table with *n* vectors of size *m* (This is an internal LSL object similar to an LSL group.) The **run_addr** argument specifies the location of the first vector (id=0). This can be a simple address or an offset in memory (see the description of the run-time address in subsection *Locating a group* in section 7.9.2, *Creating and Locating Groups of Sections*). A vector table defines symbols `_lc_ub_foo` and `_lc_ue_foo` pointing to start and end of the table.

  **vector_table** "vtable" (**vector_size**=*m*, **size**=*n*, **run_addr**=*x*, **...**)

  See the following example of a vector table definition:

```
vector_table "vtable" (vector_size = 4, size = 256, run_addr=0,
                       template=".text.vector_template",
                       template_symbol="_lc_vector_target",
                       vector_prefix="_vector_",
                       id_symbol_prefix="foo",
                       no_inline,
                       /* default: empty, or */
                       fill="foo", /* or */
                       fill=[1,2,3,4], /* or */
                       fill=loop)
{
    vector (id=0, fill="_START");
    vector (id=12, fill=[0xab, 0x21, 0x32, 0x43]);
    vector (id=[1..11], fill=[0]);
    vector (id=[18..23], fill=loop);
}
```

  The **template** argument defines the name of the section that holds the code to jump to a handler function from the vector table. This template section does not get located and is removed when the locate phase is completed. This argument is required.

  The **template_symbol** argument is the symbol reference in the template section that must be replaced by the address of the handler function. This symbol name should start with the linker prefix for the symbol to be ignored in the link phase. This argument is required.

  The **vector_prefix** argument defines the names of vector sections: the section for a vector with id *vector_id* is $(*vector_prefix*)$(*vector_id*). Vectors defined in C or assembly source files that should be included in the vector table must have the correct symbol name. The compiler uses the prefix that is defined in the default LSL file(s); if this attribute is changed, the vectors declared in C source files are not included in the vector table. When a vector supplied in an object file has exactly one relocation, the linker will assume it is a branch to a handler function, and can be removed when the handler is inlined in the vector table. Otherwise, no inlining is done. This argument is required.

  With the optional **no_inline** argument the vectors handlers are not inlined in the vector table.

  With the optional **copy** argument a ROM copy of the vector table is made and the vector table is copied to RAM at startup.

  With the optional **id_symbol_prefix** argument you can set an internal string representing a symbol name prefix that may be found on symbols in vector handler code. When the linker detects such a symbol in a handler, the symbol is assigned the vector number. If the symbol was already assigned a vector number, a warning is issued.

  The **fill** argument sets the default contents of vectors. If nothing is specified for a vector, this setting is used. See below. When no default is provided, empty vectors may be used to locate large vector handlers and other sections. Only one **fill** argument is allowed.

  The **vector** field defines the content of vector with the number specified by **id**. If a range is specified for **id** ([p..q,s..t]) all vectors in the ranges (inclusive) are defined the same way.

  With **fill=***symbol_name*, the vector must jump to this symbol. If the section in which the symbol is defined fits in the vector table (size may be >*m*), locate the section at the location of the vector. Otherwise, insert code to jump to the symbol's value. A template handler section name + symbol name for the target code must be supplied in the LSL file.

  **fill=[***value(s)***]**, fills the vector with the specified MAU values.

  With **fill=loop** the vector jumps to itself. With the optional **[***offset***]** you can specify an offset from the vector table entry.

### *Reserved address ranges*

- The **reserved** keyword specifies to reserve a part of an address space even if not all of the range is covered by memory. See also the **reserved** keyword in section 7.9.3, *Creating or Modifying Special Sections*.

### *Start address*

- The **start_address** keyword specifies the start address for the position where the C startup code is located. When a processor is reset, it initializes its program counter to a certain start address, sometimes called the *reset vector*. In the architecture definition, you must specify this start address in the correct address space in combination with the name of the label in the application code which must be located here.

  The **run_addr** argument specifies the start address (reset vector). If the core starts executing using an entry from a vector table, and directly jumps to the start label, you should omit this argument.

  The **symbol** argument specifies the name of the label in the application code that should be located at the specified start address. The **symbol** argument is required. The linker will resolve the start symbol and use its value after locating for the start address field in IEEE-695 files and Intel Hex files. If you also specified the **run_addr** argument, the start symbol (label) must point to a section. The linker locates this section such that the start symbol ends up on the start address.

```
space space_name
{
      id = 1;
      mau = 8;
      align = 8;
      page_size = 1;
      stack name (min_size = 1k, grows = low_to_high);
      reserved start_address .. end_address;
      start_address ( run_addr = 0x0000,
                      symbol = "start_label" )
      map ( map_description );
}
```

## 7.5.4 Mappings

You can use a mapping when you define a space, bus or memory. With the **map** field you specify how addresses from the source (space, bus or memory) are translated to addresses of a destination (space, bus). The following mappings are possible:

- space => space
- space => bus
- bus => bus
- memory => bus

With a mapping you specify a range of source addresses you want to map (specified by a source offset and a size), the destination to which you want to map them (a bus or another address space), and the offset address in the destination.

- The **dest** argument specifies the destination. This can be a **bus** or another address **space** (only for a space to space mapping). This argument is required.
- The **src_offset** argument specifies the offset of the source addresses. In combination with size, this specifies the range of address that are mapped. By default the source offset is 0x0000.
- The **size** argument specifies the number of addresses that are mapped. This argument is required.
- The **dest_offset** argument specifies the position in the destination to which the specified range of addresses is mapped. By default the destination offset is 0x0000.

If you are mapping a bus to another bus, the number of data lines of each bus may differ. In this case you have to specify a range of source data lines you want to map (**src_dbits =** *begin***..***end*) and the range of destination data lines you want to map them to (**dest_dbits =** *first***..***last*).

- The **src_dbits** argument specifies a range of data lines of the source bus. By default all data lines are mapped.
- The **dest_dbits** argument specifies a range of data lines of the destination bus. By default, all data lines from the source bus are mapped on the data lines of the destination bus (starting with line 0).

### *From space to space*

If you map an address space to another address space (nesting), you can do this by mapping the subspace to the containing larger space. In this example a small space of 64k is mapped on a large space of 16M.

```
space small
{
   id = 2;
   mau = 4;
   map (src_offset = 0, dest_offset = 0,
        dest = space : large, size = 64k);
}
```

### *From space to bus*

All spaces that are not mapped to another space must map to a bus in the architecture:

```
space large
{
   id = 1;
   mau = 4;
   map (src_offset = 0, dest_offset = 0,
        dest = bus:bus_name, size = 16M );
}
```

### *From bus to bus*

The next example maps an external bus called `e_bus` to an internal bus called `i_bus`. This internal bus resides on a core called `mycore`. The source bus has 16 data lines whereas the destination bus has only 8 data lines. Therefore, the keywords **`src_dbits`** and **`dest_dbits`** specify which source data lines are mapped on which destination data lines.

```
architecture mycore
{
    bus i_bus
    {
       mau = 4;
    }

    space i_space
    {
       map (dest=bus:i_bus, size=256);
    }
}

bus e_bus
{
   mau = 16;
   width = 16;
   map (dest = bus:mycore:i_bus, src_dbits = 0..7, dest_dbits = 0..7 )
}
```

It is not possible to map an internal bus to an external bus.

# 7.6 Semantics of the Derivative Definition

***Keywords in the derivative definition***

```
derivative
   extends
core
   architecture
bus
   mau
   width
   map
memory
   type             reserved  rom  ram  nvram
   mau
   size
   speed
   map
section_layout
section_setup

   map
      dest          bus  space
      dest_dbits
      dest_offset
      size
      src_dbits
      src_offset
```

## 7.6.1 Defining a Derivative

With the keyword **derivative** you define a derivative and assign a unique name to it. The name is used to refer to it at other places in the LSL file:

```
derivative name
{
     definitions
}
```

If you are defining multiple derivatives that show great resemblance, you can define the common features in a parent derivative and extend this with a child derivative that contains specific features. The child inherits all features of the parent (cores and memories). With the keyword **extends** you create a child derivative:

```
derivative name_child_deriv extends name_parent_deriv
{
     definitions
}
```

As with a core architecture, a derivative can have any number of parameters. These are identifiers which get values assigned on instantiation or extension of the derivative. You can use them in any expression within the derivative definition.

```
derivative name_child_deriv (parm1,parm2=1)
           extends name_parent_derivh (arguments)
{
     definitions
}
```

## 7.6.2 Instantiating Core Architectures

With the keyword **core** you instantiate a core architecture in a derivative.

- With the keyword **architecture** you tell the linker that the given core has a certain architecture. The architecture name refers to an existing architecture definition in the same LSL file.

  For example, if you have two cores (called `mycore_1` and `mycore_2`) that have the same architecture (called `mycorearch`), you must instantiate both cores as follows:

```
core mycore_1
{
      architecture = mycorearch;
}

core mycore_2
{
      architecture = mycorearch;
}
```

  If the architecture definition has parameters you must specify the arguments that correspond with the parameters. For example `mycorearch1` expects two parameters which are used in the architecture definition:

```
core mycore
{
      architecture = mycorearch1 (1,2);
}
```

### 7.6.3 Defining Internal Memory and Buses

With the **memory** keyword you define physical memory that is present on the target board. The memory name is used to identify the memory and does not conflict with other identifiers. It is common to define internal memory (on-chip) in the derivative definition. External memory (off-chip memory) is usually defined in the board specification (See section 7.7.3, *Defining External Memory and Buses*).

- The **type** field specifies a memory type:
  - **rom**: read only memory – it can only be written at load-time
  - **ram**: random access volatile writable memory – writing at run-time is possible while writing at load-time has no use since the data is not retained after a power-down
  - **nvram**: non volatile ram – writing is possible both at load-time and run-time

  The optional **reserved** qualifier before the memory type, tells the linker not to locate any section in the memory by default. You can locate sections in such memories using an absolute address or range restriction (see subsection *Locating a group* in section 7.9.2, *Creating and Locating Groups of Sections*).
- The **mau** field specifies the MAU size (Minimum Addressable Unit) of the memory. This field is required.
- The **size** field specifies the size in MAU of the memory. This field is required.
- The **speed** field specifies a symbolic speed for the memory (1..4): 1 is the fastest, 4 the slowest. The linker uses the relative speed of the memories in such a way, that optimal speed is achieved. The default speed is 1.
- The **map** field specifies how this memory maps onto an (internal) bus. Mappings are described in section 7.5.4, *Mappings*.

```
memory mem_name
{
   type = rom;
   mau = 8;
   size = 64k;
   speed = 2;
   map ( map_description );
}
```

With the **bus** keyword you define a bus in a derivative definition. Buses are described in section 7.5.2, *Defining Internal Buses*.

## 7.7 Semantics of the Board Specification

***Keywords in the board specification***

```
processor
   derivative
bus
   mau
   width
   map
memory
   type              reserved  rom  ram  nvram
   mau
   size
   speed
   map

   map
      dest           bus  space
      dest_dbits
      dest_offset
      size
      src_dbits
      src_offset
```

### 7.7.1 Defining a Processor

If you have a target board with multiple processors that have the same derivative, you need to instantiate each individual processor in a processor definition. This information tells the linker which processor has which derivative and enables the linker to distinguish between the present processors.

If you use processors that all have a unique derivative, you may omit the processor definitions. In this case the linker assumes that for each derivative definition in the LSL file there is one processor. The linker uses the derivative name also for the processor.

With the keyword **processor** you define a processor. You can freely choose the processor name. The name is used to refer to it at other places in the LSL file:

```
processor proc_name
{
   processor definition
}
```

### 7.7.2 Instantiating Derivatives

With the keyword **derivative** you tell the linker that the given processor has a certain derivative. The derivative name refers to an existing derivative definition in the same LSL file.

For examples, if you have two processors on your target board (called `myproc_1` and `myproc_2`) that have the same derivative (called `myderiv`), you must instantiate both processors as follows:

```
processor myproc_1
{
     derivative = myderiv;
}

processor myproc_2
{
     derivative = myderiv;
}
```

If the derivative definition has parameters you must specify the arguments that correspond with the parameters. For example `myderiv1` expects two parameters which are used in the derivative definition:

```
processor myproc
{
      derivative = myderiv1 (2,4);
}
```

### 7.7.3 Defining External Memory and Buses

It is common to define external memory (off-chip) and external buses at the global scope (outside any enclosing definition). Internal memory (on-chip memory) is usually defined in the scope of a derivative definition.

With the keyword **memory** you define physical memory that is present on the target board. The memory name is used to identify the memory and does not conflict with other identifiers. If you define memory parts in the LSL file, only the memory defined in these parts is used for placing sections.

If no external memory is defined in the LSL file and if the linker option to allocate memory on demand is set then the linker will assume that all virtual addresses are mapped on physical memory. You can override this behavior by specifying one or more memory definitions.

```
memory mem_name
{
   type = rom;
   mau = 8;
   size = 64k;
   speed = 2;
   map ( map_description );
}
```

For a description of the keywords, see section 7.6.3, *Defining Internal Memory and Buses*.

With the keyword **bus** you define a bus (the combination of data and corresponding address bus). The bus name is used to identify a bus and does not conflict with other identifiers. Bus descriptions at the global scope (outside any definition) define *external* buses. These are buses that are present on the target board.

```
bus bus_name
{
      mau = 8;
      width = 8;
      map ( map_description );
}
```

For a description of the keywords, see section 7.5.2, *Defining Internal Buses*.

You can connect off-chip memory to any derivative: you need to map the off-chip memory to a bus and map that bus on the internal bus of the derivative you want to connect it to.

## 7.8 Semantics of the Section Setup Definition

***Keywords in the section setup definition***

```
section_setup
   stack
      min_size
      grows          low_to_high   high_to_low
      align
      fixed
      id
   heap
      min_size
      grows          low_to_high   high_to_low
      align
      fixed
      id
   vector_table
      vector_size
      size
      id_symbol_prefix
      run_addr
      template
      template_symbol
      vector_prefix
      fill
      no_inline
      copy
      vector
         id
         fill        loop
   reserved
```

### 7.8.1 Setting up a Section

With the keyword **`section_setup`** you can define stacks, heaps, vector tables, and/or reserved address ranges outside their address space definition.

```
section_setup ::my_space
{
   vector table statements
   reserved address range
   stack definition
   heap definition
}
```

See the subsections *Stacks and heaps*, *Vector table* and *Reserved address ranges* in section 7.5.3, *Defining Address Spaces*, for details on the keywords **`stack`**, **`heap`**, **`vector_table`** and **`reserved`**.

## 7.9 Semantics of the Section Layout Definition

***Keywords in the section layout definition***

```
section_layout
   direction      low_to_high  high_to_low
group
   align
   attributes     + -  r w x b i s
   copy
   nocopy
   fill
   ordered
   contiguous
   clustered
   overlay
   allow_cross_references
   load_addr
      mem
   run_addr
      mem
   page
   page_size
   priority
select
stack
   size
heap
   size
reserved
   size
   attributes     r w x
   fill
   alloc_allowed absolute
copytable
section
   size
   blocksize
   attributes     r w x
   fill
   overflow

if
else
```

### 7.9.1 Defining a Section Layout

With the keyword **`section_layout`** you define a section layout for exactly one address space. In the section layout you can specify how input sections are placed in the address space, relative to each other, and what the absolute run and load addresses of each section will be.

You can define one or more section definitions. Each section definition arranges the sections in one address space. You can precede the address space name with a processor name and/or core name, separated by colons. You can omit the processor name and/or the core name if only one processor is defined and/or only one core is present in the processor. A reference to a space in the only core of the only processor in the system would look like "`::my_space`". A reference to a space of the only core on a specific processor in the system could be "`my_chip::my_space`". The next example shows a section definition for sections in the `my_space` address space of the processor called `my_chip`:

```
section_layout my_chip::my_space ( locate_direction )
{
   section statements
}
```

With the optional keyword **`direction`** you specify whether the linker starts locating sections from **`low_to_high`** (default) or from **`high_to_low`**. In the second case the linker starts locating sections at the highest addresses in the address space but preserves the order of sections when necessary (one processor and core in this example).

```
section_layout ::my_space ( direction = high_to_low )
{
   section statements
}
```

If you do not explicitly tell the linker how to locate a section, the linker decides on the basis of the section attributes in the object file and the information in the architecture definition and memory parts where to locate the section.

## 7.9.2 Creating and Locating Groups of Sections

Sections are located per group. A group can contain one or more (sets of) input sections as well as other groups. Per group you can assign a mutual order to the sets of sections and locate them into a specific memory part.

```
group ( group_specifications )
{
   section_statements
}
```

With the *section_statements* you generally select sets of sections to form the group. This is described in subsection *Selecting sections for a group*.

Instead of selecting sections, you can also modify special sections like stack and heap or create a reserved section. This is described in section 7.9.3, *Creating or Modifying Special Sections*.

With the *group_specifications* you actually locate the sections in the group. This is described in subsection *Locating a group*.

### *Selecting sections for a group*

With the **`select`** keyword you can select one or more sections for the group. You can select a section by name or by attributes. If you select a section by name, you can use a wildcard pattern:

| | |
|---|---|
| "*" | matches with all section names |
| "?" | matches with a single character in the section name |
| "\" | takes the next character literally |
| "[abc]" | matches with a single 'a', 'b' or 'c' character |
| "[a-z]" | matches with any single character in the range 'a' to 'z' |

```
group ( ... )
{
   select "mysection";
   select "*";
}
```

The first **`select`** statement selects the section with the name "mysection". The second **`select`** statement selects all sections that were not selected yet.

A section is selected by the first **`select`** statement that matches, in the union of all section layouts for the address space. Global section layouts are processed in the order in which they appear in the LSL file. Internal core architecture section layouts always take precedence over global section layouts.

- The **`attributes`** field selects all sections that carry (or do not carry) the given attribute. With +*attribute* you select sections that have the specified attribute set. With **-***attribute* you select sections that do not have the specified attribute set. You can specify one or more of the following attributes:
  - **`r`** readable sections
  - **`w`** writable sections

- **x** executable sections
- **i** initialized sections
- **b** sections that should be cleared at program startup
- **s** scratch sections (not cleared and not initialized)

To select all read-only sections:

```
group ( ... )
{
    select (attributes = +r-w);
}
```

Keep in mind that all section selections are restricted to the address space of the section layout in which this group definition occurs.

- With the **ref_tree** field you can select a group of related sections. The relation between sections is often expressed by means of references. By selecting just the 'root' of tree, the complete tree is selected. This is for example useful to locate a group of related sections in special memory (e.g. fast memory). The (referenced) sections must meet the following conditions in order to be selected:

  1. The sections are within the section layout's address space
  2. The sections match the specified attributes
  3. The sections have no absolute restriction (as is the case for all wildcard selections)

  For example, to select the code sections referenced from `foo1`:

  ```
  group refgrp (ordered, contiguous, run_addr=mem:ext_c)
  {
      select ref_tree "foo1" (attributes=+x);
  }
  ```

  If section `foo1` references `foo2` and `foo2` references `foo3`, then all these sections are selected by the selection shown above.

### *Locating a group*

```
group group_name ( group_specifications )
{
    section_statements
}
```

With the *group_specifications* you actually define how the linker must locate the group. You can roughly define three things: 1) assign properties to the group like alignment and read/write attributes, 2) define the mutual order in the address space for sections in the group and 3) restrict the possible addresses for the sections in a group.

The linker creates labels that allow you to refer to the begin and end address of a group from within the application software. Labels **__lc_gb_***group_name* and **__lc_ge_***group_name* mark the begin and end of the group respectively, where the begin is the lowest address used within this group and the end is the highest address used. Notice that a group not necessarily occupies all memory between begin and end address. The given label refers to where the section is located at run-time (versus load-time).

1. Assign properties to the group like alignment and read/write attributes.
   These properties are assigned to all sections in the group (and subgroups) and override the attributes of the input sections.

   - The **align** field tells the linker to align all sections in the group and the group as a whole according to the align value. By default the linker uses the largest alignment constraint of either the input sections or the alignment of the address space.
   - The **attributes** field tells the linker to assign one or more attributes to all sections in the group. This overrules the default attributes. By default the linker uses the attributes of the input sections. You can set the **r**, **w** or **rw** attributes and you can switch between the **b** and **s** attributes.
   - The **copy** field tells the linker to locate a read-only section in RAM and generate a ROM copy and a copy action in the copy table. This property makes the sections in the group writable which causes the linker to generate ROM copies for the sections.

- The effect of the **nocopy** field is the opposite of the copy field. It prevents the linker from generating ROM copies of the selected sections.

2. Define the mutual order of the sections in the group.
   By default, a group is *unrestricted* which means that the linker has total freedom to place the sections of the group in the address space.

   - The **ordered** keyword tells the linker to locate the sections in the same order in the address space as they appear in the group (but not necessarily adjacent).

     Suppose you have an ordered group that contains the sections 'A', 'B' and 'C'. By default the linker places the sections in the address space like 'A' – 'B' – 'C', where section 'A' gets the lowest possible address. With **direction=high_to_low** in the **section_layout** space properties, the linker places the sections in the address space like 'C' – 'B' – 'A', where section 'A' gets the highest possible address.

   - The **contiguous** keyword tells the linker to locate the sections in the group in a single address range. Within a contiguous group the input sections are located in arbitrary order, however the group occupies one contigous range of memory. Due to alignment of sections there can be 'alignment gaps' between the sections.

     When you define a group that is both **ordered** and **contiguous**, this is called a *sequential* group. In a sequential group the linker places sections in the same order in the address space as they appear in the group and it occupies a contiguous range of memory.

   - The **clustered** keyword tells the linker to locate the sections in the group in a number of *contiguous* blocks. It tries to keep the number of these blocks to a minimum. If enough memory is available, the group will be located as if it was specified as **contiguous**. Otherwise, it gets split into two or more blocks.

     If a contiguous or clustered group contains *alignment gaps*, the linker can locate sections that are not part of the group in these gaps. To prevent this, you can use the **fill** keyword. If the group is located in RAM, the gaps are treated as reserved (scratch) space. If the group is located in ROM, the alignment gaps are filled with zeros by default. You can however change the fill pattern by specifying a bit pattern. The result of the expression, or list of expressions, is used as values to write to memory, each in MAU.

   - The **overlay** keyword tells the linker to overlay the sections in the group. The linker places all sections in the address space using a contiguous range of addresses. (Thus an overlay group is automatically also a contiguous group.) To overlay the sections, all sections in the overlay group share the same run-time address.

     For each input section within the overlay the linker automatically defines two symbols. The symbol **__lc_cb_***section_name* is defined as the load-time start address of the section. The symbol **__lc_ce_***section_name* is defined as the load-time end address of the section. C (or assembly) code may be used to copy the overlaid sections.

     If sections in the overlay group contain references between groups, the linker reports an error. The keyword **allow_cross_references** tells the linker to accept cross-references. Normally, it does not make sense to have references between sections that are overlaid.

     ```
     group ovl (overlay)
     {
         group a
         {
             select "my_ovl_p1";
             select "my_ovl_p2";
         }
         group b
         {
             select "my_ovl_q1";
         }
     }
     ```

It may be possible that one of the sections in the overlay group already has been defined in another group where it received a load-time address. In this case the linker does not overrule this load-time address and excludes the section from the overlay group.

3. Restrict the possible addresses for the sections in a group.
   The load-time address specifies where the group's elements are loaded in memory at download time. The run-time address specifies where sections are located at run-time, that is when the program is executing. If you do not explicitly restrict the address in the LSL file, the linker assigns addresses to the sections based on the restrictions relative to other sections in the LSL file and section alignments. The program is responsible for copying overlay sections at appropriate moment from its load-time location to its run-time location (this is typically done by the startup code).

   - The **run_addr** keyword defines the run-time address. If the run-time location of a group is set explicitly, the given order between groups specify whether the run-time address propagates to the parent group or not. The location of the sections a group can be restricted either to a single absolute address, or to a number of address ranges. With an *expression* you can specify that the group should be located at the absolute address specified by the expression:

     ```
     group (run_addr = 0xa00f0000)
     ```

     You can use the '**[***offset***]**' variant to locate the group at the given absolute offset in memory:

     ```
     group (run_addr = mem:A[0x1000])
     ```

     A range can be an absolute space address range, written as **[** *expr* **..** *expr* **]**, a complete memory device, written as **mem:***mem_name*, or a memory address range,
     **mem:***mem_name***[***expr* **..** *expr***]**

     ```
     group (run_addr = mem:my_dram)
     ```

     You can use the '|' to specify an address range of more than one physical memory device:

     ```
     group (run_addr = mem:A | mem:B)
     ```

   - The **load_addr** keyword changes the meaning of the section selection in the group: the linker selects the load-time ROM copy of the named section(s) instead of the regular sections. Just like **run_addr** you can specify an absolute address or an address range.

     The **load_addr** keyword itself (without an assignment) specifies that the group's position in the LSL file defines its load-time address.

     ```
     group (load_addr)
           select "mydata";  // select ROM copy of mydata: "[mydata]"
     ```

   The load-time and run-time addresses of a group cannot be set at the same time. If the load-time property is set for a group, the group (only) restricts the positioning at load-time of the group's sections. It is not possible to set the address of a group that has a not-unrestricted parent group.

   The properties of the load-time and run-time start address are:

   - At run-time, before using an element in an overlay group, the application copies the sections from their load location to their run-time location, but only if these two addresses are different. For non-overlay sections this happens at program start-up.
   - The start addresses cannot be set to absolute values for unrestricted groups.
   - For non-overlay groups that do not have an overlay parent, the load-time start address equals the run-time start address.
   - For any group, if the run-time start address is not set, the linker selects an appropriate address.
   - If an ordered group or sequential group has an absolute address and contains sections that have separate page restrictions (not defined in LSL), all those sections are located in a single page. In other cases, for example when an unrestricted group has an address range assigned to it, the paged sections may be located in different pages.

   For overlays, the linker reserves memory at the run-time start address as large as the largest element in the overlay group.

   - The **page** keyword tells the linker to place the group in one page. Instead of specifying a run-time address, you can specify a page and optional a page number. Page numbers start from zero. If you omit the page number, the linker chooses a page.

     The **page** keyword refers to pages in the address space as defined in the architecture definition.

   - With the **page_size** keyword you can override the page alignment and size set on the address space. When you set the page size to zero, the linker removes simple (auto generated) page restrictions from the selected sections. See also the **page_size** keyword in section 7.5.3, *Defining Address Spaces*.

     ```
     group (page, ... )
     group (page = 3, ...)
     ```

- With the **priority** keyword you can change the order in which sections are located. This is useful when some sections are considered important for good performance of the application and a small amount of fast memory is available. The value is a number for which the default is 1, so higher priorities start at 2. Sections with a higher priority are located before sections with a lower priority, unless their relative locate priority is already determined by other restrictions like **run_addr** and **page**.

```
group (priority=2)
{
  select "importantcode1";
  select "importantcode2";
}
```

## 7.9.3 Creating or Modifying Special Sections

Instead of selecting sections, you can also create a reserved section or an output section or modify special sections like a stack or a heap. Because you cannot define these sections in the input files, you must use the linker to create them.

### *Stack*

- The keyword **stack** tells the linker to reserve memory for the stack. The name for the stack section refers to the stack as defined in the architecture definition. If no name was specified in the architecture definition, the default name is `stack`.

  With the keyword **size** you can specify the size for the stack. If the **size** is not specified, the linker uses the size given by the **min_size** argument as defined for the stack in the architecture definition. Normally the linker automatically tries to maximize the size, unless you specified the keyword **fixed**.

```
group ( ... )
{
   stack "mystack" ( size = 2k );
}
```

  The linker creates two labels to mark the begin and end of the stack, **__lc_ub_***stack_name* for the begin of the stack and **__lc_ue_***stack_name* for the end of the stack. The linker allocates space for the stack when there is a reference to either of the labels.

  See also the **stack** keyword in section 7.5.3, *Defining Address Spaces*.

### *Heap*

- The keyword **heap** tells the linker to reserve a dynamic memory range for the `malloc()` function. Optionally you can assign a name to the heap section. With the keyword **size** you can change the size for the heap. If the **size** is not specified, the linker uses the size given by the **min_size** argument as defined for the heap in the architecture definition. Normally the linker automatically tries to maximize the size, unless you specified the keyword **fixed**.

```
group ( ... )
{
   heap "myheap" ( size = 2k );
}
```

  The linker creates two labels to mark the begin and end of the heap, **__lc_ub_***heap_name* for the begin of the heap and **__lc_ue_***heap_name* for the end of the heap. The linker allocates space for the heap when a reference to either of the section labels exists in one of the input object files.

### *Reserved section*

- The keyword **reserved** tells the linker to create an area or section of a given size. The linker will not locate any other sections in the memory occupied by a reserved section, with some exceptions. Optionally you can assign a name to a reserved section. With the keyword **size** you can specify a size for a given reserved area or section.

```
group ( ... )
{
   reserved "myreserved" ( size = 2k );
}
```

The optional **fill** field contains a bit pattern that the linker writes to all memory addresses that remain unoccupied during the locate process. The result of the expression, or list of expressions, is used as values to write to memory, each in MAU. The first MAU of the fill pattern is always the first MAU in the section.

By default, no sections can overlap with a reserved section. With **alloc_allowed=absolute** sections that are located at an absolute address due to an absolute group restriction can overlap a reserved section.

With the **attributes** field you can set the access type of the reserved section. The linker locates the reserved section in its space with the restrictions that follow from the used attributes, **r**, **w** or **x** or a valid combination of them. The allowed attributes are shown in the following table. A value between < and > in the table means this value is set automatically by the linker.

| Properties set in LSL | | Resulting section properties | | |
|---|---|---|---|---|
| **attributes** | **filled** | **access** | **memory** | **content** |
| x | yes | | <rom> | executable |
| r | yes | r | <rom> | data |
| r | no | r | <rom> | scratch |
| rx | yes | r | <rom> | executable |
| rw | yes | rw | <ram> | data |
| rw | no | rw | <ram> | scratch |
| rwx | yes | rw | <ram> | executable |

```
group ( ... )
{
   reserved "myreserved" ( size = 2k,
               attributes = rw, fill = 0xaa );
}
```

If you do not specify any attributes, the linker will reserve the given number of maus, no matter what type of memory lies beneath. If you do not specify a fill pattern, no section is generated.

The linker creates two labels to mark the begin and end of the section, **__lc_ub_***name* for the start, and **__lc_ue_***name* for the end of the reserved section.

### *Output sections*

- The keyword **section** tells the linker to accumulate sections obtained from object files ("input sections") into an output section of a fixed size in the locate phase. You can select the input sections with **select** statements. You can use groups inside output sections, but you can only set the **align**, **attributes** and **load_addr** attributes.

  The **fill** field contains a bit pattern that the linker writes to all unused space in the output section. When all input sections have an image (code/data) you must specify a fill pattern. If you do not specify a fill pattern, all input sections must be scratch sections. The fill pattern is aligned at the start of the output section.

  As with a reserved section you can use the **attributes** field to set the access type of the output section.

```
group ( ... )
{
   section "myoutput" ( size = 4k, attributes = rw, fill = 0xaa )
   {
      select "myinput1";
      select "myinput2";
   }
}
```

The available room for input sections is determined by the **size**, **blocksize** and **overflow** fields. With the keyword **size** you specify the fixed size of the output section. Input sections are placed from output section start towards higher addresses (offsets). When the end of the output section is reached and one or more input sections are not yet placed, an error is emitted. If however, the **overflow** field is set to another output section, remaining sections are located as if they were selected for the overflow output section.

```
group ( ... )
{
  section "tsk1_data" (size=4k, attributes=rw, fill=0,
                       overflow = "overflow_data")
  {
          select ".data.tsk1.*"
  }
  section "tsk2_data" (size=4k, attributes=rw, fill=0,
                       overflow = "overflow_data")
  {
          select ".data.tsk2.*"
  }
  section "overflow_data" (size=4k, attributes=rx,
                           fill=0)
  {
  }
}
```

With the keyword **blocksize** , the size of the output section will adapt to the size of its content. For example:

```
group flash_area (run_addr = 0x10000)
{
   section "flash_code" (blocksize=4k, attributes=rx,
                         fill=0)
   {
     select "*.flash";
   }
}
```

If the content of the section is 1 mau, the size will be 4k, if the content is 11k, the section will be 12k, etc. If you use **size** in combination with **blocksize**, the **size** value is used as default (minimal) size for this section. If it is omitted, the default size will be of **blocksize**. It is not allowed to omit both **size** and **blocksize** from the section definition.

The linker creates two labels to mark the begin and end of the section, **__lc_ub_***name* for the start, and **__lc_ue_***name* for the end of the output section.

### *Copy table*

- The keyword **copytable** tells the linker to select a section that is used as *copy table*. The content of the copy table is created by the linker. It contains the start address and length of all sections that should be initialized by the startup code.

  The linker creates two labels to mark the begin and end of the section, **__lc_ub_table** for the start, and **__lc_ue_table** for the end of the copy table. The linker generates a copy table when a reference to either of the section labels exists in one of the input object files.

## 7.9.4 Creating Symbols

You can tell the linker to create symbols before locating by putting assignments in the section layout definition. Symbol names are represented by double-quoted strings. Any string is allowed, but object files may not support all characters for symbol names. You can use two different assignment operators. With the simple assignment operator '=', the symbol is created unconditionally. With the ':=' operator, the symbol is only created if it already exists as an undefined reference in an object file.

The expression that represents the value to assign to the symbol may contain references to other symbols. If such a referred symbol is a special section symbol, creation of the symbol in the left hand side of the assignment will cause creation of the special section.

```
section_layout
{
   "__lc_bs" := "__lc_ub_stack";
    // when the symbol __lc_bs occurs as an undefined reference
    // in an object file, the linker allocates space for the stack
}
```

### 7.9.5 Conditional Group Statements

Within a group, you can conditionally select sections or create special sections.

- With the **if** keyword you can specify a condition. The succeeding section statement is executed if the condition evaluates to TRUE (1).
- The optional **else** keyword is followed by a section statement which is executed in case the if-condition evaluates to FALSE (0).

```
group ( ... )
{
   if ( exists ( "mysection" ) )
      select "mysection";
   else
      reserved "myreserved" ( size=2k );
}
```

# 8 MISRA-C Rules

**Summary**

This chapter contains an overview of the supported and unsupported MISRA-C rules.

## 8.1 MISRA-C:1998

This section lists all supported and unsupported MISRA-C:1998 rules.

See also section 2.7, *C Code Checking: MISRA-C*, in Chapter *Using the Compiler* of the *User's Manual*.

A number of MISRA-C rules leave room for interpretation. Other rules can only be checked in a limited way. In such cases the implementation decisions and possible restrictions for these rules are listed.

x means that the rule is not supported by the TASKING C compiler.
(R) is a required rule, (A) is an advisory rule.

| | | | |
|---|---|---|---|
| | 1. | (R) | The code shall conform to standard C, without language extensions |
| x | 2. | (A) | Other languages should only be used with an interface standard |
| | 3. | (A) | Inline assembly is only allowed in dedicated C functions |
| x | 4. | (A) | Provision should be made for appropriate run-time checking |
| | 5. | (R) | Only use characters and escape sequences defined by ISO C |
| x | 6. | (R) | Character values shall be restricted to a subset of ISO 106460-1 |
| | 7. | (R) | Trigraphs shall not be used |
| | 8. | (R) | Multibyte characters and wide string literals shall not be used |
| | 9. | (R) | Comments shall not be nested |
| | 10. | (A) | Sections of code should not be "commented out"<br>In general, it is not possible to decide whether a piece of comment is C code that is commented out, or just some pseudo code. Instead, the following heuristics are used to detect possible C code inside a comment:<br>- a line ends with ';', or<br>- a line starts with '}', possibly preceded by white space |
| | 11. | (R) | Identifiers shall not rely on significance of more than 31 characters |
| | 12. | (A) | The same identifier shall not be used in multiple name spaces |
| | 13. | (A) | Specific-length typedefs should be used instead of the basic types |
| | 14. | (R) | Use 'unsigned char' or 'signed char' instead of plain 'char' |
| x | 15. | (A) | Floating-point implementations should comply with a standard |
| | 16. | (R) | The bit representation of floating-point numbers shall not be used<br>A violation is reported when a pointer to a floating-point type is converted to a pointer to an integer type. |
| | 17. | (R) | "typedef" names shall not be reused |
| | 18. | (A) | Numeric constants should be suffixed to indicate type<br>A violation is reported when the value of the constant is outside the range indicated by the suffixes, if any. |
| | 19. | (R) | Octal constants (other than zero) shall not be used |
| | 20. | (R) | All object and function identifiers shall be declared before use |
| | 21. | (R) | Identifiers shall not hide identifiers in an outer scope |
| | 22. | (A) | Declarations should be at function scope where possible |

x 23. (A) All declarations at file scope should be static where possible

24. (R) Identifiers shall not have both internal and external linkage

x 25. (R) Identifiers with external linkage shall have exactly one definition

26. (R) Multiple declarations for objects or functions shall be compatible

x 27. (A) External objects should not be declared in more than one file

28. (A) The "register" storage class specifier should not be used

29. (R) The use of a tag shall agree with its declaration

30. (R) All automatics shall be initialized before being used

This rule is checked using worst-case assumptions. This means that violations are reported not only for variables that are guaranteed to be uninitialized, but also for variables that are uninitialized on some execution paths.

31. (R) Braces shall be used in the initialization of arrays and structures

32. (R) Only the first, or all enumeration constants may be initialized

33. (R) The right hand operand of && or || shall not contain side effects

34. (R) The operands of a logical && or || shall be primary expressions

35. (R) Assignment operators shall not be used in Boolean expressions

36. (A) Logical operators should not be confused with bitwise operators

37. (R) Bitwise operations shall not be performed on signed integers

38. (R) A shift count shall be between 0 and the operand width minus 1

This violation will only be checked when the shift count evaluates to a constant value at compile time.

39. (R) The unary minus shall not be applied to an unsigned expression

40. (A) "sizeof" should not be used on expressions with side effects

x 41. (A) The implementation of integer division should be documented

42. (R) The comma operator shall only be used in a "for" condition

43. (R) Don't use implicit conversions which may result in information loss

44. (A) Redundant explicit casts should not be used

45. (R) Type casting from any type to or from pointers shall not be used

46. (R) The value of an expression shall be evaluation order independent

This rule is checked using worst-case assumptions. This means that a violation will be reported when a possible alias may cause the result of an expression to be evaluation order dependent.

47. (A) No dependence should be placed on operator precedence rules

48. (A) Mixed arithmetic should use explicit casting

49. (A) Tests of a (non-Boolean) value against 0 should be made explicit

50. (R) F.P. variables shall not be tested for exact equality or inequality

51. (A) Constant unsigned integer expressions should not wrap-around

52. (R) There shall be no unreachable code

53. (R) All non-null statements shall have a side-effect

54. (R) A null statement shall only occur on a line by itself

55. (A) Labels should not be used

56. (R) The "goto" statement shall not be used

57. (R) The "continue" statement shall not be used

58. (R) The "break" statement shall not be used (except in a "switch")

59. (R) An "if" or loop body shall always be enclosed in braces

60. (A) All "if", "else if" constructs should contain a final "else"

61. (R) Every non-empty "case" clause shall be terminated with a "break"

62. (R) All "switch" statements should contain a final "default" case

63. (A) A "switch" expression should not represent a Boolean case

64. (R) Every "switch" shall have at least one "case"

65. (R) Floating-point variables shall not be used as loop counters

66. (A) A "for" should only contain expressions concerning loop control

    A violation is reported when the loop initialization or loop update expression modifies an object that is not referenced in the loop test.

67. (A) Iterator variables should not be modified in a "for" loop

68. (R) Functions shall always be declared at file scope

69. (R) Functions with variable number of arguments shall not be used

70. (R) Functions shall not call themselves, either directly or indirectly

    A violation will be reported for direct or indirect recursive function calls in the source file being checked. Recursion via functions in other source files, or recursion via function pointers is not detected.

71. (R) Function prototypes shall be visible at the definition and call

72. (R) The function prototype of the declaration shall match the definition

73. (R) Identifiers shall be given for all prototype parameters or for none

74. (R) Parameter identifiers shall be identical for declaration/definition

75. (R) Every function shall have an explicit return type

76. (R) Functions with no parameters shall have a "void" parameter list

77. (R) An actual parameter type shall be compatible with the prototype

78. (R) The number of actual parameters shall match the prototype

79. (R) The values returned by "void" functions shall not be used

80. (R) Void expressions shall not be passed as function parameters

81. (A) "const" should be used for reference parameters not modified

82. (A) A function should have a single point of exit

83. (R) Every exit point shall have a "return" of the declared return type

84. (R) For "void" functions, "return" shall not have an expression

85. (A) Function calls with no parameters should have empty parentheses

86. (A) If a function returns error information, it should be tested

    A violation is reported when the return value of a function is ignored.

87. (R) #include shall only be preceded by other directives or comments

88. (R) Non-standard characters shall not occur in #include directives

89. (R) #include shall be followed by either <filename> or "filename"

90. (R) Plain macros shall only be used for constants/qualifiers/specifiers

91. (R) Macros shall not be #define'd and #undef'd within a block

92. (A) #undef should not be used

93. (A) A function should be used in preference to a function-like macro

94. (R) A function-like macro shall not be used without all arguments

95. (R) Macro arguments shall not contain pre-preprocessing directives

    A violation is reported when the first token of an actual macro argument is '#'.

96. (R) Macro definitions/parameters should be enclosed in parentheses

97. (A) Don't use undefined identifiers in pre-processing directives

98. (R) A macro definition shall contain at most one # or ## operator

99. (R) All uses of the #pragma directive shall be documented

    This rule is really a documentation issue. The compiler will flag all #pragma directives as violations.

100. (R) "defined" shall only be used in one of the two standard forms

101. (A) Pointer arithmetic should not be used

102. (A) No more than 2 levels of pointer indirection should be used

A violation is reported when a pointer with three or more levels of indirection is declared.

103. (R) No relational operators between pointers to different objects

In general, checking whether two pointers point to the same object is impossible. The compiler will only report a violation for a relational operation with incompatible pointer types.

104. (R) Non-constant pointers to functions shall not be used

105. (R) Functions assigned to the same pointer shall be of identical type

106. (R) Automatic address may not be assigned to a longer lived object

107. (R) The null pointer shall not be de-referenced

A violation is reported for every pointer dereference that is not guarded by a NULL pointer test.

108. (R) All struct/union members shall be fully specified

109. (R) Overlapping variable storage shall not be used

A violation is reported for every 'union' declaration.

110. (R) Unions shall not be used to access the sub-parts of larger types

A violation is reported for a 'union' containing a 'struct' member.

111. (R) bit-fields shall have type "unsigned int" or "signed int"

112. (R) bit-fields of type "signed int" shall be at least 2 bits long

113. (R) All struct/union members shall be named

114. (R) Reserved and standard library names shall not be redefined

115. (R) Standard library function names shall not be reused

x 116. (R) Production libraries shall comply with the MISRA-C restrictions

x 117. (R) The validity of library function parameters shall be checked

118. (R) Dynamic heap memory allocation shall not be used

119. (R) The error indicator "errno" shall not be used

120. (R) The macro "offsetof" shall not be used

121. (R) <locale.h> and the "setlocale" function shall not be used

122. (R) The "setjmp" and "longjmp" functions shall not be used

123. (R) The signal handling facilities of <signal.h> shall not be used

124. (R) The <stdio.h> library shall not be used in production code

125. (R) The functions atof/atoi/atol shall not be used

126. (R) The functions abort/exit/getenv/system shall not be used

127. (R) The time handling functions of library <time.h> shall not be used

See also section 2.7, *C Code Checking: MISRA-C*, in Chapter *Using the Compiler* of the User's manual.

## 8.2 MISRA-C:2004

This section lists all supported and unsupported MISRA-C:2004 rules.

See also section 2.7, *C Code Checking: MISRA-C*, in Chapter *Using the Compiler* of the *User's Manual*.

A number of MISRA-C rules leave room for interpretation. Other rules can only be checked in a limited way. In such cases the implementation decisions and possible restrictions for these rules are listed.

x means that the rule is not supported by the TASKING C compiler.
(R) is a required rule, (A) is an advisory rule.

### *Environment*

| | | | |
|---|---|---|---|
| | 1.1 | (R) | All code shall conform to ISO 9899:1990 "Programming languages - C", amended and corrected by ISO/IEC 9899/COR1:1995, ISO/IEC 9899/AMD1:1995, and ISO/IEC 9899/COR2:1996. |
| | 1.2 | (R) | No reliance shall be placed on undefined or unspecified behavior. |
| x | 1.3 | (R) | Multiple compilers and/or languages shall only be used if there is a common defined interface standard for object code to which the languages/compilers/assemblers conform. |
| x | 1.4 | (R) | The compiler/linker shall be checked to ensure that 31 character significance and case sensitivity are supported for external identifiers. |
| x | 1.5 | (A) | Floating-point implementations should comply with a defined floating-point standard. |

### *Language extensions*

| | | | |
|---|---|---|---|
| | 2.1 | (R) | Assembly language shall be encapsulated and isolated. |
| | 2.2 | (R) | Source code shall only use `/* ... */` style comments. |
| | 2.3 | (R) | The character sequence `/*` shall not be used within a comment. |
| | 2.4 | (A) | Sections of code should not be "commented out".<br>In general, it is not possible to decide whether a piece of comment is C code that is commented out, or just some pseudo code. Instead, the following heuristics are used to detect possible C code inside a comment:<br>- a line ends with ';', or<br>- a line starts with '}', possibly preceded by white space |

### *Documentation*

| | | | |
|---|---|---|---|
| x | 3.1 | (R) | All usage of implementation-defined behavior shall be documented. |
| x | 3.2 | (R) | The character set and the corresponding encoding shall be documented. |
| x | 3.3 | (A) | The implementation of integer division in the chosen compiler should be determined, documented and taken into account. |
| | 3.4 | (R) | All uses of the `#pragma` directive shall be documented and explained.<br>This rule is really a documentation issue. The compiler will flag all `#pragma` directives as violations. |
| | 3.5 | (R) | The implementation-defined behavior and packing of bit-fields shall be documented if being relied upon. |
| x | 3.6 | (R) | All libraries used in production code shall be written to comply with the provisions of this document, and shall have been subject to appropriate validation. |

### *Character sets*

| | | | |
|---|---|---|---|
| | 4.1 | (R) | Only those escape sequences that are defined in the ISO C standard shall be used. |
| | 4.2 | (R) | Trigraphs shall not be used. |

### Identifiers

| | | | |
|---|---|---|---|
| | 5.1 | (R) | Identifiers (internal and external) shall not rely on the significance of more than 31 characters. |
| | 5.2 | (R) | Identifiers in an inner scope shall not use the same name as an identifier in an outer scope, and therefore hide that identifier. |
| | 5.3 | (R) | A `typedef` name shall be a unique identifier. |
| | 5.4 | (R) | A tag name shall be a unique identifier. |
| x | 5.5 | (A) | No object or function identifier with static storage duration should be reused. |
| | 5.6 | (A) | No identifier in one name space should have the same spelling as an identifier in another name space, with the exception of structure and union member names. |
| x | 5.7 | (A) | No identifier name should be reused. |

### Types

| | | | |
|---|---|---|---|
| | 6.1 | (R) | The plain `char` type shall be used only for storage and use of character values. |
| x | 6.2 | (R) | `signed` and `unsigned char` type shall be used only for the storage and use of numeric values. |
| | 6.3 | (A) | `typedefs` that indicate size and signedness should be used in place of the basic types. |
| | 6.4 | (R) | bit-fields shall only be defined to be of type `unsigned int` or `signed int`. |
| | 6.5 | (R) | bit-fields of type `signed int` shall be at least 2 bits long. |

### Constants

| | | | |
|---|---|---|---|
| | 7.1 | (R) | Octal constants (other than zero) and octal escape sequences shall not be used. |

### Declarations and definitions

| | | | |
|---|---|---|---|
| | 8.1 | (R) | Functions shall have prototype declarations and the prototype shall be visible at both the function definition and call. |
| | 8.2 | (R) | Whenever an object or function is declared or defined, its type shall be explicitly stated. |
| | 8.3 | (R) | For each function parameter the type given in the declaration and definition shall be identical, and the return types shall also be identical. |
| | 8.4 | (R) | If objects or functions are declared more than once their types shall be compatible. |
| | 8.5 | (R) | There shall be no definitions of objects or functions in a header file. |
| | 8.6 | (R) | Functions shall be declared at file scope. |
| | 8.7 | (R) | Objects shall be defined at block scope if they are only accessed from within a single function. |
| x | 8.8 | (R) | An external object or function shall be declared in one and only one file. |
| x | 8.9 | (R) | An identifier with external linkage shall have exactly one external definition. |
| x | 8.10 | (R) | All declarations and definitions of objects or functions at file scope shall have internal linkage unless external linkage is required. |
| | 8.11 | (R) | The `static` storage class specifier shall be used in definitions and declarations of objects and functions that have internal linkage. |
| | 8.12 | (R) | When an array is declared with external linkage, its size shall be stated explicitly or defined implicitly by initialization. |

### Initialization

9.1 (R) All automatic variables shall have been assigned a value before being used.

This rule is checked using worst-case assumptions. This means that violations are reported not only for variables that are guaranteed to be uninitialized, but also for variables that are uninitialized on some execution paths.

9.2 (R) Braces shall be used to indicate and match the structure in the non-zero initialization of arrays and structures.

9.3 (R) In an enumerator list, the "=" construct shall not be used to explicitly initialize members other than the first, unless all items are explicitly initialized.

### Arithmetic type conversions

10.1 (R) The value of an expression of integer type shall not be implicitly converted to a different underlying type if:
a) it is not a conversion to a wider integer type of the same signedness, or
b) the expression is complex, or
c) the expression is not constant and is a function argument, or
d) the expression is not constant and is a return expression.

10.2 (R) The value of an expression of floating type shall not be implicitly converted to a different type if:
a) it is not a conversion to a wider floating type, or
b) the expression is complex, or
c) the expression is a function argument, or
d) the expression is a return expression.

10.3 (R) The value of a complex expression of integer type may only be cast to a type that is narrower and of the same signedness as the underlying type of the expression.

10.4 (R) The value of a complex expression of floating type may only be cast to a narrower floating type.

10.5 (R) If the bitwise operators ~ and << are applied to an operand of underlying type `unsigned char` or `unsigned short`, the result shall be immediately cast to the underlying type of the operand.

10.6 (R) A "U" suffix shall be applied to all constants of `unsigned` type.

### Pointer type conversions

11.1 (R) Conversions shall not be performed between a pointer to a function and any type other than an integral type.

11.2 (R) Conversions shall not be performed between a pointer to object and any type other than an integral type, another pointer to object type or a pointer to void.

11.3 (A) A cast should not be performed between a pointer type and an integral type.

11.4 (A) A cast should not be performed between a pointer to object type and a different pointer to object type.

11.5 (R) A cast shall not be performed that removes any `const` or `volatile` qualification from the type addressed by a pointer.

### Expressions

12.1 (A) Limited dependence should be placed on C's operator precedence rules in expressions.

12.2 (R) The value of an expression shall be the same under any order of evaluation that the standard permits.

This rule is checked using worst-case assumptions. This means that a violation will be reported when a possible alias may cause the result of an expression to be evaluation order dependent.

12.3 (R) The `sizeof` operator shall not be used on expressions that contain side effects.

12.4 (R) The right-hand operand of a logical `&&` or `||` operator shall not contain side effects.

12.5 (R) The operands of a logical `&&` or `||` shall be *primary-expressions*.

12.6 (A) The operands of logical operators (`&&`, `||` and `!`) should be effectively Boolean. Expressions that are effectively Boolean should not be used as operands to operators other than (`&&`, `||` and `!`).

12.7 (R) Bitwise operators shall not be applied to operands whose underlying type is signed.

12.8 (R) The right-hand operand of a shift operator shall lie between zero and one less than the width in bits of the underlying type of the left-hand operand.

This violation will only be checked when the shift count evaluates to a constant value at compile time.

12.9 (R) The unary minus operator shall not be applied to an expression whose underlying type is unsigned.

12.10 (R) The comma operator shall not be used.

12.11 (A) Evaluation of constant unsigned integer expressions should not lead to wrap-around.

12.12 (R) The underlying bit representations of floating-point values shall not be used.

A violation is reported when a pointer to a floating-point type is converted to a pointer to an integer type.

12.13 (A) The increment (++) and decrement (--) operators should not be mixed with other operators in an expression.

### *Control statement expressions*

13.1 (R) Assignment operators shall not be used in expressions that yield a Boolean value.

13.2 (A) Tests of a value against zero should be made explicit, unless the operand is effectively Boolean.

13.3 (R) Floating-point expressions shall not be tested for equality or inequality.

13.4 (R) The controlling expression of a `for` statement shall not contain any objects of floating type.

13.5 (R) The three expressions of a `for` statement shall be concerned only with loop control.

A violation is reported when the loop initialization or loop update expression modifies an object that is not referenced in the loop test.

13.6 (R) Numeric variables being used within a `for` loop for iteration counting shall not be modified in the body of the loop.

13.7 (R) Boolean operations whose results are invariant shall not be permitted.

### *Control flow*

14.1 (R) There shall be no unreachable code.

14.2 (R) All non-null statements shall either:
a) have at least one side effect however executed, or
b) cause control flow to change.

14.3 (R) Before preprocessing, a null statement shall only occur on a line by itself; it may be followed by a comment provided that the first character following the null statement is a white-space character.

14.4 (R) The `goto` statement shall not be used.

14.5 (R) The `continue` statement shall not be used.

14.6 (R) For any iteration statement there shall be at most one break statement used for loop termination.

14.7 (R) A function shall have a single point of exit at the end of the function.

14.8 (R) The statement forming the body of a `switch`, `while`, `do ... while` or `for` statement be a compound statement.

14.9 (R) An `if (`*`expression`*`)` construct shall be followed by a compound statement. The `else` keyword shall be followed by either a compound statement, or another `if` statement.

14.10 (R) All `if ... else if` constructs shall be terminated with an `else` clause.

### *Switch statements*

15.1 (R) A switch label shall only be used when the most closely-enclosing compound statement is the body of a `switch` statement.

15.2 (R) An unconditional `break` statement shall terminate every non-empty `switch` clause.

15.3 (R) The final clause of a switch statement shall be the `default` clause.

15.4 (R) A `switch` expression shall not represent a value that is effectively Boolean.

15.5 (R) Every `switch` statement shall have at least one `case` clause.

### *Functions*

16.1 (R) Functions shall not be defined with variable numbers of arguments.

16.2 (R) Functions shall not call themselves, either directly or indirectly.

A violation will be reported for direct or indirect recursive function calls in the source file being checked. Recursion via functions in other source files, or recursion via function pointers is not detected.

16.3 (R) Identifiers shall be given for all of the parameters in a function prototype declaration.

16.4 (R) The identifiers used in the declaration and definition of a function shall be identical.

16.5 (R) Functions with no parameters shall be declared with parameter type `void`.

16.6 (R) The number of arguments passed to a function shall match the number of parameters.

16.7 (A) A pointer parameter in a function prototype should be declared as pointer to `const` if the pointer is not used to modify the addressed object.

16.8 (R) All exit paths from a function with non-void return type shall have an explicit `return` statement with an expression.

16.9 (R) A function identifier shall only be used with either a preceding `&`, or with a parenthesized parameter list, which may be empty.

16.10 (R) If a function returns error information, then that error information shall be tested.

A violation is reported when the return value of a function is ignored.

### *Pointers and arrays*

x 17.1 (R) Pointer arithmetic shall only be applied to pointers that address an array or array element.

x 17.2 (R) Pointer subtraction shall only be applied to pointers that address elements of the same array.

17.3 (R) >, >=, <, <= shall not be applied to pointer types except where they point to the same array.

In general, checking whether two pointers point to the same object is impossible. The compiler will only report a violation for a relational operation with incompatible pointer types.

17.4 (R) Array indexing shall be the only allowed form of pointer arithmetic.

17.5 (A) The declaration of objects should contain no more than 2 levels of pointer indirection.

A violation is reported when a pointer with three or more levels of indirection is declared.

17.6 (R) The address of an object with automatic storage shall not be assigned to another object that may persist after the first object has ceased to exist.

### *Structures and unions*

18.1 (R) All structure or union types shall be complete at the end of a translation unit.

18.2 (R) An object shall not be assigned to an overlapping object.

x 18.3 (R) An area of memory shall not be reused for unrelated purposes.

18.4 (R) Unions shall not be used.

### *Preprocessing directives*

19.1 (A) `#include` statements in a file should only be preceded by other preprocessor directives or comments.

19.2 (A) Non-standard characters should not occur in header file names in `#include` directives.

x 19.3 (R) The `#include` directive shall be followed by either a <filename> or ”filename” sequence.

19.4 (R) C macros shall only expand to a braced initializer, a constant, a parenthesized expression, a type qualifier, a storage class specifier, or a do-while-zero construct.

19.5 (R) Macros shall not be `#define`’d or `#undef`’d within a block.

19.6 (R) `#undef` shall not be used.

19.7 (A) A function should be used in preference to a function-like macro.

19.8 (R) A function-like macro shall not be invoked without all of its arguments.

19.9 (R) Arguments to a function-like macro shall not contain tokens that look like preprocessing directives.

A violation is reported when the first token of an actual macro argument is '#'.

19.10 (R) In the definition of a function-like macro each instance of a parameter shall be enclosed in parentheses unless it is used as the operand of # or ##.

19.11 (R) All macro identifiers in preprocessor directives shall be defined before use, except in `#ifdef` and `#ifndef` preprocessor directives and the `defined()` operator.

19.12 (R) There shall be at most one occurrence of the # or ## preprocessor operators in a single macro definition.

19.13 (A) The # and ## preprocessor operators should not be used.

19.14 (R) The `defined` preprocessor operator shall only be used in one of the two standard forms.

19.15 (R) Precautions shall be taken in order to prevent the contents of a header file being included twice.

19.16 (R) Preprocessing directives shall be syntactically meaningful even when excluded by the preprocessor.

19.17 (R) All `#else`, `#elif` and `#endif` preprocessor directives shall reside in the same file as the `#if` or `#ifdef` directive to which they are related.

### *Standard libraries*

20.1 (R) Reserved identifiers, macros and functions in the standard library, shall not be defined, redefined or undefined.

20.2 (R) The names of standard library macros, objects and functions shall not be reused.

x 20.3 (R) The validity of values passed to library functions shall be checked.

20.4 (R) Dynamic heap memory allocation shall not be used.

20.5 (R) The error indicator `errno` shall not be used.

20.6 (R) The macro `offsetof`, in library `<stddef.h>`, shall not be used.

20.7 (R) The `setjmp` macro and the `longjmp` function shall not be used.

20.8 (R) The signal handling facilities of `<signal.h>` shall not be used.

20.9 (R) The input/output library `<stdio.h>` shall not be used in production code.

20.10 (R) The library functions `atof`, `atoi` and `atol` from library `<stdlib.h>` shall not be used.

20.11 (R) The library functions `abort`, `exit`, `getenv` and `system` from library `<stdlib.h>` shall not be used.

20.12 (R) The time handling functions of library `<time.h>` shall not be used.

### *Run-time failures*

x 21.1 (R) Minimization of run-time failures shall be ensured by the use of at least one of:
a) static analysis tools/techniques;
b) dynamic analysis tools/techniques;
c) explicit coding of checks to handle run-time faults.

# Index

## B



## C