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# MLIB User's Guide

DSP56800EX

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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 DSP56800EX core-based digital signal controllers. This library contains optimized functions.

#### 1.1.2 Data types

MLIB supports several data types: (un)signed integer, fractional, and accumulator. 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 following list shows the integer types defined in the libraries:

- **Unsigned 16-bit integer** — $\langle 0 ; 65535 \rangle$  with the minimum resolution of 1
- **Signed 16-bit integer** — $\langle -32768 ; 32767 \rangle$  with the minimum resolution of 1
- **Unsigned 32-bit integer** — $\langle 0 ; 4294967295 \rangle$  with the minimum resolution of 1
- **Signed 32-bit integer** — $\langle -2147483648 ; 2147483647 \rangle$  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  $2^{-15}$

### 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

### 1.1.4 Supported compilers

MLIB for the DSP56800EX core is written in assembly language with C-callable interface. The library is built and tested using the following compilers:

- CodeWarrior™ Development Studio

For the CodeWarrior™ Development Studio, 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 Library configuration

## 1.1.6 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 require the core saturation mode to be turned off, otherwise the results can be incorrect. Several specific library functions are immune to the setting of the saturation mode.
3. The library functions round the result (the API contains Rnd) to the nearest (two's complement rounding) or to the nearest even number (convergent round). The mode used depends on the core option mode register (OMR) setting. See the core manual for details.
4. All non-inline functions are implemented without storing any of the volatile registers (refer to the compiler manual) used by the respective routine. Only the non-volatile registers (C10, D10, R5) are saved by pushing the registers on the stack. Therefore, if the particular registers initialized before the library function call are to be used after the function call, it is necessary to save them manually.

## 1.2 Library integration into project (CodeWarrior™ Development Studio)

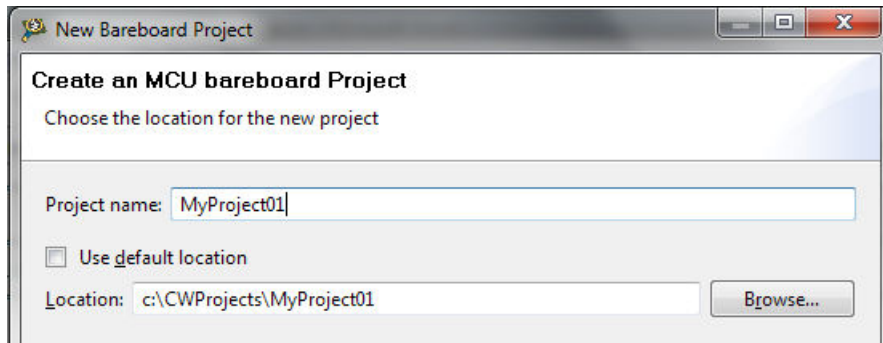
This section provides a step-by-step guide to quickly and easily integrate the MLIB into an empty project using CodeWarrior™ Development Studio. This example uses the MC56F84789 part, and the default installation path (C:\NXPARTCESL\DSP56800EX\_RTCESL\_4.5) is supposed. If you have a different installation path, you must use that path instead.

### 1.2.1 New project

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

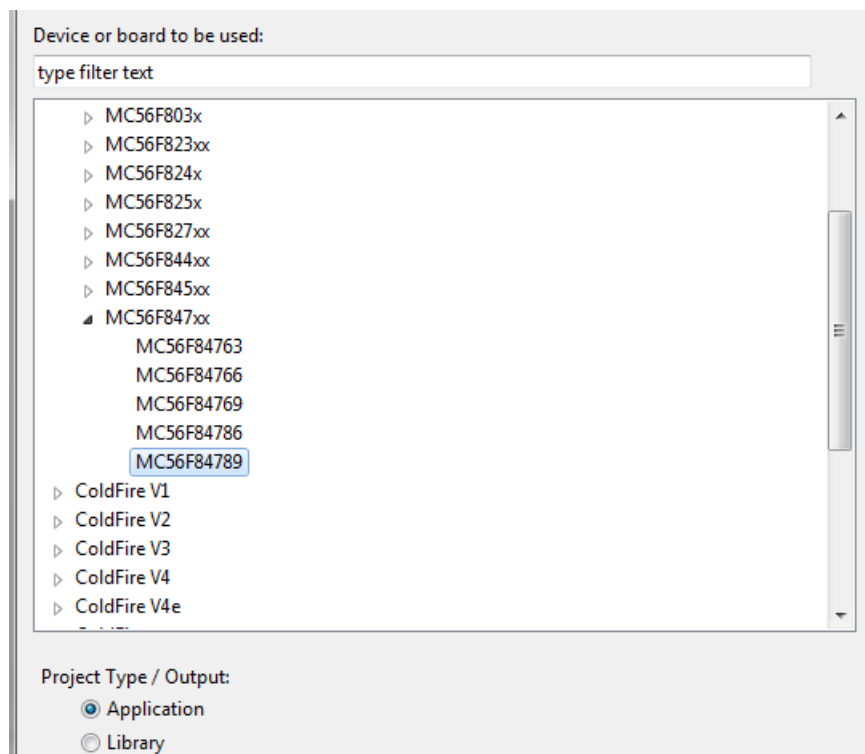
1. Launch CodeWarrior™ Development Studio.

2. Choose File > New > Bareboard Project, so that the "New Bareboard Project" dialog appears.
3. Type a name of the project, for example, MyProject01.
4. If you don't use the default location, untick the "Use default location" checkbox, and type the path where you want to create the project folder; for example, C:\CWProjects\MyProject01, and click Next. See [Figure 1-1](#).



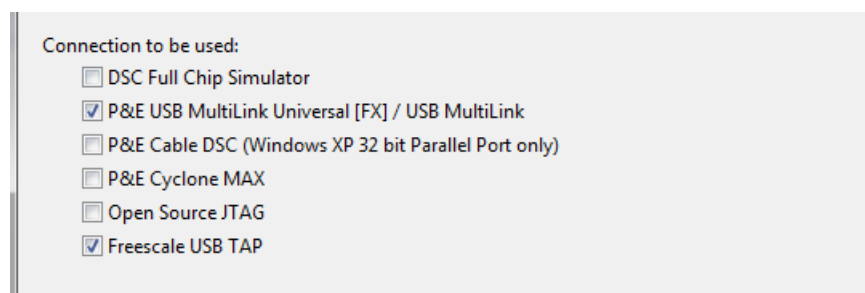
**Figure 1-1. Project name and location**

5. Expand the tree by clicking the 56800/E (DSC) and MC56F84789. Select the Application option and click Next. See [Figure 1-2](#).



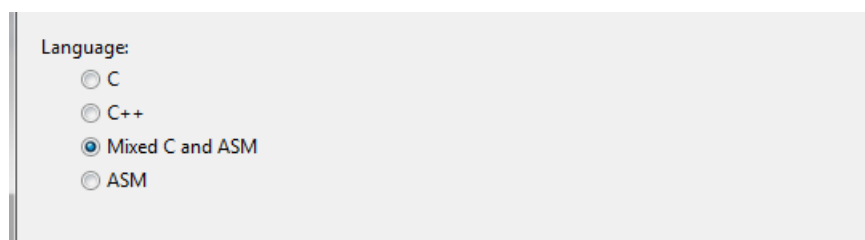
**Figure 1-2. Processor selection**

6. Now select the connection that will be used to download and debug the application. In this case, select the option P&E USB MultiLink Universal[FX] / USB MultiLink and Freescale USB TAP, and click Next. See [Figure 1-3](#).



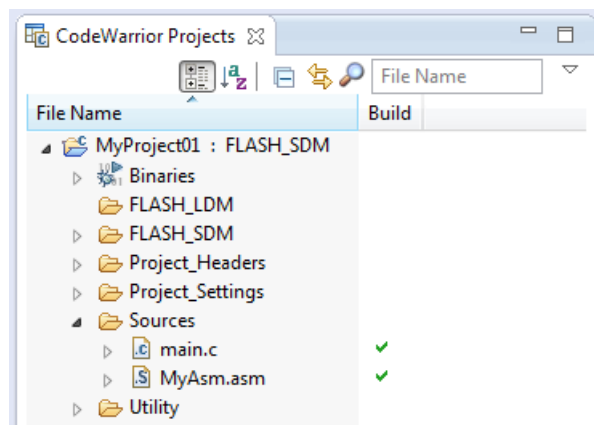
**Figure 1-3. Connection selection**

7. From the options given, select the Simple Mixed Assembly and C language, and click Finish. See [Figure 1-4](#).



**Figure 1-4. Language choice**

The new project is now visible in the left-hand part of CodeWarrior™ Development Studio. See [Figure 1-5](#).



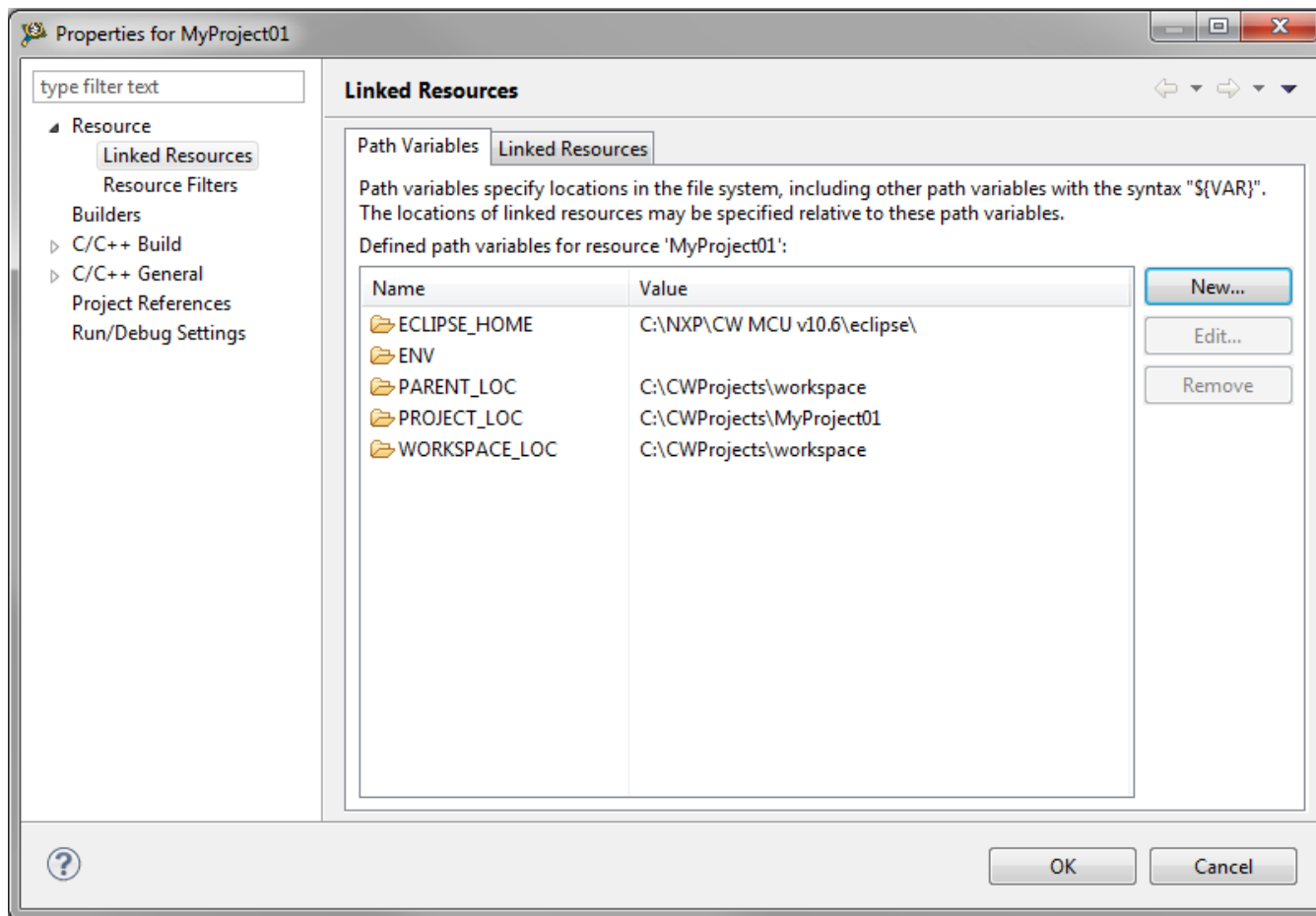
**Figure 1-5. Project folder**

## 1.2.2 Library path variable

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

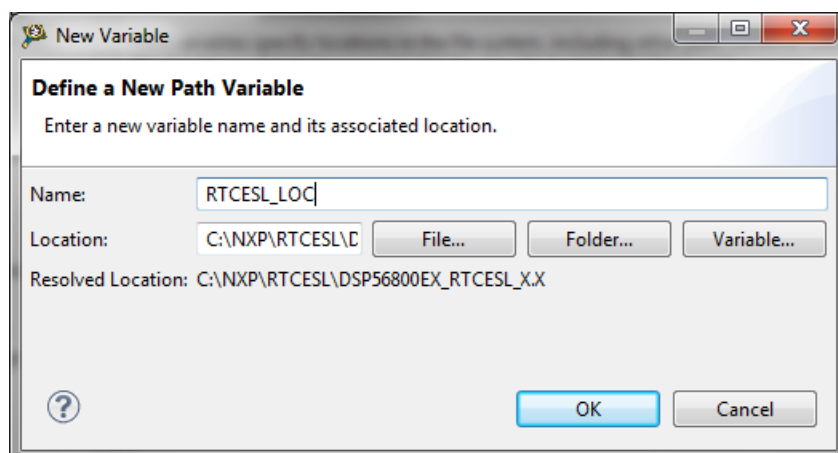
1. Right-click the MyProject01 node in the left-hand part and click Properties, or select Project > Properties from the menu. The project properties dialog appears.

2. Expand the Resource node and click Linked Resources. See [Figure 1-6](#).



**Figure 1-6. Project properties**

3. Click the 'New...' button on the right-hand side.
4. In the dialog that appears (see [Figure 1-7](#)), type this variable name into the Name box: RTCESL\_LOC
5. Select the library parent folder by clicking 'Folder...' or just typing the following path into the Location box: C:\NXP\RTCESL\DSP56800EX\_RTCELSL\_4.5\_CW and click OK.
6. Click OK in the previous dialog.



**Figure 1-7. New variable**

### 1.2.3 Library folder addition

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

1. Right-click the MyProject01 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 third option—Link to alternate location (Linked Folder).
4. Click Variables..., and select the RTCESL\_LOC variable in the dialog that appears, 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](#)

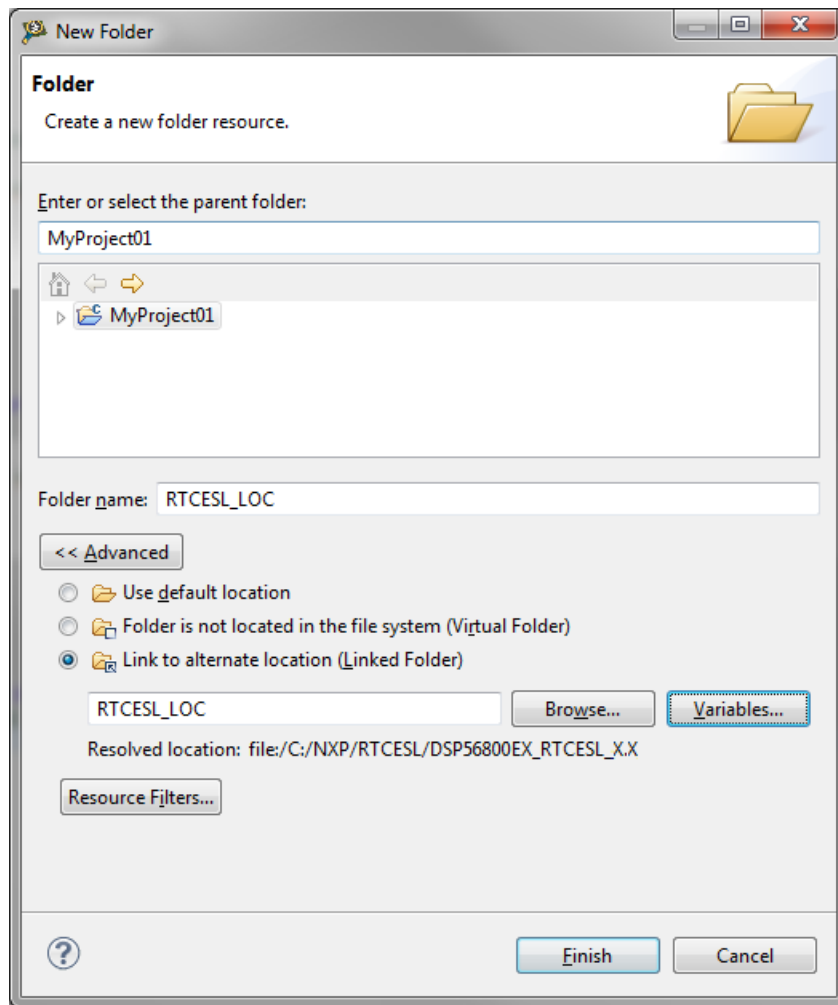


Figure 1-8. Folder link

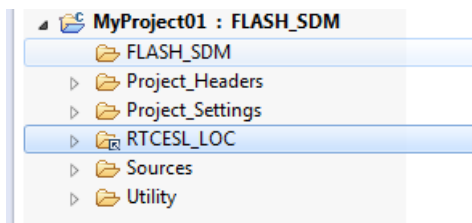
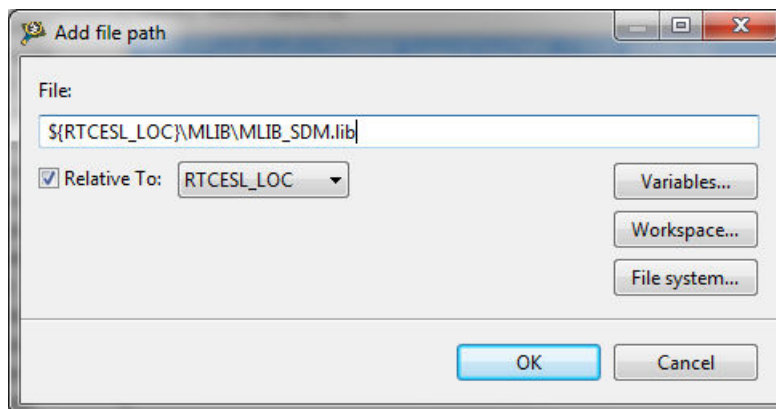


Figure 1-9. Projects libraries paths

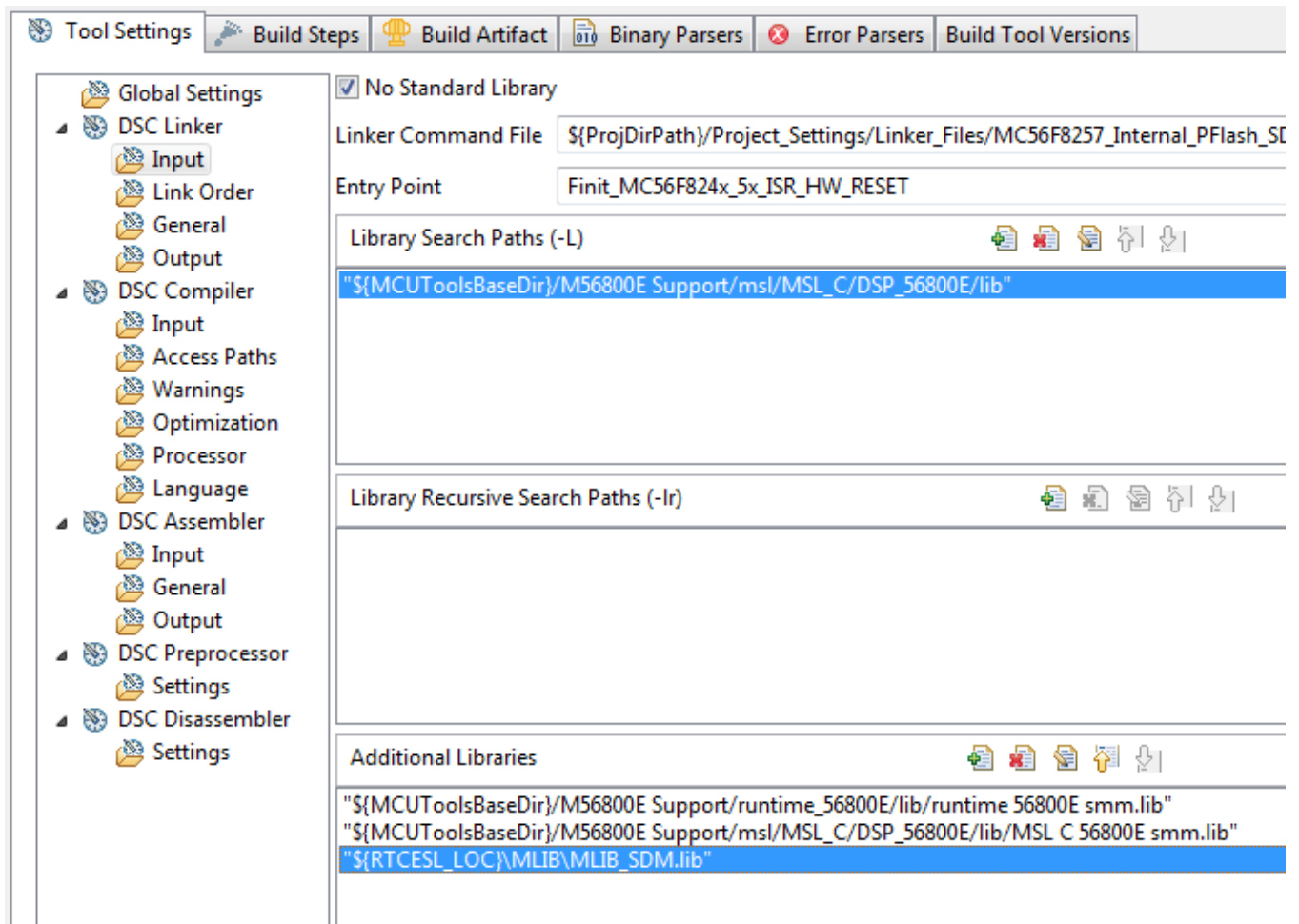
### 1.2.4 Library path setup

1. Right-click the MyProject01 node in the left-hand part and click Properties, or select Project > Properties from the menu. A dialog with the project properties appears.
2. Expand the C/C++ Build node, and click Settings.
3. In the right-hand tree, expand the DSC Linker node, and click Input. See [Figure 1-11](#).
4. In the third dialog Additional Libraries, click the 'Add...' icon, and a dialog appears.

5. Look for the RTCESL\_LOC variable by clicking Variables..., and then finish the path in the box by adding one of the following:
  - `${RTCESL_LOC}\MLIB\mllib_SDM.lib`—for small data model projects
  - `${RTCESL_LOC}\MLIB\mllib_LDM.lib`—for large data model projects
6. Tick the box Relative To, and select RTCESL\_LOC next to the box. See [Figure 1-9](#). Click OK.
7. Now, you will see the library added in the box. See [Figure 1-11](#).



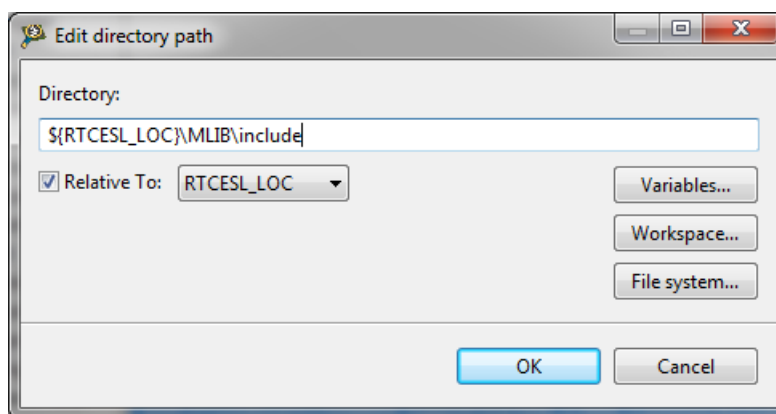
**Figure 1-10. Library file inclusion**



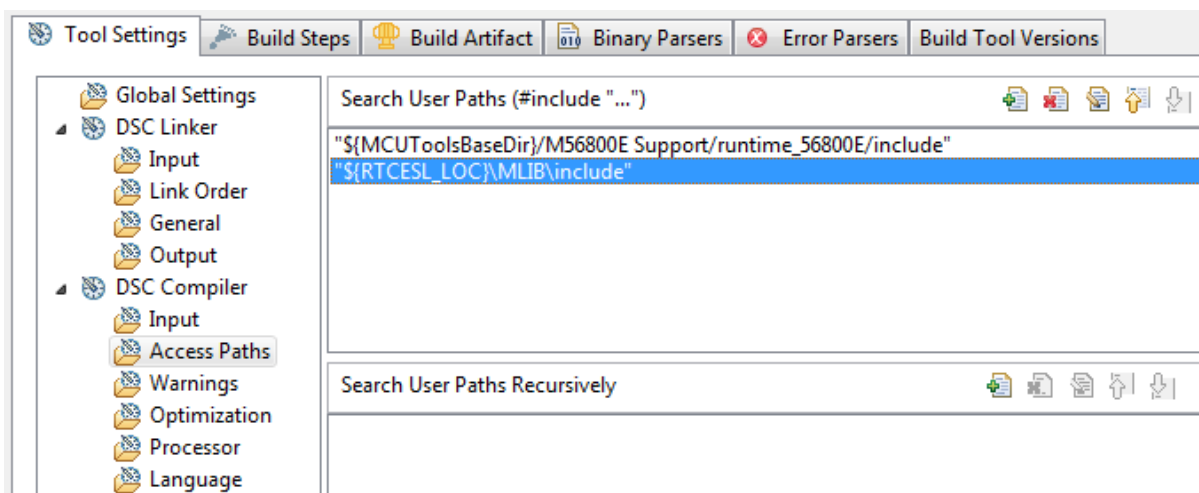
**Figure 1-11. Linker setting**

8. In the tree under the DSC Compiler node, click Access Paths.
9. In the Search User Paths dialog (#include "..."), click the 'Add...' icon, and a dialog will appear.
10. Look for the RTCESL\_LOC variable by clicking Variables..., and then finish the path in the box to be: `${RTCESL_LOC}\\MLIB\\include`.
11. Tick the box Relative To, and select RTCESL\_LOC next to the box. See [Figure 1-12](#). Click OK.
12. Now you will see the path added in the box. See [Figure 1-13](#). Click OK.





**Figure 1-12. Library include path addition**



**Figure 1-13. Compiler setting**

The final step is typing 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 into the `#include` section:

```
#include "mlib.h"
```

When you click the Build icon (hammer), 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.

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).

#### 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)
```

## 2.1.3 Function use

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

### Fixed-point version:

```
#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  $\langle -1 ; 1 \rangle$ . The result may overflow.

## MLIB\_Add

- 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.

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).

## 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)
```

## 2.3.3 Function use

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

### Fixed-point version:

```
#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.

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 $<-1 ; 1$ ).

### 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)
```

## 2.5.3 Function use

The use of the `MLIB_Add4` function is shown in the following examples:

### Fixed-point version:

```
#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:

## MLIB\_Add4Sat

- 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 */
```

## MLIB\_Conv

```
/* 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).

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_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).

### 2.8.2 Declaration

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

```
frac16\_t MLIB_Conv_F16l(frac32\_t f32Val)  
frac32\_t MLIB_Conv_F32s(frac16\_t f16Val)
```

### 2.8.3 Function use

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

#### Fixed-point version:

```
#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\_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:

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

**Equation 7. Algorithm formula**

### 2.9.1 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).

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

**Table 2-9. Function versions**

Function name	Input type		Result type	Description
	Num.	Denom.		
MLIB_Div_F16	frac16_t	frac16_t	frac16_t	Division of a 16-bit fractional numerator and denominator. The output is within the range <-1 ; 1).
MLIB_Div_F16ls	frac32_t	frac16_t	frac16_t	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	frac32_t	frac32_t	frac16_t	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	frac32_t	frac16_t	frac32_t	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).

*Table continues on the next page...*

Table 2-9. Function versions (continued)

Function name	Input type		Result type	Description
	Num.	Denom.		
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).

## 2.9.2 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_A32ll(frac32_t f32Num, frac32_t f32Denom)
acc32_t MLIB_Div_A32as(acc32_t a32Num, frac16_t f16Denom)

```

## 2.9.3 Function use

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

### Fixed-point version:

```

#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);
}
```

## 2.10 MLIB\_DivSat

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

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

**Equation 8. 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 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 2-10. 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).

## 2.10.2 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)
```

## 2.10.3 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);
}
```

## 2.11 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**

### 2.11.1 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  $<0 ; 1)$ . 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 2-11. 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 $<0 ; 1)$ .
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.

## 2.11.2 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)

```

### 2.11.3 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);
}

```

## 2.12 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**

### 2.12.1 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 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 2-12. 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.

## 2.12.2 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)

```

## 2.12.3 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 */

```

## MLIB\_Log2

```
f16Denom = FRAC16(0.4);          /* f16Denom = 0.4 */  
  
/* f32Result = f32Num / f16Denom */  
f32Result = MLIB_Div1QSat_F32ls(f32Num, f16Denom);  
}
```

## 2.13 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**

### 2.13.1 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 2-13. Function versions**

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

### 2.13.2 Declaration

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

```
uint16_t MLIB_Log2_U16(uint16_t u16Val)
```

### 2.13.3 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);
}

```

## 2.14 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**

### 2.14.1 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\\_Mac](#) function are shown in the following table.

**Table 2-14. 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 $<-1 ; 1$ ).

*Table continues on the next page...*

Table 2-14. Function versions (continued)

Function name	Input type			Result type	Description
	Accum.	Mult. 1	Mult. 2		
MLIB_Mac_A32ass	acc32_t	frac16_t	frac16_t	acc32_t	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).

## 2.14.2 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)
```

## 2.14.3 Function use

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

### Fixed-point version:

```
#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);
}
```

## 2.15 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**

## 2.15.1 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 saturate.

The available versions of the [MLIB\\_MacSat](#) 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_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).

## 2.15.2 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)
```

## 2.15.3 Function use

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

## MLIB\_MacRnd

```
#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);
}
```

## 2.16 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**

### 2.16.1 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 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 2-16. 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 $<-1 ; 1$ ).

*Table continues on the next page...*



Table 2-16. Function versions (continued)

Function name	Input type			Result type	Description
	Accum.	Mult. 1	Mult. 2		
MLIB_MacRnd_F32lls	frac32_t	frac32_t	frac16_t	frac32_t	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	frac32_t	frac32_t	frac32_t	frac32_t	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	acc32_t	frac16_t	frac16_t	acc32_t	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).

## 2.16.2 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)
```

## 2.16.3 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);
}
```

## 2.17 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**

### 2.17.1 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 saturate.

The available versions of the [MLIB\\_MacRndSat](#) 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_MacRndSat_F16	frac16_t	frac16_t	frac16_t	frac16_t	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	frac32_t	frac32_t	frac16_t	frac32_t	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	frac32_t	frac32_t	frac32_t	frac32_t	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).

## 2.17.2 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)
```

## 2.17.3 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);
}
```

## 2.18 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**

### 2.18.1 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 overflow.

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

**Table 2-18. 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).

## 2.18.2 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)
```

## 2.18.3 Function use

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

### Fixed-point version:

```
#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);
}
```

## 2.19 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**

### 2.19.1 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 saturate.

The available versions of the [MLIB\\_Mac4Sat](#) 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_Mac4Sat_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).

### 2.19.2 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)
```

## 2.19.3 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);
}
```

## 2.20 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**

### 2.20.1 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 overflow.

The available versions of the [MLIB\\_Mac4Rnd](#) 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_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).

## 2.20.2 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)
```

## 2.20.3 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);
}
```

## 2.21 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**

### 2.21.1 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 2-21. 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).

### 2.21.2 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)
```

### 2.21.3 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);
}
```

## 2.22 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**

### 2.22.1 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\\_Mnac](#) function are shown in the following table.

**Table 2-22. 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).

## 2.22.2 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)
```

## 2.22.3 Function use

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

### Fixed-point version:

```
#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);
}

```

## 2.23 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**

### 2.23.1 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 saturate.

The available versions of the [MLIB\\_MnacSat](#) 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_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).

### 2.23.2 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)
```

### 2.23.3 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);
}
```

## 2.24 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**

### 2.24.1 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 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 2-24. 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 $<-1 ; 1$ ).

## 2.24.2 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)
```

## 2.24.3 Function use

The use of the [MLIB\\_MnacRnd](#) 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 */
}
```

## MLIB\_MnacRndSat

```
f16Mult2 = FRAC16(-0.2);          /* f16Mult2 = -0.2 */

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

## 2.25 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**

### 2.25.1 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 saturate.

The available versions of the [MLIB\\_MnacRndSat](#) 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_MnacRndSat_F16	frac16_t	frac16_t	frac16_t	frac16_t	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	frac32_t	frac32_t	frac16_t	frac32_t	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_MnacRndSat_F32	frac32_t	frac32_t	frac32_t	frac32_t	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).

## 2.25.2 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)
```

## 2.25.3 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);
}
```

## 2.26 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**

### 2.26.1 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 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\\_Msu](#) 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_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 $<-1 ; 1$ ).

## 2.26.2 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)
```

## 2.26.3 Function use

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

### Fixed-point version:

```
#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);
}

```

## 2.27 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**

### 2.27.1 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 saturate.

The available versions of the [MLIB\\_MsuSat](#) 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_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).

## 2.27.2 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)
```

## 2.27.3 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);
}
```

## 2.28 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**

### 2.28.1 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 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 2-28. 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 $<-1 ; 1$ ).

## 2.28.2 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)

```

## 2.28.3 Function use

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

```
#include "mlib.h"
```

## MLIB\_MsuRndSat

```
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);
}
```

## 2.29 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**

### 2.29.1 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 saturate.

The available versions of the [MLIB\\_MsuRndSat](#) 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_MsuRndSat_F16	frac16_t	frac16_t	frac16_t	frac16_t	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	frac32_t	frac32_t	frac16_t	frac32_t	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).

*Table continues on the next page...*

Table 2-29. Function versions (continued)

Function name	Input type			Result type	Description
	Accum.	Mult. 1	Mult. 2		
MLIB_MsuRndSat_F32	frac32_t	frac32_t	frac32_t	frac32_t	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).

## 2.29.2 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)
```

## 2.29.3 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);
}
```

## 2.30 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**

## 2.30.1 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\\_Msu4](#) function are shown in the following table.

**Table 2-30. Function versions**

Function name	Input type				Result type	Description
	Minuend product		Subtrahend product			
	Mult. 1	Mult. 2	Mult. 1	Mult. 2		
MLIB_Msu4_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>	Subtraction of two 32-bit fractional products (of two 16-bit fractional multiplicands). The output is within the range $<-1 ; 1$ ).

## 2.30.2 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)
```

## 2.30.3 Function use

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

### Fixed-point version:

```
#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);
}

```

## 2.31 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**

### 2.31.1 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 2-31. 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).

### 2.31.2 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)
```

### 2.31.3 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);
}
```

## 2.32 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**

### 2.32.1 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 overflow.



The available versions of the [MLIB\\_Msu4Rnd](#) 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_Msu4Rnd_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_Msu4Rnd_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), rounded to the upper 32 bits. The output is within the range <-1 ; 1).

## 2.32.2 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)
```

## 2.32.3 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);
}
```

## 2.33 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**

### 2.33.1 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 saturate.

The available versions of the [MLIB\\_Msu4RndSat](#) 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_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), rounded to the upper 32 bits. The output is within the range $<-1 ; 1$ ).

### 2.33.2 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)
```

### 2.33.3 Function use

The use of the `MLIB_Msu4RndSat` function is shown in the following example:

```
#include "mlib.h"

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);
}
```

## 2.34 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**

### 2.34.1 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.

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- 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\\_Mul](#) function are shown in the following table:

**Table 2-34. 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 $<-65536.0 ; 65536.0$ ).

### 2.34.2 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)
```

### 2.34.3 Function use

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

#### Fixed-point version:

```
#include "mlib.h"
```

```

static frac32_t f32Result;
static frac16_t f16Mult1, 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);
}

```

## 2.35 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**

### 2.35.1 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 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 2-35. 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).

*Table continues on the next page...*

Table 2-35. Function versions (continued)

Function name	Input type		Result type	Description
	Mult. 1	Mult. 2		
MLIB_MulSat_F16as	acc32_t	frac16_t	frac16_t	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	frac16_t	frac16_t	frac32_t	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	frac32_t	frac32_t	frac32_t	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	acc32_t	acc32_t	acc32_t	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).

## 2.35.2 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)
```

## 2.35.3 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);
}
```

## 2.36 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**

### 2.36.1 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.
- 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\\_MulNeg](#) function are shown in the following table.

**Table 2-36. 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 $<-1 ; 1$ ).
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 $<-65536.0 ; 65536.0$ ).

### 2.36.2 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)
```

### 2.36.3 Function use

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

#### Fixed-point version:

```
#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);
}
```

## 2.37 MLIB\_MulNegSat

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

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

**Equation 35. Algorithm formula**

### 2.37.1 Available versions

This function is available in the following versions:

- 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\\_MulNegSat](#) function are shown in the following table:

**Table 2-37. Function versions**

Function name	Input type		Result type	Description
	Mult. 1	Mult. 2		
MLIB_MulNegSat_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).
MLIB_MulNegSat_A32	<a href="#">acc32_t</a>	<a href="#">acc32_t</a>	<a href="#">acc32_t</a>	Negative product of two 32-bit accumulator multiplicands; the output is a 32-bit accumulator, which has the middle bits of the result [16..47]. The output is within the range <-65536.0 ; 65536.0).

## 2.37.2 Declaration

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

```
frac16\_t MLIB_MulNegSat_F16as(acc32\_t a32Accum, frac16\_t f16Mult)
acc32\_t MLIB_MulNegSat_A32(acc32\_t a32Mult1, acc32\_t a32Mult2)
```

## 2.37.3 Function use

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

```
#include "mlib.h"

static acc32\_t a32M1, a32M2, a32Result;

void main(void)
{
    a32M1 = ACC32(1.5);          /* a32M1 = 1.5 */
    a32M2 = ACC32(4.1);          /* a32M2 = 4.1 */

    /* f16Result = sat(-a32M1 * f32M2) */
    a32Result = MLIB_MulNegSat_A32(a32M1, a32M2);
}
```

## 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 36. 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 37. 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:

```
#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 38. 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	frac16_t	frac16_t	frac16_t	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\_MulNegRndSat

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

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

**Equation 39. Algorithm formula**

### 2.41.1 Available versions

This function is available in the following versions:

- 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\\_MulNegRndSat](#) function are shown in the following table:

**Table 2-41. Function versions**

Function name	Input type		Result type	Description
	Mult. 1	Mult. 2		
MLIB_MulNegRndSat_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 rounded to the upper 16 bits of the fractional portion of the result [16..31]. The output is within the range <-1 ; 1).
MLIB_MulNegRndSat_A32	<a href="#">acc32_t</a>	<a href="#">acc32_t</a>	<a href="#">acc32_t</a>	Negative product of two 32-bit accumulator multiplicands; the output is rounded to the middle 32 bits of the result [16..47]. The output is within the range <-65536.0 ; 65536.0).

### 2.41.2 Declaration

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

```
frac16_t MLIB_MulNegRndSat_F16as(acc32_t a32Accum, frac16_t f16Mult)
acc32_t MLIB_MulNegRndSat_A32(acc32_t a32Mult1, acc32_t a32Mult2)
```

### 2.41.3 Function use

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

```
#include "mlib.h"

static acc32_t a32M1, a32M2, a32Result;

void main(void)
{
    a32M1 = ACC32(-5.5);          /* a32M1 = -5.5 */
    a32M2 = ACC32(3.1);          /* a32M2 = 3.1 */

    /* f16Result = sat(round(-a32M1 * f32M2)) */
    a32Result = MLIB_MulNegRndSat_A32(a32M1, a32M2);
}
```

## 2.42 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 40. Algorithm formula**

### 2.42.1 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\\_Neg](#) function are shown in the following table:

**Table 2-42. 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 $<-1 ; 1$ ).



## 2.42.2 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)
```

## 2.42.3 Function use

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

### Fixed-point version:

```
#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);
}
```

## 2.43 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 41. Algorithm formula**

### 2.43.1 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 2-43. 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).

## 2.43.2 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)
```

## 2.43.3 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);
}
```

## 2.44 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:

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

**Equation 42. 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 absolute value of the result is greater than or equal to 1. The input is the fractional type.

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

**Table 2-44. 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.

## 2.44.2 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)
```

## 2.44.3 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);
}
```

## 2.45 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 43. Algorithm formula**

### 2.45.1 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 2-45. 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.

### 2.45.2 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)
```

## 2.45.3 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);
}
```

## 2.46 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 44. 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 overflow.

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

**Table 2-46. Function versions**

Function name	Input type	Result type	Description
MLIB_Rnd_F16I	<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\\_Rnd](#) functions have the following declarations:

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

## 2.46.3 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);
}
```

## 2.47 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 45. Algorithm formula**

### 2.47.1 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 2-47. 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 $<-1 ; 1$ ).

## 2.47.2 Declaration

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

```
frac16_t MLIB_RndSat_F16l(frac32_t f32Val)
```

## 2.47.3 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);
}
```

## 2.48 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 46. Algorithm formula**

### 2.48.1 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 2-48. 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).

## 2.48.2 Declaration

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

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

## 2.48.3 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);
}
```

## 2.49 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 47. Algorithm formula**

### 2.49.1 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 2-49. 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 $<-1 ; 1$ ).

## 2.49.2 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)
```

## 2.49.3 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);
}
```

## 2.50 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 48. 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 <-1 ; 1). The result may saturate.

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

**Table 2-50. 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).

## 2.50.2 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)
```

## 2.50.3 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);
}
```

## 2.51 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 49. 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 <-0.5 ; 0.5).

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

**Table 2-51. 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).

### 2.51.2 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)
```

### 2.51.3 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);
}

```

## 2.52 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 50. 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 overflow.

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

**Table 2-52. 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).

### 2.52.2 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)

```

### 2.52.3 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);
}
```

### 2.53 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 51. 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 result may saturate.

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

**Table 2-53. 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>.

## 2.53.2 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)
```

## 2.53.3 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);
}
```

## 2.54 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 52. Algorithm formula**

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## 2.54.1 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 2-54. 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 $<-1 ; 1)$ .

## 2.54.2 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)
```

## 2.54.3 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);
}
```

## 2.55 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 53. Algorithm formula**

### 2.55.1 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 2-55. 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).

### 2.55.2 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)
```



### 2.55.3 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);
}
```

## 2.56 MLIB\_ShLbiSat

The [MLIB\\_ShLbiSat](#) 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:

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

**Equation 54. 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 saturate.

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

**Table 2-56. Function versions**

Function name	Input type		Result type	Description
	Value	Shift		
MLIB_ShLBI_Sat_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_Sat_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>.

## 2.56.2 Declaration

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

```
frac16_t MLIB_ShLBI_Sat_F16(frac16_t f16Val, int16_t i16Sh)
frac32_t MLIB_ShLBI_Sat_F32(frac32_t f32Val, int16_t i16Sh)
```

## 2.56.3 Function use

The use of the [MLIB\\_ShLBI\\_Sat](#) 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_ShLBI_Sat_F16(f16Val, i16Sh);
}
```

## 2.57 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 55. 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  $\langle -1 ; 1 \rangle$ . The result may overflow.

The available versions of the `MLIB_ShRBi` function are shown in the following table.

**Table 2-57. Function versions**

Function name	Input type		Result type	Description
	Value	Shift		
MLIB_ShRBi_F16	<code>frac16_t</code>	<code>int16_t</code>	<code>frac16_t</code>	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 $\langle -15 ; 15 \rangle$ . The output is within the range $\langle -1 ; 1 \rangle$ .
MLIB_ShRBi_F32	<code>frac32_t</code>	<code>int16_t</code>	<code>frac32_t</code>	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 $\langle -31 ; 31 \rangle$ . The output is within the range $\langle -1 ; 1 \rangle$ .

### 2.57.2 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)
```

### 2.57.3 Function use

The use of the `MLIB_ShRBi` function is shown in the following example:

## MLIB\_ShrBiSat

```
#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);
}
```

## 2.58 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:

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

Equation 56. 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). The result may saturate.

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

Table 2-58. Function versions

Function name	Input type		Result type	Description
	Value	Shift		
MLIB_ShrBiSat_F16	frac16_t	int16_t	frac16_t	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 2-58. Function versions (continued)

Function name	Input type		Result type	Description
	Value	Shift		
MLIB_ShRBiSat_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).

## 2.58.2 Declaration

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

```
frac16_t MLIB_ShRBiSat_F16(frac16_t f16Val, int16_t i16Sh)
frac32_t MLIB_ShRBiSat_F32(frac32_t f32Val, int16_t i16Sh)
```

## 2.58.3 Function use

The use of the [MLIB\\_ShRBiSat](#) 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);
}
```

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

**Table 2-59. 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 $<-1 ; 1$ ).

## 2.59.2 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)
```

## 2.59.3 Function use

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

### Fixed-point version:

```
#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);
}
```

## 2.60 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 58. 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 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.

The available versions of the `MLIB_Sub` function are shown in the following table.

**Table 2-60. Function versions**

Function name	Input type		Result type	Description
	Minuend	Subtrahend		
MLIB_Sub_F16	<code>frac16_t</code>	<code>frac16_t</code>	<code>frac16_t</code>	Subtraction of a 16-bit fractional subtrahend from a 16-bit fractional minuend. The output is within the range $<-1 ; 1$ ).
MLIB_Sub_F32	<code>frac32_t</code>	<code>frac32_t</code>	<code>frac32_t</code>	Subtraction of a 32-bit fractional subtrahend from a 32-bit fractional minuend. The output is within the range $<-1 ; 1$ ).
MLIB_Sub_A32ss	<code>frac16_t</code>	<code>frac16_t</code>	<code>acc32_t</code>	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	<code>acc32_t</code>	<code>frac16_t</code>	<code>acc32_t</code>	Subtraction of a 16-bit fractional subtrahend from a 32-bit accumulator. The output may be out of the range $<-1 ; 1$ ).

## 2.60.2 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)
```

## 2.60.3 Function use

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

### Fixed-point version:

```
#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);
}
```

## 2.61 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 59. 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 saturate.



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

**Table 2-61. 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).

## 2.61.2 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)
```

## 2.61.3 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);
}
```

## 2.62 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 60. 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 overflow.

The available versions of the [MLIB\\_Sub4](#) 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_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 $<-1 ; 1$ ).

## 2.62.2 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)
```

## 2.62.3 Function use

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

### Fixed-point version:

```
#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);
}

```

## 2.63 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 61. Algorithm formula**

### 2.63.1 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 2-63. 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).

### 2.63.2 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)

### 2.63.3 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	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				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  $\langle 0 ; 65535 \rangle$ . 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  $\langle 0 ; 4294967295 \rangle$ . 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**

Value	31	24 23		16 15		8 7		0
	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  $\langle -128 ; 127 \rangle$ . 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**

Value	7	6	5	4	3	2	1	0
	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  $\langle -32768 ; 32767 \rangle$ . 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  $\langle -2147483648 ; 2147483647 \rangle$ . 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	8				0				0				0			
	0	0	1	1	1	1	0	0	1	0	0	1	1	1	1	0
-0.75586	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**

Value	31	24 23		16 15		8 7		0
	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 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.14 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.15 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.16 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.17 FRAC32

The **FRAC32** macro serves to convert a real number to the `frac32_t` type. Its definition is as follows:

```
#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.18 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.19 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  $\langle -65536.0 ; 65536.0-2^{-15} \rangle$ .

```
#include "mlib.h"
static acc32_t a32Val;
void main(void)
{
    a32Val = ACC32(-13.654437);      /* a32Val = -13.654437 */
}
```

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