SH-2, SH-2A

Fixed-point Library (Ver. 1.02)

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Introduction

This document describes the usage of SH-2, SH-2A Fixed-point Library

Target Device

SH-2, SH-2A

Contents

1. Fixed-point Library

1.1 Overview

This library provides real-number operations using fixed-point format[1] for SH-2 and SH-2A.

The fixed-point library enables fast real-number operations, especially on CPU's without FPU.

This library supports the following functions for fixed-point type with 16, 24, or 29 fraction bits.

1. Multiplication and division
2. Mathematical functions (sin, cos, atan, and sqrt)
3. Conversion between floating point data.

Use 16-bit or 24-bit depending on the required precision of your application. 29-bit precision is supported as the most precise type which can represent the input range of trigonometric functions ($-\pi \sim +\pi$).

In fixed-point arithmetic, the range of values is restricted compared with floating point. So appropriate precision should be selected according to the input/output values of each operations. For this reason, this library supports multiplication, division, conversion for all the precision (from 1 to 31) of fixed-point type.

1.1 Format of Fixed-point Data

Following is the format of fixed-point data supported in this library.

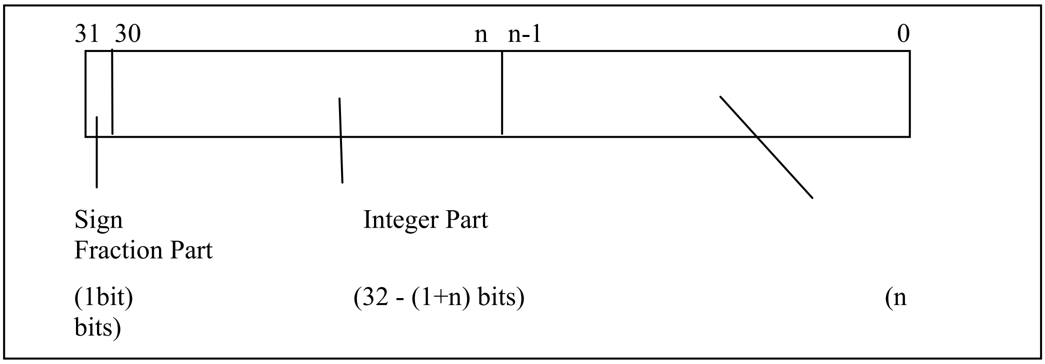

Figure 1. Fixed-point Data Format

According to the number of bits in fraction part, types from FIX1 to FIX31 are supported. The number indicates the number of bits in the fraction type.

Generic fixed-point type FIX is also supported, and generic fixed-point operations are supported for this type.

1.3 Library Files

The following include file and library files are provided.
When using this library, include the file indicated in table 1, and link the library file (corresponding to the compiler option) indicated in table 2.

[1] Fixed-point format represents a real number by assuming a decimal point at some fixed bit position.

Table 1. Include File for Fixed-point Library

Library	Function	
Fixed-point library	Implements fixed-point operations	"fixmath.h"

Table 2. Fixed-point Libraries

Library name	Compiler Option		
	cpu	pic	endian
sh2fix.lib	sh2	0	big
sh2afix.lib	sh2a	0	big

Before using, copy these files into your local include or library directories.

```
include directory       ──────   fixmath.h

library directory   ─────┬────   sh2fix.lib
                         └────   sh2afix.lib
```

Figure 2. Sample Configuration

1.4 Example of Usage

The following example shows a program using FIX16 operation and how to specify the library undef High-performance Embedded-Workshop.

[Source Program]

```
#include <stdio.h>
#include "fixmath.h"                  // Necessary when using
                                         // fixed-point library

void main()
  {
      float r_flt;
      FIX16 d_fix16, r_fix16;

      d_fix16 = FIX16_fromfloat(3.14f);    // convert float type constant
                                         // to FIX16
      r_fix16 = FIX16_sin(d_fix16);        // computes sin
      r_flt = FIX16_tofloat(r_fix16);      // Convert back for printing
      printf("%f\n", r_flt);
  }
```

[How to specify the library under High-Performance Embedded-Workshop]

Select [SuperH RISC engine Standard Toolchain] in [build] menu. In the dialog box [SuperH RISC engine Standard Toolchain], select tab [optimizing linker], and specify "input" for [category] and specify "library file" for [option item], and click [add] button. In the dialog box [Add library file], select the library to be linked.

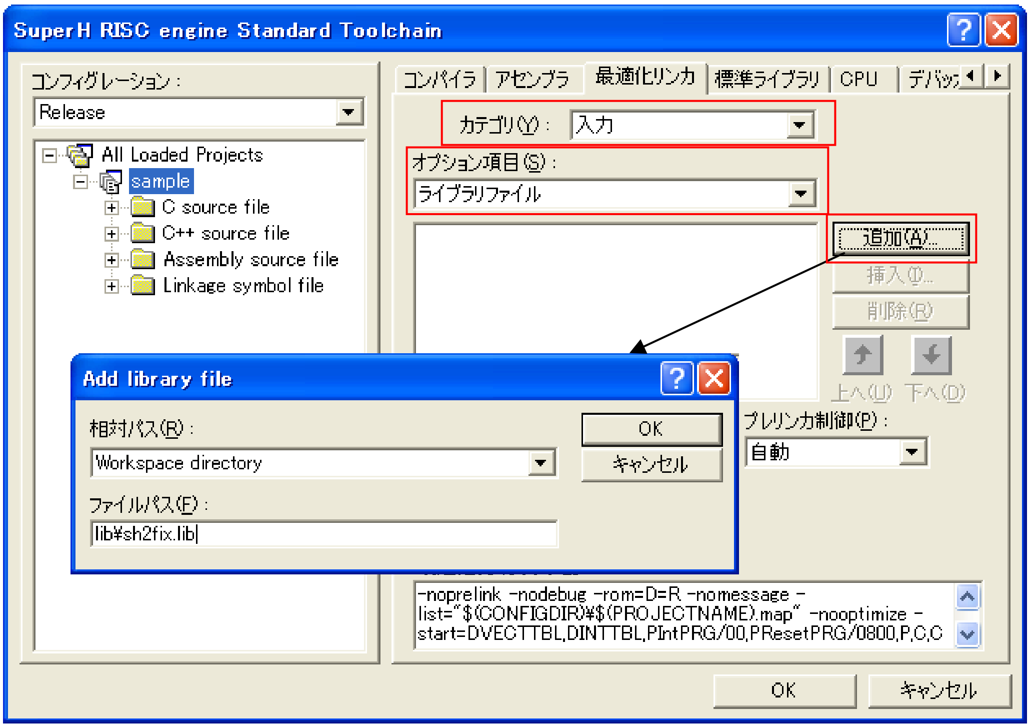

Figure 3. Specifying library

[To be replaced with English version window]

1.5 Notes on Library Usage

If the result of operation or conversion exceeds the range of fixed-point type, the result is not guaranteed.

2. Specification of Fixed-point Library

2.1 "fixmath.h"

This header file defines types and functions for fixed-point operations.
Table 3 shows the types defined in the file and supported functions (macros).

NOTATION: The notation <n> in type, function, or macro names represents a number from 1 to 31. The number in the function or macro name corresponds to the number in the type name.

Table 3. Types and Supported Functions

Type	Supported functions and macros
FIX1-FIX31 (except FIX16, FIX24 or FIX29)	FIX<n>_mul_short, FIX<n>_mul, FIX<n>_div, FIX<n>_tofloat, FIX<n>_fromfloat, FIX<n>_todouble, FIX<n>_fromdouble, FIX<n>_mul_frac, FIX<n>_mul_sat
FIX16, FIX24, FIX29	FIX<n>_mul_short, FIX<n>_mul, FIX<n>_div, FIX<n>_tofloat, FIX<n>_fromfloat, FIX<n>_todouble, FIX<n>_fromdouble, FIX<n>_mul_frac, FIX<n>_mul_sat, FIX<n>_sin, FIX<n>_cos, FIX<n>_atan, FIX<n>_sqrt
FIX	FIX_mul_scale<n>, FIX_mul_frac_scale<n>, FIX_mul_sat_scale<n>, FIX_mul_scale, FIX_mul_frac_scale, FIX_mul_sat_scale

These types are defined as long type.

When the operands and the result of an operation are the same type (FIX<n>), use the function corresponding to that type. Otherwise, use a function corresponding to the generic fixed-point type FIX.

[Hints on Fixed-point Library Usage]

(1) Select one of the standard fixed-point type (FIX16 or FIX24) according to the requirement of your application.
(2) Compared with floating-point types, fixed-point types have limited range of values. It is recommended to select appropriate fixed-point types according to the range of input or intermediate result, or required precision of arithmetic.
(3) When converting data between different fixed-point types, use shift operator of C language.

Example: Conversion from FIX16 to FIX24

```
FIX16 x, FIX24 y;
x=y>>8;
```

(4) When adding or subtracting between data of the same fixed-point type, use integer addition or subtraction of the C language.

Example: Addition of FIX16.

```
FIX16 x, y, z;
z=x+y;
```

(5) Conversion between floating-point types and fixed-point types should be done only when required. Unnecessary conversions reduces the efficiency. But the conversion function applied to a constant generates a constant expression by expanding a macro, and fixed-point constant can be specified without any overhead.

Example: Fixed-point constant.

```
FIX16 x;
x=FIX16_fromfloat(3.14f);
```

Table 4 shows the representations and ranges of fixed types.

Table 4. Representation and Ranges of Fixed Types

Type	Size (byte)	Alignment (byte)	Sign	Range	
				Minimum Value	Maximum Value
FIX1	4	4	signed	-2^{30}(-1073741824.0)	$2^{30}-2^{-1}$(1073741823.5)
FIX2	4	4	signed	-2^{29}(-536870912.0)	$2^{29}-2^{-2}$ (536870911.75)
FIX3	4	4	signed	-2^{28}(-268435456.0)	$2^{28}-2^{-3}$ (268435455.875)
FIX4	4	4	signed	-2^{27}(-134217728.0)	$2^{27}-2^{-4}$ (134217727.9375)
FIX5	4	4	signed	-2^{26}(-67108864.0)	$2^{26}-2^{-5}$ (67108863.96875)
FIX6	4	4	signed	-2^{25}(-33554432.0)	$2^{25}-2^{-6}$ (33554431.984375)
FIX7	4	4	signed	-2^{24}(-16777216.0)	$2^{24}-2^{-7}$ (16777215.9921875)
FIX8	4	4	signed	-2^{23}(-8388608.0)	$2^{23}-2^{-8}$ (8388607.99609375)
FIX9	4	4	signed	-2^{22}(-4194304.0)	$2^{22}-2^{-9}$ (4194303. 998046875)
FIX10	4	4	signed	-2^{21}(-2097152.0)	$2^{21}-2^{-10}$ (2097151. 9990234375)
FIX11	4	4	signed	-2^{20}(-1048576.0)	$2^{20}-2^{-11}$(1048575. 99951171875)
FIX12	4	4	signed	-2^{19}(-524288.0)	$2^{19}-2^{-12}$ (524287. 999755859375)
FIX13	4	4	signed	-2^{18}(-262144.0)	$2^{18}-2^{-13}$ (262143. 9998779296875)
FIX14	4	4	signed	-2^{17}(-131072.0)	$2^{17}-2^{-14}$ (131071. 99993896484375)
FIX15	4	4	signed	-2^{16}(-65536.0)	$2^{16}-2^{-15}$(65535. 999969482421875)
FIX16	4	4	signed	-2^{15}(-32768.0)	$2^{15}-2^{-16}$(32767.9999847412109375)
FIX17	4	4	signed	-2^{14}(-16384.0)	$2^{14}-2^{-17}$ (16383.99999237060546875)
FIX18	4	4	signed	-2^{13}(-8192.0)	$2^{13}-2^{-18}$ (8191.999996185302734375)
FIX19	4	4	signed	-2^{12}(-4096.0)	$2^{12}-2^{-19}$ (4095.9999980926513671875)
FIX20	4	4	signed	-2^{11}(-2048.0)	$2^{11}-2^{-20}$ (2047.99999904632568359375)
FIX21	4	4	signed	-2^{10}(-1024.0)	$2^{10}-2^{-21}$ (1023.999999523162841796875)
FIX22	4	4	signed	-2^{9}(-512.0)	$2^{9}-2^{-22}$ (511.9999997615814208984375)
FIX23	4	4	signed	-2^{8}(-256.0)	$2^{8}-2^{-23}$ (255.99999988079071044921875)
FIX24	4	4	signed	-2^{7}(-128.0)	$2^{7}-2^{-24}$ (127.999999940395355224609375)
FIX25	4	4	signed	-2^{6}(-64.0)	$2^{6}-2^{-25}$ (63.9999999701976776123046875)
FIX26	4	4	signed	-2^{5}(-32.0)	$2^{5}-2^{-26}$ (31.99999998509883880615234375)
FIX27	4	4	signed	-2^{4}(-16.0)	$2^{4}-2^{-27}$ (15.999999992549419403076171875)
FIX28	4	4	signed	-2^{3}(-8.0)	$2^{3}-2^{-28}$ (7.9999999962747097015380859375)
FIX29	4	4	signed	-2^{2}(-4.0)	$2^{2}-2^{-29}$ (3.99999999813735485076904296875)
FIX30	4	4	signed	-2^{1}(-2.0)	$2^{1}-2^{-30}$ (1.999999999068677425384521484375)
FIX31	4	4	signed	-2^{0}(-1.0)	$2^{0}-2^{-31}$ (0.9999999995343387126922607421875)
FIX	4	4	signed	Represents one of above ranges, depending on the number of fraction bits assumed.	

The macros defined are listed in table 5.

Table 5. List of Macros

Category	Name	Parameter Type	Return Type	Description
Multiplication	FIX<n>_mul_short	FIX<n> n=1~31	FIX<n> n=1~31	Computes multiplication of fixed-point data (If the multiplication result exceeds 32-bits, the result is not guaranteed).
	FIX<n>_mul_frac	FIX<n> n=1~31	FIX<n> n=1~31	Computes fractional part f of the fixed-point multiplication (0<=f<1.0).
Division	FIX<n>_div	FIX<n> n=1~31	FIX<n> n=1~31	Computes division of fixed-point data.
Conversion	FIX<n>_tofloat	FIX<n> n=1~31	float	Converts FIX<n> to float.
	FIX<n>_fromfloat	float	FIX<n> n=1~31	Converts float to FIX<n>.
	FIX<n>_todouble	FIX<n> n=1~31	double	Converts FIX<n> to double.
	FIX<n>_fromdouble	double	FIX<n> n=1~31	Converts double to FIX<n>.
Multiplication of generic fixed-point	FIX_mul_scale<n>	FIX	FIX	Computes multiplication of generic fixed-point data.
	FIX_mul_frac_scale<n>	FIX	FIX	Computes fractional part f of the generic fixed-point multiplication (0<=f<1.0).
	FIX_mul_sat_scale<n>	FIX	FIX	Computes multiplication of generic fixed-point data. When overflow occurs, the result is maximum or minimum value of the range.
	FIX_mul_frac_scale	FIX	FIX	Computes fractional part f of the generic fixed-point multiplication (0<=f<1.0).

If the result of operation is outside the range of the data type, its value is not guaranteed.

The functions declared are listed in table 6.

Table 6. List of Functions

Category	Name	Parameter Type	Return Type	Description
Multiplication	`FIX<n>_mul`	FIX<n> n=1~31	FIX<n> n=1~31	Computes multiplication of fixed-point data.
	`FIX<n>_mul_sat`	FIX<n> n=1~31	FIX<n> n=1~31	Computes multiplication of fixed-point data. When overflow occurs, the result is maximum or minimum value of the range.
Sine	`FIX<n>_sin`	FIX<n> n=16, 24, 29	FIX<n> n=16, 24, 29	Computes sine of fixed-oint data (radian)
Cosine	`FIX<n>_cos`	FIX<n> n=16, 24, 29	FIX<n> n=16, 24, 29	Computes cosine of fixed-point data (radian).
Arctangent	`FIX<n>_atan`	FIX<n> n=16, 24, 29	FIX<n> n=16, 24, 29	Computes radian value of arctangent of fixed-point data.
Square Root	`FIX<n>_sqrt`	FIX<n> n=16, 24, 29	FIX<n> n=16, 24, 29	Computes square root of fixed-point data
Multiplication of generic fixed-point	`FIX_mul_scale`	FIX	FIX	Computes multiplication of generic fixed-point data.
	`FIX_mul_sat_scale`	FIX	FIX	Computes multiplication of generic fixed-point data. When overflow occurs, the result is maximum or minimum value of the range.

If the result of operation is outside the range of the data type, its value is not guaranteed.

2.2 Description of Functions

2.2.1 Multiplication (macro)

[Interfrace] `FIX<n> FIX<n>_mul_short(FIX<n> x, FIX<n> y)`

n: 1~31

[Description] Two 32-bit data are multiplied and shifted right by n bits. This computes the multiplication of two fixed-point data of FIX<n> type.

[Header] "fixmath.h"

[Return Value] Result of multiplication

[Parameters] x: Fixed-point data.
y: Fixed-point data

[Example]

```
#include "fixmath.h"
fix16 x, y, ret;

      ret=FIX16_mul_short(x, y);
```

[Note] Short multiplication uses 32-bit integer arithmetic. The result is not guaranteed if the intermediate result exceeds 32 bits.

2.2.2 Division (macro)

[Interfrace] `FIX<n> FIX<n>_div(FIX<n> x, FIX<n> y)`

n: 1~31

[Description] Computes the quotient of two fixed-point data.

[Header] "fixmath.h"

[Return Value] Result of division

[Parameters] x: Dividend.
y: divisor

[Example]

```
#include "fixmath.h"
fix16 x, y, ret;

      ret=FIX16_div(x, y);
```

2.2.3 Conversion (macro)

(1) Conversion from float type to fixed-point

[Interfrace] FIX<n> FIX<n>_fromfloat(float x)

n: 1~31

[Description] Converts float type data to fixed-point type.

[Header] "fixmath.h"

[Return Value] Result of conversion

[Parameters] x: Source of conversion

[Example]

```
#include "fixmath.h"
float x;
FIX16 ret;

      ret=FIX16_fromfloat(x);
```

(2) Conversion from double type to fixed-point

[Interfrace] FIX<n> FIX<n>_fromdouble(double x)

n: 1~31

[Description] Converts double type data to fixed-point type.

[Header] "fixmath.h"

[Return Value] Result of conversion

[Parameters] x: Source of conversion

[Example]

```
#include "fixmath.h"
double x;
FIX16 ret;

      ret=FIX16_fromdouble(x);
```

(3) Conversion from fixed-point type to float

[Interfrace] `float FIX<n>_tofloat(FIX<n> x)`

n: 1~31

[Description] Converts fixed-point data to float.

[Header] "fixmath.h"

[Return Value] Result of conversion

[Parameters] x: Source of conversion

[Example]

```
#include "fixmath.h"
FIX16 x;
float ret;

      ret=FIX16_tofloat(x);
```

(3) Conversion from fixed-point type to double

[Interfrace] `double FIX<n>_todouble(FIX<n> x)`

n: 1~31

[Description] Converts fixed-point data to double.

[Header] "fixmath.h"

[Return Value] Result of conversion

[Parameters] x: Source of conversion

[Example]

```
#include "fixmath.h"
FIX16 x;
double ret;

      ret=FIX16_todouble(x);
```

2.2.4 Multiplication

[Interfrace] `FIX<n> FIX<n>_mul(FIX<n> x, FIX<n> y)`

n: 1~31

[Description] Computes the multiplication of two fixed-point data of FIX<n> type. 64-bit intermediate result is used.

[Header] "fixmath.h"

[Return Value] Result of multiplication

[Parameters] x: Fixed-point data.
y: Fixed-point data

[Example]

```
#include "fixmath.h"
FIX16 x, y, ret;

      ret=FIX16_mul(x, y);
```

2.2.5 Sine Function

[Interfrace] `FIX<n> FIX<n>_sin(FIX<n> x)`

n: 16, 24, 29

[Description] Computes the sine function of FIX<n> fixed-point data (radian value).

[Header] "fixmath.h"

[Return Value] Result of sine.

[Parameters] x: Fixed-point data (radian)

[Example]

```
#include "fixmath.h"
FIX16 x, ret;

      ret=FIX16_sin(x);
```

2.2.6 Cosine Function

[Interfrace] `FIX<n> FIX<n>_cos(FIX<n> x)`

n: 16, 24, 29

[Description] Computes the cosine function of FIX<n> fixed-point data (radian value).

[Header] "fixmath.h"

[Return Value] Result of cosine.

[Parameters] x: Fixed-point data (radian)

[Example]

```
#include "fixmath.h"
FIX16 x, ret;

      ret=FIX16_cos(x);
```

2.2.7 Arctangent Function

[Interfrace] `FIX<n> FIX<n>_atan(FIX<n> x)`

n: 16, 24, 29

[Description] Computes the arctangent function of FIX<n> fixed-point data. The result is radian value.

[Header] "fixmath.h"

[Return Value] Result of arctangent (in radian).

[Parameters] x: Fixed-point data.

[Example]

```
#include "fixmath.h"
FIX16 x, ret;

      ret=FIX16_atan(x);
```

2.2.8 Square Root Function

[Interfrace]

```
FIX<n> FIX<n>_sqrt(FIX<n> x)
```

n: 16, 24, 29

[Description] Computes the square root of FIX<n> fixed-point data.

[Header] "fixmath.h"

[Return Value] Result of square root.

[Parameters] x: Fixed-point data.

[Example]

```
#include "fixmath.h"
FIX16 x, ret;

      ret=FIX16_sqrt(x);
```

2.2.9 Multiplication (fraction part) (macro)

[Interfrace] FIX<n> FIX<n>_mul_frac(FIX<n> x, FIX<n> y)

n: 1~31

[Description] Computes the fraction part of the product. The result will always be positive (0<=result<1.0).

[Header] "fixmath.h"

[Return Value] Fractional part of the product.

[Parameters] x: Fixed-point data.
y: Fixed-point data.

[Example]

```
#include "fixmath.h"
FIX16 x, y, ret;

      ret=FIX16_mul_frac(x, y);
```

2.2.10 Multiplication (saturated) (macro)

[Interfrace] `FIX<n> FIX<n>_mul_sat(FIX<n> x, FIX<n> y)`

n: 1~31

[Description] Computes the product of two fixed-point data. When the result overflows, the return value will be the maximum or minimum value, according to the sign of the result.

[Header] "fixmath.h"

[Return Value] Product of fixed point data.

[Parameters] x: Fixed-point data.
y: Fixed-point data.

[Example]

```
#include "fixmath.h"
FIX16 x, y, ret;

      ret=FIX16_mul_sat(x, y);
```

2.2.11 Multiplication (FIX-type) (macro)

[Interfrace] `FIX FIX_mul_scale<n>(FIX x, FIX y)`

n: 1~31

[Description] Computes the product of two generic fixed-point data. The values of x and y are multiplied as long data, and shifted n bits to the right.

[Header] "fixmath.h"

[Return Value] Product of fixed point data.

[Parameters] x: Fixed-point data.
y: Fixed-point data.

[Example]

```
#include "fixmath.h"
FIX x, y, ret;

      ret=FIX_mul_scale16(x, y);
```

[Note] If the result cannot be represented in 32-bit, its value is not guaranteed. When multiplying FIX<n_1> and FIX<n_2> to get FIX<n_3> type, shift count is $n_1+n_2-n_3$, and you can specify this value (1~31) as <n>.

2.2.12 Multiplication (FIX-type)

[Interfrace] `FIX FIX_mul_scale(FIX x, FIX y, int n)`

n: 1~31

[Description] Computes the product of two generic fixed-point data. The values of x and y are multiplied as long data, and shifted n bits to the right.

[Header] "fixmath.h"

[Return Value] Product of fixed point data.

[Parameters] x: Fixed-point data.
y: Fixed-point data.

[Example]

```
#include "fixmath.h"
FIX x, y, ret;
int n=16;

      ret=FIX_mul_scale(x, y, n);
```

[Note] If the result cannot be represented in 32-bit, its value is not guaranteed. When multiplying FIX<n_1> and FIX<n_2> to get FIX<n_3> type, shift count is $n_1+n_2-n_3$, and you can specify this value (1~31) as <n>.

2.2.13 Multiplication (fraction part, FIX-type) (macro)

[Interfrace] `FIX FIX_mul_frac_scale<n>(FIX x, FIX y)`

n: 1~31

[Description] Computes the fraction part of the product of two generic fixed-point data. The values of x and y are multiplied as long data, shifted n bits to the right, and lower n-bits are returned.

[Header] "fixmath.h"

[Return Value] Product of fixed point data.

[Parameters] x: Fixed-point data.
y: Fixed-point data.

[Example]

```
#include "fixmath.h"
FIX x, y, ret;

      ret=FIX_mul_frac_scale16(x, y);
```

[Note] This function can be used to compute the fractional part of FIX<n> type by multiplying FIX<n+d> type and FIX<n-d> type.

2.2.14 Multiplication (fraction part, FIX-type) (macro)

[Interfrace]
```
FIX FIX_mul_frac_scale(FIX x, FIX y, int n)
```
n: 1~31

[Description] Computes the fraction part of the product of two generic fixed-point data. The values of x and y are multiplied as long data, shifted n bits to the right, and lower n-bits are returned.

[Header] "fixmath.h"

[Return Value] Product of fixed point data.

[Parameters]
x: Fixed-point data.
y: Fixed-point data.

[Example]
```
#include "fixmath.h"
FIX x, y, ret;
int n=16;

        ret=FIX_mul_frac_scale(x, y, n);
```

[Note] This function can be used to compute the fractional part of FIX<n> type by multiplying FIX<n+d> type and FIX<n-d> type.

2.2.15 Multiplication (saturated, FIX-type) (macro)

[Interfrace]
```
FIX FIX_mul_sat_scale<n>(FIX x, FIX y)
```
n: 1~31

[Description] Computes the product of two generic fixed-point data. The values of x and y are multiplied as long data, and shifted n bits to the right. When the result overflows, the return value will be the maximum or minimum value, according to the sign of the result.

[Header] "fixmath.h"

[Return Value] Product of fixed point data.

[Parameters]
x: Fixed-point data.
y: Fixed-point data.

[Example]
```
#include "fixmath.h"
FIX x, y, ret;

        ret=FIX_mul_sat_scale16(x, y);
```

[Note] If the result cannot be represented in 32-bit, its value is not guaranteed. When multiplying FIX<n_1> and FIX<n_2> to get FIX<n_3> type, shift count is $n_1+n_2-n_3$, and you can specify this value (1~31) as <n>.

2.2.12 Multiplication (saturated, FIX-type)

[Interfrace]

```
FIX FIX_mul_sat_scale(FIX x, FIX y, int n)
```

n: 1~31

[Description] Computes the product of two generic fixed-point data. The values of x and y are multiplied as long data, and shifted n bits to the right. When the result overflows, the return value will be the maximum or minimum value, according to the sign of the result.

[Header] "fixmath.h"

[Return Value] Product of fixed point data.

[Parameters]
x: Fixed-point data.
y: Fixed-point data.

[Example]

```
#include "fixmath.h"
FIX x, y, ret;
int n=16;

      ret=FIX_mul_sat_scale(x, y, n);
```

[Note] If the result cannot be represented in 32-bit, its value is not guaranteed. When multiplying FIX<n_1> and FIX<n_2> to get FIX<n_3> type, shift count is $n_1+n_2-n_3$, and you can specify this value (1~31) as <n>.

3. Performance and Precision

3.1 Evaluation Condition

Compiler: SuperH RISC engine C/C++ Compiler V.9.03.00

Configuration: See table 7 for library configuration.

Table 7. Library Configuration

Condition	Compilation Options		
	cpu	pic	endian
1	sh2	0	big
2	sh2a	0	big

3.2 Execution Cycles

The executino cycles of fixed-point mathematical functions are shown in table 8.

Table 8. Execution Cycles of Fixed-point Mathematical Functions

CPU		SH-2	SH-2A
Configuration (see table 7)		1	2
Sine	FIX16_sin	105	64
	FIX24_sin	104	64
	FIX29_sin	95	63
Cosine	FIX16_cos	103	64
	FIX24_cos	105	63
	FIX32_cos	100	69
Arctangent	FIX16_atan	213	130
	FIX24_atan	214	131
	FIX32_atan	212	133
Square Root	FIX16_sqrt	179	99
	FIX24_sqrt	179	100
	FIX32_sart	177	102

[Note] The numbers are in cycles. Measurement may include some error.

3.3 Precision

The maximum error of these mathematics functions is ±2 in the last place except FIX29_sqrt. The precision of FIX29_sqrt is ±3 in the last place.

Website and Support

Renesas Electronics Website
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Revision Record

Rev.	Date	Description	
		Page	Summary
1.00	Sep.01.09	—	First edition issued
1.02	Sep.11.12	—	Fixed a problem of atan function

General Precautions in the Handling of MPU/MCU Products

The following usage notes are applicable to all MPU/MCU products from Renesas. For detailed usage notes on the products covered by this manual, refer to the relevant sections of the manual. If the descriptions under General Precautions in the Handling of MPU/MCU Products and in the body of the manual differ from each other, the description in the body of the manual takes precedence.

1. Handling of Unused Pins
   Handle unused pins in accord with the directions given under Handling of Unused Pins in the manual.
   — The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible. Unused pins should be handled as described under Handling of Unused Pins in the manual.
2. Processing at Power-on
   The state of the product is undefined at the moment when power is supplied.
   — The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the moment when power is supplied.
   In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the moment when power is supplied until the reset process is completed.
   In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the moment when power is supplied until the power reaches the level at which resetting has been specified.
3. Prohibition of Access to Reserved Addresses
   Access to reserved addresses is prohibited.
   — The reserved addresses are provided for the possible future expansion of functions. Do not access these addresses; the correct operation of LSI is not guaranteed if they are accessed.
4. Clock Signals
   After applying a reset, only release the reset line after the operating clock signal has become stable. When switching the clock signal during program execution, wait until the target clock signal has stabilized.
   — When the clock signal is generated with an external resonator (or from an external oscillator) during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Moreover, when switching to a clock signal produced with an external resonator (or by an external oscillator) while program execution is in progress, wait until the target clock signal is stable.
5. Differences between Products
   Before changing from one product to another, i.e. to one with a different type number, confirm that the change will not lead to problems.
   — The characteristics of MPU/MCU in the same group but having different type numbers may differ because of the differences in internal memory capacity and layout pattern. When changing to products of different type numbers, implement a system-evaluation test for each of the products.

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Refer to "http://www.renesas.com/" for the latest and detailed information.

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