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# MLIB User's Guide

ARM® Cortex® M7F

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# Chapter 1

## Library

### 1.1 Introduction

#### 1.1.1 Overview

This user's guide describes the Math Library (MLIB) for the family of ARM Cortex M7F core-based microcontrollers. This library contains optimized functions.

#### 1.1.2 Data types

MLIB supports several data types: (un)signed integer, fractional, and accumulator, and floating point. The integer data types are useful for general-purpose computation; they are familiar to the MPU and MCU programmers. The fractional data types enable powerful numeric and digital-signal-processing algorithms to be implemented. The accumulator data type is a combination of both; that means it has the integer and fractional portions. The floating-point data types are capable of storing real numbers in wide dynamic ranges. The type is represented by binary digits and an exponent. The exponent allows scaling the numbers from extremely small to extremely big numbers. Because the exponent takes part of the type, the overall resolution of the number is reduced when compared to the fixed-point type of the same size.

The following list shows the integer types defined in the libraries:

- [Unsigned 16-bit integer](#) —<0 ; 65535> with the minimum resolution of 1
- [Signed 16-bit integer](#) —<-32768 ; 32767> with the minimum resolution of 1
- [Unsigned 32-bit integer](#) —<0 ; 4294967295> with the minimum resolution of 1
- [Signed 32-bit integer](#) —<-2147483648 ; 2147483647> with the minimum resolution of 1

The following list shows the fractional types defined in the libraries:

- **Fixed-point 16-bit fractional** — $\langle -1 ; 1 - 2^{-15} \rangle$  with the minimum resolution of  $2^{-15}$
- **Fixed-point 32-bit fractional** — $\langle -1 ; 1 - 2^{-31} \rangle$  with the minimum resolution of  $2^{-31}$

The following list shows the accumulator types defined in the libraries:

- **Fixed-point 16-bit accumulator** — $\langle -256.0 ; 256.0 - 2^{-7} \rangle$  with the minimum resolution of  $2^{-7}$
- **Fixed-point 32-bit accumulator** — $\langle -65536.0 ; 65536.0 - 2^{-15} \rangle$  with the minimum resolution of  $2^{-15}$

The following list shows the floating-point types defined in the libraries:

- **Floating point 32-bit single precision** — $\langle -3.40282 \cdot 10^{38} ; 3.40282 \cdot 10^{38} \rangle$  with the minimum resolution of  $2^{-23}$

### 1.1.3 API definition

MLIB uses the types mentioned in the previous section. To enable simple usage of the algorithms, their names use set prefixes and postfixes to distinguish the functions' versions. See the following example:

```
f32Result = MLIB_Mac_F32lss(f32Accum, f16Mult1, f16Mult2);
```

where the function is compiled from four parts:

- **MLIB**—this is the library prefix
- **Mac**—the function name—Multiply-Accumulate
- **F32**—the function output type
- **lss**—the types of the function inputs; if all the inputs have the same type as the output, the inputs are not marked

The input and output types are described in the following table:

**Table 1-1. Input/output types**

Type	Output	Input
<a href="#">frac16_t</a>	F16	s
<a href="#">frac32_t</a>	F32	l
<a href="#">acc32_t</a>	A32	a
<a href="#">float_t</a>	FLT	f



### 1.1.4 Supported compilers

MLIB for the ARM Cortex M7F core is written in C. The library is built and tested using the following compilers:

- Kinetis Design Studio
- IAR Embedded Workbench
- Keil  $\mu$ Vision

For the Kinetis Design Studio, the library is delivered in the *mlib.a* file.

For the IAR Embedded Workbench, the library is delivered in the *mlib.a* file.

For the Keil  $\mu$ Vision, the library is delivered in the *mlib.lib* file.

The interfaces to the algorithms included in this library are combined into a single public interface include file, *mlib.h*. This is done to lower the number of files required to be included in your application.

### 1.1.5 Special issues

1. The equations describing the algorithms are symbolic. If there is positive 1, the number is the closest number to 1 that the resolution of the used fractional type allows. If there are maximum or minimum values mentioned, check the range allowed by the type of the particular function version.
2. The library functions that round the result (the API contains Rnd) round to nearest (half up).

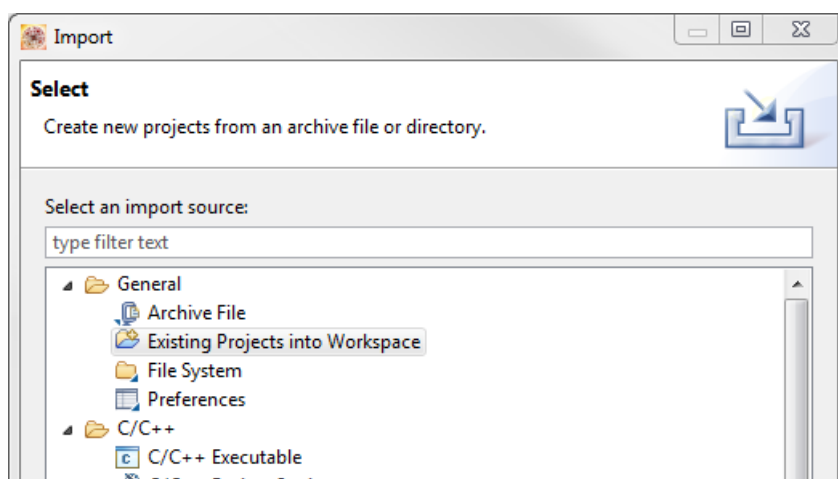
## 1.2 Library integration into project (Kinetis Design Studio)

This section provides a step-by-step guide on how to quickly and easily include MLIB into an empty project or any SDK example or demo application projects using Kinetis Design Studio. This example uses the default installation path (C:\NXP\RTCESL\CM7F\_RTCESL\_4.3\_KDS). If you have a different installation path, use that path instead. If you want to use an existing SDK project (for example the hello\_world project) see [Library path variable](#). If not, continue with the next section.

## 1.2.1 New project (without SDK)

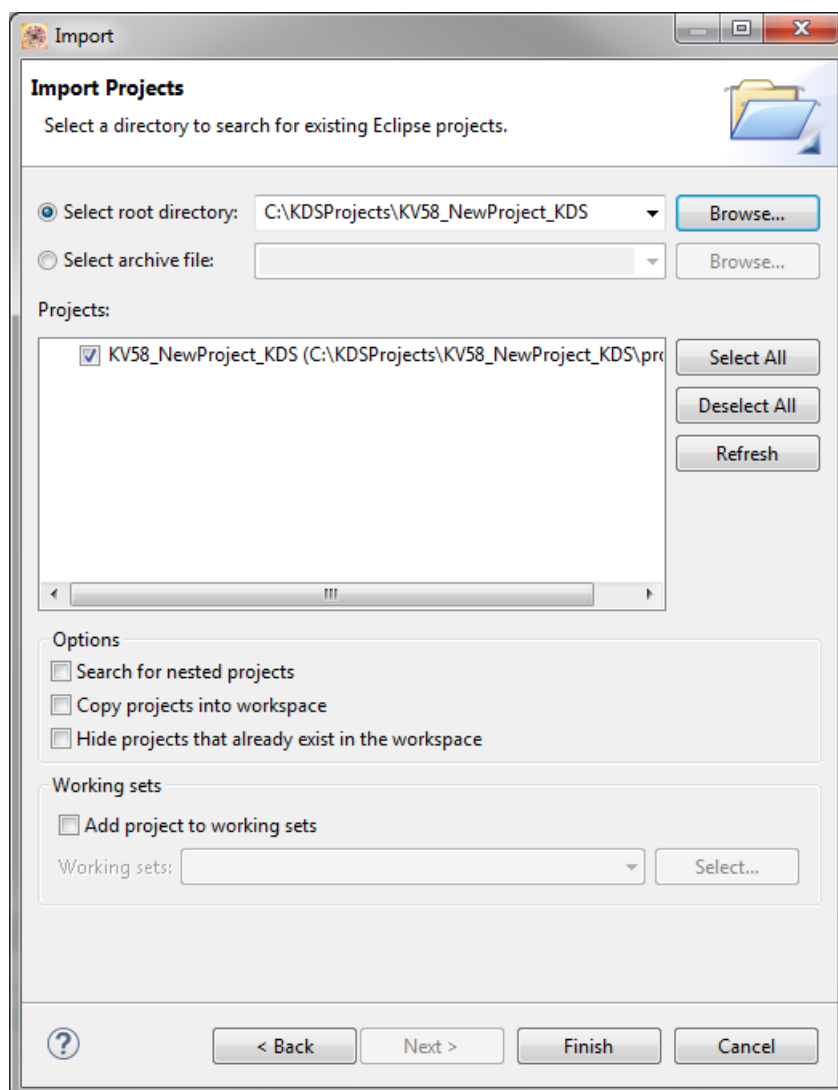
To start working on an application, create a new project. If the project already exists and is opened, skip to the next section. Follow these steps to create a new project:

1. Because Kinetis Design Studio does not have any stationary for Kinetis CM7-based platforms, the library installation comes with an empty project for the KV5x family (the empty project is not attached if NXP Kinetis Expert was used for RTCESL download). Copy the existing empty project folder KV58\_NewProject\_KDS (located in the library installation sub-folder Projects) to your projects folder (for example, C:\KDSProjects).
2. Launch Kinetis Design Studio.
3. Select File > Import... so that the Import dialog appears. See [Figure 1-1](#).



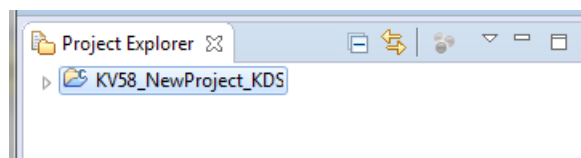
**Figure 1-1. Project import**

4. Select the General > Existing Projects into Workspace node and click Next.
5. In the Select root directory box, type the path to which you copied the project (C:\KDSProjects\KV58\_NewProject\_KDS), or look for it by clicking Browse. See [Figure 1-2](#).



**Figure 1-2. Project import folder**

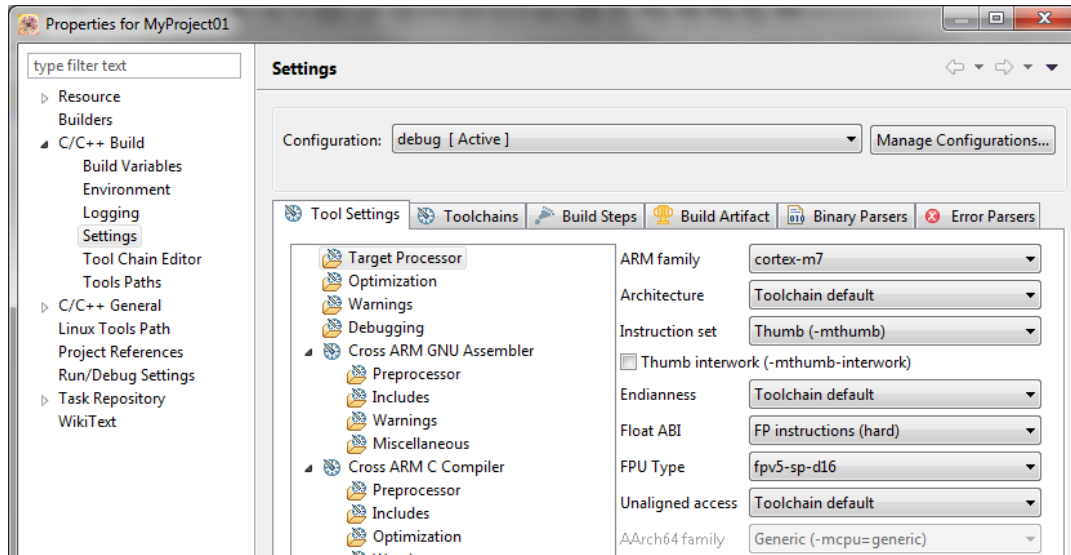
6. In the Projects dialog, tick the right project and then click Finish.
7. In the Project Explorer dialog, right-click the newly-imported project KV58\_NewProject\_KDS and select Rename. See [Figure 1-3](#).



**Figure 1-3. Project Explorer**

8. In the next dialog, type the name of your project (for example MyProject01) and click OK.
9. Right-click the MyProject01 node, click Properties in the Project Explorer, or select Project > Properties from the menu. A project properties dialog appears.
10. Expand the C/C++ Build node and select Settings.

11. In the right-hand part, set the Float ABI as FP instructions (hard) and the FPU type as fpv5\_sp\_d16. See [Figure 1-4](#).



**Figure 1-4. FPU setting**

## 1.2.2 Library path variable

To make the library integration easier, create a variable that will hold the information about the library path.

1. Right-click the MyProject01 or SDK project name node in the left-hand part and click Properties, or select Project > Properties from the menu. A project properties dialog appears.
2. Expand the Resource node and click Linked Resources. See [Figure 1-5](#).

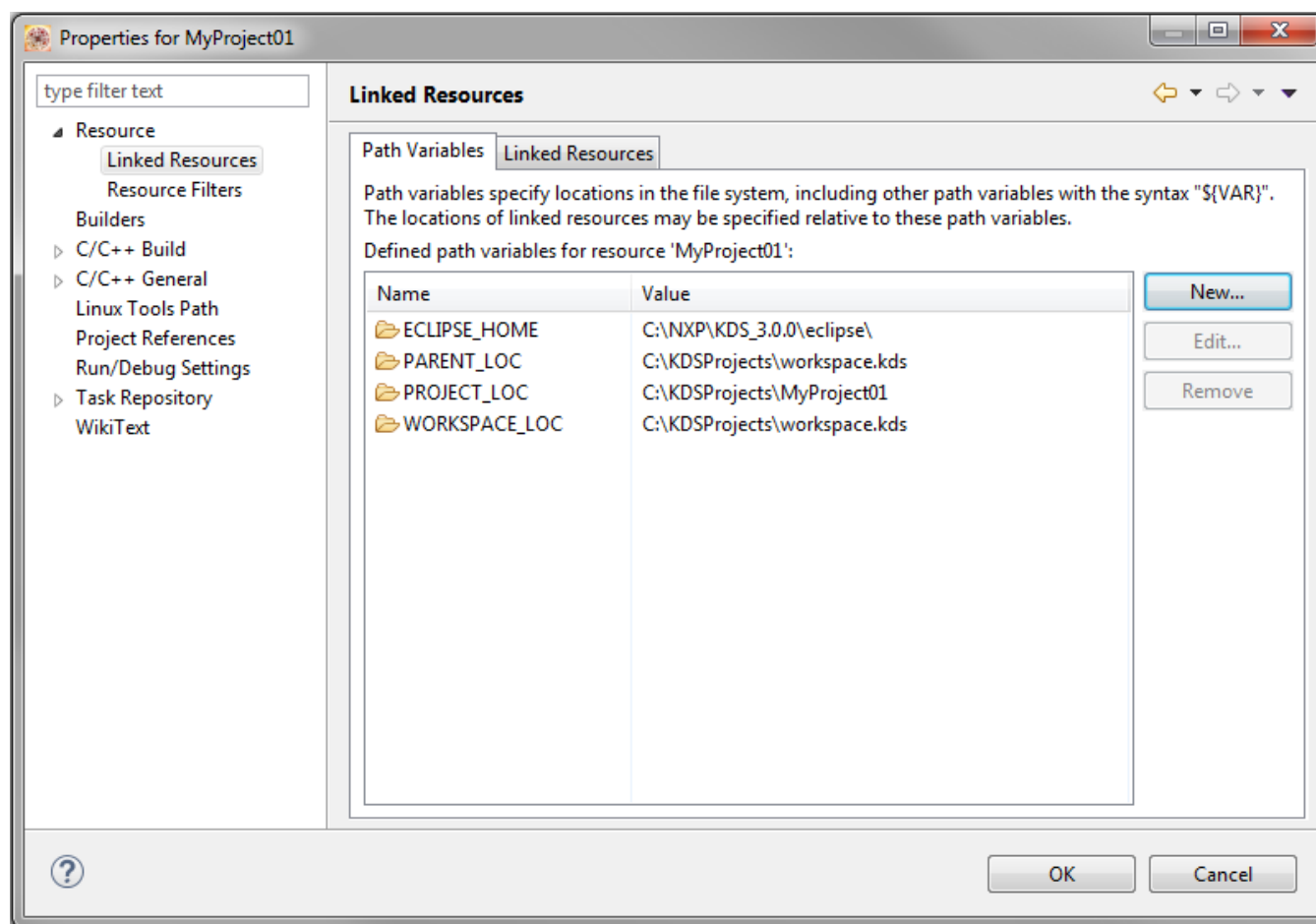


Figure 1-5. Project properties

3. Click the New... button in the right-hand side.
4. In the dialog that appears (see Figure 1-6), type this variable name into the Name box: RTCESL\_LOC.
5. Select the library parent folder by clicking Folder..., or just type the following path into the Location box: C:\NXP\RTCESL\CM7F\_RTCESL\_4.3\_KDS. Click OK.

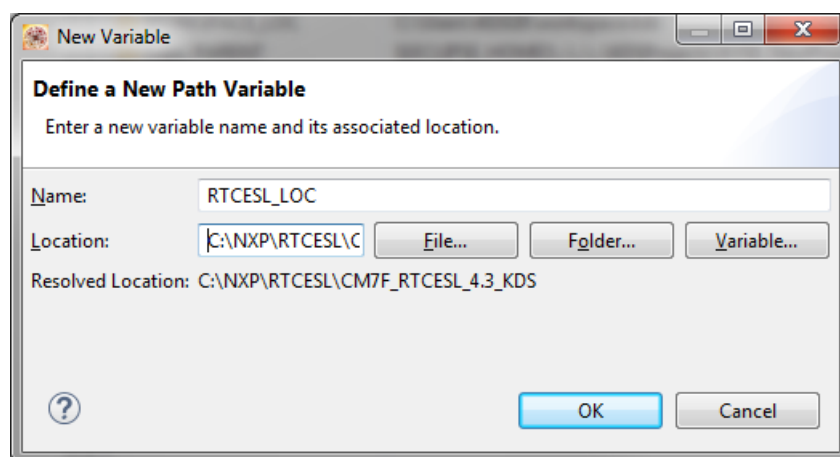


Figure 1-6. New variable

6. Create such variable for the environment. Expand the C/C++ Build node and click Environment.
7. Click the Add... button in the right-hand side.
8. In the dialog that appears (see [Figure 1-7](#)), type this variable name into the Name box: RTCESL\_LOC.
9. Type the library parent folder path into the Value box: C:\NXP\RTCESL\CM7F\_RTCESEL\_4.3\_KDS.
10. Tick the Add to all configurations box to use this variable in all configurations. See [Figure 1-7](#).
11. Click OK.
12. In the previous dialog, click OK.

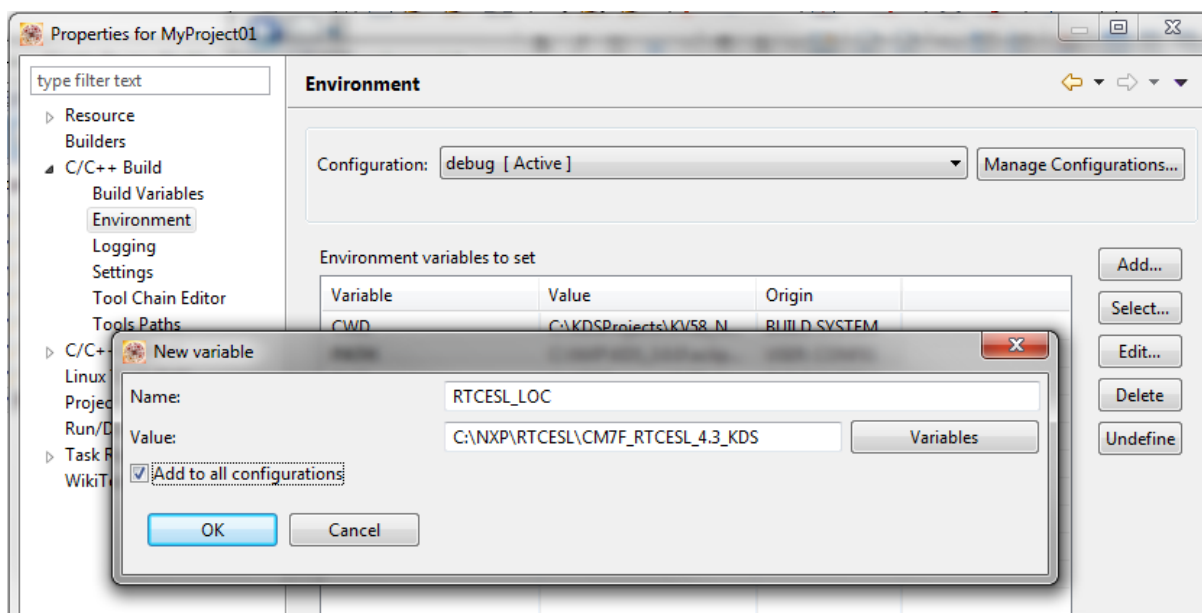


Figure 1-7. Environment variable

### 1.2.3 Library folder addition

To use the library, add it into the Project tree dialog.

1. Right-click the MyProject01 or SDK project name node in the left-hand part and click New > Folder, or select File > New > Folder from the menu. A dialog appears.
2. Click Advanced to show the advanced options.
3. To link the library source, select the option Link to alternate location (Linked Folder).
4. Click Variables..., select the RTCESL\_LOC variable in the dialog, click OK, and/or type the variable name into the box. See [Figure 1-8](#).
5. Click Finish, and you will see the library folder linked in the project. See [Figure 1-9](#).

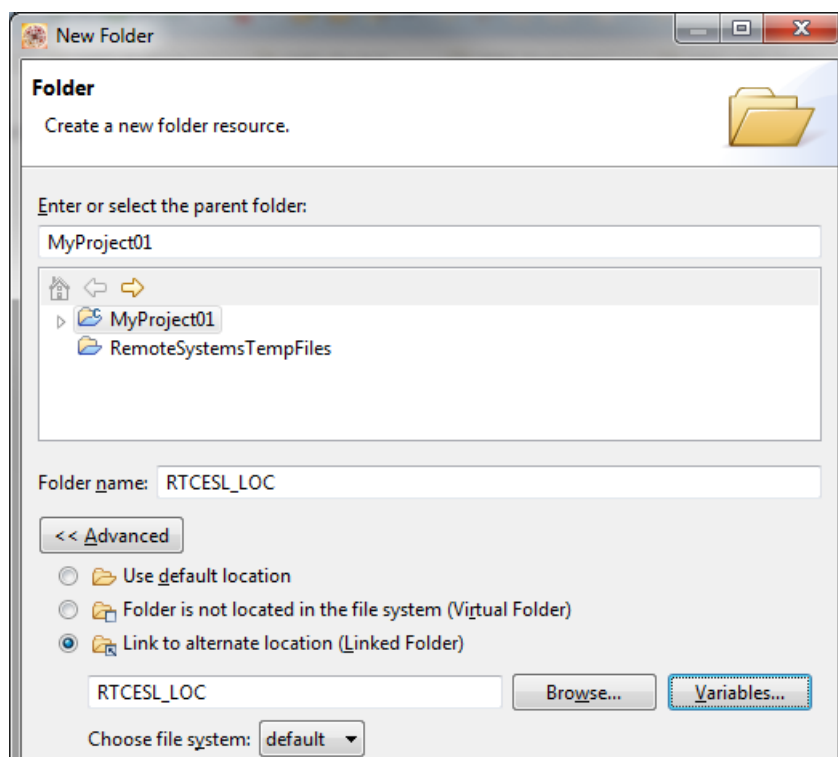


Figure 1-8. Folder link

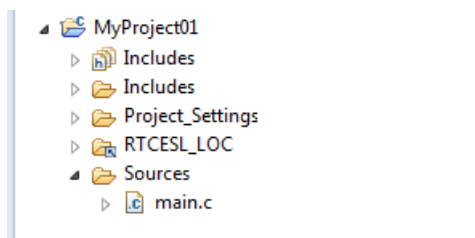
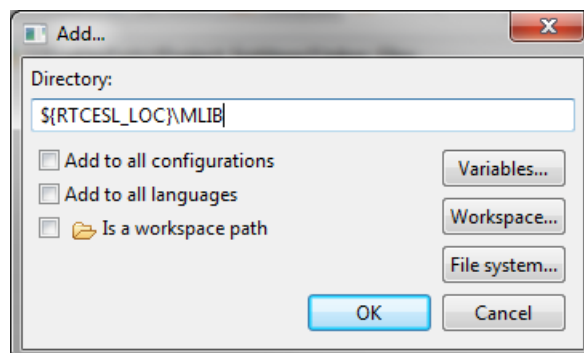


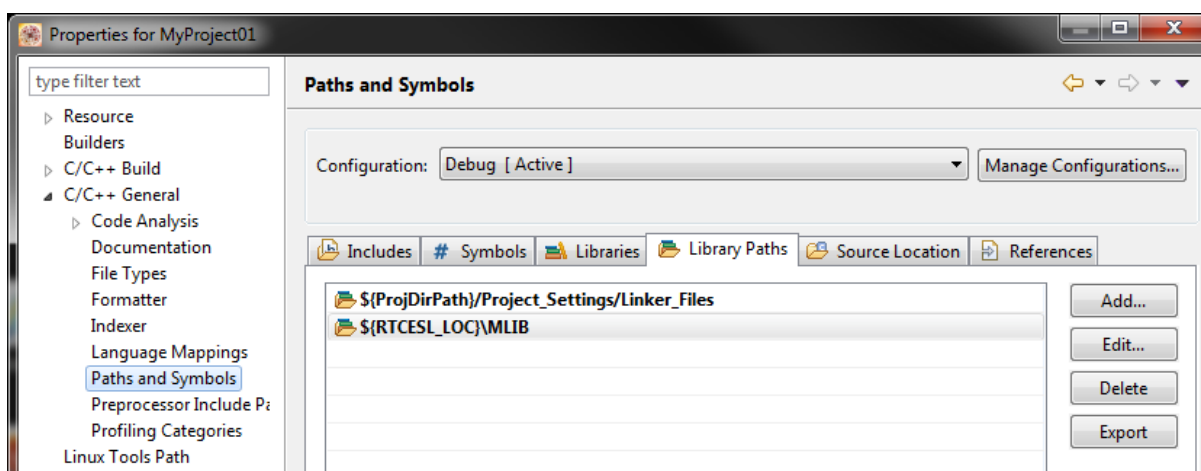
Figure 1-9. Projects libraries paths

## 1.2.4 Library path setup

1. Right-click the MyProject01 or SDK project name node in the left-hand part and click Properties, or select Project > Properties from the menu. A project properties dialog appears.
2. Expand the C/C++ General node, and click Paths and Symbols.
3. In the right-hand dialog, select the Library Paths tab. See [Figure 1-11](#).
4. Click the Add... button on the right, and a dialog appears.
5. Look for the RTCESL\_LOC variable by clicking Variables..., and then finish the path in the box by adding the following (see [Figure 1-10](#)): `${RTCESL_LOC}\MLIB`.
6. Click OK, and the path will be visible in the list. See [Figure 1-11](#).

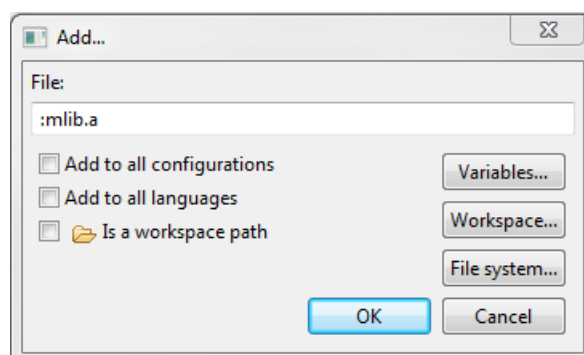


**Figure 1-10. Library path inclusion**



**Figure 1-11. Library paths**

7. After adding the library path, add the library file. Click the Libraries tab. See [Figure 1-13](#).
8. Click the Add... button on the right, and a dialog appears.
9. Type the following into the File text box (see [Figure 1-12](#)): :mlib.a
10. Click OK, and you will see the library added in the list. See [Figure 1-13](#).



**Figure 1-12. Library file inclusion**



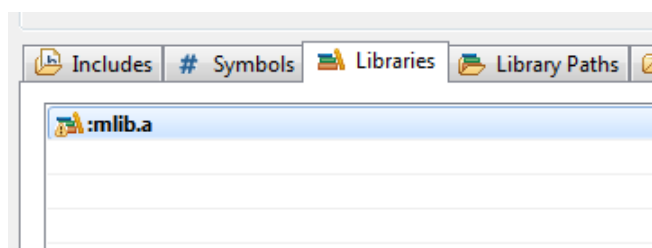


Figure 1-13. Libraries

11. In the right-hand dialog, select the Includes tab, and click GNU C in the Languages list. See Figure 1-15.
12. Click the Add... button on the right, and a dialog appears. See Figure 1-14.
13. Look for the RTCESL\_LOC variable by clicking Variables..., and then finish the path in the box to be: \${RTCESL\_LOC}\MLIB\include
14. Click OK, and you will see the path added in the list. See Figure 1-15. Click OK.

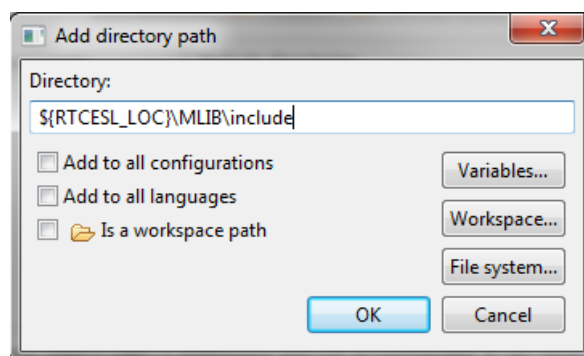


Figure 1-14. Library include path addition

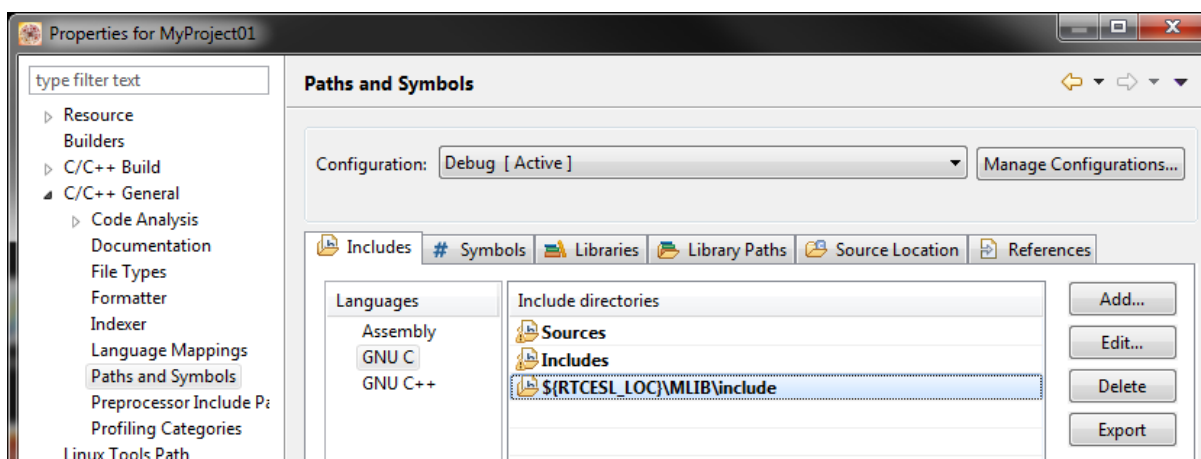


Figure 1-15. Compiler setting

Type the `#include` syntax into the code. Include the library into the *main.c* file. In the left-hand dialog, open the Sources folder of the project, and double-click the *main.c* file. After the *main.c* file opens up, include the following line in the `#include` section:

```
#include "mlib_fp.h"
```

When you click the Build icon (hammer), the project will be compiled without errors.

## 1.3 Library integration into project (Keil $\mu$ Vision)

This section provides a step-by-step guide on how to quickly and easily include MLIB into an empty project or any SDK example or demo application projects using Keil  $\mu$ Vision. This example uses the default installation path (C:\NXP\RTCESL\CM7F\_RTCESL\_4.3\_KEIL). If you have a different installation path, use that path instead. If any SDK project is intended to use (for example hello\_world project) go to [Linking the files into the project](#) chapter otherwise read next chapter.

### 1.3.1 NXP pack installation for new project (without SDK)

This example uses the NXP MKV58F1M0xxx22 part, and the default installation path (C:\NXP\RTCESL\CM7F\_RTCESL\_4.3\_KEIL) is supposed. If the compiler has never been used to create any NXP MCU-based projects before, check whether the NXP MCU pack for the particular device is installed. Follow these steps:

1. Launch Keil  $\mu$ Vision.
2. In the main menu, go to Project > Manage > Pack Installer....
3. In the left-hand dialog (under the Devices tab), expand the All Devices > Freescale (NXP) node.
4. Look for a line called "KVxx Series" and click it.
5. In the right-hand dialog (under the Packs tab), expand the Device Specific node.
6. Look for a node called "Keil::Kinetis\_KVxx\_DFP." If there are the Install or Update options, click the button to install/update the package. See [Figure 1-16](#).
7. When installed, the button has the "Up to date" title. Now close the Pack Installer.

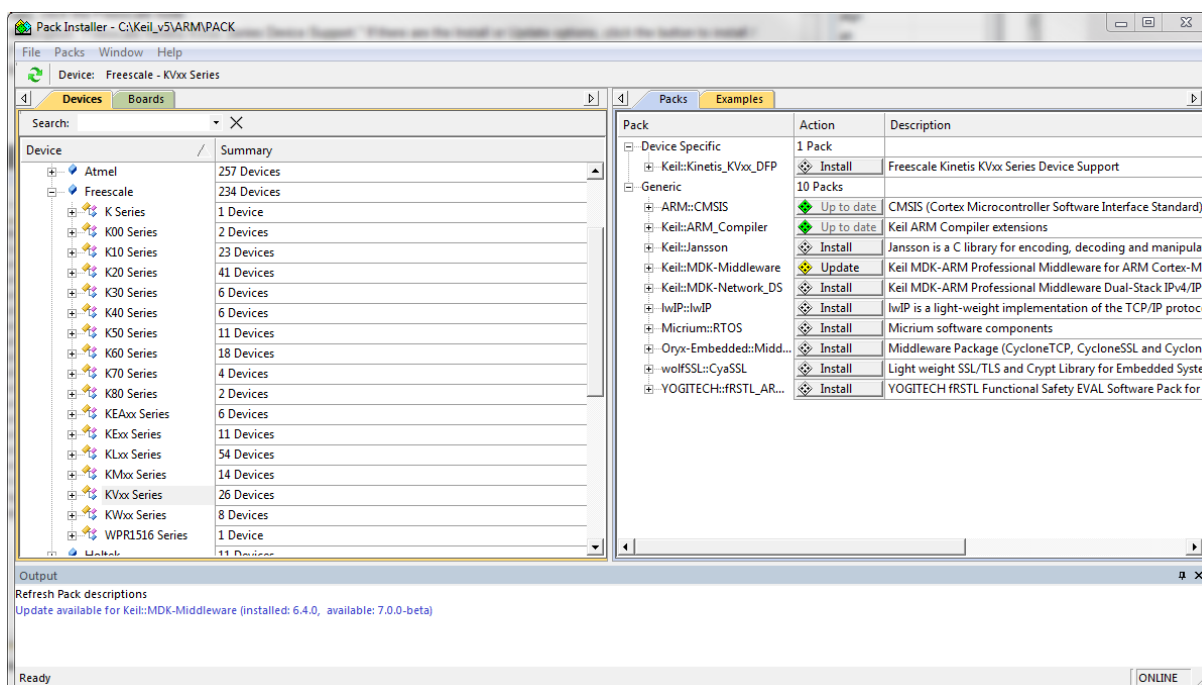


Figure 1-16. Pack Installer

### 1.3.2 New project (without SDK)

To start working on an application, create a new project. If the project already exists and is opened, skip to the next section. Follow these steps to create a new project:

1. Launch Keil  $\mu$ Vision.
2. In the main menu, select Project > New  $\mu$ Vision Project..., and the Create New Project dialog appears.
3. Navigate to the folder where you want to create the project, for example C:\KeilProjects\MyProject01. Type the name of the project, for example MyProject01. Click Save. See Figure 1-17.

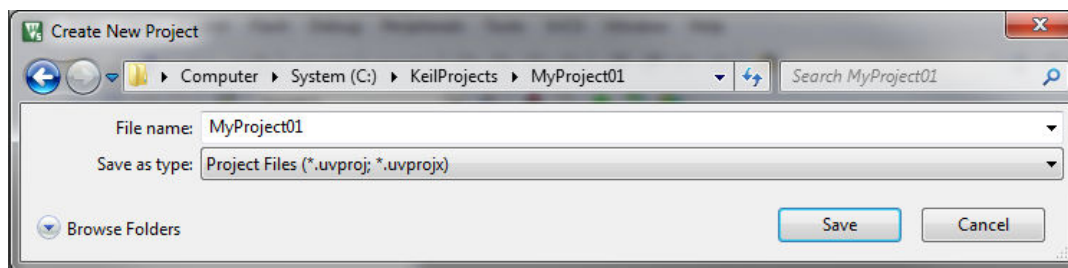
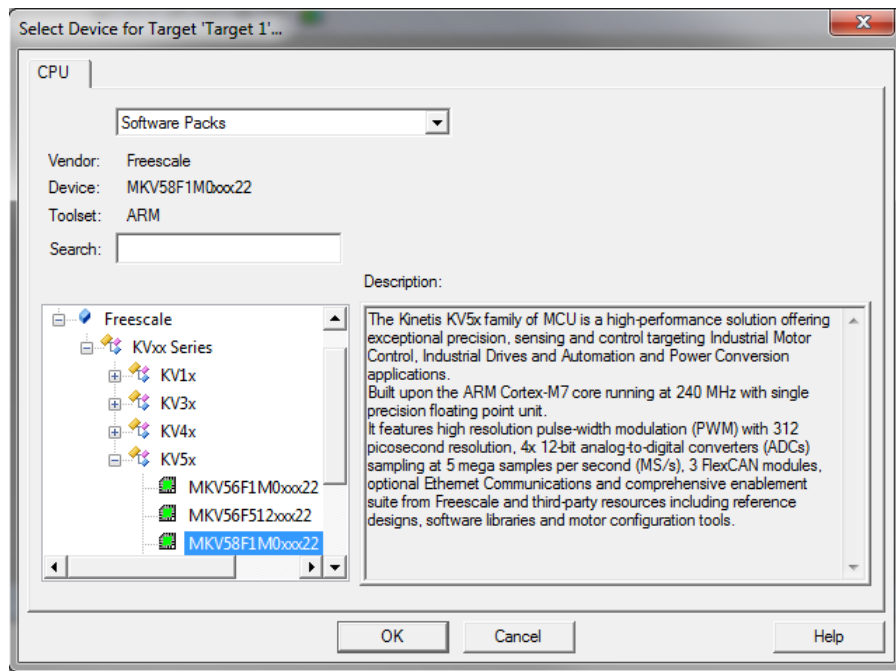


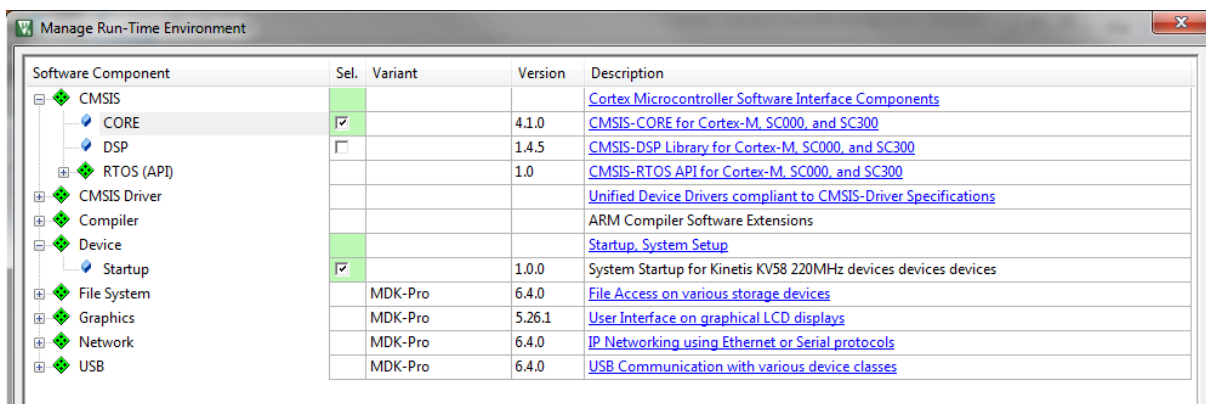
Figure 1-17. Create New Project dialog

4. In the next dialog, select the Software Packs in the very first box.
5. Type " into the Search box, so that the device list is reduced to the devices.
6. Expand the node.
7. Click the MKV58F1M0xxx22 node, and then click OK. See Figure 1-18.



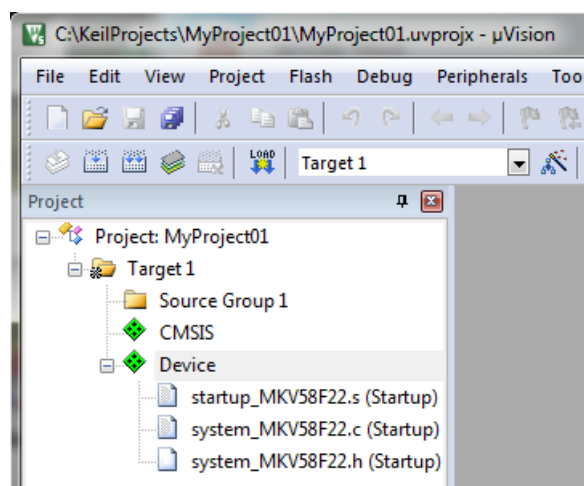
**Figure 1-18. Select Device dialog**

8. In the next dialog, expand the Device node, and tick the box next to the Startup node. See [Figure 1-19](#).
9. Expand the CMSIS node, and tick the box next to the CORE node.



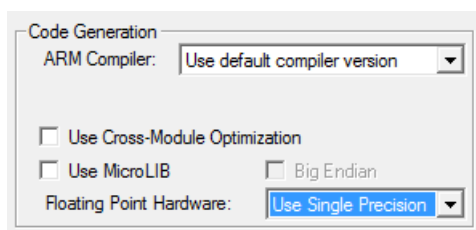
**Figure 1-19. Manage Run-Time Environment dialog**

10. Click OK, and a new project is created. The new project is now visible in the left-hand part of Keil µVision. See [Figure 1-20](#).



**Figure 1-20. Project**

11. In the main menu, go to Project > Options for Target 'Target1'..., and a dialog appears.
12. Select the Target tab.
13. Select Use Single Precision in the Floating Point Hardware option. See [Figure 1-20](#).

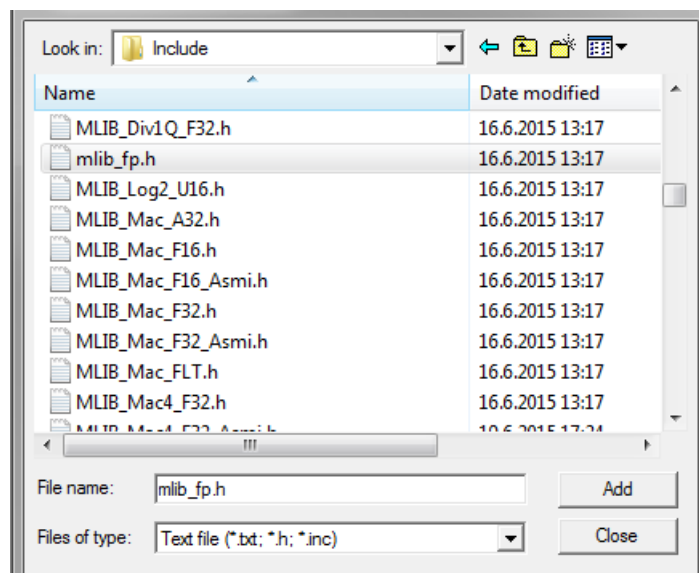


**Figure 1-21. FPU**

### 1.3.3 Linking the files into the project

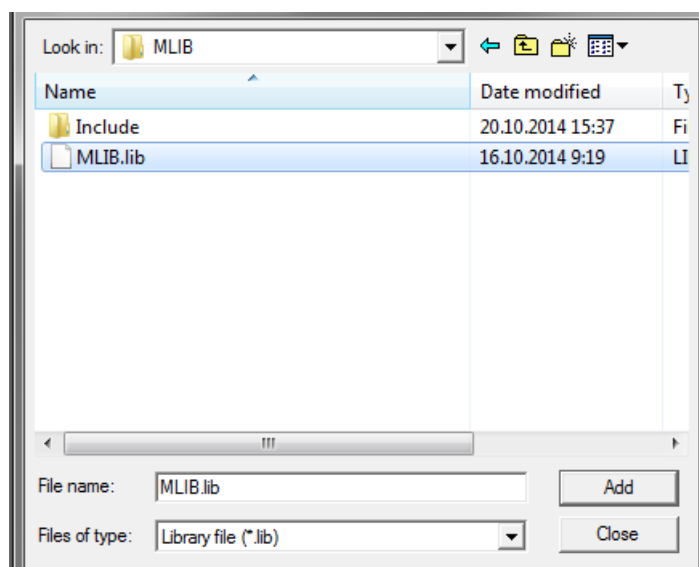
To include the library files in the project, create groups and add them.

1. Right-click the Target 1 node in the left-hand part of the Project tree, and select Add Group... from the menu. A new group with the name New Group is added.
2. Click the newly created group, and press F2 to rename it to RTCESL.
3. Right-click the RTCESL node, and select Add Existing Files to Group 'RTCESL'... from the menu.
4. Navigate into the library installation folder C:\NXP\RTCESL\CM7F\_RTCESL\_4.3\_KEIL\MLIB\Include, and select the *mlib\_fp.h* file. If the file does not appear, set the Files of type filter to Text file. Click Add. See [Figure 1-22](#).



**Figure 1-22. Adding .h files dialog**

5. Navigate to the parent folder C:\NXP\RTCESL\CM7F\_RTCESL\_4.3\_KEIL\MLIB, and select the *mllib.lib* file. If the file does not appear, set the Files of type filter to Library file. Click Add. See [Figure 1-23](#).



**Figure 1-23. Adding .lib files dialog**

6. Now, all necessary files are in the project tree; see [Figure 1-24](#). Click Close.

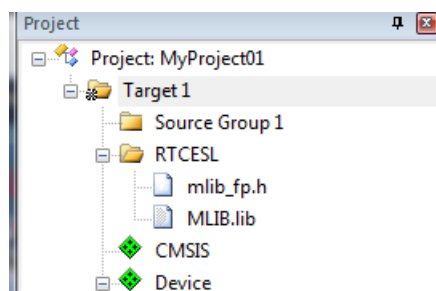


Figure 1-24. Project workspace

### 1.3.4 Library path setup

The following steps show the inclusion of all dependent modules.

1. In the main menu, go to Project > Options for Target 'Target1'..., and a dialog appears.
2. Select the C/C++ tab. See [Figure 1-25](#).
3. In the Include Paths text box, type the following path (if there are more paths, they must be separated by ';') or add it by clicking the ... button next to the text box:
  - "C:\NXP\RTCESL\CM7F\_RTCESL\_4.3\_KEIL\MLIB\Include"
4. Click OK.
5. Click OK in the main dialog.

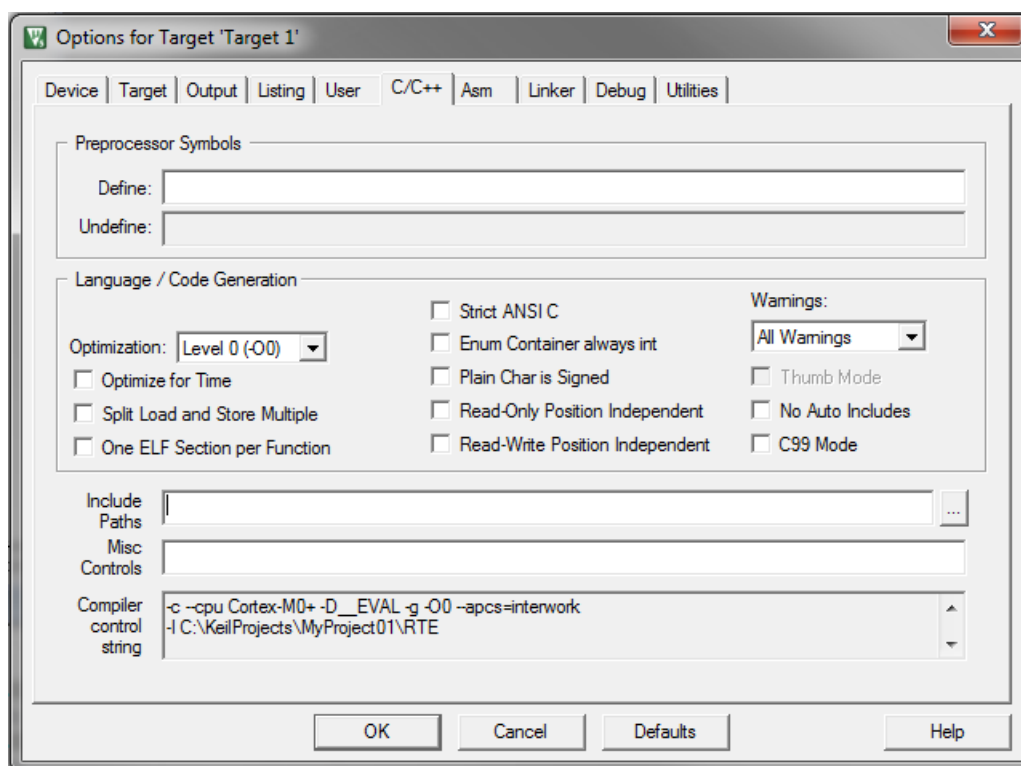
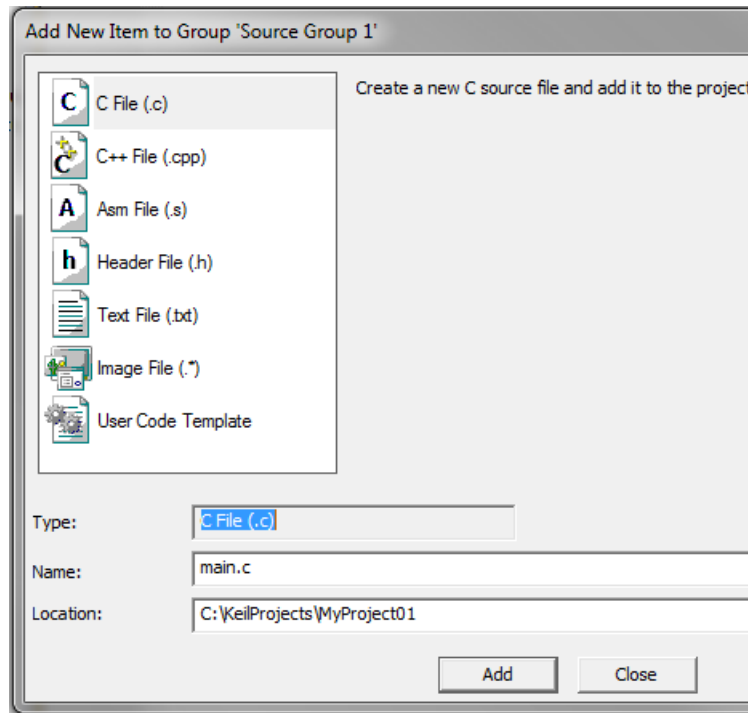


Figure 1-25. Library path addition

Type the `#include` syntax into the code. Include the library into a source file. In the new project, it is necessary to create a source file:

1. Right-click the Source Group 1 node, and Add New Item to Group 'Source Group 1'... from the menu.
2. Select the C File (.c) option, and type a name of the file into the Name box, for example '*main.c*'. See [Figure 1-26](#).



**Figure 1-26. Adding new source file dialog**

3. Click Add, and a new source file is created and opened up.
4. In the opened source file, include the following line into the `#include` section, and create a main function:

```
#include "mlib_fp.h"

int main(void)
{
    while(1);
}
```

When you click the Build (F7) icon, the project will be compiled without errors.

## 1.4 Library integration into project (IAR Embedded Workbench)

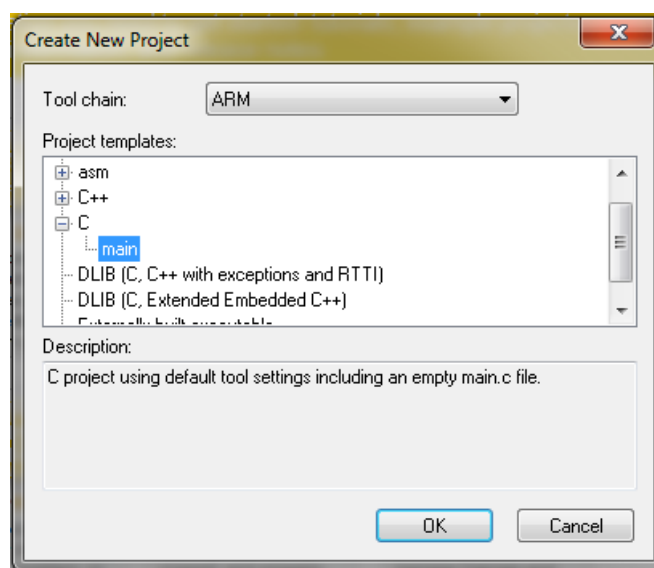


This section provides a step-by-step guide on how to quickly and easily include the MLIB into an empty project or any SDK example or demo application projects using IAR Embedded Workbench. This example uses the default installation path (C:\NXP\RTCESL\CM7F\_RTCESL\_4.3\_IAR). If you have a different installation path, use that path instead. If any SDK project is intended to use (for example hello\_world project) go to [Linking the files into the project](#) chapter otherwise read next chapter.

### 1.4.1 New project (without SDK)

This example uses the NXP MKV58F1M0xxx22 part, and the default installation path (C:\NXP\RTCESL\CM7F\_RTCESL\_4.3\_IAR) is supposed. To start working on an application, create a new project. If the project already exists and is opened, skip to the next section. Perform these steps to create a new project:

1. Launch IAR Embedded Workbench.
2. In the main menu, select Project > Create New Project... so that the "Create New Project" dialog appears. See [Figure 1-27](#).



**Figure 1-27. Create New Project dialog**

3. Expand the C node in the tree, and select the "main" node. Click OK.
4. Navigate to the folder where you want to create the project, for example, C:\IARProjects\MyProject01. Type the name of the project, for example, MyProject01. Click Save, and a new project is created. The new project is now visible in the left-hand part of IAR Embedded Workbench. See [Figure 1-28](#).

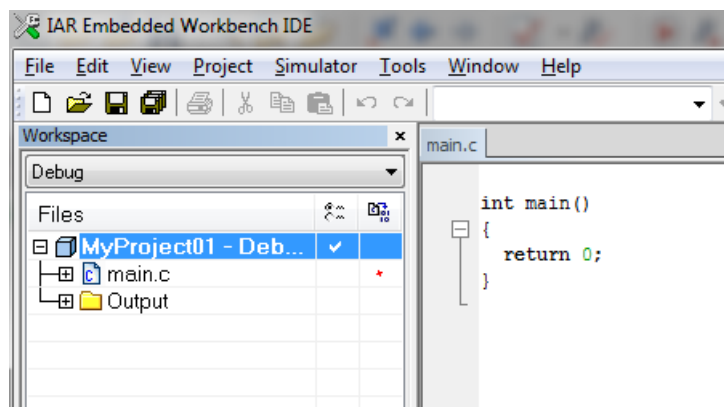


Figure 1-28. New project

5. In the main menu, go to Project > Options..., and a dialog appears.
6. In the Target tab, select the Device option, and click the button next to the dialog to select the MCU. In this example, select NXP > KV5x > NXP MKV58F1M0xxx22. Select VFPv5 single precision in the FPU option. Click OK. See [Figure 1-29](#).

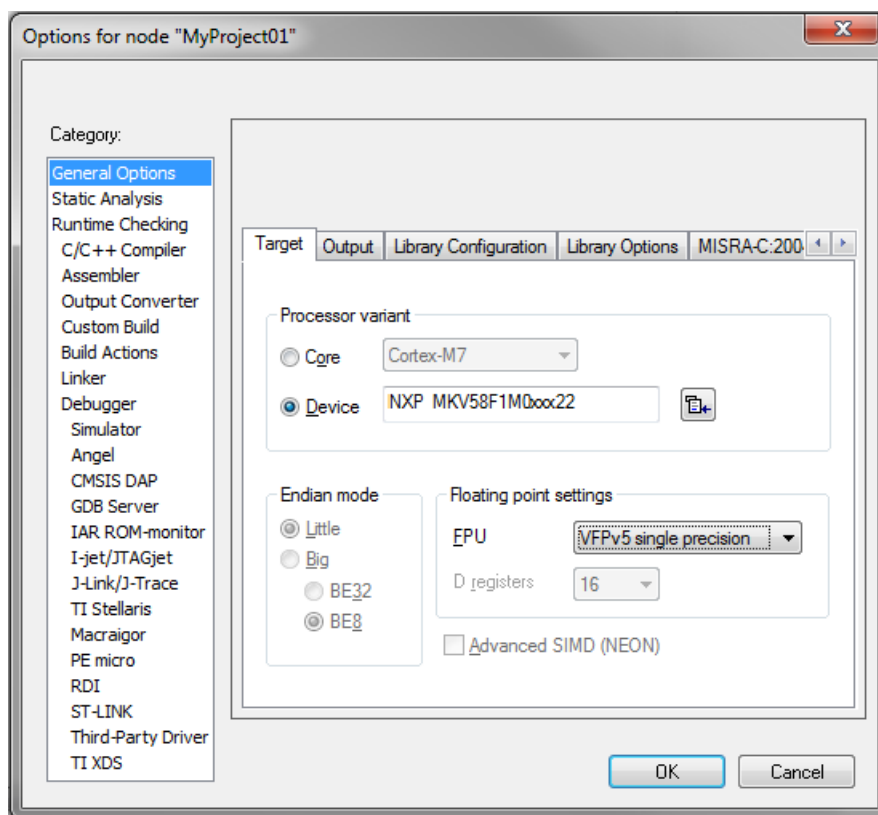
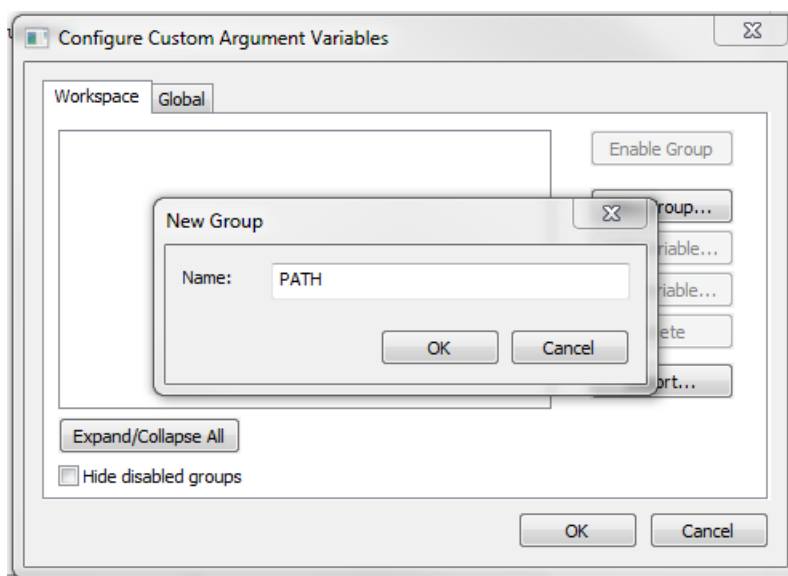


Figure 1-29. Options dialog

## 1.4.2 Library path variable

To make the library integration easier, create a variable that will hold the information about the library path.

1. In the main menu, go to Tools > Configure Custom Argument Variables..., and a dialog appears.
2. Click the New Group button, and another dialog appears. In this dialog, type the name of the group PATH, and click OK. See [Figure 1-30](#).



**Figure 1-30. New Group**

3. Click on the newly created group, and click the Add Variable button. A dialog appears.
4. Type this name: RTCESL\_LOC
5. To set up the value, look for the library by clicking the '...' button, or just type the installation path into the box: C:\NXP\RTCESL\CM7F\_RTCESL\_4.3\_IAR. Click OK.
6. In the main dialog, click OK. See [Figure 1-31](#).

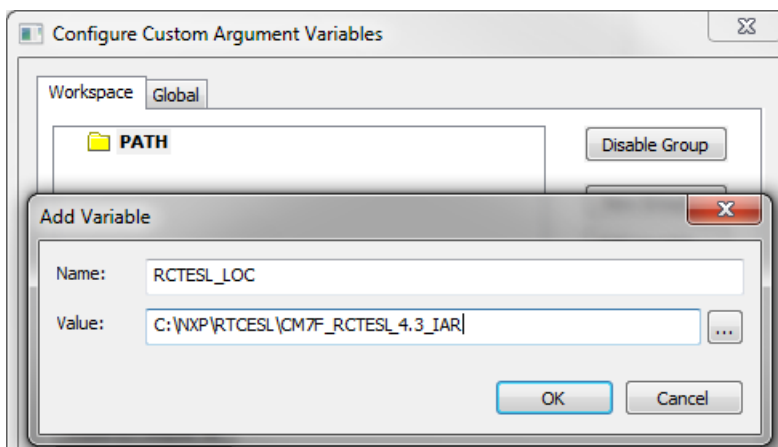


Figure 1-31. New variable

### 1.4.3 Linking the files into the project

To include the library files into the project, create groups and add them.

1. Go to the main menu Project > Add Group...
2. Type RTCESL, and click OK.
3. Click on the newly created node RTCESL, go to Project > Add Group..., and create a MLIB subgroup.
4. Click on the newly created node MLIB, and go to the main menu Project > Add Files... See [Figure 1-33](#).
5. Navigate into the library installation folder C:\NXP\RTCESL\CM7F\_RTCESL\_4.3\_IAR\MLIB\Include, and select the *mlib\_fp.h* file. (If the file does not appear, set the file-type filter to Source Files.) Click Open. See [Figure 1-32](#).
6. Navigate into the library installation folder C:\NXP\RTCESL\CM7F\_RTCESL\_4.3\_IAR\MLIB, and select the *mlib.a* file. If the file does not appear, set the file-type filter to Library / Object files. Click Open.

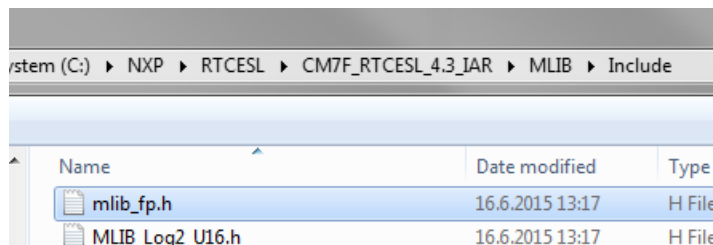
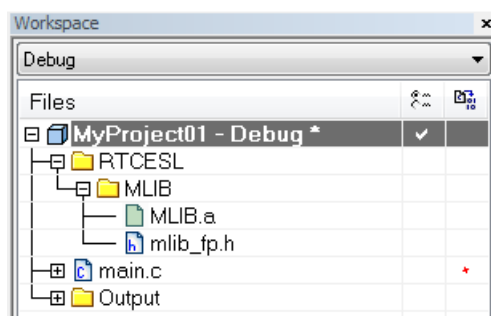


Figure 1-32. Add Files dialog

7. Now you will see the files added in the workspace. See [Figure 1-33](#).



**Figure 1-33. Project workspace**

### 1.4.4 Library path setup

1. In the main menu, go to Project > Options..., and a dialog appears.
2. In the left-hand column, select C/C++ Compiler.
3. In the right-hand part of the dialog, click on the Preprocessor tab (it can be hidden in the right; use the arrow icons for navigation).
4. In the text box (at the Additional include directories title), type the following folder (using the created variable):
  - \$RTCESL\_LOC\$MLIB\Include
5. Click OK in the main dialog. See [Figure 1-34](#).

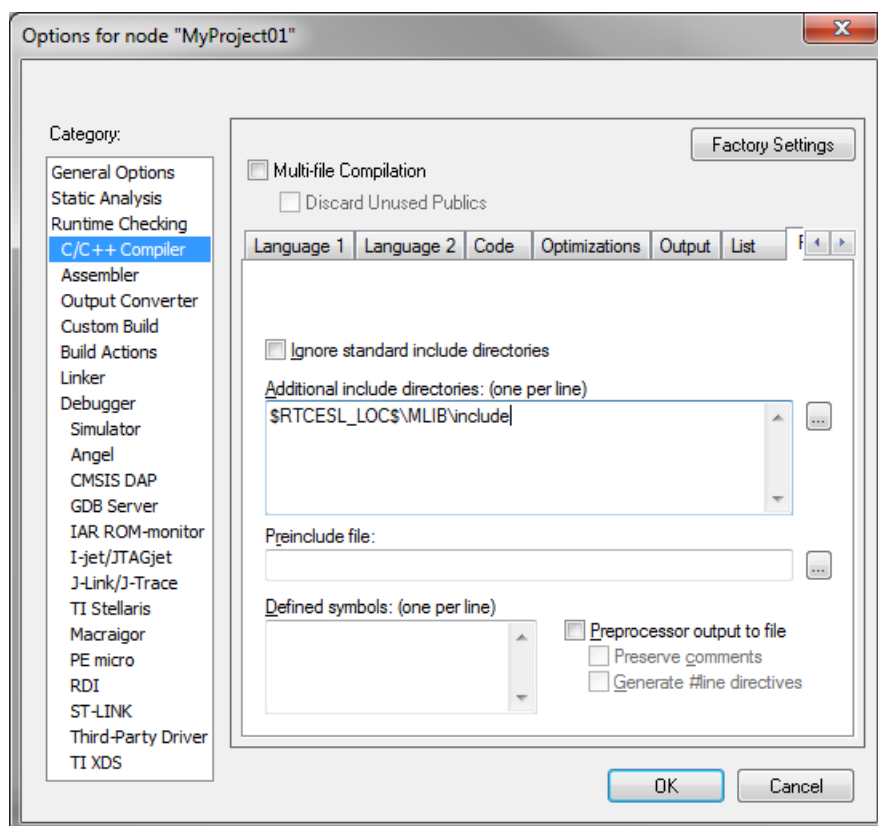


Figure 1-34. Library path addition

Type the `#include` syntax into the code. Include the library included into the *main.c* file. In the workspace tree, double-click the *main.c* file. After the *main.c* file opens up, include the following line into the `#include` section:

```
#include "mlib_fp.h"
```

When you click the Make icon, the project will be compiled without errors.

## Chapter 2

# Algorithms in detail

## 2.1 MLIB\_Abs

The [MLIB\\_Abs](#) functions return the absolute value of the input. The function does not saturate the output. See the following equation:

$$\text{MLIB\_Abs}(x) = |x|$$

**Equation 1. Algorithm formula**

### 2.1.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range  $<-1 ; 1$ ). The result may overflow.
- Floating-point output - the output is a floating-point number; the result is a non-negative value.

The available versions of the [MLIB\\_Abs](#) function are shown in the following table.

**Table 2-1. Function versions**

Function name	Input type	Result type	Description
MLIB_Abs_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	Absolute value of a 16-bit fractional value. The output is within the range $<-1 ; 1$ ).
MLIB_Abs_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	Absolute value of a 32-bit fractional value. The output is within the range $<-1 ; 1$ ).
MLIB_Abs_FLT	<a href="#">float_t</a>	<a href="#">float_t</a>	Absolute value of a 32-bit single precision floating-point value. The output is a non-negative value.

## 2.1.2 Declaration

The available [MLIB\\_Abs](#) functions have the following declarations:

```
frac16_t MLIB_Abs_F16(frac16_t f16Val)
frac32_t MLIB_Abs_F32(frac32_t f32Val)
float_t MLIB_Abs_FLT(float_t fltVal)
```

## 2.1.3 Function use

The use of the [MLIB\\_Abs](#) function is shown in the following example:

```
#include "mlib.h"

static frac32_t f32Result;
static frac32_t f32Val;

void main(void)
{
    f32Val = FRAC32(-0.354);          /* f32Val = -0.354 */

    /* f32Result = |f32Val| */
    f32Result = MLIB_Abs_F32(f32Val);
}
```

## 2.2 MLIB\_AbsSat

The [MLIB\\_AbsSat](#) functions return the absolute value of the input. The function saturates the output. See the following equation:

$$\text{MLIB\_AbsSat}(x) = |x|$$

**Equation 2. Algorithm formula**

### 2.2.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range <0 ; 1). The result may saturate.



The available versions of the [MLIB\\_AbsSat](#) function are shown in the following table.

**Table 2-2. Function versions**

Function name	Input type	Result type	Description
MLIB_AbsSat_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	Absolute value of a 16-bit fractional value. The output is within the range <0 ; 1).
MLIB_AbsSat_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	Absolute value of a 32-bit fractional value. The output is within the range <0 ; 1).

## 2.2.2 Declaration

The available [MLIB\\_AbsSat](#) functions have the following declarations:

```
frac16\_t MLIB_AbsSat_F16(frac16\_t f16Val)
frac32\_t MLIB_AbsSat_F32(frac32\_t f32Val)
```

## 2.2.3 Function use

The use of the [MLIB\\_AbsSat](#) function is shown in the following example:

```
#include "mlib.h"

static frac16\_t f16Val, f16Result;

void main(void)
{
    f16Val = FRAC16(-0.835);          /* f16Val = -0.835 */

    /* f16Result = sat(|f16Val|)      */
    f16Result = MLIB_AbsSat_F16(f16Val);
}
```

## 2.3 MLIB\_Add

The [MLIB\\_Add](#) functions return the sum of two addends. The function does not saturate the output. See the following equation:

$$\text{MLIB\_Add}(a, b) = a + b$$

**Equation 3. Algorithm formula**

## 2.3.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range  $<-1 ; 1$ ). The result may overflow.
- Accumulator output with fractional inputs - the output is the accumulator type, where the result can be out of the range  $<-1 ; 1$ ). The inputs are the fractional values only.
- Accumulator output with mixed inputs - the output is the accumulator type, where the result can be out of the range  $<-1 ; 1$ ). The inputs are the accumulator and fractional values. The result may overflow.
- Floating-point output - the output is a floating-point number; the result is within the full range.

The available versions of the [MLIB\\_Add](#) function are shown in the following table.

**Table 2-3. Function versions**

Function name	Input type		Result type	Description
	Addend 1	Addend 2		
MLIB_Add_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	Addition of two 16-bit fractional addends. The output is within the range $<-1 ; 1$ ).
MLIB_Add_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	Addition of two 32-bit fractional addends. The output is within the range $<-1 ; 1$ ).
MLIB_Add_A32ss	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">acc32_t</a>	Addition of two 16-bit fractional addends; the result is a 32-bit accumulator. The output may be out of the range $<-1 ; 1$ ).
MLIB_Add_A32as	<a href="#">acc32_t</a>	<a href="#">frac16_t</a>	<a href="#">acc32_t</a>	A 16-bit fractional addend is added to a 32-bit accumulator. The output may be out of the range $<-1 ; 1$ ).
MLIB_Add_FLT	<a href="#">float_t</a>	<a href="#">float_t</a>	<a href="#">float_t</a>	Addition of two 32-bit single precision floating-point addends. The output is within the full range.

## 2.3.2 Declaration

The available [MLIB\\_Add](#) functions have the following declarations:

```

frac16\_t MLIB_Add_F16(frac16\_t f16Add1, frac16\_t f16Add2)
frac32\_t MLIB_Add_F32(frac32\_t f32Add1, frac32\_t f32Add2)
acc32\_t MLIB_Add_A32ss(frac16\_t f16Add1, frac16\_t f16Add2)
acc32\_t MLIB_Add_A32as(acc32\_t a32Accum, frac16\_t f16Add)
float\_t MLIB_Add_FLT(float\_t fltAdd1, float\_t fltAdd2)

```

## 2.3.3 Function use

The use of the [MLIB\\_Add](#) function is shown in the following example:

```
#include "mlib.h"

static acc32_t a32Result;
static frac16_t f16Add1, f16Add2;

void main(void)
{
    f16Add1 = FRAC16(-0.8);      /* f16Add1 = -0.8 */
    f16Add2 = FRAC16(-0.5);      /* f16Add2 = -0.5 */

    /* a32Result = f16Add1 + f16Add2 */
    a32Result = MLIB_Add_A32ss(f16Add1, f16Add2);
}
```

## 2.4 MLIB\_AddSat

The [MLIB\\_AddSat](#) functions return the sum of two addends. The function saturates the output. See the following equation:

$$\text{MLIB\_AddSat}(a, b) = \begin{cases} 1, & a+b > 1 \\ -1, & a+b < -1 \\ a+b, & \text{else} \end{cases}$$

**Equation 4. Algorithm formula**

### 2.4.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range <-1 ; 1). The result may saturate.

The available versions of the [MLIB\\_AddSat](#) function are shown in the following table.

**Table 2-4. Function versions**

Function name	Input type		Result type	Description
	Addend 1	Addend 2		
MLIB_AddSat_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	Addition of two 16-bit fractional addends. The output is within the range <-1 ; 1).
MLIB_AddSat_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	Addition of two 32-bit fractional addends. The output is within the range <-1 ; 1).

## 2.4.2 Declaration

The available [MLIB\\_AddSat](#) functions have the following declarations:

```
frac16_t MLIB_Add_F16(frac16_t f16Add1, frac16_t f16Add2)
frac32_t MLIB_Add_F32(frac32_t f32Add1, frac32_t f32Add2)
```

## 2.4.3 Function use

The use of the [MLIB\\_AddSat](#) function is shown in the following example:

```
#include "mlib.h"

static frac32_t f32Add1, f32Add2, f32Result;

void main(void)
{
    f32Add1 = FRAC32(-0.8);          /* f32Add1 = -0.8 */
    f32Add2 = FRAC32(-0.5);          /* f32Add2 = -0.5 */

    /* f32Result = sat(f32Add1 + f32Add2) */
    f32Result = MLIB_AddSat_F32(f32Add1, f32Add2);
}
```

## 2.5 MLIB\_Add4

The [MLIB\\_Add4](#) functions return the sum of four addends. The function does not saturate the output. See the following equation:

$$\text{MLIB\_Add4}(a, b, c, d) = a + b + c + d$$

**Equation 5. Algorithm formula**

### 2.5.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range  $<-1 ; 1$ ). The result may overflow.
- Floating-point output - the output is a floating-point number; the result is within the full range.

The available versions of the [MLIB\\_Add4](#) function are shown in the following table.

**Table 2-5. Function versions**

Function name	Input type				Result type	Description
	Add. 1	Add. 2	Add. 3	Add. 4		
MLIB_Add4_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	Addition of four 16-bit fractional addends. The output is within the range <-1 ; 1).
MLIB_Add4_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	Addition of four 32-bit fractional addends. The output is within the range <-1 ; 1).
MLIB_Add4_FLT	<a href="#">float_t</a>	<a href="#">float_t</a>	<a href="#">float_t</a>	<a href="#">float_t</a>	<a href="#">float_t</a>	Addition of four 32-bit single precision floating-point addends. The output is within the full range.

## 2.5.2 Declaration

The available [MLIB\\_Add4](#) functions have the following declarations:

```
frac16\_t MLIB_Add4_F16(frac16\_t f16Add1, frac16\_t f16Add2, frac16\_t f16Add3, frac16\_t
f16Add4)
frac32\_t MLIB_Add4_F32(frac32\_t f32Add1, frac32\_t f32Add2, frac32\_t f32Add3, frac32\_t
f32Add4)
float\_t MLIB_Add4_FLT(float\_t fltAdd1, float\_t fltAdd2, float\_t fltAdd3, float\_t fltAdd4)
```

## 2.5.3 Function use

The use of the [MLIB\\_Add4](#) function is shown in the following example:

```
#include "mlib.h"

static frac32\_t f32Result;
static frac32\_t f32Add1, f32Add2, f32Add3, f32Add4;

void main(void)
{
    f32Add1 = FRAC32(-0.3);          /* f32Add1 = -0.3 */
    f32Add2 = FRAC32(0.5);           /* f32Add2 = 0.5 */
    f32Add3 = FRAC32(-0.2);          /* f32Add3 = -0.2 */
    f32Add4 = FRAC32(-0.4);          /* f32Add4 = -0.4 */

    /* f32Result = f32Add1 + f32Add2 + f32Add3 + f32Add4 */
    f32Result = MLIB_Add4_F32(f32Add1, f32Add2, f32Add3, f32Add4);
}
```

## 2.6 MLIB\_Add4Sat

The [MLIB\\_Add4Sat](#) functions return the sum of four addends. The function saturates the output. See the following equation:

$$\text{MLIB\_Add4Sat}(a, b, c, d) = \begin{cases} 1, & a+b+c+d > 1 \\ -1, & a+b+c+d < -1 \\ a+b+c+d, & \text{else} \end{cases}$$

**Equation 6. Algorithm formula**

## 2.6.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range <-1 ; 1). The result may saturate.

The available versions of the [MLIB\\_Add4Sat](#) function are shown in the following table.

**Table 2-6. Function versions**

Function name	Input type				Result type	Description
	Add. 1	Add. 2	Add. 3	Add. 4		
MLIB_Add4Sat_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	Addition of four 16-bit fractional addends. The output is within the range <-1 ; 1).
MLIB_Add4Sat_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	Addition of four 32-bit fractional addends. The output is within the range <-1 ; 1).

## 2.6.2 Declaration

The available [MLIB\\_Add4Sat](#) functions have the following declarations:

```
frac16\_t MLIB_Add4Sat_F16(frac16\_t f16Add1, frac16\_t f16Add2, frac16\_t f16Add3, frac16\_t
f16Add4)
frac32\_t MLIB_Add4Sat_F32(frac32\_t f32Add1, frac32\_t f32Add2, frac32\_t f32Add3, frac32\_t
f32Add4)
```

## 2.6.3 Function use

The use of the [MLIB\\_Add4Sat](#) function is shown in the following example:

```
#include "mlib.h"

static frac16\_t f16Result, f16Add1, f16Add2, f16Add3, f16Add4;
```

```

void main(void)
{
    f16Add1 = FRAC16(-0.7);      /* f16Add1 = -0.7 */
    f16Add2 = FRAC16(0.9);      /* f16Add2 = 0.9 */
    f16Add3 = FRAC16(0.4);      /* f16Add3 = 0.4 */
    f16Add4 = FRAC16(0.7);      /* f16Add4 = 0.7 */

    /* f16Result = sat(f16Add1 + f16Add2 + f16Add3 + f16Add4) */
    f16Result = MLIB_Add4Sat_F16(f16Add1, f16Add2, f16Add3, f16Add4);
}

```

## 2.7 MLIB\_Clb

The [MLIB\\_Clb](#) functions return the number of leading bits of the input. If the input is 0, it returns the size of the type minus one.

### 2.7.1 Available versions

This function is available in the following versions:

- Integer output with fractional input - the output is the unsigned integer value when the input is fractional; the result is greater than or equal to 0.

The available versions of the [MLIB\\_Clb](#) function are shown in the following table.

**Table 2-7. Function versions**

Function name	Input type	Result type	Description
MLIB_Clb_U16s	<a href="#">frac16_t</a>	<a href="#">uint16_t</a>	Counts the leading bits of a 16-bit fractional value. The output is within the range <0 ; 15>.
MLIB_Clb_U16l	<a href="#">frac32_t</a>	<a href="#">uint16_t</a>	Counts the leading bits of a 32-bit fractional value. The output is within the range <0 ; 31>.

### 2.7.2 Declaration

The available [MLIB\\_Clb](#) functions have the following declarations:

```

uint16_t MLIB_Clb_U16s(frac16\_t f16Val)
uint16_t MLIB_Clb_U16l(frac32\_t f32Val)

```

### 2.7.3 Function use

The use of the [MLIB\\_Clb](#) function is shown in the following example:

```

#include "mlib.h"

static uint16_t u16Result;
static frac32_t f32Val;

void main(void)
{
    f32Val = FRAC32(0.00000452);          /* f32Val = 0.00000452 */

    /* u16Result = clb(f32Val) */
    u16Result = MLIB_Clb_U16l(f32Val);
}

```

## 2.8 MLIB\_Conv

The [MLIB\\_Conv](#) functions return the input value, converted to the output type.

### 2.8.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range  $<-1 ; 1$ ).
- Accumulator output - the output is the accumulator type, where the result may be out of the range  $<-1 ; 1$ ).
- Floating-point output - the output is a floating-point number; the result is within the range  $<-1 ; 1$ )

The available versions of the [MLIB\\_Conv](#) function are shown in the following table.

**Table 2-8. Function versions**

Function name	Input type	Result type	Description
MLIB_Conv_F16l	<a href="#">frac32_t</a>	<a href="#">frac16_t</a>	Conversion of a 32-bit fractional value to a 16-bit fractional value. The output is within the range $<-1 ; 1$ ).
MLIB_Conv_F16f	<a href="#">float_t</a>	<a href="#">frac16_t</a>	Conversion of a 32-bit single precision floating-point value to a 16-bit fractional value. The output is within the range $<-1 ; 1$ ). If the result is out of this range, it is saturated.
MLIB_Conv_F32s	<a href="#">frac16_t</a>	<a href="#">frac32_t</a>	Conversion of a 16-bit fractional value to a 32-bit fractional value. The output is within the range $<-1 ; 1$ ).
MLIB_Conv_F32f	<a href="#">float_t</a>	<a href="#">frac32_t</a>	Conversion of a 32-bit single precision floating-point value to a 32-bit fractional value. The output is within the range $<-1 ; 1$ ). If the result is out of this range, it is saturated.
MLIB_Conv_A32f	<a href="#">float_t</a>	<a href="#">acc32_t</a>	Conversion of a 32-bit single precision floating-point value to a 32-bit accumulator value. The output is within the range $<-65536.0 ; 65536.0$ ). If the result is out of this range, it is saturated.

*Table continues on the next page...*



**Table 2-8. Function versions (continued)**

Function name	Input type	Result type	Description
MLIB_Conv_FLTs	<a href="#">frac16_t</a>	<a href="#">float_t</a>	Conversion of a 16-bit fractional value to a 32-bit single precision floating-point value. The output is within the range <-1 ; 1).
MLIB_Conv_FLTl	<a href="#">frac32_t</a>	<a href="#">float_t</a>	Conversion of a 32-bit fractional value to a 32-bit single precision floating-point value. The output is within the range <-1 ; 1).
MLIB_Conv_FLTa	<a href="#">acc32_t</a>	<a href="#">float_t</a>	Conversion of a 32-bit accumulator value to a 32-bit single precision floating-point value. The output is within the range <-65536.0 ; 65536.0).

## 2.8.2 Declaration

The available [MLIB\\_Conv](#) functions have the following declarations:

```

frac16\_t MLIB_Conv_F16l(frac32\_t f32Val)
frac16\_t MLIB_Conv_F16f(float\_t fltVal)
frac32\_t MLIB_Conv_F32s(frac16\_t f16Val)
frac32\_t MLIB_Conv_F32f(float\_t fltVal)
acc32\_t MLIB_Conv_A32f(float\_t fltVal)
float\_t MLIB_Conv_FLTs(frac16\_t f16Val)
float\_t MLIB_Conv_FLTl(frac32\_t f32Val)
float\_t MLIB_Conv_FLTa(acc32\_t a32Val)

```

## 2.8.3 Function use

The use of the [MLIB\\_Conv](#) function is shown in the following example:

```

#include "mlib.h"

static frac32\_t f32Result;
static frac16\_t f16Val;

void main(void)
{
    f16Val = FRAC16(-0.354);          /* f16Val = -0.354 */

    /* f32Result = (frac32_t)f16Val << 16 */
    f32Result = MLIB_Conv_F32s(f16Val);
}

```

## 2.9 MLIB\_ConvSc

The [MLIB\\_ConvSc](#) functions return the input value converted to the output type using a scale coefficient.

## 2.9.1 Available versions

The function is available in the following versions:

- Fractional output - the output is the fractional portion of the result. The input value is divided by the scale to be within the range  $<-1 ; 1$ ). The result may be saturated.
- Accumulator output - the output is the accumulator type, where the result may be out of the range  $<-1 ; 1$ ).
- Floating-point output - the output is a floating-point number. The input value is multiplied by the scale to transform the fractional value into the real floating-point number. The result is within the full range.

The available versions of the [MLIB\\_ConvSc](#) function are shown in the following table.

**Table 2-9. Function versions**

Function name	Input type		Result type	Description
	Value	Scale		
MLIB_ConvSc_F16ff	<a href="#">float_t</a>	<a href="#">float_t</a>	<a href="#">float_t</a>	Conversion of a 32-bit single precision floating-point value to a 16-bit fractional value using a 32-bit single precision floating-point scale. The output is within the range $<-1 ; 1$ ); the result may saturate.
MLIB_ConvSc_F32ff	<a href="#">float_t</a>	<a href="#">float_t</a>	<a href="#">float_t</a>	Conversion of a 32-bit single precision floating-point value to a 32-bit fractional value using a 32-bit single precision floating-point scale. The output is within the range $<-1 ; 1$ ); the result may saturate.
MLIB_ConvSc_A32ff	<a href="#">float_t</a>	<a href="#">float_t</a>	<a href="#">float_t</a>	Conversion of a 32-bit single precision floating-point value to a 32-bit accumulator value using a 32-bit single precision floating-point scale. The output is within the range $<-65536.0 ; 65536.0$ ); the result may saturate.
MLIB_ConvSc_FLTsf	<a href="#">frac16_t</a>	<a href="#">float_t</a>	<a href="#">float_t</a>	Conversion of a 16-bit fractional value to a 32-bit single precision floating-point value using a 32-bit single precision floating-point scale. The output is within the range $<-1 ; 1$ ).
MLIB_ConvSc_FLTlf	<a href="#">frac32_t</a>	<a href="#">float_t</a>	<a href="#">float_t</a>	Conversion of a 32-bit fractional value to a 32-bit single precision floating-point value using a 32-bit single precision floating-point scale. The output is within the range $<-1 ; 1$ ).
MLIB_ConvSc_FLTaf	<a href="#">acc32_t</a>	<a href="#">float_t</a>	<a href="#">float_t</a>	Conversion of a 32-bit accumulator value to a 32-bit single precision floating-point value using a 32-bit single precision floating-point scale. The output is within the range $<-65536.0 ; 65536.0$ ); the result may saturate.

## 2.9.2 Declaration

The available [MLIB\\_ConvSc](#) functions have the following declarations:

```

frac16_t MLIB_ConvSc_F16ff(float_t fltVal, float_t fltSc)
frac32_t MLIB_ConvSc_F32ff(float_t fltVal, float_t fltSc)
acc32_t MLIB_ConvSc_A32ff(float_t fltVal, float_t fltSc)
float_t MLIB_ConvSc_FLTsf(frac16_t f16Val, float_t fltSc)
float_t MLIB_ConvSc_FLTlf(frac32_t f32Val, float_t fltSc)
float_t MLIB_ConvSc_FLTaf(acc32_t a32Val, float_t fltSc)

```

## 2.9.3 Function use

The use of the [MLIB\\_ConvSc](#) function is shown in the following example:

```

#include "mlib.h"

static frac32_t f32Result;
static float_t fltVal, fltScale;

void main(void)
{
    fltVal = -0.736;          /* fltVal = -0.736 */
    fltScale = 435;           /* Scale is 435 */

    /* f32Result = (frac32_t)((fltVal / fltScale) * 2 ^ 32) */
    f32Result = MLIB_ConvSc_F32ff(fltVal, fltScale);
}

```

## 2.10 MLIB\_Div

The [MLIB\\_Div](#) functions return the fractional division of the numerator and denominator. The function does not saturate the output. See the following equation:

$$\text{MLIB\_Div}(a, b) = \begin{cases} \max, & a \geq 0 \wedge b = 0 \vee a \leq -0 \wedge b = -0 \\ \min, & a \leq -0 \wedge b = 0 \vee a \geq 0 \wedge b = -0 \\ \frac{a}{b}, & \text{else} \end{cases}$$

**Equation 7. Algorithm formula**

### 2.10.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range <-1 ; 1). The function is only defined for: |nominator| < |denominator|. The function returns undefined results out of this condition.

- Accumulator output - the output is the accumulator type, where the result may be out of the range <-1 ; 1).
- Floating-point output - the output is a floating-point number; the result is within the full range.

The available versions of the [MLIB\\_Div](#) function are shown in the following table:

**Table 2-10. Function versions**

Function name	Input type		Result type	Description
	Num.	Denom.		
MLIB_Div_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	Division of a 16-bit fractional numerator and denominator. The output is within the range <-1 ; 1).
MLIB_Div_F16ls	<a href="#">frac32_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	Division of a 32-bit fractional numerator by a 16-bit fractional denominator; the output is a 16-bit fractional result. The output is within the range <-1 ; 1).
MLIB_Div_F16ll	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac16_t</a>	Division of a 32-bit fractional numerator and denominator; the output is a 16-bit fractional result. The output is within the range <-1 ; 1).
MLIB_Div_F32ls	<a href="#">frac32_t</a>	<a href="#">frac16_t</a>	<a href="#">frac32_t</a>	Division of a 32-bit fractional numerator by a 16-bit fractional denominator; the output is a 32-bit fractional result. The output is within the range <-1 ; 1).
MLIB_Div_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	Division of a 32-bit fractional numerator and denominator. The output is within the range <-1 ; 1).
MLIB_Div_A32ss	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">acc32_t</a>	Division of a 16-bit fractional numerator and denominator; the output is a 32-bit accumulator result. The output may be out of the range <-1 ; 1).
MLIB_Div_A32ls	<a href="#">frac32_t</a>	<a href="#">frac16_t</a>	<a href="#">acc32_t</a>	Division of a 32-bit fractional numerator by a 16-bit fractional denominator; the output is a 32-bit accumulator result. The output may be out of the range <-1 ; 1).
MLIB_Div_A32ll	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">acc32_t</a>	Division of a 32-bit fractional numerator and denominator; the output is a 32-bit accumulator result. The output may be out of the range <-1 ; 1).
MLIB_Div_A32as	<a href="#">acc32_t</a>	<a href="#">frac16_t</a>	<a href="#">acc32_t</a>	Division of a 32-bit accumulator numerator by a 16-bit fractional denominator; the output is a 32-bit accumulator result. The output may be out of the range <-1 ; 1).
MLIB_Div_FLT	<a href="#">float_t</a>	<a href="#">float_t</a>	<a href="#">float_t</a>	Division of a 32-bit single precision floating-point numerator and denominator. The output is within the full range.

## 2.10.2 Declaration

The available [MLIB\\_Div](#) functions have the following declarations:

```

frac16\_t MLIB_Div_F16(frac16\_t f16Num, frac16\_t f16Denom)
frac16\_t MLIB_Div_F16ls(frac32\_t f32Num, frac16\_t f16Denom)
frac16\_t MLIB_Div_F16ll(frac32\_t f32Num, frac32\_t f32Denom)
frac32\_t MLIB_Div_F32ls(frac32\_t f32Num, frac16\_t f16Denom)
frac32\_t MLIB_Div_F32(frac32\_t f32Num, frac32\_t f32Denom)
acc32\_t MLIB_Div_A32ss(frac16\_t f16Num, frac16\_t f16Denom)
acc32\_t MLIB_Div_A32ls(frac32\_t f32Num, frac16\_t f16Denom)

```

```

acc32_t MLIB_Div_A32l1(frac32_t f32Num, frac32_t f32Denom)
acc32_t MLIB_Div_A32as(acc32_t a32Num, frac16_t f16Denom)
float_t MLIB_Div_FLT(float_t fltNum, float_t fltDenom)

```

### 2.10.3 Function use

The use of the [MLIB\\_Div](#) function is shown in the following example:

```

#include "mlib.h"

static frac32_t f32Num, f32Result;
static frac16_t f16Denom;

void main(void)
{
    f32Num = FRAC32(0.2);          /* f32Num = 0.2 */
    f16Denom = FRAC16(-0.495);     /* f16Denom = -0.495 */

    /* f32Result = f32Num / f16Denom */
    f32Result = MLIB_Div_F32ls(f32Num, f16Denom);
}

```

## 2.11 MLIB\_DivSat

The [MLIB\\_DivSat](#) functions return the fractional division of the numerator and denominator. The function saturates the output. See the following equation:

$$\text{MLIB\_DivSat}(a, b) = \begin{cases} \max, & \frac{a}{b} > \max \vee a \geq 0 \wedge b = 0 \\ \min, & \frac{a}{b} < \min \vee a < 0 \wedge b = 0 \\ \frac{a}{b}, & \text{else} \end{cases}$$

**Equation 8. Algorithm formula**

### 2.11.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range <-1 ; 1). The result may saturate.
- Accumulator output - the output is the accumulator type, where the result may be out of the range <-1 ; 1).

The available versions of the [MLIB\\_DivSat](#) function are shown in the following table:

**Table 2-11. Function versions**

Function name	Input type		Result type	Description
	Num.	Denom.		
MLIB_DivSat_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	Division of a 16-bit fractional numerator and denominator. The output is within the range <-1 ; 1).
MLIB_DivSat_F16ls	<a href="#">frac32_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	Division of a 32-bit fractional numerator by a 16-bit fractional denominator; the output is a 16-bit fractional result. The output is within the range <-1 ; 1).
MLIB_DivSat_F16ll	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac16_t</a>	Division of a 32-bit fractional numerator and denominator; the output is a 16-bit fractional result. The output is within the range <-1 ; 1).
MLIB_DivSat_F32ls	<a href="#">frac32_t</a>	<a href="#">frac16_t</a>	<a href="#">frac32_t</a>	Division of a 32-bit fractional numerator by a 16-bit fractional denominator; the output is a 32-bit fractional result. The output is within the range <-1 ; 1).
MLIB_DivSat_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	Division of a 32-bit fractional numerator and denominator. The output is within the range <-1 ; 1).
MLIB_DivSat_A32as	<a href="#">acc32_t</a>	<a href="#">frac16_t</a>	<a href="#">acc32_t</a>	Division of a 32-bit accumulator numerator by a 16-bit fractional denominator; the output is a 32-bit accumulator result. The output may be out of the range <-1 ; 1).

## 2.11.2 Declaration

The available [MLIB\\_DivSat](#) functions have the following declarations:

```

frac16\_t MLIB_DivSat_F16(frac16\_t f16Num, frac16\_t f16Denom)
frac16\_t MLIB_DivSat_F16ls(frac32\_t f32Num, frac16\_t f16Denom)
frac16\_t MLIB_DivSat_F16ll(frac32\_t f32Num, frac32\_t f32Denom)
frac32\_t MLIB_DivSat_F32ls(frac32\_t f32Num, frac16\_t f16Denom)
frac32\_t MLIB_DivSat_F32(frac32\_t f32Num, frac32\_t f32Denom)
acc32\_t MLIB_DivSat_A32as(acc32\_t a32Num, frac16\_t f16Denom)

```

## 2.11.3 Function use

The use of the [MLIB\\_DivSat](#) function is shown in the following example:

```

#include "mlib.h"

static frac32\_t f32Num, f32Denom, f32Result;

void main(void)
{
    f32Num = FRAC32(0.4);           /* f32Num = 0.4 */
    f32Denom = FRAC32(-0.02);       /* f32Denom = -0.02 */

    /* f32Result = f32Num / f32Denom */
}

```

```
f32Result = MLIB_DivSat_F32(f32Num, f32Denom);
}
```

## 2.12 MLIB\_Div1Q

The [MLIB\\_Div1Q](#) functions return the single-quadrant fractional division of the numerator and denominator. The numerator and denominator must be non-negative numbers, otherwise the function returns undefined results. The function does not saturate the output. See the following equation:

$$\text{MLIB\_Div1Q}(a, b) = \begin{cases} \max, & a \geq 0 \wedge b = 0 \\ \frac{a}{b}, & a \geq 0 \wedge b > 0 \end{cases}$$

**Equation 9. Algorithm formula**

### 2.12.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range  $<0 ; 1$ ). The function is only defined for: nominator  $<$  denominator, and both are non-negative. The function returns undefined results out of this condition.
- Accumulator output - the output is the accumulator type, where the result is greater than or equal to 0.

The available versions of the [MLIB\\_Div1Q](#) function are shown in the following table:

**Table 2-12. Function versions**

Function name	Input type		Result type	Description
	Num.	Denom.		
MLIB_Div1Q_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	Division of a non-negative 16-bit fractional numerator and denominator. The output is within the range $<0 ; 1$ ).
MLIB_Div1Q_F16ls	<a href="#">frac32_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	Division of a non-negative 32-bit fractional numerator by a non-negative 16-bit fractional denominator; the output is a non-negative 16-bit fractional result. The output is within the range $<0 ; 1$ ).
MLIB_Div1Q_F16ll	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac16_t</a>	Division of a non-negative 32-bit fractional numerator and denominator; the output is a non-negative 16-bit fractional result. The output is within the range $<0 ; 1$ ).
MLIB_Div1Q_F32ls	<a href="#">frac32_t</a>	<a href="#">frac16_t</a>	<a href="#">frac32_t</a>	Division of a non-negative 32-bit fractional numerator by a non-negative 16-bit fractional denominator; the output is a non-negative 32-bit fractional result. The output is within the range $<0 ; 1$ ).

*Table continues on the next page...*

**Table 2-12. Function versions (continued)**

Function name	Input type		Result type	Description
	Num.	Denom.		
MLIB_Div1Q_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	Division of a non-negative 32-bit fractional numerator and denominator. The output is within the range <0 ; 1).
MLIB_Div1Q_A32ss	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">acc32_t</a>	Division of a non-negative 16-bit fractional numerator and denominator; the output is a non-negative 32-bit accumulator result. The output is greater than or equal to 0.
MLIB_Div1Q_A32ls	<a href="#">frac32_t</a>	<a href="#">frac16_t</a>	<a href="#">acc32_t</a>	Division of a non-negative 32-bit fractional numerator by a non-negative 16-bit fractional denominator; the output is a non-negative 32-bit accumulator result. The output is greater than or equal to 0.
MLIB_Div1Q_A32ll	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">acc32_t</a>	Division of a non-negative 32-bit fractional numerator and denominator; the output is a non-negative 32-bit accumulator result. The output is greater than or equal to 0.
MLIB_Div1Q_A32as	<a href="#">acc32_t</a>	<a href="#">frac16_t</a>	<a href="#">acc32_t</a>	Division of a non-negative 32-bit accumulator numerator by a non-negative 16-bit fractional denominator; the output is a 32-bit accumulator result. The output is greater than or equal to 0.

## 2.12.2 Declaration

The available [MLIB\\_Div1Q](#) functions have the following declarations:

```

frac16\_t MLIB_Div1Q_F16(frac16\_t f16Num, frac16\_t f16Denom)
frac16\_t MLIB_Div1Q_F16ls(frac32\_t f32Num, frac16\_t f16Denom)
frac16\_t MLIB_Div1Q_F16ll(frac32\_t f32Num, frac32\_t f32Denom)
frac32\_t MLIB_Div1Q_F32ls(frac32\_t f32Num, frac16\_t f16Denom)
frac32\_t MLIB_Div1Q_F32(frac32\_t f32Num, frac32\_t f32Denom)
acc32\_t MLIB_Div1Q_A32ss(frac16\_t f16Num, frac16\_t f16Denom)
acc32\_t MLIB_Div1Q_A32ls(frac32\_t f32Num, frac16\_t f16Denom)
acc32\_t MLIB_Div1Q_A32ll(frac32\_t f32Num, frac32\_t f32Denom)
acc32\_t MLIB_Div1Q_A32as(acc32\_t a32Num, frac16\_t f16Denom)

```

## 2.12.3 Function use

The use of the [MLIB\\_Div1Q](#) function is shown in the following example:

```

#include "mlib.h"

static frac32\_t f32Num, f32Denom, f32Result;

void main(void)
{
    f32Num = FRAC32(0.2);           /* f32Num = 0.2 */
    f32Denom = FRAC32(0.865);       /* f32Denom = 0.865 */

    /* f32Result = f32Num / f32Denom */
    f32Result = MLIB_Div1Q_F32(f32Num, f32Denom);
}

```



## 2.13 MLIB\_Div1QSat

The [MLIB\\_Div1QSat](#) functions return the fractional division of the numerator and denominator. The numerator and denominator must be non-negative numbers. The function saturates the output. See the following equation:

$$\text{MLIB\_Div1QSat}(a, b) = \begin{cases} \max, & \frac{a}{b} > \max \wedge a \geq 0 \wedge b \geq 0 \\ \frac{a}{b}, & a \geq 0 \wedge b > 0 \end{cases}$$

**Equation 10. Algorithm formula**

### 2.13.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range <0 ; 1). The result may saturate.
- Accumulator output - the output is the accumulator type, where the result is greater than or equal to 0.

The available versions of the [MLIB\\_Div1QSat](#) function are shown in the following table:

**Table 2-13. Function versions**

Function name	Input type		Result type	Description
	Num.	Denom.		
MLIB_Div1QSat_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	Division of a non-negative 16-bit fractional numerator and denominator. The output is within the range <0 ; 1).
MLIB_Div1QSat_F16ls	<a href="#">frac32_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	Division of a non-negative 32-bit fractional numerator by a non-negative 16-bit fractional denominator; the output is a non-negative 16-bit fractional result. The output is within the range <0 ; 1).
MLIB_Div1QSat_F16ll	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac16_t</a>	Division of a non-negative 32-bit fractional numerator and denominator; the output is a non-negative 16-bit fractional result. The output is within the range <0 ; 1).
MLIB_Div1QSat_F32ls	<a href="#">frac32_t</a>	<a href="#">frac16_t</a>	<a href="#">frac32_t</a>	Division of a non-negative 32-bit fractional numerator by a non-negative 16-bit fractional denominator; the output is a non-negative 32-bit fractional result. The output is within the range <0 ; 1).
MLIB_Div1QSat_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	Division of a non-negative 32-bit fractional numerator and denominator. The output is within the range <0 ; 1).
MLIB_Div1QSat_A32as	<a href="#">acc32_t</a>	<a href="#">frac16_t</a>	<a href="#">acc32_t</a>	Division of a non-negative 32-bit accumulator numerator by a non-negative 16-bit fractional denominator; the output is a 32-bit accumulator result. The output is greater than or equal to 0.

## 2.13.2 Declaration

The available [MLIB\\_Div1QSat](#) functions have the following declarations:

```
frac16_t MLIB_Div1QSat_F16(frac16_t f16Num, frac16_t f16Denom)
frac16_t MLIB_Div1QSat_F16ls(frac32_t f32Num, frac16_t f16Denom)
frac16_t MLIB_Div1QSat_F16ll(frac32_t f32Num, frac32_t f32Denom)
frac32_t MLIB_Div1QSat_F32ls(frac32_t f32Num, frac16_t f16Denom)
frac32_t MLIB_Div1QSat_F32(frac32_t f32Num, frac32_t f32Denom)
acc32_t MLIB_Div1QSat_A32as(acc32_t a32Num, frac16_t f16Denom)
```

## 2.13.3 Function use

The use of the [MLIB\\_Div1QSat](#) function is shown in the following example:

```
#include "mlib.h"

static frac32_t f32Num, f32Result;
static frac16_t f16Denom;

void main(void)
{
    f32Num = FRAC32(0.02);          /* f32Num = 0.02 */
    f16Denom = FRAC16(0.4);         /* f16Denom = 0.4 */

    /* f32Result = f32Num / f16Denom */
    f32Result = MLIB_Div1QSat_F32ls(f32Num, f16Denom);
}
```

## 2.14 MLIB\_Log2

The [MLIB\\_Log2](#) functions return the binary logarithm of the input. See the following equation:

$$\text{MLIB\_Log2}(x) = \begin{cases} 0, & x \leq 1 \\ \text{Log}_2(x), & \text{else} \end{cases}$$

**Equation 11. Algorithm formula**

### 2.14.1 Available versions

This function is available in the following versions:

- Unsigned integer output - the output is the unsigned integer result.

The available versions of the [MLIB\\_Log2](#) function are shown in the following table.

**Table 2-14. Function versions**

Function name	Input type	Result type	Description
MLIB_Log2_U16	<a href="#">uint16_t</a>	<a href="#">uint16_t</a>	Binary logarithm of a 16-bit unsigned integer value. The output is greater than or equal to 0.

## 2.14.2 Declaration

The available [MLIB\\_Log2](#) functions have the following declarations:

```
uint16\_t MLIB_Log2_U16(uint16\_t u16Val)
```

## 2.14.3 Function use

The use of the [MLIB\\_Log2](#) function is shown in the following example:

```
#include "mlib.h"

static uint16\_t u16Result, u16Val;

void main(void)
{
    u16Val = 5;                /* u16Val = 5 */

    /* u16Result = log2(u16Val) */
    u16Result = MLIB_Log2_U16(u16Val);
}
```

## 2.15 MLIB\_Mac

The [MLIB\\_Mac](#) functions return the sum of the input accumulator, and the fractional product of two multiplicands. The function does not saturate the output. See the following equation:

$$\text{MLIB\_Mac}(a, b, c) = a + b \cdot c$$

**Equation 12. Algorithm formula**

## 2.15.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range  $<-1 ; 1$ ). The result may overflow.
- Accumulator output with mixed inputs - the output is the accumulator type, where the result can be out of the range  $<-1 ; 1$ ). The accumulator is the accumulator type, the multiplicands are the fractional types. The result may overflow.
- Floating-point output - the output is a floating-point number; the result is within the full range.

The available versions of the [MLIB\\_Mac](#) function are shown in the following table.

**Table 2-15. Function versions**

Function name	Input type			Result type	Description
	Accum.	Mult. 1	Mult. 2		
MLIB_Mac_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	The upper 16-bit portion [16..31] of the fractional product (of two 16-bit fractional multiplicands) is added to a 16-bit fractional accumulator. The output is within the range $<-1 ; 1$ ).
MLIB_Mac_F32lss	<a href="#">frac32_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac32_t</a>	The 32-bit fractional product (of two 16-bit fractional multiplicands) is added to a 32-bit fractional accumulator. The output is within the range $<-1 ; 1$ ).
MLIB_Mac_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	The upper 32-bit portion [32..63] of the fractional product (of two 32-bit fractional multiplicands) is added to a 32-bit fractional accumulator. The output is within the range $<-1 ; 1$ ).
MLIB_Mac_A32ass	<a href="#">acc32_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">acc32_t</a>	The upper 16-bit portion [16..31] of the fractional product (of two 16-bit fractional multiplicands) is added to a 32-bit accumulator. The output may be out of the range $<-1 ; 1$ ).
MLIB_Mac_FLT	<a href="#">float_t</a>	<a href="#">float_t</a>	<a href="#">float_t</a>	<a href="#">float_t</a>	The product (of two 32-bit single-point floating-point multiplicands) is added to a single-point floating-point accumulator. The output is within the full range.

## 2.15.2 Declaration

The available [MLIB\\_Mac](#) functions have the following declarations:

```

frac16_t MLIB_Mac_F16(frac16_t f16Accum, frac16_t f16Mult1, frac16_t f16Mult2)
frac32_t MLIB_Mac_F32lss(frac32_t f32Accum, frac16_t f16Mult1, frac16_t f16Mult2)
frac32_t MLIB_Mac_F32(frac32_t f32Accum, frac32_t f32Mult1, frac32_t f32Mult2)
acc32_t MLIB_Mac_A32ass(acc32_t a32Accum, frac16_t f16Mult1, frac16_t f16Mult2)
float_t MLIB_Mac_FLT(float_t fltAccum, float_t fltMult1, float_t fltMult2)

```

## 2.15.3 Function use

The use of the [MLIB\\_Mac](#) function is shown in the following example:

```
#include "mlib.h"

static frac32_t f32Accum, f32Result;
static frac16_t f16Mult1, f16Mult2;

void main(void)
{
    f32Accum = FRAC32(0.3);          /* f32Accum = 0.3 */
    f16Mult1 = FRAC16(0.1);          /* f16Mult1 = 0.1 */
    f16Mult2 = FRAC16(-0.2);         /* f16Mult2 = -0.2 */

    /* f32Result = f32Accum + f16Mult1 * f16Mult2 */
    f32Result = MLIB_Mac_F32lss(f32Accum, f16Mult1, f16Mult2);
}
```

## 2.16 MLIB\_MacSat

The [MLIB\\_MacSat](#) functions return the sum of the input accumulator and the fractional product of two multiplicands. The function saturates the output. See the following equation:

$$\text{MLIB\_MacSat}(a, b, c) = \begin{cases} 1, & a+b \cdot c > 1 \\ -1, & a+b \cdot c < -1 \\ a+b \cdot c, & \text{else} \end{cases}$$

**Equation 13. Algorithm formula**

### 2.16.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range <-1 ; 1). The result may saturate.

The available versions of the [MLIB\\_MacSat](#) function are shown in the following table.

**Table 2-16. Function versions**

Function name	Input type			Result type	Description
	Accum.	Mult. 1	Mult. 2		
MLIB_MacSat_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	The upper 16-bit portion [16..31] of the fractional product (of two 16-bit fractional multiplicands) is added to a 16-bit fractional accumulator. The output is within the range <-1 ; 1).
MLIB_MacSat_F32lss	<a href="#">frac32_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac32_t</a>	The 32-bit fractional product (of two 16-bit fractional multiplicands) is added to a 32-bit fractional accumulator. The output is within the range <-1 ; 1).
MLIB_MacSat_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	The upper 32-bit portion [32..63] of the fractional product (of two 32-bit fractional multiplicands) is added to a 32-bit fractional accumulator. The output is within the range <-1 ; 1).

## 2.16.2 Declaration

The available [MLIB\\_MacSat](#) functions have the following declarations:

```
frac16\_t MLIB_MacSat_F16(frac16\_t f16Accum, frac16\_t f16Mult1, frac16\_t f16Mult2)
frac32\_t MLIB_MacSat_F32lss(frac32\_t f32Accum, frac16\_t f16Mult1, frac16\_t f16Mult2)
frac32\_t MLIB_MacSat_F32(frac32\_t f32Accum, frac32\_t f32Mult1, frac32\_t f32Mult2)
```

## 2.16.3 Function use

The use of the [MLIB\\_MacSat](#) function is shown in the following example:

```
#include "mlib.h"

static frac16\_t f16Mult1, f16Mult2;
static frac32\_t f32Accum, f32Result;

void main(void)
{
    f32Accum = FRAC32(-0.7);           /* f32Accum = -0.7 */
    f16Mult1 = FRAC16(-1.0);          /* f16Mult1 = -1.0 */
    f16Mult2 = FRAC16(0.8);           /* f16Mult2 = 0.8 */

    /* f32Result = sat(f32Accum + f16Mult1 * f16Mult2) */
    f32Result = MLIB_MacSat_F32lss(f32Accum, f16Mult1, f16Mult2);
}
```

## 2.17 MLIB\_MacRnd

The [MLIB\\_MacRnd](#) functions return the sum of the input accumulator and the rounded fractional product of two multiplicands. The round method is the round to nearest. The function does not saturate the output. See the following equation:

$$\text{MLIB\_MacRnd}(a, b, c) = a + \text{round}(b \cdot c)$$

**Equation 14. Algorithm formula**

### 2.17.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range  $<-1 ; 1$ ). The result may overflow.
- Accumulator output with mixed inputs - the output is the accumulator type where the result can be out of the range  $<-1 ; 1$ ). The accumulator is the accumulator type, the multiplicands are the fractional types. The result may overflow.

The available versions of the [MLIB\\_MacRnd](#) function are shown in the following table.

**Table 2-17. Function versions**

Function name	Input type			Result type	Description
	Accum.	Mult. 1	Mult. 2		
MLIB_MacRnd_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	The fractional product (of two 16-bit fractional multiplicands), rounded to the upper 16 bits, is added to a 16-bit fractional accumulator. The output is within the range $<-1 ; 1$ ).
MLIB_MacRnd_F32lls	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac16_t</a>	<a href="#">frac32_t</a>	The fractional product (of a 32-bit and 16-bit fractional multiplicand), rounded to the upper 32 bits [16..48], is added to a 32-bit fractional accumulator. The output is within the range $<-1 ; 1$ ).
MLIB_MacRnd_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	The fractional product (of two 32-bit fractional multiplicands), rounded to the upper 32 bits [32..63], is added to a 32-bit fractional accumulator. The output is within the range $<-1 ; 1$ ).
MLIB_MacRnd_A32ass	<a href="#">acc32_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">acc32_t</a>	The fractional product (of two 16-bit fractional multiplicands), rounded to the upper 16 bits [16..31], is added to a 32-bit accumulator. The output may be out of the range $<-1 ; 1$ ).

## 2.17.2 Declaration

The available [MLIB\\_MacRnd](#) functions have the following declarations:

```
frac16_t MLIB_MacRnd_F16(frac16_t f16Accum, frac16_t f16Mult1, frac16_t f16Mult2)
frac32_t MLIB_MacRnd_F32lls(frac32_t f32Accum, frac32_t f32Mult1, frac16_t f16Mult2)
frac32_t MLIB_MacRnd_F32(frac32_t f32Accum, frac32_t f32Mult1, frac32_t f32Mult2)
acc32_t MLIB_MacRnd_A32ass(acc32_t a32Accum, frac16_t f16Mult1, frac16_t f16Mult2)
```

## 2.17.3 Function use

The use of the [MLIB\\_MacRnd](#) function is shown in the following example:

```
#include "mlib.h"

static frac16_t f16Accum, f16Mult1, f16Mult2, f16Result;

void main(void)
{
    f16Accum = FRAC16(0.3);           /* f16Accum = 0.3 */
    f16Mult1 = FRAC16(0.1);           /* f16Mult1 = 0.1 */
    f16Mult2 = FRAC16(-0.2);          /* f16Mult2 = -0.2 */

    /* f16Result = round(f16Accum + f16Mult1 * f16Mult2) */
    f16Result = MLIB_MacRnd_F16(f16Accum, f16Mult1, f16Mult2);
}
```

## 2.18 MLIB\_MacRndSat

The [MLIB\\_MacRndSat](#) functions return the sum of the input accumulator and the rounded fractional product of two multiplicands. The round method is the round to nearest. The function saturates the output. See the following equation:

$$\text{MLIB\_MacRndSat}(a, b, c) = \begin{cases} 1, & a + \text{round}(b \cdot c) > 1 \\ -1, & a + \text{round}(b \cdot c) < -1 \\ a + \text{round}(b \cdot c), & \text{else} \end{cases}$$

**Equation 15. Algorithm formula**

### 2.18.1 Available versions

This function is available in the following versions:



- Fractional output - the output is the fractional portion of the result; the result is within the range  $<-1 ; 1$ ). The result may saturate.

The available versions of the [MLIB\\_MacRndSat](#) function are shown in the following table.

**Table 2-18. Function versions**

Function name	Input type			Result type	Description
	Accum.	Mult. 1	Mult. 2		
MLIB_MacRndSat_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	The fractional product (of two 16-bit fractional multiplicands), rounded to the upper 16 bits, is added to a 16-bit fractional accumulator. The output is within the range $<-1 ; 1$ ).
MLIB_MacRndSat_F32lls	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac16_t</a>	<a href="#">frac32_t</a>	The fractional product (of a 32-bit and 16-bit fractional multiplicands), rounded to the upper 32 bits [16..48], is added to a 32-bit fractional accumulator. The output is within the range $<-1 ; 1$ ).
MLIB_MacRndSat_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	The fractional product (of two 32-bit fractional multiplicands), rounded to the upper 32 bits [32..63], is added to a 32-bit fractional accumulator. The output is within the range $<-1 ; 1$ ).

## 2.18.2 Declaration

The available [MLIB\\_MacRndSat](#) functions have the following declarations:

```
frac16_t MLIB_MacRndSat_F16(frac16_t f16Accum, frac16_t f16Mult1, frac16_t f16Mult2)
frac32_t MLIB_MacRndSat_F32lls(frac32_t f32Accum, frac32_t f32Mult1, frac16_t f16Mult2)
frac32_t MLIB_MacRndSat_F32(frac32_t f32Accum, frac32_t f32Mult1, frac32_t f32Mult2)
```

## 2.18.3 Function use

The use of the [MLIB\\_MacRndSat](#) function is shown in the following example:

```
#include "mlib.h"

static frac32_t f32Accum, f32Mult1, f32Mult2, f32Result;

void main(void)
{
    f32Accum = FRAC32(-0.7);          /* f32Accum = -0.7 */
    f32Mult1 = FRAC32(-1.0);          /* f32Mult1 = -1.0 */
    f32Mult2 = FRAC32(0.8);           /* f32Mult2 = 0.8 */

    /* f32Result = sat(round(f32Accum + f32Mult1 * f32Mult2)) */
```

```

    f32Result = MLIB_MacRndSat_F32(f32Accum, f32Mult1, f32Mult2);
}

```

## 2.19 MLIB\_Mac4

The [MLIB\\_Mac4](#) functions return the sum of two products of two pairs of multiplicands. The function does not saturate the output. See the following equation:

$$\text{MLIB\_Mac4}(a, b, c, d) = a \cdot b + c \cdot d$$

**Equation 16. Algorithm formula**

### 2.19.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range <-1 ; 1). The result may overflow.
- Floating-point output - the output is a floating-point number; the result is within the full range.

The available versions of the [MLIB\\_Mac4](#) function are shown in the following table.

**Table 2-19. Function versions**

Function name	Input type				Result type	Description
	Product 1		Product 2			
	Mult. 1	Mult. 2	Mult. 1	Mult. 2		
MLIB_Mac4_F32ssss	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac32_t</a>	Addition of two 32-bit fractional products (of two 16-bit fractional multiplicands). The output is within the range <-1 ; 1).
MLIB_Mac4_FLT	<a href="#">float_t</a>	<a href="#">float_t</a>	<a href="#">float_t</a>	<a href="#">float_t</a>	<a href="#">float_t</a>	Addition of two 32-bit single-point floating-point products (of two 32-bit single-point floating-point multiplicands). The output is within the full range.

### 2.19.2 Declaration

The available [MLIB\\_Mac4](#) functions have the following declarations:

```
frac32_t MLIB_Mac4_F32ssss(frac16_t f16Add1Mult1, frac16_t f16Add1Mult2, frac16_t
f16Add2Mult1, frac16_t f16Add2Mult2)
float_t MLIB_Mac4_FLT(float_t f1tAdd1Mult1, float_t f1tAdd1Mult2, float_t f1tAdd2Mult1,
float_t f1tAdd2Mult2)
```

### 2.19.3 Function use

The use of the [MLIB\\_Mac4](#) function is shown in the following example:

```
#include "mlib.h"

static frac32_t f32Result;
static frac16_t f16Add1Mult1, f16Add1Mult2, f16Add2Mult1, f16Add2Mult2;

void main(void)
{
    f16Add1Mult1 = FRAC16(0.2);          /* f16Add1Mult1 = 0.2 */
    f16Add1Mult2 = FRAC16(-0.7);         /* f16Add1Mult2 = -0.7 */
    f16Add2Mult1 = FRAC16(0.3);          /* f16Add2Mult1 = 0.3 */
    f16Add2Mult2 = FRAC16(-0.25);        /* f16Add2Mult2 = -0.25 */

    /* f32Result = f16Add1Mult1 * f16Add1Mult2 + f16Add2Mult1 * f16Add2Mult2 */
    f32Result = MLIB_Mac4_F32ssss(f16Add1Mult1, f16Add1Mult2, f16Add2Mult1, f16Add2Mult2);
}
```

## 2.20 MLIB\_Mac4Sat

The [MLIB\\_Mac4Sat](#) functions return the sum of two products of two pairs of multiplicands. The function saturates the output. See the following equation:

$$\text{MLIB\_Mac4Sat}(a, b, c, d) = \begin{cases} 1, & a \cdot b + c \cdot d > 1 \\ -1, & a \cdot b + c \cdot d < -1 \\ a \cdot b + c \cdot d, & \text{else} \end{cases}$$

**Equation 17. Algorithm formula**

### 2.20.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range <-1 ; 1). The result may saturate.

The available versions of the [MLIB\\_Mac4Sat](#) function are shown in the following table.

**Table 2-20. Function versions**

Function name	Input type				Result type	Description
	Product 1		Product 2			
	Mult. 1	Mult. 2	Mult. 1	Mult. 2		
MLIB_Mac4Sat_F32ssss	frac16_t	frac16_t	frac16_t	frac16_t	frac32_t	Addition of two 32-bit fractional products (of two 16-bit fractional multiplicands). The output is within the range <-1 ; 1).

## 2.20.2 Declaration

The available [MLIB\\_Mac4Sat](#) functions have the following declarations:

```
frac32\_t MLIB_Mac4Sat_F32ssss(frac16\_t f16Add1Mult1, frac16\_t f16Add1Mult2, frac16\_t f16Add2Mult1, frac16\_t f16Add2Mult2)
```

## 2.20.3 Function use

The use of the [MLIB\\_Mac4Sat](#) function is shown in the following example:

```
#include "mlib.h"

static frac32\_t f32Result;
static frac16\_t f16Add1Mult1, f16Add1Mult2, f16Add2Mult1, f16Add2Mult2;

void main(void)
{
    f16Add1Mult1 = FRAC16(-1.0);          /* f16Add1Mult1 = -1.0 */
    f16Add1Mult2 = FRAC16(-0.9);          /* f16Add1Mult2 = -0.9 */
    f16Add2Mult1 = FRAC16(0.8);           /* f16Add2Mult1 = 0.8 */
    f16Add2Mult2 = FRAC16(0.7);           /* f16Add2Mult2 = 0.7 */

    /* f32Result = sat(f16Add1Mult1 * f16Add1Mult2 + f16Add2Mult1 * f16Add2Mult2) */
    f32Result = MLIB_Mac4Sat_F32ssss(f16Add1Mult1, f16Add1Mult2, f16Add2Mult1, f16Add2Mult2);
}
```

## 2.21 MLIB\_Mac4Rnd

The [MLIB\\_Mac4Rnd](#) functions return the rounded sum of two products of two pairs of multiplicands. The round method is the round to nearest. The function does not saturate the output. See the following equation:

$$\text{MLIB\_Mac4Rnd}(a, b, c, d) = \text{round}(a \cdot b + c \cdot d)$$

**Equation 18. Algorithm formula**

## 2.21.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range  $<-1 ; 1$ ). The result may overflow.

The available versions of the [MLIB\\_Mac4Rnd](#) function are shown in the following table.

**Table 2-21. Function versions**

Function name	Input type				Result type	Description
	Product 1		Product 2			
	Mult. 1	Mult. 2	Mult. 1	Mult. 2		
MLIB_Mac4Rnd_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	Addition of two 16-bit fractional products (of two 16-bit fractional multiplicands), rounded to the upper 16 bits. The output is within the range <-1 ; 1).
MLIB_Mac4Rnd_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	Addition of two 32-bit fractional products (of two 32-bit fractional multiplicands), rounded to the upper 32 bits. The output is within the range <-1 ; 1).

## 2.21.2 Declaration

The available [MLIB\\_Mac4Rnd](#) functions have the following declarations:

```

frac16\_t MLIB_Mac4Rnd_F16(frac16\_t f16Add1Mult1, frac16\_t f16Add1Mult2, frac16\_t
f16Add2Mult1, frac16\_t f16Add2Mult2)
frac32\_t MLIB_Mac4Rnd_F32(frac32\_t f32Add1Mult1, frac32\_t f32Add1Mult2, frac32\_t
f32Add2Mult1, frac32\_t f32Add2Mult2)

```

## 2.21.3 Function use

The use of the [MLIB\\_Mac4Rnd](#) function is shown in the following example:

```

#include "mlib.h"

static frac16\_t f16Result, f16Add1Mult1, f16Add1Mult2, f16Add2Mult1, f16Add2Mult2;

void main(void)

```

```

{
    f16Add1Mult1 = FRAC16(0.256);          /* f16Add1Mult1 = 0.256 */
    f16Add1Mult2 = FRAC16(-0.724);         /* f16Add1Mult2 = -0.724 */
    f16Add2Mult1 = FRAC16(0.365);          /* f16Add2Mult1 = 0.365 */
    f16Add2Mult2 = FRAC16(-0.25);          /* f16Add2Mult2 = -0.25 */

    /* f16Result = round(f16Add1Mult1 * f16Add1Mult2 + f16Add2Mult1 * f16Add2Mult2) */
    f16Result = MLIB_Mac4Rnd_F16(f16Add1Mult1, f16Add1Mult2, f16Add2Mult1, f16Add2Mult2);
}

```

## 2.22 MLIB\_Mac4RndSat

The [MLIB\\_Mac4RndSat](#) functions return the rounded sum of two products of two pairs of multiplicands. The round method is the round to nearest. The function saturates the output. See the following equation:

$$\text{MLIB\_Mac4RndSat}(a, b, c, d) = \begin{cases} 1, & \text{round}(a \cdot b + c \cdot d) > 1 \\ -1, & \text{round}(a \cdot b + c \cdot d) < -1 \\ \text{round}(a \cdot b + c \cdot d), & \text{else} \end{cases}$$

**Equation 19. Algorithm formula**

### 2.22.1 Available versions

The function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range <-1 ; 1). The result may saturate.

The available versions of the [MLIB\\_Mac4RndSat](#) function are shown in the following table.

**Table 2-22. Function versions**

Function name	Input type				Result type	Description
	Product 1		Product 2			
	Mult. 1	Mult. 2	Mult. 1	Mult. 2		
MLIB_Mac4RndSat_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	Addition of two 16-bit fractional products (of two 16-bit fractional multiplicands), rounded to the upper 16 bits. The output is within the range <-1 ; 1).
MLIB_Mac4RndSat_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	Addition of two 32-bit fractional products (of two 32-bit fractional multiplicands), rounded to the upper 32 bits. The output is within the range <-1 ; 1).

## 2.22.2 Declaration

The available [MLIB\\_Mac4RndSat](#) functions have the following declarations:

```
frac16_t MLIB_Mac4RndSat_F16(frac16_t f16Add1Mult1, frac16_t f16Add1Mult2, frac16_t
f16Add2Mult1, frac16_t f16Add2Mult2)
frac32_t MLIB_Mac4RndSat_F32(frac32_t f32Add1Mult1, frac32_t f32Add1Mult2, frac32_t
f32Add2Mult1, frac32_t f32Add2Mult2)
```

## 2.22.3 Function use

The use of the [MLIB\\_Mac4RndSat](#) function is shown in the following example:

```
#include "mlib.h"

static frac32_t f32Result, f32Add1Mult1, f32Add1Mult2, f32Add2Mult1, f32Add2Mult2;

void main(void)
{
    f32Add1Mult1 = FRAC32(-1.0);          /* f32Add1Mult1 = -1.0 */
    f32Add1Mult2 = FRAC32(-0.9);          /* f32Add1Mult2 = -0.9 */
    f32Add2Mult1 = FRAC32(0.8);           /* f32Add2Mult1 = 0.8 */
    f32Add2Mult2 = FRAC32(0.7);           /* f32Add2Mult2 = 0.7 */

    /* f32Result = sat(round(f32Add1Mult1 * f32Add1Mult2 + f32Add2Mult1 * f32Add2Mult2)) */
    f32Result = MLIB_Mac4RndSat_F32(f32Add1Mult1, f32Add1Mult2, f32Add2Mult1, f32Add2Mult2);
}
```

## 2.23 MLIB\_Mnac

The [MLIB\\_Mnac](#) functions return the product of two multiplicands minus the input accumulator. The function does not saturate the output. See the following equation:

$$\text{MLIB\_Mnac}(a, b, c) = b \cdot c - a$$

**Equation 20. Algorithm formula**

### 2.23.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range <-1 ; 1). The result may overflow.

- Accumulator output with mixed inputs - the output is the accumulator type, where the result can be out of the range  $<-1 ; 1$ ). The accumulator is the accumulator type, the multiplicands are the fractional types. The result may overflow.
- Floating-point output - the output is a floating-point number; the result is within the full range.

The available versions of the [MLIB\\_Mnac](#) function are shown in the following table.

**Table 2-23. Function versions**

Function name	Input type			Result type	Description
	Accum.	Mult. 1	Mult. 2		
MLIB_Mnac_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	The 16-bit fractional accumulator is subtracted from the upper 16-bit portion [16..31] of the fractional product (of two 16-bit fractional multiplicands). The output is within the range $<-1 ; 1$ ).
MLIB_Mnac_F32lss	<a href="#">frac32_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac32_t</a>	The 32-bit fractional accumulator is subtracted from the 32-bit fractional product (of two 16-bit fractional multiplicands). The output is within the range $<-1 ; 1$ ).
MLIB_Mnac_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	The 32-bit fractional accumulator is subtracted from the upper 32-bit portion [32..63] of the fractional product (of two 32-bit fractional multiplicands). The output is within the range $<-1 ; 1$ ).
MLIB_Mnac_A32ass	<a href="#">acc32_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">acc32_t</a>	The 32-bit accumulator is subtracted from the upper 16-bit portion [16..31] of the fractional product (of two 16-bit fractional multiplicands). The output may be out of the range $<-1 ; 1$ ).
MLIB_Mnac_FLT	<a href="#">float_t</a>	<a href="#">float_t</a>	<a href="#">float_t</a>	<a href="#">float_t</a>	The single-point floating-point accumulator is subtracted from the product (of two 32-bit single-point floating-point multiplicands). The output is within the full range.

## 2.23.2 Declaration

The available [MLIB\\_Mnac](#) functions have the following declarations:

```

frac16\_t MLIB_Mnac_F16(frac16\_t f16Accum, frac16\_t f16Mult1, frac16\_t f16Mult2)
frac32\_t MLIB_Mnac_F32lss(frac32\_t f32Accum, frac16\_t f16Mult1, frac16\_t f16Mult2)
frac32\_t MLIB_Mnac_F32(frac32\_t f32Accum, frac32\_t f32Mult1, frac32\_t f32Mult2)
acc32\_t MLIB_Mnac_A32ass(acc32\_t a32Accum, frac16\_t f16Mult1, frac16\_t f16Mult2)
float\_t MLIB_Mnac_FLT(float\_t fltAccum, float\_t fltMult1, float\_t fltMult2)

```

## 2.23.3 Function use

The use of the [MLIB\\_Mnac](#) function is shown in the following example:



```
#include "mlib.h"

static frac32_t f32Accum, f32Result;
static frac16_t f16Mult1, f16Mult2;

void main(void)
{
    f32Accum = FRAC32(0.3);           /* f32Accum = 0.3 */
    f16Mult1 = FRAC16(0.1);           /* f16Mult1 = 0.1 */
    f16Mult2 = FRAC16(-0.2);          /* f16Mult2 = -0.2 */

    /* f32Result = f16Mult1 * f16Mult2 - f32Accum */
    f32Result = MLIB_Mnac_F32lss(f32Accum, f16Mult1, f16Mult2);
}
```

## 2.24 MLIB\_MnacSat

The [MLIB\\_MnacSat](#) functions return the product of two multiplicands minus the input accumulator. The function saturates the output. See the following equation:

$$\text{MLIB\_MnacSat}(a, b, c) = \begin{cases} 1, & b \cdot c - a > 1 \\ -1, & b \cdot c - a < -1 \\ b \cdot c - a, & \text{else} \end{cases}$$

**Equation 21. Algorithm formula**

### 2.24.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range <-1 ; 1). The result may saturate.

The available versions of the [MLIB\\_MnacSat](#) function are shown in the following table.

**Table 2-24. Function versions**

Function name	Input type			Result type	Description
	Accum.	Mult. 1	Mult. 2		
MLIB_MnacSat_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	The 16-bit fractional accumulator is subtracted from the upper 16-bit portion [16..31] of the fractional product (of two 16-bit fractional multiplicands). The output is within the range <-1 ; 1).
MLIB_MnacSat_F32lss	<a href="#">frac32_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac32_t</a>	The 32-bit fractional accumulator is subtracted from the 32-bit fractional product (of two 16-bit fractional multiplicands). The output is within the range <-1 ; 1).
MLIB_MnacSat_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	The 32-bit fractional accumulator is subtracted from the upper 32-bit portion [32..63] of the fractional product (of two 32-bit fractional multiplicands). The output is within the range <-1 ; 1).

## 2.24.2 Declaration

The available [MLIB\\_MnacSat](#) functions have the following declarations:

```
frac16_t MLIB_MnacSat_F16(frac16_t f16Accum, frac16_t f16Mult1, frac16_t f16Mult2)
frac32_t MLIB_MnacSat_F32lss(frac32_t f32Accum, frac16_t f16Mult1, frac16_t f16Mult2)
frac32_t MLIB_MnacSat_F32(frac32_t f32Accum, frac32_t f32Mult1, frac32_t f32Mult2)
```

## 2.24.3 Function use

The use of the [MLIB\\_MnacSat](#) function is shown in the following example:

```
#include "mlib.h"

static frac32_t f32Accum, f32Result;
static frac16_t f16Mult1, f16Mult2;

void main(void)
{
    f32Accum = FRAC32(0.3);           /* f32Accum = 0.3 */
    f16Mult1 = FRAC16(0.1);          /* f16Mult1 = 0.1 */
    f16Mult2 = FRAC16(-0.2);         /* f16Mult2 = -0.2 */

    /* f32Result = f16Mult1 * f16Mult2 - f32Accum */
    f32Result = MLIB_MnacSat_F32lss(f32Accum, f16Mult1, f16Mult2);
}
```

## 2.25 MLIB\_MnacRnd

The [MLIB\\_MnacRnd](#) functions return the rounded product of two multiplicands minus the input accumulator. The round method is the round to nearest. The function does not saturate the output. See the following equation:

$$\text{MLIB\_MnacRnd}(a, b, c) = \text{round}(b \cdot c) - a$$

**Equation 22. Algorithm formula**

### 2.25.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range  $<-1 ; 1$ ). The result may overflow.
- Accumulator output with mixed inputs - the output is the accumulator type, where the result can be out of the range  $<-1 ; 1$ ). The accumulator is the accumulator type, the multiplicands are the fractional types. The result may overflow.

The available versions of the [MLIB\\_MnacRnd](#) function are shown in the following table.

**Table 2-25. Function versions**

Function name	Input type			Result type	Description
	Accum.	Mult. 1	Mult. 2		
MLIB_MnacRnd_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	The 16-bit fractional accumulator is subtracted from the fractional product (of two 16-bit fractional multiplicands) rounded to the upper 16 bits. The output is within the range $<-1 ; 1$ ).
MLIB_MnacRnd_F32lls	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac16_t</a>	<a href="#">frac32_t</a>	The 32-bit fractional accumulator is subtracted from the fractional product (of a 32-bit and a 16-bit fractional multiplicand) rounded to the upper 32 bits [16..48]. The output is within the range $<-1 ; 1$ ).
MLIB_MnacRnd_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	The 32-bit fractional accumulator is subtracted from the fractional product (of two 32-bit fractional multiplicands) rounded to the upper 32 bits [32..63]. The output is within the range $<-1 ; 1$ ).
MLIB_MnacRnd_A32ass	<a href="#">acc32_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">acc32_t</a>	The 32-bit accumulator is subtracted from the fractional product (of two 16-bit fractional multiplicands) rounded to the upper 16-bits [16..31]. The output may be out of the range $<-1 ; 1$ ).

## 2.25.2 Declaration

The available [MLIB\\_MnacRnd](#) functions have the following declarations:

```

frac16\_t MLIB_MnacRnd_F16(frac16\_t f16Accum, frac16\_t f16Mult1, frac16\_t f16Mult2)
frac32\_t MLIB_MnacRnd_F32lls(frac32\_t f32Accum, frac32\_t f32Mult1, frac16\_t f16Mult2)
frac32\_t MLIB_MnacRnd_F32(frac32\_t f32Accum, frac32\_t f32Mult1, frac32\_t f32Mult2)
acc32\_t MLIB_MnacRnd_A32ass(acc32\_t a32Accum, frac16\_t f16Mult1, frac16\_t f16Mult2)

```

## 2.25.3 Function use

The use of the [MLIB\\_MnacRnd](#) function is shown in the following example:

## MLIB\_MnacRndSat

```
#include "mlib.h"

static frac32_t f32Accum, f32Result, f32Mult1;
static frac16_t f16Mult2;

void main(void)
{
    f32Accum = FRAC32(0.3);           /* f32Accum = 0.3 */
    f32Mult1 = FRAC32(0.4);           /* f32Mult1 = 0.4 */
    f16Mult2 = FRAC16(-0.2);          /* f16Mult2 = -0.2 */

    /* f32Result = round(f32Mult1 * f16Mult2 - f32Accum) */
    f32Result = MLIB_MnacRnd_F32lls(f32Accum, f32Mult1, f16Mult2);
}
```

## 2.26 MLIB\_MnacRndSat

The [MLIB\\_MnacRndSat](#) functions return the rounded product of two multiplicands minus the input accumulator. The round method is the round to nearest. The function saturates the output. See the following equation:

$$\text{MLIB\_MnacRndSat}(a, b, c) = \begin{cases} 1, & \text{round}(b \cdot c) - a > 1 \\ -1, & \text{round}(b \cdot c) - a < -1 \\ \text{round}(b \cdot c) - a, & \text{else} \end{cases}$$

**Equation 23. Algorithm formula**

### 2.26.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range <-1 ; 1). The result may saturate.

The available versions of the [MLIB\\_MnacRndSat](#) function are shown in the following table.

**Table 2-26. Function versions**

Function name	Input type			Result type	Description
	Accum.	Mult. 1	Mult. 2		
MLIB_MnacRndSat_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	The 16-bit fractional accumulator is subtracted from the fractional product (of two 16-bit fractional multiplicands) rounded to the upper 16 bits. The output is within the range <-1 ; 1).
MLIB_MnacRndSat_F32lls	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac16_t</a>	<a href="#">frac32_t</a>	The 32-bit fractional accumulator is subtracted from the fractional product (of a 32-bit and a 16-bit fractional

*Table continues on the next page...*

**Table 2-26. Function versions (continued)**

Function name	Input type			Result type	Description
	Accum.	Mult. 1	Mult. 2		
					multiplicand) rounded to the upper 32 bits [16..48]. The output is within the range <-1 ; 1).
MLIB_MnacRndSat_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	The 32-bit fractional accumulator is subtracted from the fractional product (of two 32-bit fractional multiplicands) rounded to the upper 32 bits [32..63]. The output is within the range <-1 ; 1).

## 2.26.2 Declaration

The available [MLIB\\_MnacRndSat](#) functions have the following declarations:

```

frac16\_t MLIB_MnacRnd_F16(frac16\_t f16Accum, frac16\_t f16Mult1, frac16\_t f16Mult2)
frac32\_t MLIB_MnacRnd_F32lls(frac32\_t f32Accum, frac32\_t f32Mult1, frac16\_t f16Mult2)
frac32\_t MLIB_MnacRnd_F32(frac32\_t f32Accum, frac32\_t f32Mult1, frac32\_t f32Mult2)

```

## 2.26.3 Function use

The use of the [MLIB\\_MnacRndSat](#) function is shown in the following example:

```

#include "mlib.h"

static frac32\_t f32Accum, f32Result, f32Mult1;
static frac16\_t f16Mult2;

void main(void)
{
    f32Accum = FRAC32(0.3);           /* f32Accum = 0.3 */
    f32Mult1 = FRAC32(0.4);           /* f32Mult1 = 0.4 */
    f16Mult2 = FRAC16(-0.2);          /* f16Mult2 = -0.2 */

    /* f32Result = round(f32Mult1 * f16Mult2 - f32Accum) */
    f32Result = MLIB_MnacRndSat_F32lls(f32Accum, f32Mult1, f16Mult2);
}

```

## 2.27 MLIB\_Msu

The [MLIB\\_Msu](#) functions return the fractional product of two multiplicands subtracted from the input accumulator. The function does not saturate the output. See the following equation:

$$\text{MLIB\_Msu}(a, b, c) = a - b \cdot c$$

### Equation 24. Algorithm formula

## 2.27.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range  $<-1 ; 1$ ). The result may overflow.
- Accumulator output with mixed inputs - the output is the accumulator type, where the result can be out of the range  $<-1 ; 1$ ). The accumulator is the accumulator type, the multiplicands are the fractional types. The result may overflow.
- Floating-point output - the output is a floating-point number; the result is within the full range.

The available versions of the [MLIB\\_Msu](#) function are shown in the following table.

**Table 2-27. Function versions**

Function name	Input type			Result type	Description
	Accum.	Mult. 1	Mult. 2		
MLIB_Msu_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	The upper 16-bit portion [16..31] of the fractional product (of two 16-bit fractional multiplicands) is subtracted from a 16-bit fractional accumulator. The output is within the range $<-1 ; 1$ ).
MLIB_Msu_F32lss	<a href="#">frac32_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac32_t</a>	The 32-bit fractional product (of two 16-bit fractional multiplicands) is subtracted from a 32-bit fractional accumulator. The output is within the range $<-1 ; 1$ ).
MLIB_Msu_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	The upper 32-bit portion [32..63] of the fractional product (of two 32-bit fractional multiplicands) is subtracted from a 32-bit fractional accumulator. The output is within the range $<-1 ; 1$ ).
MLIB_Msu_A32ass	<a href="#">acc32_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">acc32_t</a>	The upper 16-bit portion [16..31] of the fractional product (of two 16-bit fractional multiplicands) is subtracted from a 32-bit accumulator. The output may be out of the range $<-1 ; 1$ ).
MLIB_Msu_FLT	<a href="#">float_t</a>	<a href="#">float_t</a>	<a href="#">float_t</a>	<a href="#">float_t</a>	The product (of two 32-bit single-point floating-point multiplicands) is subtracted from a single-point floating-point accumulator. The output is within the full range.

## 2.27.2 Declaration

The available [MLIB\\_Msu](#) functions have the following declarations:

```

frac16_t MLIB_Msu_F16(frac16_t f16Accum, frac16_t f16Mult1, frac16_t f16Mult2)
frac32_t MLIB_Msu_F32lss(frac32_t f32Accum, frac16_t f16Mult1, frac16_t f16Mult2)
frac32_t MLIB_Msu_F32(frac32_t f32Accum, frac32_t f32Mult1, frac32_t f32Mult2)
acc32_t MLIB_Msu_A32ass(acc32_t a32Accum, frac16_t f16Mult1, frac16_t f16Mult2)
float_t MLIB_Msu_FLT(float_t fltAccum, float_t fltMult1, float_t fltMult2)

```

### 2.27.3 Function use

The use of the [MLIB\\_Msu](#) function is shown in the following example:

```

#include "mlib.h"

static acc32_t a32Accum, a32Result;
static frac16_t f16Mult1, f16Mult2;

void main(void)
{
    a32Accum = ACC32(2.3);           /* a32Accum = 2.3 */
    f16Mult1 = FRAC16(0.1);          /* f16Mult1 = 0.1 */
    f16Mult2 = FRAC16(-0.2);         /* f16Mult2 = -0.2 */

    /* a32Result = a32Accum - f16Mult1 * f16Mult2 */
    a32Result = MLIB_Msu_A32ass(a32Accum, f16Mult1, f16Mult2);
}

```

## 2.28 MLIB\_MsuSat

The [MLIB\\_MsuSat](#) functions return the fractional product of two multiplicands subtracted from the input accumulator. The function saturates the output. See the following equation:

$$\text{MLIB\_MsuSat}(a, b, c) = \begin{cases} 1, & a - b \cdot c > 1 \\ -1, & a - b \cdot c < -1 \\ a - b \cdot c, & \text{else} \end{cases}$$

**Equation 25. Algorithm formula**

### 2.28.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range <-1 ; 1). The result may saturate.

The available versions of the [MLIB\\_MsuSat](#) function are shown in the following table.

**Table 2-28. Function versions**

Function name	Input type			Result type	Description
	Accum.	Mult. 1	Mult. 2		
MLIB_MsuSat_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	The upper 16-bit portion [16..31] of the fractional product (of two 16-bit fractional multiplicands) is subtracted from a 16-bit fractional accumulator. The output is within the range <-1 ; 1).
MLIB_MsuSat_F32lss	<a href="#">frac32_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac32_t</a>	The 32-bit fractional product (of two 16-bit fractional multiplicands) is subtracted from a 32-bit fractional accumulator. The output is within the range <-1 ; 1).
MLIB_MsuSat_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	The upper 32-bit portion [32..63] of the fractional product (of two 32-bit fractional multiplicands) is subtracted from a 32-bit fractional accumulator. The output is within the range <-1 ; 1).

## 2.28.2 Declaration

The available [MLIB\\_MsuSat](#) functions have the following declarations:

```
frac16\_t MLIB_MsuSat_F16(frac16\_t f16Accum, frac16\_t f16Mult1, frac16\_t f16Mult2)
frac32\_t MLIB_MsuSat_F32lss(frac32\_t f32Accum, frac16\_t f16Mult1, frac16\_t f16Mult2)
frac32\_t MLIB_MsuSat_F32(frac32\_t f32Accum, frac32\_t f32Mult1, frac32\_t f32Mult2)
```

## 2.28.3 Function use

The use of the [MLIB\\_MsuSat](#) function is shown in the following example:

```
#include "mlib.h"

static frac32\_t f32Accum, f32Mult1, f32Mult2, f32Result;

void main(void)
{
    f32Accum = FRAC32(0.9);           /* f32Accum = 0.9 */
    f32Mult1 = FRAC32(-1.0);          /* f32Mult1 = -1.0 */
    f32Mult2 = FRAC32(0.2);           /* f32Mult2 = 0.2 */

    /* f32Result = sat(f32Accum - f32Mult1 * f32Mult2) */
    f32Result = MLIB_MsuSat_F32(f32Accum, f32Mult1, f32Mult2);
}
```

## 2.29 MLIB\_MsuRnd



The [MLIB\\_MsuRnd](#) functions return the rounded fractional product of two multiplicands subtracted from the input accumulator. The round method is the round to nearest. The function does not saturate the output. See the following equation:

$$\text{MLIB\_MsuRnd}(a, b, c) = a - \text{round}(b \cdot c)$$

**Equation 26. Algorithm formula**

## 2.29.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range  $<-1 ; 1$ ). The result may overflow.
- Accumulator output with mixed inputs - the output is the accumulator type, where the result can be out of the range  $<-1 ; 1$ ). The accumulator is the accumulator type, the multiplicands are the fractional types. The result may overflow.

The available versions of the [MLIB\\_MsuRnd](#) function are shown in the following table.

**Table 2-29. Function versions**

Function name	Input type			Result type	Description
	Accum.	Mult. 1	Mult. 2		
MLIB_MsuRnd_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	The fractional product (of two 16-bit fractional multiplicands), rounded to the upper 16 bits, is subtracted from a 16-bit fractional accumulator. The output is within the range $<-1 ; 1$ ).
MLIB_MsuRnd_F32lls	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac16_t</a>	<a href="#">frac32_t</a>	The fractional product (of a 32-bit and 16-bit fractional multiplicands), rounded to the upper 32 bits [16..48], is subtracted from a 32-bit fractional accumulator. The output is within the range $<-1 ; 1$ ).
MLIB_MsuRnd_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	The fractional product (of two 32-bit fractional multiplicands), rounded to the upper 32 bits [32..63], is subtracted from a 32-bit fractional accumulator. The output is within the range $<-1 ; 1$ ).
MLIB_MsuRnd_A32ass	<a href="#">acc32_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">acc32_t</a>	The fractional product (of two 16-bit fractional multiplicands), rounded to the upper 16 bits [16..31], is subtracted from a 32-bit accumulator. The output may be out of the range $<-1 ; 1$ ).

## 2.29.2 Declaration

The available [MLIB\\_MsuRnd](#) functions have the following declarations:

```

frac16_t MLIB_MsuRnd_F16(frac16_t f16Accum, frac16_t f16Mult1, frac16_t f16Mult2)
frac32_t MLIB_MsuRnd_F32lls(frac32_t f32Accum, frac32_t f32Mult1, frac16_t f16Mult2)
frac32_t MLIB_MsuRnd_F32(frac32_t f32Accum, frac32_t f32Mult1, frac32_t f32Mult2)
acc32_t MLIB_MsuRnd_A32ass(acc32_t a32Accum, frac16_t f16Mult1, frac16_t f16Mult2)

```

## 2.29.3 Function use

The use of the [MLIB\\_MsuRnd](#) function is shown in the following example:

```

#include "mlib.h"

static frac16_t f16Accum, f16Mult1, f16Mult2, f16Result;

void main(void)
{
    f16Accum = FRAC16(0.3);           /* f16Accum = 0.3 */
    f16Mult1 = FRAC16(0.1);           /* f16Mult1 = 0.1 */
    f16Mult2 = FRAC16(-0.2);          /* f16Mult2 = -0.2 */

    /* f16Result = round(f16Accum - f16Mult1 * f16Mult2) */
    f16Result = MLIB_MsuRnd_F16(f16Accum, f16Mult1, f16Mult2);
}

```

## 2.30 MLIB\_MsuRndSat

The [MLIB\\_MsuRndSat](#) functions return the rounded fractional product of two multiplicands subtracted from the input accumulator. The round method is the round to nearest. The function saturates the output. See the following equation:

$$\text{MLIB\_MsuRndSat}(a, b, c) = \begin{cases} 1, & a - \text{round}(b \cdot c) > 1 \\ -1, & a - \text{round}(b \cdot c) < -1 \\ a - \text{round}(b \cdot c), & \text{else} \end{cases}$$

**Equation 27. Algorithm formula**

### 2.30.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range <-1 ; 1). The result may saturate.

The available versions of the [MLIB\\_MsuRndSat](#) function are shown in the following table.

**Table 2-30. Function versions**

Function name	Input type			Result type	Description
	Accum.	Mult. 1	Mult. 2		
MLIB_MsuRndSat_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	The fractional product (of two 16-bit fractional multiplicands), rounded to the upper 16 bits, is subtracted from a 16-bit fractional accumulator. The output is within the range <-1 ; 1).
MLIB_MsuRndSat_F32lls	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac16_t</a>	<a href="#">frac32_t</a>	The fractional product (of a 32-bit and 16-bit fractional multiplicands), rounded to the upper 32 bits [16..48], is subtracted from a 32-bit fractional accumulator. The output is within the range <-1 ; 1).
MLIB_MsuRndSat_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	The fractional product (of two 32-bit fractional multiplicands), rounded to the upper 32 bits [32..63], is subtracted from a 32-bit fractional accumulator. The output is within the range <-1 ; 1).

## 2.30.2 Declaration

The available [MLIB\\_MsuRndSat](#) functions have the following declarations:

```
frac16\_t MLIB_MsuRndSat_F16(frac16\_t f16Accum, frac16\_t f16Mult1, frac16\_t f16Mult2)
frac32\_t MLIB_MsuRndSat_F32lls(frac32\_t f32Accum, frac32\_t f32Mult1, frac16\_t f16Mult2)
frac32\_t MLIB_MsuRndSat_F32(frac32\_t f32Accum, frac32\_t f32Mult1, frac32\_t f32Mult2)
```

## 2.30.3 Function use

The use of the [MLIB\\_MsuRndSat](#) function is shown in the following example:

```
#include "mlib.h"

static frac32\_t f32Accum, f32Mult1, f32Mult2, f32Result;

void main(void)
{
    f32Accum = FRAC32(0.3);           /* f32Accum = 0.3 */
    f32Mult1 = FRAC32(0.1);           /* f32Mult1 = 0.1 */
    f32Mult2 = FRAC32(-0.2);          /* f32Mult2 = -0.2 */

    /* f32Result = sat(round(f32Accum - f32Mult1 * f32Mult2)) */
    f32Result = MLIB_MsuRndSat_F32(f32Accum, f32Mult1, f32Mult2);
}
```

## 2.31 MLIB\_Msu4

The [MLIB\\_Msu4](#) functions return the subtraction of the products of two multiplicands. The function does not saturate the output. See the following equation:

$$\text{MLIB\_Msu4}(a, b, c, d) = a \cdot b - c \cdot d$$

**Equation 28. Algorithm formula**

### 2.31.1 Available versions

The function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range <-1 ; 1). The result may overflow.
- Floating-point output - the output is a floating-point number; the result is within the full range.

The available versions of the [MLIB\\_Msu4](#) function are shown in the following table.

**Table 2-31. Function versions**

Function name	Input type				Result type	Description
	Minuend product		Subtrahend product			
	Mult. 1	Mult. 2	Mult. 1	Mult. 2		
MLIB_Msu4_F32ssss	frac16_t	frac16_t	frac16_t	frac16_t	frac32_t	Subtraction of two 32-bit fractional products (of two 16-bit fractional multiplicands). The output is within the range <-1 ; 1).
MLIB_Msu4_FLT	float_t	float_t	float_t	float_t	float_t	Subtraction of two 32-bit single-point floating-point products (of two 32-bit single-point floating-point multiplicands). The output is within the full range.

### 2.31.2 Declaration

The available [MLIB\\_Msu4](#) functions have the following declarations:

```
frac32_t MLIB_Msu4_F32ssss(frac16_t f16MinMult1, frac16_t f16MinMult2, frac16_t f16SubMult1,
frac16_t f16SubMult2)
float_t MLIB_Msu4_FLT(float_t fltMinMult1, float_t fltMinMult2, float_t fltSubMult1, float_t
fltSubMult2)
```

### 2.31.3 Function use

The use of the [MLIB\\_Msu4](#) function is shown in the following example:

```
#include "mlib.h"

static frac32_t f32Result;
static frac16_t f16MinMult1, f16MinMult2, f16SubMult1, f16SubMult2;

void main(void)
{
    f16MinMult1 = FRAC16(0.2);          /* f16MinMult1 = 0.2 */
    f16MinMult2 = FRAC16(-0.7);         /* f16MinMult2 = -0.7 */
    f16SubMult1 = FRAC16(0.3);          /* f16SubMult1 = 0.3 */
    f16SubMult2 = FRAC16(-0.25);        /* f16SubMult2 = -0.25 */

    /* f32Result = f16MinMult1 * f16MinMult2 - f16SubMult1 * f16SubMult2 */
    f32Result = MLIB_Msu4_F32ssss(f16MinMult1, f16MinMult2, f16SubMult1, f16SubMult2);
}
```

## 2.32 MLIB\_Msu4Sat

The [MLIB\\_Msu4Sat](#) functions return the subtraction of the products of two multiplicands. The function saturates the output. See the following equation:

$$\text{MLIB\_Msu4Sat}(a, b, c, d) = \begin{cases} 1, & a \cdot b - c \cdot d > 1 \\ -1, & a \cdot b - c \cdot d < -1 \\ a \cdot b - c \cdot d, & \text{else} \end{cases}$$

**Equation 29. Algorithm formula**

### 2.32.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range <-1 ; 1). The result may saturate.

The available versions of the [MLIB\\_Msu4Sat](#) function are shown in the following table.

**Table 2-32. Function versions**

Function name	Input type				Result type	Description
	Minuend product		Subtrahend product			
	Mult. 1	Mult. 2	Mult. 1	Mult. 2		
MLIB_Msu4Sat_F32ssss	frac16_t	frac16_t	frac16_t	frac16_t	frac32_t	Subtraction of two 32-bit fractional products (of two 16-bit fractional multiplicands). The output is within the range <-1 ; 1).

## 2.32.2 Declaration

The available [MLIB\\_Msu4Sat](#) functions have the following declarations:

```
frac32\_t MLIB_Msu4Sat_F32ssss(frac16\_t f16MinMult1, frac16\_t f16MinMult2, frac16\_t f16SubMult1, frac16\_t f16SubMult2)
```

## 2.32.3 Function use

The use of the [MLIB\\_Msu4Sat](#) function is shown in the following example:

```
#include "mlib.h"

static frac32\_t f32Result;
static frac16\_t f16MinMult1, f16MinMult2, f16SubMult1, f16SubMult2;

void main(void)
{
    f16MinMult1 = FRAC16(0.8);           /* f16MinMult1 = 0.8 */
    f16MinMult2 = FRAC16(-0.9);          /* f16MinMult2 = -0.9 */
    f16SubMult1 = FRAC16(0.7);           /* f16SubMult1 = 0.7 */
    f16SubMult2 = FRAC16(0.9);          /* f16SubMult2 = 0.9 */

    /* f32Result = sat(f16MinMult1 * f16MinMult2 - f16SubMult1 * f16SubMult2) */
    f32Result = MLIB_Msu4Sat_F32ssss(f16MinMult1, f16MinMult2, f16SubMult1, f16SubMult2);
}
```

## 2.33 MLIB\_Msu4Rnd

The [MLIB\\_Msu4Rnd](#) functions return the rounded subtraction of two products of two pairs of multiplicands. The round method is the round to nearest. The function does not saturate the output. See the following equation:

$$\text{MLIB\_Msu4Rnd}(a, b, c, d) = \text{round}(a \cdot b - c \cdot d)$$

**Equation 30. Algorithm formula**

### 2.33.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range <-1 ; 1). The result may overflow.

The available versions of the [MLIB\\_Msu4Rnd](#) function are shown in the following table.

**Table 2-33. Function versions**

Function name	Input type				Result type	Description
	Minuend product		Subtrahend product			
	Mult. 1	Mult. 2	Mult. 1	Mult. 2		
MLIB_Msu4Rnd_F16	frac16_t	frac16_t	frac16_t	frac16_t	frac16_t	Subtraction of two 16-bit fractional products (of two 16-bit fractional multiplicands), rounded to the upper 16 bits. The output is within the range <-1 ; 1).
MLIB_Msu4Rnd_F32	frac32_t	frac32_t	frac32_t	frac32_t	frac32_t	Subtraction of two 32-bit fractional products (of two 32-bit fractional multiplicands), rounded to the upper 32 bits. The output is within the range <-1 ; 1).

### 2.33.2 Declaration

The available [MLIB\\_Msu4Rnd](#) functions have the following declarations:

```
frac16\_t MLIB_Msu4Rnd_F16(frac16\_t f16MinMult1, frac16\_t f16MinMult2, frac16\_t f16SubMult1,
frac16\_t f16SubMult2)
frac32\_t MLIB_Msu4Rnd_F32(frac32\_t f32MinMult1, frac32\_t f32MinMult2, frac32\_t f32SubMult1,
frac32\_t f32SubMult2)
```

### 2.33.3 Function use

The use of the [MLIB\\_Msu4Rnd](#) function is shown in the following example:

```
#include "mlib.h"

static frac16\_t f16Result, f16MinMult1, f16MinMult2, f16SubMult1, f16SubMult2;
```

```

void main(void)
{
    f16MinMult1 = FRAC16(0.256);          /* f16MinMult1 = 0.256 */
    f16MinMult2 = FRAC16(-0.724);         /* f16MinMult2 = -0.724 */
    f16SubMult1 = FRAC16(0.365);          /* f16SubMult1 = 0.365 */
    f16SubMult2 = FRAC16(-0.25);          /* f16SubMult2 = -0.25 */

    /* f32Result = round(f16MinMult1 * f16MinMult2 - f16SubMult1 * f16SubMult2) */
    f16Result = MLIB_Msu4Rnd_F16(f16MinMult1, f16MinMult2, f16SubMult1, f16SubMult2);
}

```

## 2.34 MLIB\_Msu4RndSat

The [MLIB\\_Msu4RndSat](#) functions return the rounded subtraction of two products of two pairs of multiplicands. The round method is the round to nearest. The function saturates the output. See the following equation:

$$\text{MLIB\_Msu4RndSat}(a, b, c, d) = \begin{cases} 1, & \text{round}(a \cdot b - c \cdot d) > 1 \\ -1, & \text{round}(a \cdot b - c \cdot d) < -1 \\ \text{round}(a \cdot b - c \cdot d), & \text{else} \end{cases}$$

**Equation 31. Algorithm formula**

### 2.34.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range  $<-1 ; 1$ ). The result may saturate.

The available versions of the [MLIB\\_Msu4RndSat](#) function are shown in the following table.

**Table 2-34. Function versions**

Function name	Input type				Result type	Description
	Minuend product		Subtrahend product			
	Mult. 1	Mult. 2	Mult. 1	Mult. 2		
MLIB_Msu4RndSat_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	Subtraction of two 16-bit fractional products (of two 16-bit fractional multiplicands), rounded to the upper 16 bits. The output is within the range <-1 ; 1).
MLIB_Msu4RndSat_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	Subtraction of two 32-bit fractional products (of two 32-bit fractional multiplicands),



Table 2-34. Function versions

Function name	Input type				Result type	Description
	Minuend product		Subtrahend product			
	Mult. 1	Mult. 2	Mult. 1	Mult. 2		
						rounded to the upper 32 bits. The output is within the range <-1 ; 1).

## 2.34.2 Declaration

The available [MLIB\\_Msu4RndSat](#) functions have the following declarations:

```
frac16_t MLIB_Msu4RndSat_F16(frac16_t f16MinMult1, frac16_t f16MinMult2, frac16_t
f16SubMult1, frac16_t f16SubMult2)
frac32_t MLIB_Msu4RndSat_F32(frac32_t f32MinMult1, frac32_t f32MinMult2, frac32_t
f32SubMult1, frac32_t f32SubMult2)
```

## 2.34.3 Function use

The use of the [MLIB\\_Msu4RndSat](#) function is shown in the following example:

```
#include "mlib.h"

static frac32_t ;
static frac16_t f16Result, f16MinMult1, f16MinMult2, f16SubMult1, f16SubMult2;

void main(void)
{
    f16MinMult1 = FRAC16(0.8);          /* f16MinMult1 = 0.8 */
    f16MinMult2 = FRAC16(-0.9);         /* f16MinMult2 = -0.9 */
    f16SubMult1 = FRAC16(0.7);          /* f16SubMult1 = 0.7 */
    f16SubMult2 = FRAC16(0.9);          /* f16SubMult2 = 0.9 */

    /* f16Result = sat(round(f16MinMult1 * f16MinMult2 - f16SubMult1 * f16SubMult2)) */
    f16Result = MLIB_Msu4RndSat_F16(f16MinMult1, f16MinMult2, f16SubMult1, f16SubMult2);
}
```

## 2.35 MLIB\_Mul

The [MLIB\\_Mul](#) functions return the product of two multiplicands. The function does not saturate the output. See the following equation:

$$\text{MLIB\_Mul}(a, b) = a \cdot b$$

**Equation 32. Algorithm formula**

## 2.35.1 Available versions

This function is available in the following versions:

- Fractional output with fractional inputs - the output is the fractional portion of the result; the result is within the range  $<-1 ; 1$ ). The inputs are the fractional values only. The result may overflow.
- Fractional output with mixed inputs - the output is the fractional portion of the result; the result is within the range  $<-1 ; 1$ ). The inputs are the accumulator and fractional values. The result may overflow.
- Accumulator output - the output is the accumulator type where the result can be out of the range  $<-1 ; 1$ ). The result may overflow.
- Floating-point output - the output is a floating-point number; the result is within the full range.

The available versions of the [MLIB\\_Mul](#) function are shown in the following table:

**Table 2-35. Function versions**

Function name	Input type		Result type	Description
	Mult. 1	Mult. 2		
MLIB_Mul_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	Product of two 16-bit fractional multiplicands; the output are the upper 16 bits of the results [16..31]. The output is within the range $<-1 ; 1$ ).
MLIB_Mul_F16as	<a href="#">acc32_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	Product of a 32-bit accumulator and a 16-bit fractional multiplicand; the output is a 16-bit fractional portion, which has the upper 16 bits of the fractional value of the result [16..31]. The output is within the range $<-1 ; 1$ ).
MLIB_Mul_F32ss	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac32_t</a>	Product of two 16-bit fractional multiplicands; the result is a 32-bit fractional value. The output is within the range $<-1 ; 1$ ).
MLIB_Mul_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	Product of two 32-bit fractional multiplicands; the output are the upper 32 bits of the results [16..31]. The output is within the range $<-1 ; 1$ ).
MLIB_Mul_A32	<a href="#">acc32_t</a>	<a href="#">acc32_t</a>	<a href="#">acc32_t</a>	Product of two 32-bit accumulator multiplicands; the output is a 32-bit accumulator, which has the upper mid bits of the result [16..47]. The output is within the range $<-65536.0 ; 65536.0$ ).
MLIB_Mul_FLT	<a href="#">float_t</a>	<a href="#">float_t</a>	<a href="#">float_t</a>	Product of two 32-bit single precision floating-point multiplicands. The output is within the full range.

## 2.35.2 Declaration

The available [MLIB\\_Mul](#) functions have the following declarations:

```

frac16_t MLIB_Mul_F16(frac16_t f16Mult1, frac16_t f16Mult2)
frac16_t MLIB_Mul_F16as(acc32_t a32Accum, frac16_t f16Mult)
frac32_t MLIB_Mul_F32ss(frac16_t f16Mult1, frac16_t f16Mult2)
frac32_t MLIB_Mul_F32(frac32_t f32Mult1, frac32_t f32Mult2)
acc32_t MLIB_Mul_A32(acc32_t a32Mult1, acc32_t a32Mult1)
float_t MLIB_Mul_FLT(float_t fltMult1, float_t fltMult2)

```

### 2.35.3 Function use

The use of the [MLIB\\_Mul](#) function is shown in the following example:

```

#include "mlib.h"

static frac32_t f32Result;
static frac16_t f32Mult1, f16Mult2;

void main(void)
{
    f16Mult1 = FRAC16(0.4);          /* f16Mult1 = 0.4 */
    f16Mult2 = FRAC16(-0.2);         /* f16Mult2 = -0.2 */

    /* f32Result = f16Mult1 * f16Mult2 */
    f32Result = MLIB_Mul_F32ss(f16Mult1, f16Mult2);
}

```

## 2.36 MLIB\_MulSat

The [MLIB\\_MulSat](#) functions return the product of two multiplicands. The function saturates the output. See the following equation:

$$\text{MLIB\_MulSat}(a, b) = \begin{cases} \text{max}, & a \cdot b > \text{max} \\ \text{min}, & a \cdot b < \text{min} \\ a \cdot b, & \text{else} \end{cases}$$

**Equation 33. Algorithm formula**

### 2.36.1 Available versions

This function is available in the following versions:

- Fractional output with fractional inputs - the output is the fractional portion of the result; the result is within the range <-1 ; 1). The inputs are the fractional values only. The result may saturate.

- Fractional output with mixed inputs - the output is the fractional portion of the result; the result is within the range  $<-1 ; 1$ ). The inputs are the accumulator and fractional values. The result may saturate.
- Accumulator output - the output is the accumulator type where the result can be out of the range  $<-1;1$ ). The result may overflow.

The available versions of the [MLIB\\_MulSat](#) function are shown in the following table:

**Table 2-36. Function versions**

Function name	Input type		Result type	Description
	Mult. 1	Mult. 2		
MLIB_MulSat_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	Product of two 16-bit fractional multiplicands; the output is the upper 16 bits of the results [16..31]. The output is within the range $<-1 ; 1$ ).
MLIB_MulSat_F16as	<a href="#">acc32_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	Product of a 32-bit accumulator and a 16-bit fractional multiplicand; the output is a 16-bit fractional value, which has the upper 16 bits of the fractional portion of the result [16..31]. The output is within the range $<-1 ; 1$ ).
MLIB_MulSat_F32ss	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac32_t</a>	Product of two 16-bit fractional multiplicands; the result is a 32-bit fractional value. The output is within the range $<-1 ; 1$ ).
MLIB_MulSat_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	Product of two 32-bit fractional multiplicands; the output are the upper 32 bits of the results [16..31]. The output is within the range $<-1 ; 1$ ).
MLIB_MulSat_A32	<a href="#">acc32_t</a>	<a href="#">acc32_t</a>	<a href="#">acc32_t</a>	Product of two 32-bit accumulator multiplicands; the output is a 32-bit accumulator, which has the mid bits of the result [16..47]. The output is within the range $<-65536.0 ; 65536.0$ ).

## 2.36.2 Declaration

The available [MLIB\\_MulSat](#) functions have the following declarations:

```

frac16\_t MLIB_MulSat_F16(frac16\_t f16Mult1, frac16\_t f16Mult2)
frac16\_t MLIB_MulSat_F16as(acc32\_t a32Accum, frac16\_t f16Mult)
frac32\_t MLIB_MulSat_F32ss(frac16\_t f16Mult1, frac16\_t f16Mult2)
frac32\_t MLIB_MulSat_F32(frac32\_t f32Mult1, frac32\_t f32Mult2)
acc32\_t MLIB_MulSat_A32(acc32\_t a32Mult1, acc32\_t a32Mult1)

```

## 2.36.3 Function use

The use of the [MLIB\\_MulSat](#) function is shown in the following example:

```

#include "mlib.h"

static acc32\_t a32Accum;
static frac16\_t f16Mult, f16Result;

```

```

void main(void)
{
    a32Accum = ACC32(-5.5);          /* a32Accum = -5.5 */
    f16Mult = FRAC16(0.3);          /* f16Mult = 0.3 */

    /* f16Result = sat(a32Accum * f16Mult) */
    f16Result = MLIB_MulSat_F16as(a32Accum, f16Mult);
}

```

## 2.37 MLIB\_MulNeg

The [MLIB\\_MulNeg](#) functions return the negative product of two multiplicands. The function does not saturate the output. See the following equation:

$$\text{MLIB\_MulNeg}(a, b) = -a \cdot b$$

**Equation 34. Algorithm formula**

### 2.37.1 Available versions

This function is available in the following versions:

- Fractional output with fractional inputs - the output is the fractional portion of the result; the result is within the range  $<-1 ; 1$ ). The inputs are the fractional values only.
- Fractional output with mixed inputs - the output is the fractional portion of the result; the result is within the range  $<-1 ; 1$ ). The inputs are the accumulator and fractional values. The result may overflow.
- Accumulator output - the output is the accumulator type where the result can be out of the range  $<-1;1$ ). The result may overflow.
- Floating-point output - the output is a floating-point number; the result is within the full range.

The available versions of the [MLIB\\_MulNeg](#) function are shown in the following table.

**Table 2-37. Function versions**

Function name	Input type		Result type	Description
	Mult. 1	Mult. 2		
MLIB_MuNegl_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	Negative product of two 16-bit fractional multiplicands; the output are the upper 16 bits of the results [16..31]. The output is within the range $<-1 ; 1$ ).
MLIB_MulNeg_F16as	<a href="#">acc32_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	Negative product of a 32-bit accumulator and a 16-bit fractional multiplicand; the output is a 16-bit fractional value, which has the upper 16 bits of the fractional portion of the result [16..31]. The output is within the range $<-1 ; 1$ ).

*Table continues on the next page...*

**Table 2-37. Function versions (continued)**

Function name	Input type		Result type	Description
	Mult. 1	Mult. 2		
MLIB_MulNeg_F32ss	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac32_t</a>	Negative product of two 16-bit fractional multiplicands; the result is a 32-bit fractional value. The output is within the range <-1 ; 1).
MLIB_MulNeg_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	Negative product of two 32-bit fractional multiplicands; the output are the upper 32 bits of the results [16..31]. The output is within the range <-1 ; 1).
MLIB_MulNeg_A32	<a href="#">acc32_t</a>	<a href="#">acc32_t</a>	<a href="#">acc32_t</a>	Product of two 32-bit accumulator multiplicands; the output is a 32-bit accumulator, which has the mid bits of the result [16..47]. The output is within the range <-65536.0 ; 65536.0).
MLIB_MulNeg_FLT	<a href="#">float_t</a>	<a href="#">float_t</a>	<a href="#">float_t</a>	Negative product of two 32-bit single precision floating-point multiplicands. The output is within the full range.

## 2.37.2 Declaration

The available [MLIB\\_MulNeg](#) functions have the following declarations:

```

frac16\_t MLIB_MulNeg_F16(frac16\_t f16Mult1, frac16\_t f16Mult2)
frac16\_t MLIB_MulNeg_F16as(acc32\_t a32Accum, frac16\_t f16Mult)
frac32\_t MLIB_MulNeg_F32ss(frac16\_t f16Mult1, frac16\_t f16Mult2)
frac32\_t MLIB_MulNeg_F32(frac32\_t f32Mult1, frac32\_t f32Mult2)
acc32\_t MLIB_MulNeg_A32(acc32\_t a32Mult1, acc32\_t a32Mult1)
float\_t MLIB_MulNeg_FLT(float\_t fltMult1, float\_t fltMult2)

```

## 2.37.3 Function use

The use of the [MLIB\\_MulNeg](#) function is shown in the following example:

```

#include "mlib.h"

static frac32\_t f32Result;
static frac16\_t f16Mult1, f16Mult2;

void main(void)
{
    f16Mult1 = FRAC16(0.5);           /* f16Mult1 = 0.5 */
    f16Mult2 = FRAC16(-0.3);          /* f16Mult2 = -0.3 */

    /* f32Result = f16Mult1 * (-f16Mult2) */
    f32Result = MLIB_MulNeg_F32ss(f16Mult1, f16Mult2);
}

```

## 2.38 MLIB\_MulRnd

The [MLIB\\_MulRnd](#) functions return the rounded product of two multiplicands. The round method is the round to nearest. The function does not saturate the output. See the following equation:

$$\text{MLIB\_MulRnd}(a, b) = \text{round}(a \cdot b)$$

**Equation 35. Algorithm formula**

## 2.38.1 Available versions

This function is available in the following versions:

- Fractional output with fractional inputs - the output is the fractional portion of the result; the result is within the range  $<-1 ; 1$ ). The inputs are the fractional values only. The result may overflow.
- Fractional output with mixed inputs - the output is the fractional portion of the result; the result is within the range  $<-1 ; 1$ ). The inputs are the accumulator and fractional values. The result may overflow.
- Accumulator output - the output is the accumulator type where the result can be out of the range  $<-1 ; 1$ ). The result may overflow.

The available versions of the [MLIB\\_MulRnd](#) function are shown in the following table:

**Table 2-38. Function versions**

Function name	Input type		Result type	Description
	Mult. 1	Mult. 2		
MLIB_MulRnd_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	Product of two 16-bit fractional multiplicands; the output is rounded to the upper 16 bits of the results [16..31]. The output is within the range $<-1 ; 1$ ).
MLIB_MulRnd_F16as	<a href="#">acc32_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	Product of a 32-bit accumulator and a 16-bit fractional multiplicand; the output is a 16-bit fractional value, which is rounded to the upper 16 bits of the fractional portion of the result [16..31]. The output is within the range $<-1 ; 1$ ).
MLIB_MulRnd_F32ls	<a href="#">frac32_t</a>	<a href="#">frac16_t</a>	<a href="#">frac32_t</a>	Product of a 32-bit and a 16-bit fractional multiplicand; the output is rounded to the upper 32 bits of the fractional portion of the result [16..47]. The output is within the range $<-1 ; 1$ ).
MLIB_MulRnd_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	Product of two 32-bit fractional multiplicands; the output is rounded to the upper 32 bits of the results [16..31]. The output is within the range $<-1 ; 1$ ).
MLIB_MulRnd_A32	<a href="#">acc32_t</a>	<a href="#">acc32_t</a>	<a href="#">acc32_t</a>	Product of two 32-bit accumulator multiplicands; the output is rounded to the middle bits of the result [16..47]. The output is within the range $<-65536.0 ; 65536.0$ ).

## 2.38.2 Declaration

The available [MLIB\\_MulRnd](#) functions have the following declarations:

```
frac16_t MLIB_MulRnd_F16(frac16_t f16Mult1, frac16_t f16Mult2)
frac16_t MLIB_MulRnd_F16as(acc32_t a32Accum, frac16_t f16Mult)
frac32_t MLIB_MulRnd_F32ls(frac32_t f32Mult1, frac16_t f16Mult2)
frac32_t MLIB_MulRnd_F32(frac32_t f32Mult1, frac32_t f32Mult2)
acc32_t MLIB_MulRnd_A32(acc32_t a32Mult1, acc32_t a32Mult1)
```

## 2.38.3 Function use

The use of the [MLIB\\_MulRnd](#) function is shown in the following example:

```
#include "mlib.h"

static frac32_t f32Mult1, f32Mult2, f32Result;

void main(void)
{
    f32Mult1 = FRAC32(0.5);          /* f32Mult1 = 0.5 */
    f32Mult2 = FRAC32(-0.24564);     /* f32Mult2 = -0.24564 */

    /* f32Result = round(f32Mult1 * f32Mult2) */
    f32Result = MLIB_MulRnd_F32(f32Mult1, f32Mult2);
}
```

## 2.39 MLIB\_MulRndSat

The [MLIB\\_MulRndSat](#) functions return the rounded product of two multiplicands. The round method is the round to nearest. The function saturates the output. See the following equation:

$$\text{MLIB\_MulRndSat}(a, b) = \begin{cases} \text{max}, & \text{round}(a \cdot b) > \text{max} \\ \text{min}, & \text{round}(a \cdot b) < \text{min} \\ \text{round}(a \cdot b), & \text{else} \end{cases}$$

**Equation 36. Algorithm formula**

### 2.39.1 Available versions

This function is available in the following versions:

- Fractional output with fractional inputs - the output is the fractional portion of the result; the result is within the range <-1 ; 1). The inputs are the fractional values only. The result may saturate.



- Fractional output with mixed inputs - the output is the fractional portion of the result; the result is within the range  $-1 ; 1$ ). The inputs are the accumulator and fractional values. The result may saturate.
- Accumulator output - the output is the accumulator type where the result can be out of the range  $-1 ; 1$ ). The result may overflow.

The available versions of the [MLIB\\_MulRndSat](#) function are shown in the following table:

**Table 2-39. Function versions**

Function name	Input type		Result type	Description
	Mult. 1	Mult. 2		
MLIB_MulRndSat_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	Product of two 16-bit fractional multiplicands; the output is rounded to the upper 16 bits of the results [16..31]. The output is within the range $-1 ; 1$ ).
MLIB_MulRndSat_F16as	<a href="#">acc32_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	Product of a 32-bit accumulator and a 16-bit fractional multiplicand; the output is a 16-bit fractional value, which is rounded to the upper 16 bits of the fractional portion of the result [16..31]. The output is within the range $-1 ; 1$ ).
MLIB_MulRndSat_F32ls	<a href="#">frac32_t</a>	<a href="#">frac16_t</a>	<a href="#">frac32_t</a>	Product of a 32-bit multiplicand and a 16-bit fractional multiplicand; the output is rounded to the upper 32 bits of the fractional portion of the result [16..47]. The output is within the range $-1 ; 1$ ).
MLIB_MulRndSat_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	Product of two 32-bit fractional multiplicands; the output is rounded to the upper 32 bits of the results [16..31]. The output is within the range $-1 ; 1$ ).
MLIB_MulRndSat_A32	<a href="#">acc32_t</a>	<a href="#">acc32_t</a>	<a href="#">acc32_t</a>	Product of two 32-bit accumulator multiplicands; the output is rounded to the the mid bits of the result [16..47]. The output is within the range $-65536.0 ; 65536.0$ ).

## 2.39.2 Declaration

The available [MLIB\\_MulRndSat](#) functions have the following declarations:

```

frac16\_t MLIB_MulRndSat_F16(frac16\_t f16Mult1, frac16\_t f16Mult2)
frac16\_t MLIB_MulRndSat_F16as(acc32\_t a32Accum, frac16\_t f16Mult)
frac32\_t MLIB_MulRndSat_F32ls(frac32\_t f32Mult1, frac16\_t f16Mult2)
frac32\_t MLIB_MulRndSat_F32(frac32\_t f32Mult1, frac32\_t f32Mult2)
acc32\_t MLIB_MulRndSat_A32(acc32\_t a32Mult1, acc32\_t a32Mult1)

```

## 2.39.3 Function use

The use of the [MLIB\\_MulRndSat](#) function is shown in the following example:

## MLIB\_MulNegRnd

```
#include "mlib.h"

static frac32_t f32Mult1, f32Mult2, f32Result;

void main(void)
{
    f32Mult1 = FRAC32(-1.0);          /* f32Mult1 = -1.0 */
    f32Mult2 = FRAC32(-1.0);          /* f32Mult2 = -1.0 */

    /* f32Result = sat(round(f32Mult1 * f32Mult2)) */
    f32Result = MLIB_MulRndSat_F32(f32Mult1, f32Mult2);
}
```

## 2.40 MLIB\_MulNegRnd

The [MLIB\\_MulNegRnd](#) functions return the rounded negative product of two multiplicands. The round method is the round to nearest. The function does not saturate the output. See the following equation:

$$\text{MLIB\_MulNegRnd}(a, b) = \text{round}(-a \cdot b)$$

### Equation 37. Algorithm formula

### 2.40.1 Available versions

This function is available in the following versions:

- Fractional output with fractional inputs - the output is the fractional portion of the result; the result is within the range  $<-1 ; 1$ ). The inputs are the fractional values only.
- Fractional output with mixed inputs - the output is the fractional portion of the result; the result is within the range  $<-1 ; 1$ ). The inputs are the accumulator and fractional values. The result may overflow.
- Accumulator output - the output is the accumulator type where the result can be out of the range  $<-1 ; 1$ ). The result may overflow.

The available versions of the [MLIB\\_MulNegRnd](#) function are shown in the following table:

**Table 2-40. Function versions**

Function name	Input type		Result type	Description
	Mult. 1	Mult. 2		
MLIB_MulNegRnd_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	Negative product of two 16-bit fractional multiplicands; the output is rounded to the upper 16 bits of the results [16..31]. The output is within the range $<-1 ; 1$ ).

*Table continues on the next page...*

Table 2-40. Function versions (continued)

Function name	Input type		Result type	Description
	Mult. 1	Mult. 2		
MLIB_MulNegRnd_F16as	acc32_t	frac16_t	frac16_t	Negative product of a 32-bit accumulator and a 16-bit fractional multiplicand; the output is a 16-bit fractional value, which is rounded to the upper 16 bits of the fractional portion of the result [16..31]. The output is within the range <-1 ; 1).
MLIB_MulNegRnd_F32ls	frac32_t	frac16_t	frac32_t	Negative product of a 32-bit fractional multiplicand and a 16-bit fractional multiplicand; the output is rounded to the upper 32 bits of the fractional portion of the result [16..47]. The output is within the range <-1 ; 1).
MLIB_MulNegRnd_F32	frac32_t	frac32_t	frac32_t	Negative product of two 32-bit fractional multiplicands; the output is rounded to the upper 32 bits of the results [16..31]. The output is within the range <-1 ; 1).
MLIB_MulNegRnd_A32	acc32_t	acc32_t	acc32_t	Product of two 32-bit accumulator multiplicands; the output is rounded to the the middle bits of the result [16..47]. The output is within the range <-65536.0 ; 65536.0).

## 2.40.2 Declaration

The available [MLIB\\_MulNegRnd](#) functions have the following declarations:

```
frac16_t MLIB_MulNegRnd_F16(frac16_t f16Mult1, frac16_t f16Mult2)
frac16_t MLIB_MulNegRnd_F16as(acc32_t a32Accum, frac16_t f16Mult)
frac32_t MLIB_MulNegRnd_F32ls(frac32_t f32Mult1, frac16_t f16Mult2)
frac32_t MLIB_MulNegRnd_F32(frac32_t f32Mult1, frac32_t f32Mult2)
acc32_t MLIB_MulNegRnd_A32(acc32_t a32Mult1, acc32_t a32Mult1)
```

## 2.40.3 Function use

The use of the [MLIB\\_MulNegRnd](#) function is shown in the following example:

```
#include "mlib.h"

static frac32_t f32Mult1, f32Mult2, f32Result;

void main(void)
{
    f32Mult1 = FRAC32(0.3);          /* f32Mult1 = 0.3 */
    f32Mult2 = FRAC32(-0.5);         /* f32Mult2 = -0.5 */

    /* f32Result = round(f32Mult1 * (-f32Mult2)) */
    f32Result = MLIB_MulNegRnd_F32(f32Mult1, f32Mult2);
}
```

## 2.41 MLIB\_Neg

The [MLIB\\_Neg](#) functions return the negative value of the input. The function does not saturate the output. See the following equation:

$$\text{MLIB\_Neg}(x) = -x$$

**Equation 38. Algorithm formula**

### 2.41.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range <-1 ; 1). The result may overflow.
- Floating-point output - the output is a floating-point number; the result is within the full range.

The available versions of the [MLIB\\_Neg](#) function are shown in the following table:

**Table 2-41. Function versions**

Function name	Input type	Result type	Description
MLIB_Neg_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	Negative value of a 16-bit fractional value. The output is within the range <-1 ; 1).
MLIB_Neg_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	Negative value of a 32-bit fractional value. The output is within the range <-1 ; 1).
MLIB_Neg_FLT	<a href="#">float_t</a>	<a href="#">float_t</a>	Negative value of a 32-bit single precision floating-point value. The output is within the full range.

### 2.41.2 Declaration

The available [MLIB\\_Neg](#) functions have the following declarations:

```
frac16_t MLIB_Neg_F16(frac16_t f16Val)
frac32_t MLIB_Neg_F32(frac32_t f32Val)
float_t MLIB_Neg_FLT(float_t fltVal)
```

### 2.41.3 Function use

The use of the [MLIB\\_Neg](#) function is shown in the following example:

```
#include "mlib.h"

static frac32_t f32Val, f32Result;

void main(void)
{
    f32Val = FRAC32(0.85);      /* f32Val = 0.85 */

    /* f32Result = -f32Val */
    f32Result = MLIB_Neg_F32(f32Val);
}
```

## 2.42 MLIB\_NegSat

The [MLIB\\_NegSat](#) functions return the negative value of the input. The function saturates the output. See the following equation:

$$\text{MLIB\_NegSat}(x) = -x$$

**Equation 39. Algorithm formula**

### 2.42.1 Available versions

The function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range <-1 ; 1). The result may saturate.

The available versions of the [MLIB\\_NegSat](#) function are shown in the following table:

**Table 2-42. Function versions**

Function name	Input type	Result type	Description
MLIB_NegSat_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	Negative value of a 16-bit value. The output is within the range <-1 ; 1).
MLIB_NegSat_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	Negative value of a 32-bit value. The output is within the range <-1 ; 1).

### 2.42.2 Declaration

The available [MLIB\\_NegSat](#) functions have the following declarations:

```
frac16\_t MLIB_NegSat_F16(frac16\_t f16Val)
frac32\_t MLIB_NegSat_F32(frac32\_t f32Val)
```

### 2.42.3 Function use

The use of the [MLIB\\_NegSat](#) function is shown in the following example:

```
#include "mlib.h"

static frac32_t f32Val, f32Result;

void main(void)
{
    f32Val = FRAC32(-1.0);          /* f32Val = -1.0*/

    /* f32Result = sat(-f32Val) */
    f32Result = MLIB_NegSat_F32(f32Val);
}
```

## 2.43 MLIB\_Rcp

The [MLIB\\_Rcp](#) functions return the reciprocal value for the input value. The function does not saturate the output. See the following equation:

$$\text{MLIB\_Rcp}(x) = \begin{cases} \text{max}, & x = 0 \\ \text{min}, & x = -0 \\ \frac{1}{x}, & \text{else} \end{cases}$$

**Equation 40. Algorithm formula**

### 2.43.1 Available versions

This function is available in the following versions:

- Accumulator output with fractional input - the output is the accumulator type, where the absolute value of the result is greater than or equal to 1. The input is the fractional type.
- Floating-point output - the output is a floating-point number; the result is within the full range.

The available versions of the [MLIB\\_Rcp](#) function are shown in the following table.

**Table 2-43. Function versions**

Function name	Input type	Result type	Description
MLIB_Rcp_A32s	<a href="#">frac16_t</a>	<a href="#">acc32_t</a>	Reciprocal for a 16-bit fractional value; the output is a 32-bit accumulator value. The absolute value of the output is greater than or equal to 1. The division is performed with 32-bit accuracy.
MLIB_Rcp1_A32s	<a href="#">frac16_t</a>	<a href="#">acc32_t</a>	Reciprocal for a 16-bit fractional value; the output is a 32-bit accumulator value. The absolute value of the output is greater than or equal to 1. Faster version, where the division is performed with 16-bit accuracy.
MLIB_Rcp_FLT	<a href="#">float_t</a>	<a href="#">float_t</a>	Reciprocal for a 32-bit single precision floating-point value; the output is a 32-bit single precision floating-point.

## 2.43.2 Declaration

The available [MLIB\\_Rcp](#) functions have the following declarations:

```
acc32_t MLIB_Rcp_A32s(frac16_t f16Denom)
acc32_t MLIB_Rcp1_A32s(frac16_t f16Denom)
float_t MLIB_Rcp_FLT(float_t f16Denom)
```

## 2.43.3 Function use

The use of the [MLIB\\_Rcp](#) function is shown in the following example:

```
#include "mlib.h"

static acc32_t a32Result;
static frac16_t f16Denom;

void main(void)
{
    f16Denom = FRAC16(0.354);          /* f16Denom = 0.354 */

    /* a32Result = 1/f16Denom */
    a32Result = MLIB_Rcp1_A32s(f16Denom);
}
```

## 2.44 MLIB\_Rcp1Q

The [MLIB\\_Rcp1Q](#) functions return the single quadrant reciprocal value for the input value. The input value must be a nonnegative number, otherwise the function returns undefined results. The function does not saturate the output. See the following equation:

$$\text{MLIB\_Rcp1Q}(x) = \begin{cases} \max, & x = 0 \\ \frac{1}{x}, & x > 0 \end{cases}$$

**Equation 41. Algorithm formula**

## 2.44.1 Available versions

This function is available in the following versions:

- Accumulator output with fractional input - the output is the accumulator type, where the result is greater than or equal to 1. The function is not defined for negative inputs. The input is the fractional type.

The available versions of the [MLIB\\_Rcp1Q](#) function are shown in the following table.

**Table 2-44. Function versions**

Function name	Input type	Result type	Description
MLIB_Rcp1Q_A32s	<a href="#">frac16_t</a>	<a href="#">acc32_t</a>	Reciprocal for a nonnegative 16-bit fractional value; the output is a positive 32-bit accumulator value. The output is greater than or equal to 1. The division is performed with 32-bit accuracy.
MLIB_Rcp1Q1_A32s	<a href="#">frac16_t</a>	<a href="#">acc32_t</a>	Reciprocal for a nonnegative 16-bit fractional value; the output is a positive 32-bit accumulator value. The output is greater than or equal to 1. Faster version, where the division is performed with 16-bit accuracy.

## 2.44.2 Declaration

The available [MLIB\\_Rcp1Q](#) functions have the following declarations:

```
acc32\_t MLIB_Rcp1Q_A32s(frac16\_t f16Denom)
acc32\_t MLIB_Rcp1Q1_A32s(frac16\_t f16Denom)
```

## 2.44.3 Function use

The use of the [MLIB\\_Rcp1Q](#) function is shown in the following example:

```
#include "mlib.h"

static acc32\_t a32Result;
static frac16\_t f16Denom;

void main(void)
{
    f16Denom = FRAC16(0.354);          /* f16Denom = 0.354 */
}
```



```

/* a32Result = 1/f16Denom */
a32Result = MLIB_Rcp1Q1_A32s(f16Denom);
}

```

## 2.45 MLIB\_Rnd

The [MLIB\\_Rnd](#) functions round the input to the nearest value to meet the return type's size. The function does not saturate the output. See the following equation:

$$\text{MLIB\_Rnd}(x) = \text{round}(x)$$

**Equation 42. Algorithm formula**

### 2.45.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range <-1 ; 1). The result may overflow.

The available versions of the [MLIB\\_Rnd](#) function are shown in the following table.

**Table 2-45. Function versions**

Function name	Input type	Result type	Description
MLIB_Rnd_F16l	<a href="#">frac32_t</a>	<a href="#">frac16_t</a>	Rounding of a 32-bit fractional value to a 16-bit fractional value. The output is within the range <-1 ; 1).

### 2.45.2 Declaration

The available [MLIB\\_Rnd](#) functions have the following declarations:

```
frac16_t MLIB_Rnd_F16l(frac32_t f32Val)
```

### 2.45.3 Function use

The use of the [MLIB\\_Rnd](#) function is shown in the following example:

```

#include "mlib.h"

static frac32_t f32Val;
static frac16_t f16Result;

```

```

void main(void)
{
    f32Val = FRAC32(0.85);          /* f32Val = 0.85 */

    /* f16Result = round(f32Val) */
    f16Result = MLIB_Rnd_F16l(f32Val);
}

```

## 2.46 MLIB\_RndSat

The [MLIB\\_RndSat](#) functions round the input to the nearest value to meet the return type's size. The function saturates the output. See the following equation:

$$\text{MLIB\_RndSat}(x) = \text{round}(x)$$

**Equation 43. Algorithm formula**

### 2.46.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range <-1 ; 1). The result may saturate.

The available versions of the [MLIB\\_RndSat](#) function are shown in the following table.

**Table 2-46. Function versions**

Function name	Input type	Result type	Description
MLIB_RndSat_F16l	<a href="#">frac32_t</a>	<a href="#">frac16_t</a>	Rounding of a 32-bit fractional value to a 16-bit fractional value. The output is within the range <-1 ; 1).

### 2.46.2 Declaration

The available [MLIB\\_RndSat](#) functions have the following declarations:

```
frac16\_t MLIB_RndSat_F16l(frac32\_t f32Val)
```

### 2.46.3 Function use

The use of the [MLIB\\_RndSat](#) function is shown in the following example:

```
#include "mlib.h"

static frac32_t f32Val;
static frac16_t f16Result;

void main(void)
{
    f32Val = FRAC32(0.9997996);    /* f32Val = 0.9997996 */

    /* f16Result = sat(round(f32Val)) */
    f16Result = MLIB_RndSat_F16l(f32Val);
}
```

## 2.47 MLIB\_Sat

The [MLIB\\_Sat](#) functions return the fractional portion of the accumulator input. The output is saturated if necessary. See the following equation:

$$\text{MLIB\_Sat}(x) = \begin{cases} 1, & x > 1 \\ -1, & x < -1 \\ x, & \text{else} \end{cases}$$

**Equation 44. Algorithm formula**

### 2.47.1 Available versions

This function is available in the following versions:

- Fractional output with accumulator input - the output is the fractional portion of the result; the result is within the range <-1 ; 1). The result is saturated.

The available versions of the [MLIB\\_Sat](#) function are shown in the following table.

**Table 2-47. Function versions**

Function name	Input type	Result type	Description
MLIB_Sat_F16a	<a href="#">acc32_t</a>	<a href="#">frac16_t</a>	Saturation of a 32-bit accumulator value to a 16-bit fractional value. The output is within the range <-1 ; 1).

### 2.47.2 Declaration

The available [MLIB\\_Sat](#) functions have the following declarations:

```
frac16\_t MLIB_Sat_F16a(acc32\_t a32Accum)
```

## 2.47.3 Function use

The use of the [MLIB\\_Sat](#) function is shown in the following example:

```
#include "mlib.h"

static acc32\_t a32Accum;
static frac16\_t f16Result;

void main(void)
{
    a32Accum = ACC32(5.6);          /* a32Accum = 5.6 */

    /* f16Result = sat(a32Accum) */
    f16Result = MLIB\_Sat\_F16a(a32Accum);
}
```

## 2.48 MLIB\_Sh1L

The [MLIB\\_Sh1L](#) functions return the arithmetically one-time-shifted value to the left. The function does not saturate the output. See the following equation:

$$\text{MLIB\_Sh1L}(x) = x \ll 1$$

**Equation 45. Algorithm formula**

### 2.48.1 Available versions

The function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range <-1 ; 1). The result may overflow.

The available versions of the [MLIB\\_Sh1L](#) function are shown in the following table.

**Table 2-48. Function versions**

Function name	Input type	Result type	Description
MLIB_Sh1L_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	Shift of a 16-bit fractional value by one time to the left. The output is within the range <-1 ; 1).
MLIB_Sh1L_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	Shift of a 32-bit fractional value by one time to the left. The output is within the range <-1 ; 1).

## 2.48.2 Declaration

The available [MLIB\\_Sh1L](#) functions have the following declarations:

```
frac16_t MLIB_Sh1L_F16(frac16_t f16Val)
frac32_t MLIB_Sh1L_F32(frac32_t f32Val)
```

## 2.48.3 Function use

The use of the [MLIB\\_Sh1L](#) function is shown in the following example:

```
#include "mlib.h"

static frac32_t f32Result, f32Val;

void main(void)
{
    f32Val = FRAC32(-0.354);          /* f32Val = -0.354 */

    /* f32Result = f32Val << 1 */
    f32Result = MLIB_Sh1L_F32(f32Val);
}
```

## 2.49 MLIB\_Sh1LSat

The [MLIB\\_Sh1LSat](#) functions return the arithmetically one-time-shifted value to the left. The function saturates the output. See the following equation:

$$\text{MLIB\_Sh1LSat}(x) = \begin{cases} 1, & x > 0.5 \\ -1, & x < -0.5 \\ x \ll 1, & \text{else} \end{cases}$$

**Equation 46. Algorithm formula**

### 2.49.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range <-1 ; 1). The result may saturate.

The available versions of the [MLIB\\_Sh1LSat](#) function are shown in the following table.

**Table 2-49. Function versions**

Function name	Input type	Result type	Description
MLIB_Sh1LSat_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	Shift of a 16-bit fractional value by one time to the left. The output is within the range <-1 ; 1).
MLIB_Sh1LSat_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	Shift of a 32-bit fractional value by one time to the left. The output is within the range <-1 ; 1).

## 2.49.2 Declaration

The available [MLIB\\_Sh1LSat](#) functions have the following declarations:

```
frac16\_t MLIB_Sh1LSat_F16(frac16\_t f16Val)
frac32\_t MLIB_Sh1LSat_F32(frac32\_t f32Val)
```

## 2.49.3 Function use

The use of the [MLIB\\_Sh1LSat](#) function is shown in the following example:

```
#include "mlib.h"

static frac16\_t f16Result, f16Val;

void main(void)
{
    f16Val = FRAC16(0.354);          /* f16Val = 0.354 */

    /* f16Result = sat(f16Val << 1) */
    f16Result = MLIB_Sh1LSat_F16(f16Val);
}
```

## 2.50 MLIB\_Sh1R

The [MLIB\\_Sh1R](#) functions return the arithmetically one-time-shifted value to the right. See the following equation:

$$\text{MLIB\_Sh1R}(x) = x \gg 1$$

**Equation 47. Algorithm formula**

## 2.50.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range  $<-0.5 ; 0.5$ ).

The available versions of the [MLIB\\_Sh1R](#) function are shown in the following table.

**Table 2-50. Function versions**

Function name	Input type	Result type	Description
MLIB_Sh1R_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	Shift of a 16-bit fractional value by one time to the right. The output is within the range $<-0.5 ; 0.5$ ).
MLIB_Sh1R_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	Shift of a 32-bit fractional value by one time to the right. The output is within the range $<-0.5 ; 0.5$ ).

## 2.50.2 Declaration

The available [MLIB\\_Sh1R](#) functions have the following declarations:

```
frac16\_t MLIB_Sh1R_F16(frac16\_t f16Val)
frac32\_t MLIB_Sh1R_F32(frac32\_t f32Val)
```

## 2.50.3 Function use

The use of the [MLIB\\_Sh1R](#) function is shown in the following example:

```
#include "mlib.h"

static frac32\_t f32Result, f32Val;

void main(void)
{
    f32Val = FRAC32(-0.354);          /* f32Val = -0.354 */

    /* f32Result = f32Val >> 1 */
    f32Result = MLIB_Sh1R_F32(f32Val);
}
```

## 2.51 MLIB\_ShL

The [MLIB\\_ShL](#) functions return the arithmetically shifted value to the left a specified number of times. The function does not saturate the output. See the following equation:

$$\text{MLIB\_ShL}(x, n) = x \ll n$$

### Equation 48. Algorithm formula

## 2.51.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range <-1 ; 1). The result may overflow.

The available versions of the [MLIB\\_ShL](#) function are shown in the following table.

**Table 2-51. Function versions**

Function name	Input type		Result type	Description
	Value	Shift		
MLIB_ShL_F16	<a href="#">frac16_t</a>	<a href="#">uint16_t</a>	<a href="#">frac16_t</a>	Shift of a 16-bit fractional value to the left by a number of times given by the second argument; the shift is allowed within the range <0 ; 15>. The output is within the range <-1 ; 1).
MLIB_ShL_F32	<a href="#">frac32_t</a>	<a href="#">uint16_t</a>	<a href="#">frac32_t</a>	Shift of a 32-bit fractional value to the left by a number of times given by the second argument; the shift is allowed within the range <0 ; 31>. The output is within the range <-1 ; 1).

## 2.51.2 Declaration

The available [MLIB\\_ShL](#) functions have the following declarations:

```
frac16\_t MLIB_ShL_F16(frac16\_t f16Val, uint16\_t u16Sh)
frac32\_t MLIB_ShL_F32(frac32\_t f32Val, uint16\_t u16Sh)
```

## 2.51.3 Function use

The use of the [MLIB\\_ShL](#) function is shown in the following example:

```
#include "mlib.h"

static frac16\_t f16Result, f16Val;
static uint16\_t u16Sh;

void main(void)
{
    f16Val = FRAC16(-0.354);      /* f16Val = -0.354 */
    u16Sh = 6;                    /* u16Sh = 6 */

    /* f16Result = f16Val << u16Sh */
```



```
f16Result = MLIB_ShL_F16(f16Val, u16Sh);
}
```

## 2.52 MLIB\_ShLSat

The [MLIB\\_ShLSat](#) functions return the arithmetically shifted value to the left a specified number of times. The function saturates the output. See the following equation:

$$\text{MLIB\_ShLSat}(x, n) = \begin{cases} 1, & x > \frac{1}{2^n} \\ -1, & x < \frac{-1}{2^n} \\ x \ll n, & \text{else} \end{cases}$$

**Equation 49. Algorithm formula**

### 2.52.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range <-1 ; 1). The result may saturate.

The available versions of the [MLIB\\_ShLSat](#) function are shown in the following table.

**Table 2-52. Function versions**

Function name	Input type		Result type	Description
	Value	Shift		
MLIB_ShLSat_F16	<a href="#">frac16_t</a>	<a href="#">uint16_t</a>	<a href="#">frac16_t</a>	Shift of a 16-bit fractional value to the left by a number of times given by the second argument; the shift is allowed within the range <0 ; 15>. The output is within the range <-1 ; 1).
MLIB_ShLSat_F32	<a href="#">frac32_t</a>	<a href="#">uint16_t</a>	<a href="#">frac32_t</a>	Shift of a 32-bit fractional value to the left by a number of times given by the second argument; the shift is allowed within the range <0 ; 31>. The output is within the range <-1 ; 1).

### 2.52.2 Declaration

The available [MLIB\\_ShLSat](#) functions have the following declarations:

```
frac16\_t MLIB_ShLSat_F16(frac16\_t f16Val, uint16\_t u16Sh)
frac32\_t MLIB_ShLSat_F32(frac32\_t f32Val, uint16\_t u16Sh)
```

## 2.52.3 Function use

The use of the [MLIB\\_ShLSat](#) function is shown in the following example:

```
#include "mlib.h"

static frac16_t f16Result, f16Val;
static uint16_t u16Sh;

void main(void)
{
    f16Val = FRAC16(-0.003);    /* f16Val = -0.003 */
    u16Sh = 6;                  /* u16Sh = 6 */

    /* f16Result = sat(f16Val << u16Sh) */
    f16Result = MLIB_ShLSat_F16(f16Val, u16Sh);
}
```

## 2.53 MLIB\_ShR

The [MLIB\\_ShR](#) functions return the arithmetically shifted value to the right a specified number of times. See the following equation:

$$\text{MLIB\_ShR}(x, n) = x \gg n$$

**Equation 50. Algorithm formula**

### 2.53.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range <-1 ; 1).

The available versions of the [MLIB\\_ShR](#) function are shown in the following table.

**Table 2-53. Function versions**

Function name	Input type		Result type	Description
	Value	Shift		
MLIB_ShR_F16	<a href="#">frac16_t</a>	<a href="#">uint16_t</a>	<a href="#">frac16_t</a>	Shift of a 16-bit fractional value to the right by a number of times given by the second argument; the shift is allowed within the range <0 ; 15>. The output is within the range <-1 ; 1).
MLIB_ShR_F32	<a href="#">frac32_t</a>	<a href="#">uint16_t</a>	<a href="#">frac32_t</a>	Shift of a 32-bit fractional value to the right by a number of times given by the second argument; the shift is allowed within the range <0 ; 31>. The output is within the range <-1 ; 1).

## 2.53.2 Declaration

The available [MLIB\\_ShR](#) functions have the following declarations:

```
frac16_t MLIB_ShR_F16(frac16_t f16Val, uint16_t u16Sh)
frac32_t MLIB_ShR_F32(frac32_t f32Val, uint16_t u16Sh)
```

## 2.53.3 Function use

The use of the [MLIB\\_ShR](#) function is shown in the following example:

```
#include "mlib.h"

static frac16_t f16Result, f16Val;
static uint16_t u16Sh;

void main(void)
{
    f16Val = FRAC32(-0.354);    /* f16Val = -0.354 */
    u16Sh = 8;                 /* u16Sh = 8 */

    /* f16Result = f16Val >> u16Sh */
    f16Result = MLIB_ShR_F16(f16Val, u16Sh);
}
```

## 2.54 MLIB\_ShLBi

The [MLIB\\_ShLBi](#) functions return the arithmetically shifted value to the left a specified number of times. If the number of shifts is positive, the shift is performed to the left; if negative, to the right. The function does not saturate the output. See the following equation:

$$\text{MLIB\_ShLBi}(x, n) = x \ll n$$

**Equation 51. Algorithm formula**

### 2.54.1 Available versions

The function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range <-1 ; 1). The result may overflow.

The available versions of the [MLIB\\_ShLbI](#) function are shown in the following table.

**Table 2-54. Function versions**

Function name	Input type		Result type	Description
	Value	Shift		
MLIB_ShLbI_F16	<a href="#">frac16_t</a>	<a href="#">int16_t</a>	<a href="#">frac16_t</a>	Bidirectional shift of a 16-bit fractional value to the left by a number of times given by the second argument; if the second argument is negative, the shift is performed to the right. The shift is allowed within the range <-15 ; 15>. The output is within the range <-1 ; 1>).
MLIB_ShLbI_F32	<a href="#">frac32_t</a>	<a href="#">int16_t</a>	<a href="#">frac32_t</a>	Bidirectional shift of a 32-bit fractional value to the left by a number of times given by the second argument; if the second argument is negative, the shift is performed to the right. The shift is allowed within the range <-31 ; 31>. The output is within the range <-1 ; 1>).

## 2.54.2 Declaration

The available [MLIB\\_ShLbI](#) functions have the following declarations:

```
frac16\_t MLIB_ShLbI_F16(frac16\_t f16Val, int16\_t i16Sh)
frac32\_t MLIB_ShLbI_F32(frac32\_t f32Val, int16\_t i16Sh)
```

## 2.54.3 Function use

The use of the [MLIB\\_ShLbI](#) function is shown in the following example:

```
#include "mlib.h"

static frac32\_t f32Result, f32Val;
static int16\_t i16Sh;

void main(void)
{
    f32Val = FRAC32(-0.354);      /* f32Val = -0.354 */
    i16Sh = -3;                  /* i16Sh = -3 */

    /* f32Result = f32Val << i16Sh */
    f32Result = MLIB_ShLbI_F32(f32Val, i16Sh);
}
```

## 2.55 MLIB\_ShLbISat

The [MLIB\\_ShLbBiSat](#) functions return the arithmetically shifted value to the left a specified number of times. If the number of shifts is positive, the shift is performed to the left; if negative, to the right. The function saturates the output. See the following equation:

$$\text{MLIB\_ShLbBiSat}(x, n) = \begin{cases} 1, & x > \frac{1}{2^n} \wedge n > 0 \\ -1, & x < \frac{-1}{2^n} \wedge n > 0 \\ x \ll n, & \text{else} \end{cases}$$

**Equation 52. Algorithm formula**

## 2.55.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range <-1 ; 1). The result may saturate.

The available versions of the [MLIB\\_ShLbBiSat](#) function are shown in the following table.

**Table 2-55. Function versions**

Function name	Input type		Result type	Description
	Value	Shift		
MLIB_ShLbBiSat_F16	<a href="#">frac16_t</a>	<a href="#">int16_t</a>	<a href="#">frac16_t</a>	Bidirectional shift of a 16-bit fractional value to the left by a number of times given by the second argument; if the second argument is negative, the shift is performed to the right. The shift is allowed within the range <-15 ; 15>. The output is within the range <-1 ; 1).
MLIB_ShLbBiSat_F32	<a href="#">frac32_t</a>	<a href="#">int16_t</a>	<a href="#">frac32_t</a>	Bidirectional shift of a 32-bit fractional value to the left by a number of times given by the second argument; if the second argument is negative, the shift is performed to the right. The shift is allowed within the range <-31 ; 31>. The output is within the range <-1 ; 1).

## 2.55.2 Declaration

The available [MLIB\\_ShLbBiSat](#) functions have the following declarations:

```
frac16\_t MLIB_ShLbBiSat_F16(frac16\_t f16Val, int16\_t i16Sh)
frac32\_t MLIB_ShLbBiSat_F32(frac32\_t f32Val, int16\_t i16Sh)
```

### 2.55.3 Function use

The use of the [MLIB\\_ShLBiSat](#) function is shown in the following example:

```
#include "mlib.h"

static frac16_t f16Result, f16Val;
static int16_t i16Sh;

void main(void)
{
    f16Val = FRAC16(-0.354);      /* f16Val = -0.354 */
    i16Sh = 14;                  /* i16Sh = 14 */

    /* f16Result = sat(f16Val << i16Sh) */
    f16Result = MLIB_ShLBiSat_F16(f16Val, i16Sh);
}
```

### 2.56 MLIB\_ShRBi

The [MLIB\\_ShRBi](#) functions return the arithmetically shifted value to the right a specified number of times. If the number of shifts is positive, the shift is performed to the right; if negative, to the left. The function does not saturate the output. See the following equation:

$$\text{MLIB\_ShRBi}(x, n) = x \gg n$$

Equation 53. Algorithm formula

#### 2.56.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range <-1 ; 1). The result may overflow.

The available versions of the [MLIB\\_ShRBi](#) function are shown in the following table.

Table 2-56. Function versions

Function name	Input type		Result type	Description
	Value	Shift		
MLIB_ShRBi_F16	<a href="#">frac16_t</a>	<a href="#">int16_t</a>	<a href="#">frac16_t</a>	Bidirectional shift of a 16-bit fractional value to the right by a number of times given by the second argument; if the second argument is negative, the shift is performed to the left. The shift is allowed within the range <-15 ; 15>. The output is within the range <-1 ; 1).

Table continues on the next page...

**Table 2-56. Function versions (continued)**

Function name	Input type		Result type	Description
	Value	Shift		
MLIB_ShRBi_F32	frac32_t	int16_t	frac32_t	Bidirectional shift of a 32-bit fractional value to the right by a number of times given by the second argument; if the second argument is negative, the shift is performed to the left. The shift is allowed within the range <-31 ; 31>. The output is within the range <-1 ; 1).

## 2.56.2 Declaration

The available [MLIB\\_ShRBi](#) functions have the following declarations:

```
frac16_t MLIB_ShRBi_F16(frac16_t f16Val, int16_t i16Sh)
frac32_t MLIB_ShRBi_F32(frac32_t f32Val, int16_t i16Sh)
```

## 2.56.3 Function use

The use of the [MLIB\\_ShRBi](#) function is shown in the following example:

```
#include "mlib.h"

static frac32_t f32Result, f32Val;
static int16_t i16Sh;

void main(void)
{
    f32Val = FRAC32(0.354);      /* f32In = 0.354 */
    i16Sh = 8;                   /* i16Sh = 8 */

    /* f32Result = f32Val >> i16Sh */
    f32Result = MLIB_ShRBi_F32(f32Val, i16Sh);
}
```

## 2.57 MLIB\_ShRBiSat

The [MLIB\\_ShRBiSat](#) functions return the arithmetically shifted value to the right a specified number of times. If the number of shifts is positive, the shift is performed to the right; if negative, to the left. The function saturates the output. See the following equation:

$$\text{MLIB\_ShRBSat}(x, n) = \begin{cases} 1, & x > \frac{1}{2^n} \wedge n < 0 \\ -1, & x < -\frac{1}{2^n} \wedge n < 0 \\ x \gg n, & \text{else} \end{cases}$$

**Equation 54. Algorithm formula**

## 2.57.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range <-1 ; 1). The result may saturate.

The available versions of the [MLIB\\_ShRBSat](#) function are shown in the following table.

**Table 2-57. Function versions**

Function name	Input type		Result type	Description
	Value	Shift		
MLIB_ShRBSat_F16	<a href="#">frac16_t</a>	<a href="#">int16_t</a>	<a href="#">frac16_t</a>	Bidirectional shift of a 16-bit fractional value to the right by a number of times given by the second argument; if the second argument is negative, the shift is performed to the left. The shift is allowed within the range <-15 ; 15>. The output is within the range <-1 ; 1).
MLIB_ShRBSat_F32	<a href="#">frac32_t</a>	<a href="#">int16_t</a>	<a href="#">frac32_t</a>	Bidirectional shift of a 32-bit fractional value to the right by a number of times given by the second argument; if the second argument is negative, the shift is performed to the left. The shift is allowed within the range <-31 ; 31>. The output is within the range <-1 ; 1).

## 2.57.2 Declaration

The available [MLIB\\_ShRBSat](#) functions have the following declarations:

```
frac16\_t MLIB_ShRBSat_F16(frac16\_t f16Val, int16\_t i16Sh)
frac32\_t MLIB_ShRBSat_F32(frac32\_t f32Val, int16\_t i16Sh)
```

## 2.57.3 Function use

The use of the [MLIB\\_ShRBSat](#) function is shown in the following example:

```
include "mlib.h"

static frac32\_t f32Result, f32Val;
```



```
static int16_t i16Sh;

void main(void)
{
    f32Val = FRAC32(-0.354);    /* f32Val = -0.354 */
    i16Sh = 13;                /* i16Sh = 13 */

    /* f32Result = sat(f32Val >> i16Sh) */
    f32Result = MLIB_ShrBiSat_F32(f32Val, i16Sh);
}
```

## 2.58 MLIB\_Sign

The [MLIB\\_Sign](#) functions return the sign of the input. See the following equation:

$$\text{MLIB\_Sign}(x) = \begin{cases} 1, & x > 0 \\ 0, & x = 0 \\ -1, & x < 0 \end{cases}$$

**Equation 55. Algorithm formula**

### 2.58.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range <-1 ; 1).
- Floating-point output - the output is a floating-point number; the result is within the full range.

The available versions of the [MLIB\\_Sign](#) function are shown in the following table.

**Table 2-58. Function versions**

Function name	Input type	Result type	Description
MLIB_Sign_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	Sign of a 16-bit fractional value. The output is within the range <-1 ; 1).
MLIB_Sign_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	Sign of a 32-bit fractional value. The output is within the range <-1 ; 1).
MLIB_Sign_FLT	<a href="#">float_t</a>	<a href="#">float_t</a>	Sign of a 32-bit single precision floating-point value. The output is within the full range.

### 2.58.2 Declaration

The available [MLIB\\_Sign](#) functions have the following declarations:

```
frac16_t MLIB_Sign_F16(frac16_t f16Val)
frac32_t MLIB_Sign_F32(frac32_t f32Val)
float_t MLIB_Sign_FLT(float_t fltVal)
```

## 2.58.3 Function use

The use of the [MLIB\\_Sign](#) function is shown in the following example:

```
#include "mlib.h"

static frac32_t f32In, f32Result;

void main(void)
{
    f32In = FRAC32(-0.95);          /* f32In = -0.95 */

    /* f32Result = sign(f32In) */
    f32Result = MLIB_Sign_F32(f32In);
}
```

## 2.59 MLIB\_Sub

The [MLIB\\_Sub](#) functions subtract the subtrahend from the minuend. The function does not saturate the output. See the following equation:

$$\text{MLIB\_Sub}(a, b) = a - b$$

**Equation 56. Algorithm formula**

### 2.59.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range <-1 ; 1). The result may overflow.
- Accumulator output with fractional inputs - the output is the accumulator type, where the result can be out of the range <-1 ; 1). The inputs are the fractional values only.
- Accumulator output with mixed inputs - the output is the accumulator type, where the result can be out of the range <-1 ; 1). The inputs are the accumulator and fractional values. The result may overflow.
- Floating-point output - the output is a floating-point number; the result is within the full range.

The available versions of the [MLIB\\_Sub](#) function are shown in the following table.

**Table 2-59. Function versions**

Function name	Input type		Result type	Description
	Minuend	Subtrahend		
MLIB_Sub_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	Subtraction of a 16-bit fractional subtrahend from a 16-bit fractional minuend. The output is within the range <-1 ; 1).
MLIB_Sub_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	Subtraction of a 32-bit fractional subtrahend from a 32-bit fractional minuend. The output is within the range <-1 ; 1).
MLIB_Sub_A32ss	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">acc32_t</a>	Subtraction of a 16-bit fractional subtrahend from a 16-bit fractional minuend; the result is a 32-bit accumulator. The output may be out of the range <-1 ; 1).
MLIB_Sub_A32as	<a href="#">acc32_t</a>	<a href="#">frac16_t</a>	<a href="#">acc32_t</a>	Subtraction of a 16-bit fractional subtrahend from a 32-bit accumulator. The output may be out of the range <-1 ; 1).
MLIB_Sub_FLT	<a href="#">float_t</a>	<a href="#">float_t</a>	<a href="#">float_t</a>	Subtraction of a 32-bit single precision floating-point subtrahend from a 32-bit single precision floating-point minuend. The output is within the full range.

## 2.59.2 Declaration

The available [MLIB\\_Sub](#) functions have the following declarations:

```

frac16\_t MLIB_Sub_F16(frac16\_t f16Min, frac16\_t f16Sub)
frac32\_t MLIB_Sub_F32(frac32\_t f32Min, frac32\_t f32Sub)
acc32\_t MLIB_Sub_A32ss(frac16\_t f16Min, frac16\_t f16Sub)
acc32\_t MLIB_Sub_A32as(acc32\_t a32Accum, frac16\_t f16Sub)
float\_t MLIB_Sub_FLT(float\_t fltMin, float\_t fltSub)

```

## 2.59.3 Function use

The use of the [MLIB\\_Sub](#) function is shown in the following example:

```

#include "mlib.h"

static acc32\_t a32Accum, a32Result;
static frac16\_t f16Sub;

void main(void)
{
    a32Accum = ACC32(4.5);           /* a32Accum = 4.5 */
    f16Sub = FRAC16(0.4);           /* f16Sub = 0.4 */

    /* a32Result = a32Accum - f16Sub */
    a32Result = MLIB_Sub_A32as(a32Accum, f16Sub);
}

```

## 2.60 MLIB\_SubSat

The [MLIB\\_SubSat](#) functions subtract the subtrahend from the minuend. The function saturates the output. See the following equation:

$$\text{MLIB\_SubSat}(a, b) = \begin{cases} 1, & a - b > 1 \\ -1, & a - b < -1 \\ a - b, & \text{else} \end{cases}$$

**Equation 57. Algorithm formula**

### 2.60.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range <-1 ; 1). The result may saturate.

The available versions of the [MLIB\\_SubSat](#) function are shown in the following table.

**Table 2-60. Function versions**

Function name	Input type		Result type	Description
	Minuend	Subtrahend		
MLIB_SubSat_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	Subtraction of a 16-bit fractional subtrahend from a 16-bit fractional minuend. The output is within the range <-1 ; 1).
MLIB_SubSat_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	Subtraction of a 32-bit fractional subtrahend from a 32-bit fractional minuend. The output is within the range <-1 ; 1).

### 2.60.2 Declaration

The available [MLIB\\_SubSat](#) functions have the following declarations:

```
frac16\_t MLIB_SubSat_F16(frac16\_t f16Min, frac16\_t f16Sub)
frac32\_t MLIB_SubSat_F32(frac32\_t f32Min, frac32\_t f32Sub)
```

### 2.60.3 Function use

The use of the [MLIB\\_SubSat](#) function is shown in the following example:

```
#include "mlib.h"

static frac32_t f32Min, f32Sub, f32Result;

void main(void)
{
    f32Min = FRAC32(-0.5);          /* f32Min = -0.5 */
    f32Sub = FRAC32(0.8);           /* f32Sub = 0.8 */

    /* f32Result = sat(f32Min - f32Sub) */
    f32Result = MLIB_SubSat_F32(f32Min, f32Sub);
}
```

## 2.61 MLIB\_Sub4

The [MLIB\\_Sub4](#) functions return the subtraction of three subtrahends from the minuend. The function does not saturate the output. See the following equation:

$$\text{MLIB\_Sub4}(a, b, c, d) = a - b - c - d$$

**Equation 58. Algorithm formula**

### 2.61.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range  $<-1 ; 1$ ). The result may overflow.
- Floating-point output - the output is a floating-point number; the result is within the full range.

The available versions of the [MLIB\\_Sub4](#) function are shown in the following table.

**Table 2-61. Function versions**

Function name	Input type				Result type	Description
	Minuend	Sub. 1	Sub. 2	Sub. 3		
MLIB_Sub4_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	Subtraction of three 16-bit fractional subtrahends from 16-bit fractional minuend. The output is within the range $<-1 ; 1$ ).
MLIB_Sub4_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	Subtraction of three 32-bit fractional subtrahends from 32-bit fractional minuend. The output is within the range $<-1 ; 1$ ).
MLIB_Sub4_FLT	<a href="#">float_t</a>	<a href="#">float_t</a>	<a href="#">float_t</a>	<a href="#">float_t</a>	<a href="#">float_t</a>	Subtraction of three 32-bit single precision floating-point subtrahends from 32-bit single precision floating-point. The output is within the full range.

## 2.61.2 Declaration

The available [MLIB\\_Sub4](#) functions have the following declarations:

```
frac16_t MLIB_Sub4_F16(frac16_t f16Min, frac16_t f16Sub1, frac16_t f16Sub2, frac16_t f16Sub3)
frac32_t MLIB_Sub4_F32(frac32_t f32Min, frac32_t f32Sub1, frac32_t f32Sub2, frac32_t f32Sub3)
float_t MLIB_Sub4_FLT(float_t fltMin, float_t fltSub1, float_t fltSub2, float_t fltSub3)
```

## 2.61.3 Function use

The use of the [MLIB\\_Sub4](#) function is shown in the following example:

```
#include "mlib.h"

static frac16_t f16Result, f16Min, f16Sub1, f16Sub2, f16Sub3;

void main(void)
{
    f16Min = FRAC16(0.2);          /* f16Min = 0.2 */
    f16Sub1 = FRAC16(0.3);         /* f16Sub1 = 0.3 */
    f16Sub2 = FRAC16(-0.5);        /* f16Sub2 = -0.5 */
    f16Sub3 = FRAC16(0.2);         /* f16Sub3 = 0.2 */

    /* f16Result = sat(f16Min - f16Sub1 - f16Sub2 - f16Sub3) */
    f16Result = MLIB_Sub4_F16(f16Min, f16Sub1, f16Sub2, f16Sub3);
}
```

## 2.62 MLIB\_Sub4Sat

The [MLIB\\_Sub4Sat](#) functions return the subtraction of three subtrahends from the minuend. The function saturates the output. See the following equation:

$$\text{MLIB\_Sub4Sat}(a, b, c, d) = \begin{cases} 1, & a - b - c - d > 1 \\ -1, & a - b - c - d < -1 \\ a - b - c - d, & \text{else} \end{cases}$$

**Equation 59. Algorithm formula**

### 2.62.1 Available versions

This function is available in the following versions:

- Fractional output - the output is the fractional portion of the result; the result is within the range <-1 ; 1). The result may saturate.

The available versions of the [MLIB\\_Sub4Sat](#) function are shown in the following table.

**Table 2-62. Function versions**

Function name	Input type				Result type	Description
	Minuend	Sub. 1	Sub. 2	Sub. 3		
MLIB_Sub4Sat_F16	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	<a href="#">frac16_t</a>	Subtraction of three 16-bit fractional subtrahends from 16-bit fractional minuend. The output is within the range <-1 ; 1).
MLIB_Sub4Sat_F32	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	<a href="#">frac32_t</a>	Subtraction of three 32-bit fractional subtrahends from 32-bit fractional minuend. The output is within the range <-1 ; 1).

## 2.62.2 Declaration

The available [MLIB\\_Sub4Sat](#) functions have the following declarations:

```
frac16\_t MLIB_Sub4Sat_F16(frac16\_t f16Min, frac16\_t f16Sub1, frac16\_t f16Sub2, frac16\_t
f16Sub3)
frac32\_t MLIB_Sub4Sat_F32(frac32\_t f32Min, frac32\_t f32Sub1, frac32\_t f32Sub2, frac32\_t
f32Sub3)
```

## 2.62.3 Function use

The use of the [MLIB\\_Sub4Sat](#) function is shown in the following example:

```
#include "mlib.h"

static frac32\_t f32Result, f32Min, f32Sub1, f32Sub2, f32Sub3;

void main(void)
{
    f32Min = FRAC32(0.2);           /* f32Min = 0.2 */
    f32Sub1 = FRAC32(0.8);          /* f32Sub1 = 0.8 */
    f32Sub2 = FRAC32(-0.1);         /* f32Sub2 = -0.1 */
    f32Sub3 = FRAC32(0.7);          /* f32Sub3 = 0.7 */

    /* f32Result = sat(f32Min - f32Sub1 - f32Sub2 - f32Sub3) */
    f32Result = MLIB_Sub4Sat_F32(f32Min, f32Sub1, f32Sub2, f32Sub3);
}
```





# Appendix A

## Library types

### A.1 bool\_t

The `bool_t` type is a logical 16-bit type. It is able to store the boolean variables with two states: TRUE (1) or FALSE (0). Its definition is as follows:

```
typedef unsigned short bool_t;
```

The following figure shows the way in which the data is stored by this type:

**Table A-1. Data storage**

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Value	Unused															Logical
TRUE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	0				0				0				1			
FALSE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0				0				0				0			

To store a logical value as `bool_t`, use the `FALSE` or `TRUE` macros.

### A.2 uint8\_t

The `uint8_t` type is an unsigned 8-bit integer type. It is able to store the variables within the range <0 ; 255>. Its definition is as follows:

```
typedef unsigned char uint8_t;
```

The following figure shows the way in which the data is stored by this type:

**Table A-2. Data storage**

	7	6	5	4	3	2	1	0
Value	Integer							
255	1	1	1	1	1	1	1	1
	F				F			
11	0	0	0	0	1	0	1	1
	0				B			
124	0	1	1	1	1	1	0	0
	7				C			
159	1	0	0	1	1	1	1	1
	9				F			

## A.3 uint16\_t

The `uint16_t` type is an unsigned 16-bit integer type. It is able to store the variables within the range  $<0 ; 65535>$ . Its definition is as follows:

```
typedef unsigned short uint16_t;
```

The following figure shows the way in which the data is stored by this type:

**Table A-3. Data storage**

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Value	Integer															
65535	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	F				F				F				F			
5	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
	0				0				0				5			
15518	0	0	1	1	1	1	0	0	1	0	0	1	1	1	1	0
	3				C				9				E			
40768	1	0	0	1	1	1	1	1	0	1	0	0	0	0	0	0
	9				F				4				0			

## A.4 uint32\_t

The `uint32_t` type is an unsigned 32-bit integer type. It is able to store the variables within the range  $<0 ; 4294967295>$ . Its definition is as follows:

```
typedef unsigned long uint32_t;
```

The following figure shows the way in which the data is stored by this type:

**Table A-4. Data storage**

	31	24	23	16	15	8	7	0
Value	Integer							
4294967295	F	F	F	F	F	F	F	F
2147483648	8	0	0	0	0	0	0	0
55977296	0	3	5	6	2	5	5	0
3451051828	C	D	B	2	D	F	3	4

## A.5 int8\_t

The `int8_t` type is a signed 8-bit integer type. It is able to store the variables within the range  $<-128 ; 127>$ . Its definition is as follows:

```
typedef char int8_t;
```

The following figure shows the way in which the data is stored by this type:

**Table A-5. Data storage**

	7	6	5	4	3	2	1	0
Value	Sign	Integer						
127	0	1	1	1	1	1	1	1
	7				F			
-128	1	0	0	0	0	0	0	0
	8				0			
60	0	0	1	1	1	1	0	0
	3				C			
-97	1	0	0	1	1	1	1	1
	9				F			

## A.6 int16\_t

The `int16_t` type is a signed 16-bit integer type. It is able to store the variables within the range  $<-32768 ; 32767>$ . Its definition is as follows:

```
typedef short int16_t;
```

The following figure shows the way in which the data is stored by this type:

**Table A-6. Data storage**

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Value	Sign	Integer														
32767	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	7				F				F				F			
-32768	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	8				0				0				0			
15518	0	0	1	1	1	1	0	0	1	0	0	1	1	1	1	0
	3				C				9				E			
-24768	1	0	0	1	1	1	1	1	0	1	0	0	0	0	0	0
	9				F				4				0			

## A.7 int32\_t

The `int32_t` type is a signed 32-bit integer type. It is able to store the variables within the range  $<-2147483648 ; 2147483647>$ . Its definition is as follows:

```
typedef long int32_t;
```

The following figure shows the way in which the data is stored by this type:

**Table A-7. Data storage**

	31	24 23				16 15				8 7				0
Value	S	Integer												
2147483647	7	F		F	F		F	F		F		F		
-2147483648	8	0		0	0		0	0		0		0		
55977296	0	3		5	6		2	5		5		0		
-843915468	C	D		B	2		D	F		3		4		

## A.8 frac8\_t

The `frac8_t` type is a signed 8-bit fractional type. It is able to store the variables within the range  $<-1 ; 1$ ). Its definition is as follows:

```
typedef char frac8_t;
```

The following figure shows the way in which the data is stored by this type:

**Table A-8. Data storage**

	7	6	5	4	3	2	1	0
Value	Sign	Fractional						
0.99219	0	1	1	1	1	1	1	1
	7				F			
-1.0	1	0	0	0	0	0	0	0
	8				0			
0.46875	0	0	1	1	1	1	0	0
	3				C			
-0.75781	1	0	0	1	1	1	1	1
	9				F			

To store a real number as `frac8_t`, use the `FRAC8` macro.

## A.9 frac16\_t

The `frac16_t` type is a signed 16-bit fractional type. It is able to store the variables within the range  $<-1 ; 1$ ). Its definition is as follows:

```
typedef short frac16_t;
```

The following figure shows the way in which the data is stored by this type:

**Table A-9. Data storage**

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Value	Sign	Fractional														
0.99997	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	7				F				F				F			
-1.0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

*Table continues on the next page...*

**Table A-9. Data storage (continued)**

0.47357  -0.75586	8				0				0				0			
	0	0	1	1	1	1	0	0	1	0	0	1	1	1	1	0
	3				C				9				E			
	1	0	0	1	1	1	1	1	0	1	0	0	0	0	0	0
	9				F				4				0			

To store a real number as `frac16_t`, use the `FRAC16` macro.

## A.10 frac32\_t

The `frac32_t` type is a signed 32-bit fractional type. It is able to store the variables within the range  $<-1 ; 1$ ). Its definition is as follows:

```
typedef long frac32_t;
```

The following figure shows the way in which the data is stored by this type:

**Table A-10. Data storage**

	31	24 23		16 15		8 7		0	
Value	S	Fractional							
0.9999999995	7	F	F	F	F	F	F	F	
-1.0	8	0	0	0	0	0	0	0	
0.02606645970	0	3	5	6	2	5	5	0	
-0.3929787632	C	D	B	2	D	F	3	4	

To store a real number as `frac32_t`, use the `FRAC32` macro.

## A.11 acc16\_t

The `acc16_t` type is a signed 16-bit fractional type. It is able to store the variables within the range  $<-256 ; 256$ ). Its definition is as follows:

```
typedef short acc16_t;
```

The following figure shows the way in which the data is stored by this type:

**Table A-11. Data storage**

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
Value	Sign	Integer								Fractional							
255.9921875	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
	7				F				F				F				
-256.0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	8				0				0				0				
1.0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	
	0				0				8				0				
-1.0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	
	F				F				8				0				
13.7890625	0	0	0	0	0	1	1	0	1	1	1	0	0	1	0	1	
	0				6				E				5				
-89.71875	1	1	0	1	0	0	1	1	0	0	1	0	0	1	0	0	
	D				3				2				4				

To store a real number as `acc16_t`, use the `ACC16` macro.

## A.12 `acc32_t`

The `acc32_t` type is a signed 32-bit accumulator type. It is able to store the variables within the range  $<-65536 ; 65536$ ). Its definition is as follows:

```
typedef long acc32_t;
```

The following figure shows the way in which the data is stored by this type:

**Table A-12. Data storage**

	31	24 23		16 15		8 7		0	
Value	S	Integer				Fractional			
65535.999969	7	F	F	F	F	F	F	F	
-65536.0	8	0	0	0	0	0	0	0	
1.0	0	0	0	0	8	0	0	0	
-1.0	F	F	F	F	8	0	0	0	
23.789734	0	0	0	B	E	5	1	6	
-1171.306793	F	D	B	6	5	8	B	C	

To store a real number as `acc32_t`, use the `ACC32` macro.

## A.13 float\_t

The `float_t` type is a signed 32-bit single precision floating-point type, defined by IEEE 754. It is able to store the full precision (normalized) finite variables within the range  $[-3.40282 \cdot 10^{38}; 3.40282 \cdot 10^{38}]$  with the minimum resolution of  $2^{-23}$ . The smallest normalized number is  $\pm 1.17549 \cdot 10^{-38}$ . Nevertheless, the denormalized numbers (with reduced precision) reach yet lower values, from  $\pm 1.40130 \cdot 10^{-45}$  to  $\pm 1.17549 \cdot 10^{-38}$ . The standard also defines the additional values:

- Negative zero
- Infinity
- Negative infinity
- Not a number

The 32-bit type is composed of:

- Sign (bit 31)
- Exponent (bits 23 to 30)
- Mantissa (bits 0 to 22)

The conversion of the number is straightforward. The sign of the number is stored in bit 31. The binary exponent is decoded as an integer from bits 23 to 30 by subtracting 127. The mantissa (fraction) is stored in bits 0 to 22. An invisible leading bit (it is not actually stored) with value 1.0 is placed in front; therefore, bit 23 has a value of 0.5, bit 22 has a value 0.25, and so on. As a result, the mantissa has a value between 1.0 and 2. If the exponent reaches -127 (binary 00000000), the leading 1.0 is no longer used to enable the gradual underflow.

The `float_t` type definition is as follows:

```
typedef float float t;
```

The following figure shows the way in which the data is stored by this type:

**Table A-13. Data storage - normalized values**

	31	24 23							16 15							8 7							0									
Value	S	Exponent							Mantissa																							
$(2.0 - 2^{-23}) \cdot 2^{127}$	0	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			
$\approx 3.40282 \cdot 10^{38}$	7							F	7							F	F							F	F							F
$-(2.0 - 2^{-23}) \cdot 2^{127}$	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			
$\approx -3.40282 \cdot 10^{38}$	F							F	7							F	F							F	F							F

*Table continues on the next page...*



**Table A-13. Data storage - normalized values (continued)**

$2^{-126}$ $\approx 1.17549 \cdot 10^{-38}$	0	0 0 0 0 0 0 0 0 1	0 0
	0	0	8 0 0 0 0 0
$-2^{-126}$ $\approx -1.17549 \cdot 10^{-38}$	1	0 0 0 0 0 0 0 0 1	0 0
	8	0	8 0 0 0 0 0
1.0	0	0 1 1 1 1 1 1 1 1	0 0
	3	F	8 0 0 0 0 0
-1.0	1	0 1 1 1 1 1 1 1 1	0 0
	B	F	8 0 0 0 0 0
$\pi$ $\approx 3.1415927$	0	1 0 0 0 0 0 0 0 0	1 0 0 1 0 0 1 0 0 0 0 1 1 1 1 1 1 1 0 1 1 0 1 1 1 1 0 1 1 1 0 1 1
	4	0	4 9 0 F D B
-20810.086	1	1 0 0 0 1 1 0 1	0 1 0 0 0 1 0 1 0 0 1 0 1 0 0 0 0 1 0 1 1 0 0 0 0 1 0 1 1 0 0 0
	C	6	A 2 9 4 2 C

**Table A-14. Data storage - denormalized values**

	31	24 23	16 15	8 7	0																					
Value	S	Exponent	Mantissa																							
0.0	0	0 0 0 0 0 0 0 0 0	0 0																							
		0 0	0 0	0 0	0 0																					
-0.0	1	0 0 0 0 0 0 0 0 0	0 0																							
		8 0	0 0	0 0	0 0																					
$(1.0 - 2^{-23}) \cdot 2^{-126}$ $\approx 1.17549 \cdot 10^{-38}$	0	0 0 0 0 0 0 0 0 0	1 1																							
		0 0	7 F	F F	F F																					
$-(1.0 - 2^{-23}) \cdot 2^{-126}$ $\approx -1.17549 \cdot 10^{-38}$	1	0 0 0 0 0 0 0 0 0	1 1																							
		8 0	7 F	F F	F F																					
$2^{-1} \cdot 2^{-126}$ $\approx 5.87747 \cdot 10^{-39}$	0	0 0 0 0 0 0 0 0 0	1 0																							
		0 0	4 0	0 0	0 0																					
$-2^{-1} \cdot 2^{-126}$ $\approx -5.87747 \cdot 10^{-39}$	1	0 0 0 0 0 0 0 0 0	1 0																							
		8 0	4 0	0 0	0 0																					
$2^{-23} \cdot 2^{-126}$ $\approx 1.40130 \cdot 10^{-45}$	0	0 0 0 0 0 0 0 0 0	0 1																							
		0 0	0 0	0 0	0 1																					
$-2^{-23} \cdot 2^{-126}$ $\approx -1.40130 \cdot 10^{-45}$	1	0 0 0 0 0 0 0 0 0	0 1																							
		8 0	0 0	0 0	0 1																					

Table A-15. Data storage - special values

	31	24 23							16 15							8 7							0								
Value	S	Exponent							Mantissa																						
∞	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
	7 F							8 0							0 0							0 0									
-∞	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
	F F							8 0							0 0							0 0									
Not a number	*	1	1	1	1	1	1	1	non zero																						
	7/F F							800001 to FFFFFFFF																							

A.14 FALSE

The FALSE macro serves to write a correct value standing for the logical FALSE value of the bool\_t type. Its definition is as follows:

```
#define FALSE      ((bool_t)0)

#include "mlib.h"

static bool_t bVal;

void main(void)
{
    bVal = FALSE;          /* bVal = FALSE */
}
```

A.15 TRUE

The TRUE macro serves to write a correct value standing for the logical TRUE value of the bool\_t type. Its definition is as follows:

```
#define TRUE       ((bool_t)1)

#include "mlib.h"

static bool_t bVal;

void main(void)
{
    bVal = TRUE;           /* bVal = TRUE */
}
```

## A.16 FRAC8

The **FRAC8** macro serves to convert a real number to the `frac8_t` type. Its definition is as follows:

```
#define FRAC8(x) ((frac8_t)((x) < 0.9921875 ? ((x) >= -1 ? (x)*0x80 : 0x80) : 0x7F))
```

The input is multiplied by 128 ( $=2^7$ ). The output is limited to the range  $\langle 0x80 ; 0x7F \rangle$ , which corresponds to  $\langle -1.0 ; 1.0 \cdot 2^{-7} \rangle$ .

```
#include "mlib.h"

static frac8_t f8Val;

void main(void)
{
    f8Val = FRAC8(0.187);          /* f8Val = 0.187 */
}
```

## A.17 FRAC16

The **FRAC16** macro serves to convert a real number to the `frac16_t` type. Its definition is as follows:

```
#define FRAC16(x) ((frac16_t)((x) < 0.999969482421875 ? ((x) >= -1 ? (x)*0x8000 : 0x8000) : 0x7FFF))
```

The input is multiplied by 32768 ( $=2^{15}$ ). The output is limited to the range  $\langle 0x8000 ; 0x7FFF \rangle$ , which corresponds to  $\langle -1.0 ; 1.0 \cdot 2^{-15} \rangle$ .

```
#include "mlib.h"

static frac16_t f16Val;

void main(void)
{
    f16Val = FRAC16(0.736);        /* f16Val = 0.736 */
}
```

## A.18 FRAC32

The **FRAC32** macro serves to convert a real number to the `frac32_t` type. Its definition is as follows:

## ACC16

```
#define FRAC32(x) ((frac32_t)((x) < 1 ? ((x) >= -1 ? (x)*0x80000000 : 0x80000000) : 0x7FFFFFFF))
```

The input is multiplied by 2147483648 ( $=2^{31}$ ). The output is limited to the range  $\langle 0x80000000 ; 0x7FFFFFFF \rangle$ , which corresponds to  $\langle -1.0 ; 1.0 \cdot 2^{-31} \rangle$ .

```
#include "mlib.h"

static frac32_t f32Val;

void main(void)
{
    f32Val = FRAC32(-0.1735667);          /* f32Val = -0.1735667 */
}
```

## A.19 ACC16

The **ACC16** macro serves to convert a real number to the `acc16_t` type. Its definition is as follows:

```
#define ACC16(x) ((acc16_t)((x) < 255.9921875 ? ((x) >= -256 ? (x)*0x80 : 0x8000) : 0x7FFF))
```

The input is multiplied by 128 ( $=2^7$ ). The output is limited to the range  $\langle 0x8000 ; 0x7FFF \rangle$  that corresponds to  $\langle -256.0 ; 255.9921875 \rangle$ .

```
#include "mlib.h"

static acc16_t a16Val;

void main(void)
{
    a16Val = ACC16(19.45627);             /* a16Val = 19.45627 */
}
```

## A.20 ACC32

The **ACC32** macro serves to convert a real number to the `acc32_t` type. Its definition is as follows:

```
#define ACC32(x) ((acc32_t)((x) < 65535.999969482421875 ? ((x) >= -65536 ? (x)*0x8000 : 0x80000000) : 0x7FFFFFFF))
```

The input is multiplied by 32768 ( $=2^{15}$ ). The output is limited to the range  $\langle 0x80000000 ; 0x7FFFFFFF \rangle$ , which corresponds to  $\langle -65536.0 ; 65536.0 \cdot 2^{-15} \rangle$ .

```
#include "mlib.h"

static acc32_t a32Val;

void main(void)
{
    a32Val = ACC32(-13.654437);          /* a32Val = -13.654437 */
}
```



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