Automotive Math and Motor Control Library Set for NXP S32K14x devices

Accuracy of Floating-Point Functions

Rev. 12 — 26 June 2020 User guide

Revision History

Revision	Date	Description
1.0	30-September-2015	Initial version.
2.0	1-April-2016	Updated GFLIB_AtanYX_FLT and GFLIB_AtanYXShifted_FLT.
3.0	31-December-2016	Added AMCLIB_BemfObsrvDQ_FLT and AMCLIB_TrackObsrv_FLT functions.
4.0	12-April-2017	Added GFLIB_Log10_FLT and GFLIB_VLog10_FLT functions.
5.0	30-September-2017	Added new AMCLIB FW, FWSpeedLoop, SpeedLoop, and CurrentLoop functions.
6.0	30-September-2018	The Service Release v1.1.14. See release notes for list of changes.
7.0	31-March-2019	The Service Release v1.1.16. See release notes for list of changes.
8.0	30-June-2019	The Service Release v1.1.17. See release notes for list of changes.
9.0	30-September-2019	The Service Release v1.1.18. See release notes for list of changes.
10.0	31-December-2019	The Service Release v1.1.19. See release notes for list of changes.
11.0	31-March-2020	The Service Release v1.1.20. See release notes for list of changes.
12.0	30-June-2020	The Service Release v1.1.21. See release notes for list of changes.

1 Introduction

Applications utilizing floating-point calculations tend to exhibit hard-to-predict behavior due to intricacies of finite-precision implementation of numerical algorithms. Such uncertainty cannot be ignored in critical systems. The risk of accidents resulting from numerical errors can be alleviated if the limitations of the algorithms are well understood.

Standard C libraries are typically designed to provide correctly rounded results for all functions (i.e. error less than ±0.5 ulp). Maintaining such accuracy is prohibitively slow for embedded applications. The Automotive Math and Motor Control Library Set for NXP S32K14x devices is tailored for embedded automotive systems requiring maximum processing speed and useful accuracy of results.

The aim of this document is to specify the guaranteed accuracy of floating-point functions contained in the Automotive Math and Motor Control Library Set for NXP S32K14x devices. The accuracy generally depends on specific numerical cases and hence is specified for all combinations of floating-point inputs, including all parameters and state variables accessed via input pointers. The guaranteed accuracy is expressed in terms of worst-case output error bounds for each specific case.

The accuracy criteria described in this document are also available in the form of Matlab® scripts suitable for automated verification systems.

1.1 About this Manual

This document employs the following typographical conventions:

Table 1. Typographical Conventions

Typographical Style	Example
Symbols in capital italic font represent sets.	*M*
Symbols in bold italic font represent vectors.	***fltTable***
symbols in italic font represent scalars.	*fltIn*
Subscript is used for indexing of vector elements.	$fltTable_n$

1.2 Acronyms and Definitions

Table 2. Acronyms and Definitions

Term	Definition
API	Application Programming Interface.
Inf	Floating-point special value "infinity".
NaN	Floating-point special value "not a number".
nmax	Maximum negative normalized single precision floating-point value.
pmax	Maximum positive normalized single precision floating-point value.
ulp	Unit in the last place. Used as a unit of measurement of floating-point calculation error.

1.3 Reference List

Table 3. Reference List

#	Title
1	IEEE 754-2008 IEEE Standard for Floating-Point Arithmetic, 2008
2	Power ISA , Version 2.06 Revision B, July 23, 2010
3	ARMv7-M Architecture Reference Manual, Issue Derrata 2010_Q3, 2010
4	ISO/IEC 9899:1999 Programming Language – C, 1999

#	Title
5	Automotive Math and Motor Control Library Set for NXP S32K14x devices User's Guide, revision 17

1.4 Common Definitions

This document uses the following set builder notation for input values of library functions:

$\{(fltIn_1, fltIn_2) \in X \mid X \cap M = \varnothing \wedge X \cap D \neq \varnothing\}$ denotes a set *X* of one or more combinations of input values $fltIn_1$, $fltIn_2$, such that *X* does not contain elements of *M* and contains at least one element of *D*. $X \subset Z$ where *Z* is a set of all possible combinations of all floating-point values which can appear on the inputs.

The guaranteed accuracy of results is defined for each subset of input values. Whenever two subsets overlap, the one with higher allowed error takes precedence.

Unless otherwise stated, variables are to be taken as real numbers. Whenever a variable is compared to Inf, -Inf, or NaN, a single precision floating-point representation of such variable in round-to-nearest mode is considered.

Unless otherwise stated, inputs to library functions are considered exactly representable in single precision floating-point format.

Let $N = \langle -(2 - 2^{-23}) \cdot 2^{127}, -2^{-126} \rangle \cup \langle 2^{-126}, (2 - 2^{-23}) \cdot 2^{127} \rangle$, i.e. a set of real numbers which are represented by normalized numbers in single precision floating-point format.

Let $D = \langle -2^{-126}, -2^{-149} \rangle \cup \langle 2^{-149}, -2^{-126} \rangle$, i.e. a set of real numbers which are represented by denormalized numbers in single precision floating-point format, excluding zero.

Let *M* = {NaN, Inf, -Inf}, i.e. a set of non-numerical floating-point values.

Let $pmax = (2 - 2^{-23}) \cdot 2^{127}$, i.e. the maximum positive normalized single precision floating-point value.

Let $nmax = -(2 - 2^{-23}) \cdot 2^{127}$, i.e. the maximum negative normalized single precision floating-point value.

Function ceil(*x*) provides *x* rounded towards positive infinity.

Function fe(*x*) provides the unbiased exponent of a single precision floating-point representation of *x*.

Function fix(*x*) provides *x* rounded towards zero.

Function floor(*x*) provides *x* rounded towards negative infinity.

Function max(*a*,*b*,*c*,...) provides the maximum value of {*a*, *b*, *c*, …}.

Function min(*a*,*b*,*c*,...) provides the minimum value of {*a*, *b*, *c*, …}.

Function sign(*x*) provides 1 if $x > 0$, 0 if $x = 0$, and -1 if $x < 0$.

If *x* lies between two finite consecutive single precision floating-point numbers *a* and *b* without being equal to one of them, then ULP(*x*) = |*b* - *a*|, otherwise ULP(*x*) is the distance between two finite single precision floating-point numbers nearest *x*. ULP(NaN) = NaN.

The error of floating-point results is measured in units of ulp by comparing the actual *result* with theoretical exact *refResult* as follows:

$$e = \frac{refResult - result}{\mathrm{ULP}(refResult)} \left[\mathrm{ulp}\right]$$

Equation 1

E.g. *e* = 10 ulp describes a result that deviates from exact result by ten times the absolute value of the least-significant mantissa bit of a single precision floating-point representation of the exact result.

All error measurements assume IEEE 754-2008 binary floating-point arithmetic with round-to-nearest rounding mode and default results mode in case of Power ISA implementation.

2 Library Functions

This sections provides error bounds for individual functions in the Automotive Math and Motor Control Library Set for NXP S32K14x devices.

2.1 Function AMCLIB_BemfObsrvDQ_FLT

Declaration

```
tFloat AMCLIB_BemfObsrvDQ_FLT(const SWLIBS_2Syst_FLT *const pIAB,
const SWLIBS_2Syst_FLT *const pUAB, tFloat fltVelocity, tFloat
fltPhase, AMCLIB_BEMF_OBSRV_DQ_T_FLT *const pCtrl);
```

Arguments

Table 4. AMCLIB_BemfObsrvDQ_FLT arguments

Type	Name	Direction	Description
const SWLIBS_2Syst_FLT *const	pIAB	**input**	Pointer to the structure with Alpha/Beta current components [A].
const SWLIBS_2Syst_FLT *const	pUAB	**input**	Pointer to the structure with Alpha/Beta voltage components [V].
tFloat	fltVelocity	**input**	Estimated electrical angular velocity [rad/s].
tFloat	fltPhase	**input**	Estimated rotor flux angle [rad], must be in range [-π, π].
AMCLIB_BEMF_OBSRV_DQ_T_FLT *const	pCtrl	**input, output**	Pointer to the structure with BEMF observer parameters and state.

Worst-Case Error Bounds

Let (*pIABArg1*, *pIABArg2*, *pUABArg1*, *pUABArg2*, *fltVelocity*, *pPhaseErr*, *pIObsrvArg1*, *pIObsrvArg2*, *DfltCC1sc*, *DfltCC2sc*, *DfltAcc*, *DfltInErrK1*, *DfltUpperLimit*, *DfltLowerLimit*, *DfltCC1sc*, *DfltCC2sc*, *DfltAcc*, *DfltInErrK1*, *DfltUpperLimit*, *DfltLowerLimit*, *pIObsrvIn_1Arg1*, *pIObsrvIn_1Arg2*, *fltIGain*, *fltUGain*, *fltWIGain*, *fltEGain*) ∊ *X* be a set of inputs to AMCLIB_BemfObsrvDQ_FLT,

pIObsrvArg1, *pIObsrvArg2*, *DfltAcc*, *QfltAcc*, *DfltInErrK1*, *QfltInErrK1*, *pIObsrvIn_1Arg1*, *pIObsrvIn_1Arg2* inputs represent real numbers with an error of max. ±0.5 ulp,

$ir_1 = pUABArg1 \cdot \cos(pPhaseErr)$,

$me_1 = 84$,

$ir_2 = pUABArg2 \cdot \sin(pPhaseErr)$,

$me_2 = 84$,

$ie_1 = \max(\mathrm{fe}(|ir_1| + me_1 \cdot \mathrm{ULP}(ir_1)), \mathrm{fe}(|ir_2| + me_2 \cdot \mathrm{ULP}(ir_2)))$,

$ir_3 = ir_1 + ir_2,$

$ie_2 = \mathrm{fe}(ir_3),$

$cb_1 = \begin{cases} 0, & ie_1 - ie_2 \le 0 \\ ie_1 - ie_2, & ie_1 - ie_2 > 0 \end{cases},$

$me_3 = 1 + 168 \cdot 2^{cb_1},$

$ir_4 = pUABArg2 \cdot \cos(pPhaseErr),$

$me_4 = 84,$

$ir_5 = -pUABArg1 \cdot \sin(pPhaseErr),$

$me_5 = 84,$

$ie_3 = \max(\mathrm{fe}(|ir_4| + 84 \cdot \mathrm{ULP}(ir_4)), \mathrm{fe}(|ir_5| + 84 \cdot \mathrm{ULP}(ir_5))),$

$ir_6 = ir_4 + ir_5,$

$ie_4 = \mathrm{fe}(ir_6),$

$cb_2 = \begin{cases} 0, & ie_3 - ie_4 \le 0 \\ ie_3 - ie_4, & ie_3 - ie_4 > 0 \end{cases},$

$me_6 = 1 + 168 \cdot 2^{cb_2},$

$ir_7 = pIABArg1 \cdot \cos(pPhaseErr),$

$me_7 = 84,$

$ir_8 = pIABArg2 \cdot \sin(pPhaseErr),$

$me_8 = 84,$

$ie_5 = \max(\mathrm{fe}(|ir_7| + 84 \cdot \mathrm{ULP}(ir_7)), \mathrm{fe}(|ir_8| + 84 \cdot \mathrm{ULP}(ir_8))),$

$ir_9 = ir_7 + ir_8,$

$ie_6 = \mathrm{fe}(ir_9),$

$cb_3 = \begin{cases} 0, & ie_5 - ie_6 \le 0 \\ ie_5 - ie_6, & ie_5 - ie_6 > 0 \end{cases},$

$me_9 = 1 + 168 \cdot 2^{cb_3},$

$ir_{10} = pIABArg2 \cdot \cos(pPhaseErr),$

$me_{10} = 84,$

$ir_{11} = -pIABArg1 \cdot \sin(pPhaseErr),$

$me_{10} = 84,$

$ie_7 = \max(\mathrm{fe}(|ir_{10}| + 84 \cdot \mathrm{ULP}(ir_{10})), \mathrm{fe}(|ir_{11}| + 84 \cdot \mathrm{ULP}(ir_{11}))),$

$ir_{12} = ir_{10} + ir_{11},$

$ie_8 = \mathrm{fe}(ir_{12}),$

$$cb_4 = \begin{cases} 0, & ie_7 - ie_8 \le 0 \\ ie_7 - ie_8, & ie_7 - ie_8 > 0 \end{cases},$$

$$me_{12} = 1 + 168 \cdot 2^{cb_4},$$

$$ie_9 = \max(\mathrm{fe}(|ir_9| + me_9 \cdot \mathrm{ULP}(ir_9)), \mathrm{fe}(|pIObsrvArg1| + 0.5 \cdot \mathrm{ULP}(pIObsrvArg1))),$$

$$ir_{13} = ir_9 - pIObsrvArg1,$$

$$ie_{10} = \mathrm{fe}(ir_{13}),$$

$$cb_5 = \begin{cases} 0, & ie_9 - ie_{10} \le 0 \\ ie_9 - ie_{10}, & ie_9 - ie_{10} > 0 \end{cases},$$

$$me_{13} = 0.5 + (me_9 + 0.5) \cdot 2^{cb_5},$$

$$ie_{11} = \max(\mathrm{fe}(|ir_{12}| + me_{12} \cdot \mathrm{ULP}(ir_{12})), \mathrm{fe}(|pIObsrvArg2| + 0.5 \cdot \mathrm{ULP}(pIObsrvArg2))),$$

$$ir_{14} = ir_{12} - pIObsrvArg2,$$

$$ie_{12} = \mathrm{fe}(ir_{14}),$$

$$cb_6 = \begin{cases} 0, & ie_{11} - ie_{12} \le 0 \\ ie_{11} - ie_{12}, & ie_{11} - ie_{12} > 0 \end{cases},$$

$$me_{14} = 0.5 + (me_{12} + 0.5) \cdot 2^{cb_6},$$

$$ir_{15} = ir_{13} \cdot DfltCC1sc,$$

$$me_{15} = 2 \cdot me_{13},$$

$$ir_{16} = DfltInErrK1 \cdot DfltCC2sc,$$

$$me_{16} = 1,$$

$$ie_{13} = \max(\mathrm{fe}(|ir_{15}| + me_{15} \cdot \mathrm{ULP}(ir_{15})), \mathrm{fe}(|ir_{16}| + \mathrm{ULP}(ir_{16}))),$$

$$ir_{17} = ir_{15} + ir_{16},$$

$$ie_{14} = \mathrm{fe}(ir_{17}),$$

$$cb_7 = \begin{cases} 0, & ie_{13} - ie_{14} \le 0 \\ ie_{13} - ie_{14}, & ie_{13} - ie_{14} > 0 \end{cases},$$

$$me_{17} = 1 + (me_{15} + 1) \cdot 2^{cb_7},$$

$$ir_{18} = ir_{14} \cdot QfltCC1sc,$$

$$me_{18} = 2 \cdot me_{14},$$

$$ir_{19} = QfltInErrK1 \cdot QfltCC2sc,$$

$$me_{19} = 1,$$

$$ie_{15} = \max(\mathrm{fe}(|ir_{18}| + me_{18} \cdot \mathrm{ULP}(ir_{18})), \mathrm{fe}(|ir_{19}| + \mathrm{ULP}(ir_{19}))),$$

$$ir_{20} = ir_{18} + ir_{19},$$

$$ie_{16} = \mathrm{fe}(ir_{20}),$$

$$cb_8 = \begin{cases} 0, & ie_{15} - ie_{16} \le 0 \\ ie_{15} - ie_{16}, & ie_{15} - ie_{16} > 0 \end{cases},$$

$$me_{20} = 1 + (me_{18} + 1) \cdot 2^{cb_8},$$

$$ie_{17} = \max(\text{fe}(|ir_{17}| + me_{17} \cdot \text{ULP}(ir_{17})), \text{fe}(|DfltAcc| + 0.5 \cdot \text{ULP}(DfltAcc))),$$

$$ir_{21} = ir_{17} + DfltAcc,$$

$$ie_{18} = \text{fe}(ir_{21}),$$

$$cb_9 = \begin{cases} 0, & ie_{17} - ie_{18} \le 0 \\ ie_{17} - ie_{18}, & ie_{17} - ie_{18} > 0 \end{cases},$$

$$me_{21} = \begin{cases} 0, & ir_{21} + \left(0.5 + (me_{17} + 0.5) \cdot 2^{cb_9}\right) \cdot \text{ULP}(ir_{21}) < DfltLowerLimit \\ 0, & ir_{21} - \left(0.5 + (me_{17} + 0.5) \cdot 2^{cb_9}\right) \cdot \text{ULP}(ir_{21}) > DfltUpperLimit \\ 0.5 + (me_{17} + 0.5) \cdot 2^{cb_9}, & \text{otherwise} \end{cases},$$

$$ie_{19} = \max(\text{fe}(|ir_{20}| + me_{20} \cdot \text{ULP}(ir_{20})), \text{fe}(|QfltAcc| + 0.5 \cdot \text{ULP}(QfltAcc))),$$

$$ir_{22} = ir_{19} + QfltAcc,$$

$$ie_{20} = \text{fe}(ir_{22}),$$

$$cb_{10} = \begin{cases} 0, & ie_{19} - ie_{20} \le 0 \\ ie_{19} - ie_{20}, & ie_{19} - ie_{20} > 0 \end{cases},$$

$$me_{22} = \begin{cases} 0, & ir_{22} + \left(0.5 + (me_{20} + 0.5) \cdot 2^{cb_{10}}\right) \cdot \text{ULP}(ir_{22}) < QfltLowerLimit \\ 0, & ir_{22} - \left(0.5 + (me_{20} + 0.5) \cdot 2^{cb_{10}}\right) \cdot \text{ULP}(ir_{22}) > QfltUpperLimit \\ 0.5 + (me_{20} + 0.5) \cdot 2^{cb_{10}}, & \text{otherwise} \end{cases},$$

$$ir_{23} = \begin{cases} DfltLowerLimit, & ir_{21} < DfltLowerLimit \\ DfltUpperLimit, & ir_{21} > DfltUpperLimit \\ ir_{21}, & \text{otherwise} \end{cases},$$

$$me_{23} = me_{21},$$

$$ir_{24} = \begin{cases} QfltLowerLimit, & ir_{22} < QfltLowerLimit \\ QfltUpperLimit, & ir_{22} > QfltUpperLimit \\ ir_{22}, & \text{otherwise} \end{cases},$$

$$me_{24} = me_{22},$$

$$ir_{25} = ir_{23} / ir_{24},$$

$$me_{25} = 0.5 + 2 \cdot me_{23} + 2 \cdot me_{24},$$

$$ir_{26} = fltVelocity \cdot fltWIGain,$$

$$me_{26} = 0.5,$$

$$ir_{27} = ir_{26} \cdot ir_{12},$$

$$me_{27} = 0.5 + 2 \cdot me_{26} + 2 \cdot me_{12},$$

$$ir_{28} = -ir_{26} \cdot ir_9,$$

$$me_{28} = 0.5 + 2 \cdot me_{26} + 2 \cdot me_{9},$$

$$ir_{29} = ir_{23} \cdot fltEGain,$$

$$me_{29} = 2 \cdot me_{23},$$

$$ir_{30} = ir_{24} \cdot fltEGain,$$

$$me_{30} = 2 \cdot me_{24},$$

$$ie_{21} = \max(\mathrm{fe}(|ir_{27}| + me_{27} \cdot \mathrm{ULP}(ir_{27})), \mathrm{fe}(|ir_{29}| + me_{29} \cdot \mathrm{ULP}(ir_{29}))),$$

$$ir_{31} = ir_{27} + ir_{29},$$

$$ie_{22} = \mathrm{fe}(ir_{31}),$$

$$cb_{11} = \begin{cases} 0, & ie_{21} - ie_{22} \le 0 \\ ie_{21} - ie_{22}, & ie_{21} - ie_{22} > 0 \end{cases},$$

$$me_{31} = 0.5 + (me_{27} + me_{29}) \cdot 2^{cb_{11}},$$

$$ie_{23} = \max(\mathrm{fe}(|ir_{28}| + me_{28} \cdot \mathrm{ULP}(ir_{28})), \mathrm{fe}(|ir_{30}| + me_{30} \cdot \mathrm{ULP}(ir_{30}))),$$

$$ir_{32} = ir_{28} + ir_{30},$$

$$ie_{24} = \mathrm{fe}(ir_{32}),$$

$$cb_{12} = \begin{cases} 0, & ie_{23} - ie_{24} \le 0 \\ ie_{23} - ie_{24}, & ie_{23} - ie_{24} > 0 \end{cases},$$

$$me_{32} = 0.5 + (me_{28} + me_{30}) \cdot 2^{cb_{12}},$$

$$ir_{33} = ir_{3} \cdot fltUGain,$$

$$me_{33} = 2 \cdot me_{3},$$

$$ir_{34} = ir_{6} \cdot fltUGain,$$

$$me_{34} = 2 \cdot me_{6},$$

$$ie_{25} = \max(\mathrm{fe}(|ir_{31}| + me_{31} \cdot \mathrm{ULP}(ir_{31})), \mathrm{fe}(|ir_{33}| + me_{33} \cdot \mathrm{ULP}(ir_{33}))),$$

$$ir_{35} = ir_{31} + ir_{33},$$

$$ie_{26} = \mathrm{fe}(ir_{35}),$$

$$cb_{13} = \begin{cases} 0, & ie_{25} - ie_{26} \le 0 \\ ie_{25} - ie_{26}, & ie_{25} - ie_{26} > 0 \end{cases},$$

$$me_{35} = 0.5 + (me_{31} + me_{33}) \cdot 2^{cb_{13}},$$

$$ie_{27} = \max(\mathrm{fe}(|ir_{32}| + me_{32} \cdot \mathrm{ULP}(ir_{32})), \mathrm{fe}(|ir_{34}| + me_{34} \cdot \mathrm{ULP}(ir_{34}))),$$

$$ir_{36} = ir_{32} + ir_{34},$$

$$ie_{28} = \mathrm{fe}(ir_{36}),$$

$$cb_{13} = \begin{cases} 0, & ie_{27} - ie_{28} \le 0 \\ ie_{27} - ie_{28}, & ie_{27} - ie_{28} > 0 \end{cases},$$

$$me_{36} = 0.5 + (me_{32} + me_{34}) \cdot 2^{cb_{13}},$$

$$ie_{29} = \max(\mathrm{fe}(|ir_{35}| + me_{35} \cdot \mathrm{ULP}(ir_{35})), \mathrm{fe}(|pIObsrvin\_1Arg1| + 0.5 \cdot \mathrm{ULP}(pIObsrvin\_1Arg1))),$$

$$ir_{37} = ir_{35} + pIObsrvin\_1Arg1,$$

$$ie_{30} = \mathrm{fe}(ir_{37}),$$

$$cb_{14} = \begin{cases} 0, & ie_{29} - ie_{30} \le 0 \\ ie_{29} - ie_{30}, & ie_{29} - ie_{30} > 0 \end{cases},$$

$$me_{37} = 0.5 + (me_{35} + 0.5) \cdot 2^{cb_{14}},$$

$$ie_{31} = \max(\mathrm{fe}(|ir_{36}| + me_{36} \cdot \mathrm{ULP}(ir_{36})), \mathrm{fe}(|pIObsrvin\_1Arg2| + 0.5 \cdot \mathrm{ULP}(pIObsrvin\_1Arg2))),$$

$$ir_{38} = ir_{36} + pIObsrvin\_1Arg2,$$

$$ie_{32} = \mathrm{fe}(ir_{38}),$$

$$cb_{15} = \begin{cases} 0, & ie_{31} - ie_{32} \le 0 \\ ie_{31} - ie_{32}, & ie_{31} - ie_{32} > 0 \end{cases},$$

$$me_{38} = 0.5 + (me_{36} + 0.5) \cdot 2^{cb_{15}},$$

$$ir_{39} = pIObsrvArg1 \cdot fltIGain,$$

$$me_{39} = 1,$$

$$ir_{40} = pIObsrvArg2 \cdot fltIGain,$$

$$me_{40} = 1,$$

$$ie_{33} = \max(\mathrm{fe}(|ir_{37}| + me_{37} \cdot \mathrm{ULP}(ir_{37})), \mathrm{fe}(|ir_{39}| + \mathrm{ULP}(ir_{39}))),$$

$$ir_{41} = ir_{37} + ir_{39},$$

$$ie_{34} = \mathrm{fe}(ir_{41}),$$

$$cb_{16} = \begin{cases} 0, & ie_{33} - ie_{34} \le 0 \\ ie_{33} - ie_{34}, & ie_{33} - ie_{34} > 0 \end{cases},$$

$$me_{41} = 0.5 + (me_{37} + 1) \cdot 2^{cb_{16}},$$

$$ie_{35} = \max(\mathrm{fe}(|ir_{38}| + me_{38} \cdot \mathrm{ULP}(ir_{38})), \mathrm{fe}(|ir_{40}| + \mathrm{ULP}(ir_{40}))),$$

$$ir_{42} = ir_{38} + ir_{40},$$

$$ie_{36} = \mathrm{fe}(ir_{42}),$$

$$cb_{17} = \begin{cases} 0, & ie_{35} - ie_{36} \le 0 \\ ie_{35} - ie_{36}, & ie_{35} - ie_{36} > 0 \end{cases},$$

$$me_{42} = 0.5 + (me_{38} + 1) \cdot 2^{cb_{17}},$$

$$me_{43} = 6 + me_{25},$$

then

Table 5. AMCLIB_BemfObsrvDQ_FLT Worst-Case Error Bounds - pParamD.fltInErrK1 output

Subset of input domain	Worst-case error bounds for pParamD.fltInErrK1 output [ulp]	Allowed specific values (regardless the error bounds) for pParamD.fltInErrK1 output
Any of the inputs is denormalized, NaN, or infinity, i.e. $\{X \mid X \cap D \neq \varnothing \vee X \cap M \neq \varnothing\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values with pPhaseErr beyond the allowed range, i.e. $\{X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert > \pi\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{ \begin{matrix} X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \leq \pi, \\ \boldsymbol{ir} \in (N \cup \{-0, +0\})^{42} \end{matrix} \right\}$	$\langle -me_{13}, me_{13} \rangle$	N/A
Normalized or zero input values which cause an underflow, i.e. $\left\{ \begin{matrix} X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \leq \pi, \\ \exists n: ir_n \neq \varnothing \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \end{matrix} \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which cause an overflow, i.e. $\left\{ \begin{matrix} X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \leq \pi, \\ \exists n: ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \end{matrix} \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Table 6. AMCLIB_BemfObsrvDQ_FLT Worst-Case Error Bounds - pParamQ.fltInErrK1 output

Subset of input domain	Worst-case error bounds for pParamQ.fltInErrK1 output [ulp]	Allowed specific values (regardless the error bounds) for pParamQ.fltInErrK1 output
Any of the inputs is denormalized, NaN, or infinity, i.e. $\{X \mid X \cap D \neq \varnothing \vee X \cap M \neq \varnothing\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values with pPhaseErr beyond the allowed range, i.e. $\{X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert > \pi\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Subset of input domain	Worst-case error bounds for pParamQ.fltInErrK1 output [ulp]	Allowed specific values (regardless the error bounds) for pParamQ.fltInErrK1 output
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{ X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \leq \pi, \; \mathbf{ir} \in (N \cup \{-0, +0\})^{42} \right\}$	$\langle -me_{14}, me_{14} \rangle$	N/A
Normalized or zero input values which cause an underflow, i.e. $\left\{ X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \leq \pi, \; \exists n : ir_n \neq \varnothing \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which cause an overflow, i.e. $\left\{ X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \leq \pi, \; \exists n : ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Table 7. AMCLIB_BemfObsrvDQ_FLT Worst-Case Error Bounds - pParamD.fltAcc output

Subset of input domain	Worst-case error bounds for pParamD.fltAcc output [ulp]	Allowed specific values (regardless the error bounds) for pParamD.fltAcc output
Any of the inputs is denormalized, NaN, or infinity, i.e. $\{ X \mid X \cap D \neq \varnothing \vee X \cap M \neq \varnothing \}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values with pPhaseErr beyond the allowed range, i.e. $\{ X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert > \pi \}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{ X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \leq \pi, \; \mathbf{ir} \in (N \cup \{-0, +0\})^{42} \right\}$	$\langle -me_{21}, me_{21} \rangle$	N/A
Normalized or zero input values which cause an underflow, i.e. $\left\{ X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \leq \pi, \; \exists n : ir_n \neq \varnothing \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Subset of input domain	Worst-case error bounds for pParamD.fltAcc output [ulp]	Allowed specific values (regardless the error bounds) for pParamD.fltAcc output
Normalized or zero input values which cause an overflow, i.e. $\left\{ X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \le \pi, \; \exists n : ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Table 8. AMCLIB_BemfObsrvDQ_FLT Worst-Case Error Bounds - pParamQ.fltAcc output

Subset of input domain	Worst-case error bounds for pParamQ.fltAcc output [ulp]	Allowed specific values (regardless the error bounds) for pParamQ.fltAcc output
Any of the inputs is denormalized, NaN, or infinity, i.e. $\{X \mid X \cap D \ne \varnothing \vee X \cap M \ne \varnothing\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values with pPhaseErr beyond the allowed range, i.e. $\{X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert > \pi\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{ X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \le \pi, \; \boldsymbol{ir} \in (N \cup \{-0, +0\})^{42} \right\}$	$\langle -me_{22}, me_{22} \rangle$	N/A
Normalized or zero input values which cause an underflow, i.e. $\left\{ X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \le \pi, \; \exists n : ir_n \ne \varnothing \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which cause an overflow, i.e. $\left\{ X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \le \pi, \; \exists n : ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Table 9. AMCLIB_BemfObsrvDQ_FLT Worst-Case Error Bounds - pPhaseErr output

Subset of input domain	Worst-case error bounds for pPhaseErr output [ulp]	Allowed specific values (regardless the error bounds) for pPhaseErr output
Any of the inputs is denormalized, NaN, or infinity, i.e. $\{X \mid X \cap D \ne \varnothing \vee X \cap M \ne \varnothing\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Subset of input domain	Worst-case error bounds for pPhaseErr output [ulp]	Allowed specific values (regardless the error bounds) for pPhaseErr output
Normalized or zero input values with pPhaseErr beyond the allowed range, i.e. $\{X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert > \pi\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{X \mid \begin{matrix} X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \le \pi, \\ \mathbf{ir} \in (N \cup \{-0, +0\})^{42} \end{matrix}\right\}$	$\langle -me_{22}, me_{22} \rangle$	N/A
Normalized or zero input values which cause an underflow, i.e. $\left\{X \mid \begin{matrix} X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \le \pi, \\ \exists n: ir_n \ne \varnothing \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \end{matrix}\right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which cause an overflow, i.e. $\left\{X \mid \begin{matrix} X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \le \pi, \\ \exists n: ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \end{matrix}\right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which lead to normalized or zero results with pEObsrv.fltArg2 close to zero, i.e. $\left\{X \mid \begin{matrix} X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \le \pi, \\ \mathbf{ir} \in (N \cup \{-0, +0\})^{42}, \\ \lvert ir_{22} \rvert \le me_{22} \cdot \mathrm{ULP}(ir_{22}) \end{matrix}\right\}$	$(-Inf, Inf)$	N/A

Table 10. AMCLIB_BemfObsrvDQ_FLT Worst-Case Error Bounds - pIObsrvIn_1.fltArg1 output

Subset of input domain	Worst-case error bounds for pIObsrvIn_1.fltArg1 output [ulp]	Allowed specific values (regardless the error bounds) for pIObsrvIn_1.fltArg1 output
Any of the inputs is denormalized, NaN, or infinity, i.e. $\{X \mid X \cap D \ne \varnothing \vee X \cap M \ne \varnothing\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values with pPhaseErr beyond the allowed range, i.e. $\{X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert > \pi\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Subset of input domain	Worst-case error bounds for pIObsrvIn_1.fltArg1 output [ulp]	Allowed specific values (regardless the error bounds) for pIObsrvIn_1.fltArg1 output
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \leq \pi, \; \boldsymbol{ir} \in (N \cup \{-0, +0\})^{42}\right\}$	$\langle -me_{35}, me_{35} \rangle$	N/A
Normalized or zero input values which cause an underflow, i.e. $\left\{X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \leq \pi, \; \exists n : ir_n \neq \varnothing \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D\right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which cause an overflow, i.e. $\left\{X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \leq \pi, \; \exists n : ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf\right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Table 11. AMCLIB_BemfObsrvDQ_FLT Worst-Case Error Bounds - pIObsrvIn_1.fltArg2 output

Subset of input domain	Worst-case error bounds for pIObsrvIn_1.fltArg2 output [ulp]	Allowed specific values (regardless the error bounds) for pIObsrvIn_1.fltArg2 output
Any of the inputs is denormalized, NaN, or infinity, i.e. $\{X \mid X \cap D \neq \varnothing \vee X \cap M \neq \varnothing\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values with pPhaseErr beyond the allowed range, i.e. $\{X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert > \pi\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \leq \pi, \; \boldsymbol{ir} \in (N \cup \{-0, +0\})^{42}\right\}$	$\langle -me_{36}, me_{36} \rangle$	N/A
Normalized or zero input values which cause an underflow, i.e. $\left\{X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \leq \pi, \; \exists n : ir_n \neq \varnothing \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D\right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Subset of input domain	Worst-case error bounds for pIObsrvIn_1.fltArg2 output [ulp]	Allowed specific values (regardless the error bounds) for pIObsrvIn_1.fltArg2 output
Normalized or zero input values which cause an overflow, i.e. $\left\{ X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \le \pi, \atop \exists n : ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Table 12. AMCLIB_BemfObsrvDQ_FLT Worst-Case Error Bounds - pIObsrv.fltArg1 output

Subset of input domain	Worst-case error bounds for pIObsrv.fltArg1 output [ulp]	Allowed specific values (regardless the error bounds) for pIObsrv.fltArg1 output
Any of the inputs is denormalized, NaN, or infinity, i.e. $\{X \mid X \cap D \ne \varnothing \vee X \cap M \ne \varnothing\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values with pPhaseErr beyond the allowed range, i.e. $\{X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert > \pi\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{ X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \le \pi, \atop \boldsymbol{ir} \in (N \cup \{-0, +0\})^{42} \right\}$	$\langle -me_{41}, me_{41} \rangle$	N/A
Normalized or zero input values which cause an underflow, i.e. $\left\{ X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \le \pi, \atop \exists n : ir_n \ne \varnothing \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which cause an overflow, i.e. $\left\{ X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \le \pi, \atop \exists n : ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Table 13. AMCLIB_BemfObsrvDQ_FLT Worst-Case Error Bounds - pIObsrv.fltArg2 output

Subset of input domain	Worst-case error bounds for pIObsrv.fltArg2 output [ulp]	Allowed specific values (regardless the error bounds) for pIObsrv.fltArg2 output
Any of the inputs is denormalized, NaN, or infinity, i.e. $\{X \mid X \cap D \ne \varnothing \vee X \cap M \ne \varnothing\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Subset of input domain	Worst-case error bounds for plObsrv.fltArg2 output [ulp]	Allowed specific values (regardless the error bounds) for plObsrv.fltArg2 output
Normalized or zero input values with pPhaseErr beyond the allowed range, i.e. $\{X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert > \pi\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{ \begin{array}{l} X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \le \pi, \\ \quad \boldsymbol{ir} \in (N \cup \{-0, +0\})^{42} \end{array} \right\}$	$\langle -me_{42}, me_{42} \rangle$	N/A
Normalized or zero input values which cause an underflow, i.e. $\left\{ \begin{array}{l} X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \le \pi, \\ \exists n : ir_n \ne \varnothing \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \end{array} \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which cause an overflow, i.e. $\left\{ \begin{array}{l} X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \le \pi, \\ \exists n : ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \end{array} \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

2.2 Function AMCLIB_CurrentLoop_FLT

Declaration

```
void AMCLIB_CurrentLoop_FLT(tFloat fltUDcBus, SWLIBS_2Syst_FLT
*const pUDQReq, AMCLIB_CURRENT_LOOP_T_FLT *pCtrl);
```

Arguments

Table 14. AMCLIB_CurrentLoop_FLT arguments

Type	Name	Direction	Description
tFloat	fltUDcBus	**input**	DC bus voltage.
SWLIBS_2Syst_FLT *const	pUDQReq	**output**	Pointer to the structure with the required stator voltages in the two-phase rotational orthogonal system (d-q).
AMCLIB_CURRENT_LOOP_T_FLT *	pCtrl	**input, output**	Pointer to the structure with AMCLIB_CurrentLoop state.

Worst-Case Error Bounds

Let (*fltUDcBus, pIDReq, pIQReq, pIDFbck, pIQFbck, fltCC1scD, fltCC2scD, fltAccD, fltInErrK1D, fltCC1scQ, fltCC2scQ, fltAccQ, fltInErrK1Q*) ∊ *X* be a set of inputs to AMCLIB_CurrentLoop_FLT,

fltAccD, fltInErrK1D, fltAccQ, fltInErrK1Q inputs represent real numbers with an error of max. ±0.5 ulp,

$ir_1 = pIQReq - pIDFbck$,

$me_1 = 0.5$,

$ir_2 = ir_1 \cdot fltCC1scD$,

$me_2 = 2 \cdot me_1$,

$ir_3 = fltInErrK1D \cdot fltCC2scD$,

$me_3 = 1$,

$ie_1 = \max(\mathrm{fe}(|ir_2| + me_2 \cdot \mathrm{ULP}(ir_2)), \mathrm{fe}(|ir_3| + me_3 \cdot \mathrm{ULP}(ir_3)))$,

$ir_4 = ir_2 + ir_3$,

$ie_2 = \mathrm{fe}(ir_4)$,

$$cb_1 = \begin{cases} 0, & ie_1 - ie_2 \le 0 \\ ie_1 - ie_2, & ie_1 - ie_2 > 0 \end{cases},$$

$me_4 = 1 + (me_2 + me_3) \cdot 2^{cb_1}$,

$ie_3 = \max(\mathrm{fe}(|ir_4| + me_4 \cdot \mathrm{ULP}(ir_4)), \mathrm{fe}(|fltAccD| + 0.5 \cdot \mathrm{ULP}(fltAccD)))$,

$ir_5 = ir_4 + fltAccD$,

$ie_4 = \mathrm{fe}(ir_5)$,

$$cb_2 = \begin{cases} 0, & ie_3 - ie_4 \le 0 \\ ie_3 - ie_4, & ie_3 - ie_4 > 0 \end{cases},$$

$me_5 = 0.5 + (me_4 + 0.5) \cdot 2^{cb_2}$,

$ir_{17} = fltUDcBus \cdot \frac{1}{\sqrt{3}}$,

$me_{17} = 1.5$,

$$me_6 = \begin{cases} \max(me_5, me_{17}), & ir_5 - me_5 \cdot \mathrm{ULP}(ir_5) > ir_{17} - me_{17} \cdot \mathrm{ULP}(ir_{17}) \\ \max(me_5, me_{17}), & ir_5 + me_5 \cdot \mathrm{ULP}(ir_5) < (-ir_{17} + me_{17} \cdot \mathrm{ULP}(ir_{17})) \\ me_5 & otherwise \end{cases},$$

$$ir_6 = \begin{cases} ir_{17}, & ir_5 > ir_{17} \\ -ir_{17}, & ir_5 < (-ir_{17}) \\ ir_5 & otherwise \end{cases},$$

$ir_7 = {ir_6}^2$,

$me_7 = 0.5 + 3 \cdot me_6$,

$ir_8 = {ir_{17}}^2$,

$me_8 = 0.5 + 3 \cdot me_{17}$,

$ie_5 = \max(\mathrm{fe}(|ir_7| + me_7 \cdot \mathrm{ULP}(ir_7)), \mathrm{fe}(|ir_8| + me_8 \cdot \mathrm{ULP}(ir_8)))$,

$ir_9 = ir_8 - ir_7$,

$ie_6 = \mathrm{fe}(ir_9)$,

$$cb_3 = \begin{cases} 0, & ie_5 - ie_6 \le 0 \\ ie_5 - ie_6, & ie_5 - ie_6 > 0 \end{cases},$$

$$me_9 = 0.5 + (me_7 + me_8) \cdot 2^{cb_3},$$

$$ir_{10} = \sqrt{ir_9},$$

$$me_8 = 0.5 + \frac{me_9}{\sqrt{2}},$$

$$ir_{11} = pIQReq - pIQFbck,$$

$$me_{11} = 0.5,$$

$$ir_{12} = ir_{11} \cdot fltCC1scQ,$$

$$me_{12} = 2 \cdot me_{11},$$

$$ir_{13} = fltInErrK1Q \cdot fltCC2scQ,$$

$$me_{13} = 1,$$

$$ie_7 = \max(\mathrm{fe}(|ir_{12}| + me_{12} \cdot \mathrm{ULP}(ir_{12})), \mathrm{fe}(|ir_{13}| + me_{13} \cdot \mathrm{ULP}(ir_{13}))),$$

$$ir_{14} = ir_{12} + ir_{13},$$

$$ie_8 = \mathrm{fe}(ir_{14}),$$

$$cb_4 = \begin{cases} 0, & ie_7 - ie_8 \le 0 \\ ie_7 - ie_8, & ie_7 - ie_8 > 0 \end{cases},$$

$$me_{14} = 1 + (me_{12} + me_{13}) \cdot 2^{cb_4},$$

$$ie_9 = \max(\mathrm{fe}(|ir_{14}| + me_{14} \cdot \mathrm{ULP}(ir_{14})), \mathrm{fe}(|fltAccQ| + 0.5 \cdot \mathrm{ULP}(fltAccQ))),$$

$$ir_{15} = ir_{14} + fltAccQ,$$

$$ie_{10} = \mathrm{fe}(ir_{15}),$$

$$cb_5 = \begin{cases} 0, & ie_9 - ie_{10} \le 0 \\ ie_9 - ie_{10}, & ie_9 - ie_{10} > 0 \end{cases},$$

$$me_{15} = 0.5 + (me_{14} + 0.5) \cdot 2^{cb_5},$$

$$me_{16} = \begin{cases} \max(me_{15}, me_{10}), & ir_{15} - me_{15} \cdot \mathrm{ULP}(ir_{15}) > ir_{10} - me_{10} \cdot \mathrm{ULP}(ir_{10}) \\ \max(me_{15}, me_{10}), & ir_{15} + me_{15} \cdot \mathrm{ULP}(ir_{15}) < (-ir_{10} + me_{10} \cdot \mathrm{ULP}(ir_{10})) \\ me_{15} & otherwise \end{cases},$$

$$ir_{16} = \begin{cases} ir_{15}, & ir_{15} > ir_{10} \\ -ir_{10}, & ir_{15} < (-ir_{10}) \\ ir_{15} & otherwise \end{cases},$$

then

Table 15. AMCLIB_CurrentLoop_FLT Worst-Case Error Bounds - pPIrAWD.fltInErrK1 output

Subset of input domain	Worst-case error bounds for pPIrAWD.fltInErrK1 output [ulp]	Allowed specific values (regardless the error bounds) for pPIrAWD.fltInErrK1 output
Any of the inputs is denormalized, NaN, or infinity, i.e. $\{X \mid X \cap D \neq \varnothing \vee X \cap M \neq \varnothing\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values with fltUDPhMax or fltUQPhMax beyond the allowed range, i.e. $\left\{\begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \\ (\lvert fltUDPhMax \rvert < 0 \vee \lvert fltUQPhMax \rvert < 0) \end{array}\right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{\begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \lvert fltUDPhMax \rvert \geq 0 \wedge \\ \lvert fltUQPhMax \rvert \geq 0 \wedge ir \in (N \cup \{-0, +0\})^{17} \end{array}\right\}$	$\langle -me_1, me_1 \rangle$	N/A
Normalized or zero input values which cause an underflow, i.e. $\left\{\begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \lvert fltUDPhMax \rvert \geq 0 \wedge \\ \lvert fltUQPhMax \rvert \geq 0, \\ \exists n : ir_n \neq \varnothing \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \end{array}\right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which cause an overflow, i.e. $\left\{\begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \lvert fltUDPhMax \rvert \geq 0 \wedge \\ \lvert fltUQPhMax \rvert \geq 0, \\ \exists n : ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \end{array}\right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Table 16. AMCLIB_CurrentLoop_FLT Worst-Case Error Bounds - pPIrAWD.fltAcc output

Subset of input domain	Worst-case error bounds for pPIrAWD.fltAcc output [ulp]	Allowed specific values (regardless the error bounds) for pPIrAWD.fltAcc output
Any of the inputs is denormalized, NaN, or infinity, i.e. $\{X \mid X \cap D \neq \varnothing \vee X \cap M \neq \varnothing\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values with fltUDPhMax or fltUQPhMax beyond the allowed range, i.e. $\left\{\begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \\ (\lvert fltUDPhMax \rvert < 0 \vee \lvert fltUQPhMax \rvert < 0) \end{array}\right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Subset of input domain	Worst-case error bounds for pPIrAWD.fltAcc output [ulp]	Allowed specific values (regardless the error bounds) for pPIrAWD.fltAcc output
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{ \begin{array}{l} X \mid X \subset N \cup \{-0, +0\} \wedge \lvert fltUDPhMax \rvert \geq 0 \wedge \\ \lvert fltUQPhMax \rvert \geq 0 \wedge ir \in (N \cup \{-0, +0\})^{17} \end{array} \right\}$	$\langle -me_6, me_6 \rangle$	N/A
Normalized or zero input values which cause an underflow, i.e. $\left\{ \begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \lvert fltUDPhMax \rvert \geq 0 \wedge \\ \lvert fltUQPhMax \rvert \geq 0, \\ \exists n : ir_n \neq \varnothing \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \end{array} \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which cause an overflow, i.e. $\left\{ \begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \lvert fltUDPhMax \rvert \geq 0 \wedge \\ \lvert fltUQPhMax \rvert \geq 0, \\ \exists n : ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \end{array} \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Table 17. AMCLIB_CurrentLoop_FLT Worst-Case Error Bounds - pUDQReq.fltArg1 output

Subset of input domain	Worst-case error bounds for pUDQReq.fltArg1 output [ulp]	Allowed specific values (regardless the error bounds) for pUDQReq.fltArg1 output
Any of the inputs is denormalized, NaN, or infinity, i.e. $\{X \mid X \cap D \neq \varnothing \vee X \cap M \neq \varnothing\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values with fltUDPhMax or fltUQPhMax beyond the allowed range, i.e. $\left\{ \begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \\ (\lvert fltUDPhMax \rvert < 0 \vee \lvert fltUQPhMax \rvert < 0) \end{array} \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{ \begin{array}{l} X \mid X \subset N \cup \{-0, +0\} \wedge \lvert fltUDPhMax \rvert \geq 0 \wedge \\ \lvert fltUQPhMax \rvert \geq 0 \wedge ir \in (N \cup \{-0, +0\})^{17} \end{array} \right\}$	$\langle -me_6, me_6 \rangle$	N/A

Subset of input domain	Worst-case error bounds for pUDQReq.fltArg1 output [ulp]	Allowed specific values (regardless the error bounds) for pUDQReq.fltArg1 output
Normalized or zero input values which cause an underflow, i.e. $\left\{ \begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \lvert fltUDPhMax \rvert \geq 0 \wedge \\ \lvert fltUQPhMax \rvert \geq 0, \\ \exists n : ir_n \neq \varnothing \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \end{array} \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which cause an overflow, i.e. $\left\{ \begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \lvert fltUDPhMax \rvert \geq 0 \wedge \\ \lvert fltUQPhMax \rvert \geq 0, \\ \exists n : ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \end{array} \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Table 18. AMCLIB_CurrentLoop_FLT Worst-Case Error Bounds - pPIrAWQ.fltInErrK1 output

Subset of input domain	Worst-case error bounds for pPIrAWQ.fltInErrK1 output [ulp]	Allowed specific values (regardless the error bounds) for pPIrAWQ.fltInErrK1 output
Any of the inputs is denormalized, NaN, or infinity, i.e. $\{X \mid X \cap D \neq \varnothing \vee X \cap M \neq \varnothing\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values with fltUDPhMax or fltUQPhMax beyond the allowed range, i.e. $\left\{ \begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \\ (\lvert fltUDPhMax \rvert < 0 \vee \lvert fltUQPhMax \rvert < 0) \end{array} \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{ \begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \lvert fltUDPhMax \rvert \geq 0 \wedge \\ \lvert fltUQPhMax \rvert \geq 0 \wedge ir \in (N \cup \{-0, +0\})^{17} \end{array} \right\}$	$\langle -me_{11}, me_{11} \rangle$	N/A
Normalized or zero input values which cause an underflow, i.e. $\left\{ \begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \lvert fltUDPhMax \rvert \geq 0 \wedge \\ \lvert fltUQPhMax \rvert \geq 0, \\ \exists n : ir_n \neq \varnothing \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \end{array} \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Subset of input domain	Worst-case error bounds for pPIrAWQ.fltInErrK1 output [ulp]	Allowed specific values (regardless the error bounds) for pPIrAWQ.fltInErrK1 output
Normalized or zero input values which cause an overflow, i.e. $$\left\{\begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \lvert fltUDPhMax \rvert \geq 0 \wedge \\ \lvert fltUQPhMax \rvert \geq 0, \\ \exists n : ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \end{array}\right\}$$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Table 19. AMCLIB_CurrentLoop_FLT Worst-Case Error Bounds - pPIrAWQ.fltAcc output

Subset of input domain	Worst-case error bounds for pPIrAWQ.fltAcc output [ulp]	Allowed specific values (regardless the error bounds) for pPIrAWQ.fltAcc output
Any of the inputs is denormalized, NaN, or infinity, i.e. $$\{X \mid X \cap D \neq \varnothing \vee X \cap M \neq \varnothing\}$$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values with fltUDPhMax or fltUQPhMax beyond the allowed range, i.e. $$\left\{\begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \\ (\lvert fltUDPhMax \rvert < 0 \vee \lvert fltUQPhMax \rvert < 0) \end{array}\right\}$$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $$\left\{\begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \lvert fltUDPhMax \rvert \geq 0 \wedge \\ \lvert fltUQPhMax \rvert \geq 0 \wedge ir \in (N \cup \{-0, +0\})^{17} \end{array}\right\}$$	$\langle -me_{16}, me_{16} \rangle$	N/A
Normalized or zero input values which cause an underflow, i.e. $$\left\{\begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \lvert fltUDPhMax \rvert \geq 0 \wedge \\ \lvert fltUQPhMax \rvert \geq 0, \\ \exists n : ir_n \neq \varnothing \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \end{array}\right\}$$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which cause an overflow, i.e. $$\left\{\begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \lvert fltUDPhMax \rvert \geq 0 \wedge \\ \lvert fltUQPhMax \rvert \geq 0, \\ \exists n : ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \end{array}\right\}$$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Table 20. AMCLIB_CurrentLoop_FLT Worst-Case Error Bounds - pUDQReq.fltArg2 output

Subset of input domain	Worst-case error bounds for pUDQReq.fltArg2 output [ulp]	Allowed specific values (regardless the error bounds) for pUDQReq.fltArg2 output
Any of the inputs is denormalized, NaN, or infinity, i.e. $\{X \mid X \cap D \neq \varnothing \vee X \cap M \neq \varnothing\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values with fltUDPhMax or fltUQPhMax beyond the allowed range, i.e. $\left\{\begin{matrix} X \mid X \subset N \cup \{-0, +0\} \wedge \\ (\lvert fltUDPhMax\rvert < 0 \vee \lvert fltUQPhMax\rvert < 0) \end{matrix}\right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{\begin{matrix} X \mid X \subset N \cup \{-0, +0\} \wedge \lvert fltUDPhMax\rvert \geq 0 \wedge \\ \lvert fltUQPhMax\rvert \geq 0 \wedge ir \in (N \cup \{-0, +0\})^{17} \end{matrix}\right\}$	$\langle -me_{16}, me_{16}\rangle$	N/A
Normalized or zero input values which cause an underflow, i.e. $\left\{\begin{matrix} X \mid X \subset N \cup \{-0, +0\} \wedge \lvert fltUDPhMax\rvert \geq 0 \wedge \\ \lvert fltUQPhMax\rvert \geq 0, \\ \exists n: ir_n \neq \varnothing \wedge \lvert ir_n\rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \end{matrix}\right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which cause an overflow, i.e. $\left\{\begin{matrix} X \mid X \subset N \cup \{-0, +0\} \wedge \lvert fltUDPhMax\rvert \geq 0 \wedge \\ \lvert fltUQPhMax\rvert \geq 0, \\ \exists n: ir_n \in M \vee \lvert ir_n\rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \end{matrix}\right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

2.3 Function AMCLIB_FW_FLT

Declaration

```
void AMCLIB_FW_FLT(tFloat fltIDQReqAmp, tFloat fltVelocityFbck,
SWLIBS_2Syst_FLT *const pIDQReq, AMCLIB_FW_T_FLT *pCtrl);
```

Arguments

Table 21. AMCLIB_FW_FLT arguments

Type	Name	Direction	Description
tFloat	fltIDQReqAmp	**input**	Required amplitude of the currents Id and Iq in the two-phase rotational orthogonal system (d-q).
tFloat	fltVelocityFbck	**input**	Actual electrical angular velocity from the feedback.

Type	Name	Direction	Description
SWLIBS_2Syst_FLT *const	pIDQReq	**input, output**	Pointer to the structure with the required stator currents in the two-phase rotational orthogonal system (d-q).
AMCLIB_FW_T_FLT *	pCtrl	**input, output**	Pointer to the structure with AMCLIB_FW state.

Worst-Case Error Bounds

Let (*fltIDQReqAmp, fltVelocityFbck, pIQFbck, pIQreqK_1, pUQReq, pUQLim, fltUmaxDivImax, fltIntegPartK_1FW, fltInK_1FW, fltAccFW, fltLambdaFW, fltPropGainFW, fltIntegGainFW, fltLowerLimitFW, fltUpperLimitFW*) ∊ *X* be a set of inputs to AMCLIB_FW_FLT,

fltIntegPartK_1Q, fltInK_1Q, fltIntegPartK_1FW, fltInK_1FW, fltAccQ, fltAccFW inputs represent real numbers with an error of max. ±0.5 ulp,

$ir_{14} = (pIQreqK\_1 - pIQFbck) \cdot \mathrm{sign}(fltVelocityFbck)$,

$me_{14} = 0.5$,

$ir_{15} = pUQLim - \mathrm{abs}(pUQReq)$,

$me_{15} = 0.5$,

$ir_{16} = fltUmaxDivImax \cdot ir_{14}$,

$me_{16} = 2 \cdot me_{14}$,

$ie_{15} = \max(\mathrm{fe}(|ir_{16}| + me_{16} \cdot \mathrm{ULP}(ir_{16})), \mathrm{fe}(|ir_{15}| + me_{15} \cdot \mathrm{ULP}(ir_{15})))$,

$ir_{17} = ir_{15} - ir_{16}$,

$ie_{16} = \mathrm{fe}(ir_{17})$,

$$cb_8 = \begin{cases} 0, & ie_{15} - ie_{16} \le 0 \\ ie_{15} - ie_{16}, & ie_{15} - ie_{16} > 0 \end{cases},$$

$me_{17} = 0.5 + (me_{16} + me_{15}) \cdot 2^{cb_8}$,

$ir_{18} = fltLambdaFW \cdot ir_{17}$,

$me_{18} = me_{17}$,

$ie_{17} = \max(\mathrm{fe}(|ir_{18}| + me_{18} \cdot \mathrm{ULP}(ir_{18})), \mathrm{fe}(|fltAccFW| + 0.5 \cdot \mathrm{ULP}(fltAccFW)))$,

$ir_{19} = ir_{18} + fltAccFW$,

$ie_{18} = \mathrm{fe}(ir_{19})$,

$$cb_9 = \begin{cases} 0, & ie_{17} - ie_{18} \le 0 \\ ie_{17} - ie_{18}, & ie_{17} - ie_{18} > 0 \end{cases},$$

$me_{19} = 0.5 + (me_{18} + 0.5) \cdot 2^{cb_9}$,

$ir_{20} = fltLambdaFW \cdot ir_{19}$,

$me_{20} = 2 \cdot me_{19}$,

$ie_{19} = \max(\mathrm{fe}(|ir_{20}| + me_{20} \cdot \mathrm{ULP}(ir_{20})), \mathrm{fe}(|ir_{19}| + me_{19} \cdot \mathrm{ULP}(ir_{19})))$,

$$ir_{21} = ir_{19} - ir_{20},$$

$$ie_{20} = \mathrm{fe}(ir_{21}),$$

$$cb_{10} = \begin{cases} 0, & ie_{19} - ie_{20} \le 0 \\ ie_{19} - ie_{20}, & ie_{19} - ie_{20} > 0 \end{cases},$$

$$me_{21} = 0.5 + (me_{20} + me_{19}) \cdot 2^{cb_{10}},$$

$$ie_{21} = \max(\mathrm{fe}(|ir_{19}| + me_{19} \cdot \mathrm{ULP}(ir_{19})), \mathrm{fe}(|fltInK\_1FW| + 0.5 \cdot \mathrm{ULP}(fltInK\_1FW))),$$

$$ir_{22} = ir_{19} + fltInK\_1FW,$$

$$ie_{22} = \mathrm{fe}(ir_{22}),$$

$$cb_{11} = \begin{cases} 0, & ie_{21} - ie_{22} \le 0 \\ ie_{21} - ie_{22}, & ie_{21} - ie_{22} > 0 \end{cases},$$

$$me_{22} = 0.5 + (me_{19} + 0.5) \cdot 2^{cb_{11}},$$

$$ir_{23} = ir_{22} \cdot fltIntegGainFW,$$

$$me_{23} = 2 \cdot me_{22},$$

$$ie_{23} = \max(\mathrm{fe}(|fltIntegPartK\_1FW| + 0.5 \cdot \mathrm{ULP}(fltIntegPartK\_1FW)), \mathrm{fe}(|ir_{23}| + me_{23} \cdot \mathrm{ULP}(ir_{23}))),$$

$$ir_{24} = fltIntegPartK\_1FW + ir_{23},$$

$$ie_{24} = \mathrm{fe}(ir_{24}),$$

$$cb_{12} = \begin{cases} 0, & ie_{23} - ie_{24} \le 0 \\ ie_{23} - ie_{24}, & ie_{23} - ie_{24} > 0 \end{cases},$$

$$me_{24} = 0.5 + (me_{23} + 0.5) \cdot 2^{cb_{12}},$$

$$me_{25} = \begin{cases} 0, & ir_{24} - me_{24} \cdot \mathrm{ULP}(ir_{24}) > fltUpperLimitFW \\ 0, & ir_{24} + me_{24} \cdot \mathrm{ULP}(ir_{24}) < fltLowerLimitFW \\ me_{24} & otherwise \end{cases},$$

$$ir_{25} = \begin{cases} fltUpperLimitFW, & ir_{24} > fltUpperLimitFW \\ fltLowerLimitFW, & ir_{24} < fltLowerLimitFW \\ ir_{24} & otherwise \end{cases},$$

$$ir_{26} = ir_{19} \cdot fltPropGainFW,$$

$$me_{26} = 2 \cdot me_{19},$$

$$ie_{25} = \max(\mathrm{fe}(|ir_{25}| + me_{25} \cdot \mathrm{ULP}(ir_{25})), \mathrm{fe}(|ir_{26}| + me_{26} \cdot \mathrm{ULP}(ir_{26}))),$$

$$ir_{27} = ir_{25} + ir_{26},$$

$$ie_{26} = \mathrm{fe}(ir_{27}),$$

$$cb_{13} = \begin{cases} 0, & ie_{25} - ie_{26} \le 0 \\ ie_{25} - ie_{26}, & ie_{25} - ie_{26} > 0 \end{cases},$$

$$me_{27} = 0.5 + (me_{25} + me_{26}) \cdot 2^{cb_{13}},$$

$$me_{28} = \begin{cases} 0, & ir_{27} - me_{27} \cdot \mathrm{ULP}(ir_{24}) > fltUpperLimitFW \\ 0, & ir_{27} + me_{27} \cdot \mathrm{ULP}(ir_{24}) < fltLowerLimitFW \\ me_{27} & otherwise \end{cases},$$

$$ir_{28} = \begin{cases} fltUpperLimitFW, & ir_{27} > fltUpperLimitFW \\ fltLowerLimitFW, & ir_{27} < fltLowerLimitFW \\ ir_{27} & otherwise \end{cases},$$

$$ie_{27} = \max(\mathrm{fe}(|ir_{28}| + me_{28} \cdot \mathrm{ULP}(ir_{28})), \mathrm{fe}(\tfrac{\pi}{2} + 0.5 \cdot \mathrm{ULP}(\tfrac{\pi}{2}))),$$

$$ir_{29} = \tfrac{\pi}{2} - ir_{28},$$

$$ie_{28} = \mathrm{fe}(ir_{29}),$$

$$cb_{14} = \begin{cases} 0, & ie_{27} - ie_{28} \le 0 \\ ie_{27} - ie_{28}, & ie_{27} - ie_{28} > 0 \end{cases},$$

$$me_{29} = 0.5 + (me_{28} + 0.5) \cdot 2^{cb_{14}},$$

$$ir_{30} = \sin(ir_{29}),$$

$$me_{30} = 42 + 8 \cdot me_{29},$$

$$ir_{31} = \cos(ir_{29}),$$

$$me_{31} = 42 + 8 \cdot me_{29},$$

$$ir_{32} = ir_{31} \cdot \mathrm{abs}(fltIDQReqAmp),$$

$$me_{32} = 0.5 + 2 \cdot me_{31},$$

$$ir_{33} = ir_{30} \cdot fltIDQReqAmp,$$

$$me_{33} = 0.5 + 2 \cdot me_{30},$$

then

Table 22. AMCLIB_FW_FLT Worst-Case Error Bounds - pPIpAWFW.fltInK_1 output

Subset of input domain	Worst-case error bounds for pPIpAWFW.fltInK_1 output [ulp]	Allowed specific values (regardless the error bounds) for pPIpAWFW.fltInK_1 output
Any of the inputs is denormalized, NaN, or infinity, i.e. $\{X \mid X \cap D \neq \emptyset \vee X \cap M \neq \emptyset\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values beyond the allowed range, i.e. $\left\{X \mid X \subset N \cup \{-0, +0\} \wedge \left(\begin{array}{c} fltLowerLimitFW < -\frac{\pi}{2} \vee \\ fltUpperLimitFW > 0 \vee \\ fltLowerLimitFW > fltUpperLimitFW \vee \\ pUQLim < 0 \vee \\ ir_{29} \notin \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle \end{array}\right)\right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Subset of input domain	Worst-case error bounds for pPIpAWFW.fltInK_1 output [ulp]	Allowed specific values (regardless the error bounds) for pPIpAWFW.fltInK_1 output
Normalized or zero input values which lead to normalized or zero results, i.e. $$\left\{\begin{matrix} X \mid X \subset N \cup \{-0, +0\} \wedge \\ ir \in (N \cup \{-0, +0\})^{33} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle \end{matrix}\right\}$$	$\langle -me_{19}, me_{19} \rangle$	N/A
Normalized or zero input values which cause an underflow, i.e. $$\left\{\begin{matrix} X \mid X \subset N \cup \{-0, +0\} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle, \\ \exists n : ir_n \neq \varnothing \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \end{matrix}\right\}$$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which cause an overflow, i.e. $$\left\{\begin{matrix} X \mid X \subset N \cup \{-0, +0\} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle, \\ \exists n : ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \end{matrix}\right\}$$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Table 23. AMCLIB_FW_FLT Worst-Case Error Bounds - pFilterFW.fltAcc output

Subset of input domain	Worst-case error bounds for pFilterFW.fltAcc output [ulp]	Allowed specific values (regardless the error bounds) for pFilterFW.fltAcc output
Any of the inputs is denormalized, NaN, or infinity, i.e. $\{X \mid X \cap D \neq \varnothing \vee X \cap M \neq \varnothing\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Subset of input domain	Worst-case error bounds for pFilterFW.fltAcc output [ulp]	Allowed specific values (regardless the error bounds) for pFilterFW.fltAcc output
Normalized or zero input values beyond the allowed range, i.e. $$\left\{ X \;\middle|\; \begin{array}{c} X \subset N \cup \{-0, +0\} \wedge \\ \left(\begin{array}{c} fltLowerLimitFW < -\frac{\pi}{2} \vee \\ fltUpperLimitFW > 0 \vee \\ fltLowerLimitFW > fltUpperLimitFW \vee \\ pUQLim < 0 \vee \\ ir_{29} \notin \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle \end{array} \right) \end{array} \right\}$$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $$\left\{ X \;\middle|\; \begin{array}{c} X \subset N \cup \{-0, +0\} \wedge \\ ir \in (N \cup \{-0, +0\})^{33} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle \end{array} \right\}$$	$\langle -me_{21}, me_{21} \rangle$	N/A
Normalized or zero input values which cause an underflow, i.e. $$\left\{ X \;\middle|\; \begin{array}{c} X \subset N \cup \{-0, +0\} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle, \\ \exists n : ir_n \neq \varnothing \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \end{array} \right\}$$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which cause an overflow, i.e. $$\left\{ X \;\middle|\; \begin{array}{c} X \subset N \cup \{-0, +0\} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle, \\ \exists n : ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \end{array} \right\}$$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Table 24. AMCLIB_FW_FLT Worst-Case Error Bounds - pPIpAWFW.fltIntegPartK_1 output

Subset of input domain	Worst-case error bounds for pPIpAWFW.fltIntegPartK_1 output [ulp]	Allowed specific values (regardless the error bounds) for pPIpAWFW.fltIntegPartK_1 output
Any of the inputs is denormalized, NaN, or infinity, i.e. $\{X \mid X \cap D \neq \emptyset \vee X \cap M \neq \emptyset\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values beyond the allowed range, i.e. $\left\{ X \mid X \subset N \cup \{-0, +0\} \wedge \left(\begin{array}{c} fltLowerLimitFW < -\frac{\pi}{2} \vee \\ fltUpperLimitFW > 0 \vee \\ fltLowerLimitFW > fltUpperLimitFW \vee \\ pUQLim < 0 \vee \\ ir_{29} \notin \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle \end{array} \right) \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{ \begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \\ ir \in (N \cup \{-0, +0\})^{33} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle \end{array} \right\}$	$\langle -me_{25}, me_{25} \rangle$	N/A
Normalized or zero input values which cause an underflow, i.e. $\left\{ \begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle, \\ \exists n : ir_n \neq \emptyset \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \end{array} \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Subset of input domain	Worst-case error bounds for pPIpAWFW.fltIntegPartK_1 output [ulp]	Allowed specific values (regardless the error bounds) for pPIpAWFW.fltIntegPartK_1 output
Normalized or zero input values which cause an overflow, i.e. $\left\{\begin{matrix} X \mid X \subset N \cup \{-0, +0\} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle, \\ \exists n: ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \end{matrix}\right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Table 25. AMCLIB_FW_FLT Worst-Case Error Bounds - pIDQReq.fltArg1 output

Subset of input domain	Worst-case error bounds for pIDQReq.fltArg1 output [ulp]	Allowed specific values (regardless the error bounds) for pIDQReq.fltArg1 output
Any of the inputs is denormalized, NaN, or infinity, i.e. $\{X \mid X \cap D \neq \emptyset \vee X \cap M \neq \emptyset\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values beyond the allowed range, i.e. $\left\{\begin{matrix} X \mid X \subset N \cup \{-0, +0\} \wedge \\ \left(\begin{matrix} fltLowerLimitFW < -\frac{\pi}{2} \vee \\ fltUpperLimitFW > 0 \vee \\ fltLowerLimitFW > fltUpperLimitFW \vee \\ pUQLim < 0 \vee \\ ir_{29} \notin \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle \end{matrix}\right) \end{matrix}\right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{\begin{matrix} X \mid X \subset N \cup \{-0, +0\} \wedge \\ ir \in (N \cup \{-0, +0\})^{33} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle \end{matrix}\right\}$	$\langle -me_{32}, me_{32} \rangle$	N/A

Subset of input domain	Worst-case error bounds for pIDQReq.fltArg1 output [ulp]	Allowed specific values (regardless the error bounds) for pIDQReq.fltArg1 output
Normalized or zero input values which cause an underflow, i.e. $\left\{\begin{matrix} X \mid X \subset N \cup \{-0, +0\} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle, \\ \exists n: ir_n \neq \varnothing \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \end{matrix}\right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which cause an overflow, i.e. $\left\{\begin{matrix} X \mid X \subset N \cup \{-0, +0\} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle, \\ \exists n: ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \end{matrix}\right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Table 26. AMCLIB_FW_FLT Worst-Case Error Bounds - pIDQReq.fltArg2 output

Subset of input domain	Worst-case error bounds for pIDQReq.fltArg2 output [ulp]	Allowed specific values (regardless the error bounds) for pIDQReq.fltArg2 output
Any of the inputs is denormalized, NaN, or infinity, i.e. $\{X \mid X \cap D \neq \varnothing \vee X \cap M \neq \varnothing\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values beyond the allowed range, i.e. $\left\{\begin{matrix} X \mid X \subset N \cup \{-0, +0\} \wedge \\ \left(\begin{matrix} fltLowerLimitFW < -\frac{\pi}{2} \vee \\ fltUpperLimitFW > 0 \vee \\ fltLowerLimitFW > fltUpperLimitFW \vee \\ pUQLim < 0 \vee \\ ir_{29} \notin \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle \end{matrix}\right) \end{matrix}\right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Subset of input domain	Worst-case error bounds for pIDQReq.fltArg2 output [ulp]	Allowed specific values (regardless the error bounds) for pIDQReq.fltArg2 output
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{ \begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \\ ir \in (N \cup \{-0, +0\})^{33} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle \end{array} \right\}$	$\langle -me_{33}, me_{33} \rangle$	N/A
Normalized or zero input values which cause an underflow, i.e. $\left\{ \begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle, \\ \exists n : ir_n \neq \varnothing \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \end{array} \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which cause an overflow, i.e. $\left\{ \begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle, \\ \exists n : ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \end{array} \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

2.4 Function AMCLIB_FWSpeedLoop_FLT

Declaration

```
void AMCLIB_FWSpeedLoop_FLT(tFloat fltVelocityReq,
tFloat fltVelocityFbck, SWLIBS_2Syst_FLT *const pIDQReq,
AMCLIB_FW_SPEED_LOOP_T_FLT *pCtrl);
```

Arguments

Table 27. AMCLIB_FWSpeedLoop_FLT arguments

Type	Name	Direction	Description
tFloat	fltVelocityReq	**input**	Required electrical angular velocity (setpoint).

Type	Name	Direction	Description
tFloat	fltVelocityFbck	**input**	Actual electrical angular velocity from the feedback.
SWLIBS_2Syst_FLT *const	pIDQReq	**input, output**	Pointer to the structure with the required stator currents in the two-phase rotational orthogonal system (d-q).
AMCLIB_FW_SPEED_LOOP_T_FLT *	pCtrl	**input, output**	Pointer to the structure with AMCLIB_FWSpeedLoop state.

Worst-Case Error Bounds

Let (*fltVelocityReq, fltVelocityFbck, fltState, pIQFbck, pIQreqK_1, pUQReq, pUQLim, fltUmaxDivImax, fltIntegPartK_1Q, fltInK_1Q, fltIntegPartK_1FW, fltInK_1FW, fltAccW, fltAccFW, fltRampUp, fltRampDown, fltLambdaW, fltLambdaFW, fltPropGainQ, fltIntegGainQ, fltLowerLimitQ, fltUpperLimitQ, fltPropGainFW, fltIntegGainFW, fltLowerLimitFW, fltUpperLimitFW*) ∊ *X* be a set of inputs to AMCLIB_FWSpeedLoop_FLT,

fltIntegPartK_1Q, fltInK_1Q, fltIntegPartK_1FW, fltInK_1FW, fltAccQ, fltAccFW inputs represent real numbers with an error of max. ±0.5 ulp,

$ie_1 = |fltState| + 0.5 \cdot \mathrm{ULP}(fltState)$,

$ir_1 = \max(fltState - fltRampUp, \min(fltState + fltRampUp, fltVelocityReq))$,

$ie_2 = \mathrm{fe}(ir_1)$,

$$cb_1 = \begin{cases} 0, & ie_1 - ie_2 \le 0 \\ ie_1 - ie_2, & ie_1 - ie_2 > 0 \end{cases},$$

$me_1 = 1 + 0.5 \cdot 2^{cb_1}$,

$ir_2 = fltLambdaW \cdot fltVelocityFbck$,

$me_2 = 1$,

$ie_3 = \max(\mathrm{fe}(|ir_2| + me_2 \cdot \mathrm{ULP}(ir_2)), \mathrm{fe}(|fltAccW| + 0.5 \cdot \mathrm{ULP}(fltAccW)))$,

$ir_3 = ir_2 + fltAccW$,

$ie_4 = \mathrm{fe}(ir_3)$,

$$cb_2 = \begin{cases} 0, & ie_3 - ie_4 \le 0 \\ ie_3 - ie_4, & ie_3 - ie_4 > 0 \end{cases},$$

$me_3 = 0.5 + (me_2 + 0.5) \cdot 2^{cb_2}$,

$ir_4 = fltLambdaW \cdot ir_3$,

$me_4 = 2 \cdot me_3$,

$ie_5 = \max(\mathrm{fe}(|ir_4| + me_4 \cdot \mathrm{ULP}(ir_4)), \mathrm{fe}(|ir_3| + me_3 \cdot \mathrm{ULP}(ir_3)))$,

$ir_5 = ir_3 - ir_4$,

$ie_6 = \mathrm{fe}(ir_5)$,

$$cb_3 = \begin{cases} 0, & ie_5 - ie_6 \le 0 \\ ie_5 - ie_6, & ie_5 - ie_6 > 0 \end{cases},$$

$me_5 = 0.5 + (me_4 + me_3) \cdot 2^{cb_3}$,

$ie_7 = \max(\mathrm{fe}(|ir_3| + me_3 \cdot \mathrm{ULP}(ir_3)), \mathrm{fe}(|ir_1| + me_1 \cdot \mathrm{ULP}(ir_1)))$,

$ir_6 = ir_1 - ir_3$,

$ie_8 = \mathrm{fe}(ir_6)$,

$$cb_4 = \begin{cases} 0, & ie_7 - ie_8 \le 0 \\ ie_7 - ie_8, & ie_7 - ie_8 > 0 \end{cases},$$

$me_6 = 0.5 + (me_3 + me_1) \cdot 2^{cb_4}$,

$ie_9 = \max(\mathrm{fe}(|ir_6| + me_6 \cdot \mathrm{ULP}(ir_6)), \mathrm{fe}(|fltInK\_1Q| + 0.5 \cdot \mathrm{ULP}(fltInK\_1Q)))$,

$ir_7 = ir_6 + fltInK\_1Q$,

$ie_{10} = \mathrm{fe}(ir_7)$,

$$cb_5 = \begin{cases} 0, & ie_9 - ie_{10} \le 0 \\ ie_9 - ie_{10}, & ie_9 - ie_{10} > 0 \end{cases},$$

$me_7 = 0.5 + (me_6 + 0.5) \cdot 2^{cb_5}$,

$ir_8 = ir_7 \cdot fltIntegGainQ$,

$me_8 = 2 \cdot me_7$,

$ie_{11} = \max(\mathrm{fe}(|fltIntegPartK\_1Q| + 0.5 \cdot \mathrm{ULP}(fltIntegPartK\_1Q)), \mathrm{fe}(|ir_8| + me_8 \cdot \mathrm{ULP}(ir_8)))$,

$ir_9 = fltIntegPartK\_1Q + ir_8$,

$ie_{12} = \mathrm{fe}(ir_9)$,

$$cb_6 = \begin{cases} 0, & ie_{11} - ie_{12} \le 0 \\ ie_{11} - ie_{12}, & ie_{11} - ie_{12} > 0 \end{cases},$$

$me_9 = 0.5 + (0.5 + me_8) \cdot 2^{cb_6}$,

$$me_{10} = \begin{cases} 0, & ir_9 - me_9 \cdot \mathrm{ULP}(ir_9) > fltUpperLimitQ \\ 0, & ir_9 + me_9 \cdot \mathrm{ULP}(ir_9) < fltLowerLimitQ \\ me_9 & otherwise \end{cases},$$

$$ir_{10} = \begin{cases} fltUpperLimitQ, & ir_9 > fltUpperLimitQ \\ fltLowerLimitQ, & ir_9 < fltLowerLimitQ \\ ir_9 & otherwise \end{cases},$$

$ir_{11} = ir_6 \cdot fltPropGainQ$,

$me_{11} = 2 \cdot me_6$,

$ie_{13} = \max(\mathrm{fe}(|ir_{10}| + me_{10} \cdot \mathrm{ULP}(ir_{10})), \mathrm{fe}(|ir_{11}| + me_{11} \cdot \mathrm{ULP}(ir_{11})))$,

$ir_{12} = ir_{10} + ir_{11}$,

$ie_{14} = \mathrm{fe}(ir_{12})$,

$$cb_7 = \begin{cases} 0, & ie_{13} - ie_{14} \le 0 \\ ie_{13} - ie_{14}, & ie_{13} - ie_{14} > 0 \end{cases},$$

$$me_{12} = 0.5 + (me_{10} + me_{11}) \cdot 2^{cb_7},$$

$$me_{13} = \begin{cases} 0, & ir_{12} - me_{12} \cdot \mathrm{ULP}(ir_{12}) > fltUpperLimitQ \\ 0, & ir_{12} + me_{12} \cdot \mathrm{ULP}(ir_{12}) < fltLowerLimitQ \\ me_{12} & otherwise \end{cases},$$

$$ir_{13} = \begin{cases} fltUpperLimitQ, & ir_{12} > fltUpperLimitQ \\ fltLowerLimitQ, & ir_{12} < fltLowerLimitQ \\ ir_{12} & otherwise \end{cases},$$

$$ir_{14} = (pIQreqK\_1 - pIQFbck) \cdot \mathrm{sign}(fltVelocityFbck),$$

$$me_{14} = 0.5,$$

$$ir_{15} = pUQLim - \mathrm{abs}(pUQReq),$$

$$me_{15} = 0.5,$$

$$ir_{16} = fltUmaxDivImax \cdot ir_{14},$$

$$me_{16} = 2 \cdot me_{14},$$

$$ie_{15} = \max(\mathrm{fe}(|ir_{16}| + me_{16} \cdot \mathrm{ULP}(ir_{16})), \mathrm{fe}(|ir_{15}| + me_{15} \cdot \mathrm{ULP}(ir_{15}))),$$

$$ir_{17} = ir_{15} - ir_{16},$$

$$ie_{16} = \mathrm{fe}(ir_{17}),$$

$$cb_8 = \begin{cases} 0, & ie_{15} - ie_{16} \le 0 \\ ie_{15} - ie_{16}, & ie_{15} - ie_{16} > 0 \end{cases},$$

$$me_{17} = 0.5 + (me_{16} + me_{15}) \cdot 2^{cb_8},$$

$$ir_{18} = fltLambdaFW \cdot ir_{17},$$

$$me_{18} = me_{17},$$

$$ie_{17} = \max(\mathrm{fe}(|ir_{18}| + me_{18} \cdot \mathrm{ULP}(ir_{18})), \mathrm{fe}(|fltAccFW| + 0.5 \cdot \mathrm{ULP}(fltAccFW))),$$

$$ir_{19} = ir_{18} + fltAccFW,$$

$$ie_{18} = \mathrm{fe}(ir_{19}),$$

$$cb_9 = \begin{cases} 0, & ie_{17} - ie_{18} \le 0 \\ ie_{17} - ie_{18}, & ie_{17} - ie_{18} > 0 \end{cases},$$

$$me_{19} = 0.5 + (me_{18} + 0.5) \cdot 2^{cb_9},$$

$$ir_{20} = fltLambdaFW \cdot ir_{19},$$

$$me_{20} = 2 \cdot me_{19},$$

$$ie_{19} = \max(\mathrm{fe}(|ir_{20}| + me_{20} \cdot \mathrm{ULP}(ir_{20})), \mathrm{fe}(|ir_{19}| + me_{19} \cdot \mathrm{ULP}(ir_{19}))),$$

$$ir_{21} = ir_{19} - ir_{20},$$

$$ie_{20} = \mathrm{fe}(ir_{21}),$$

$$cb_{10} = \begin{cases} 0, & ie_{19} - ie_{20} \le 0 \\ ie_{19} - ie_{20}, & ie_{19} - ie_{20} > 0 \end{cases},$$

$$me_{21} = 0.5 + (me_{20} + me_{19}) \cdot 2^{cb_{10}},$$

$$ie_{21} = \max(\mathrm{fe}(|ir_{19}| + me_{19} \cdot \mathrm{ULP}(ir_{19})), \mathrm{fe}(|fltInK\_1FW| + 0.5 \cdot \mathrm{ULP}(fltInK\_1FW))),$$

$$ir_{22} = ir_{19} + fltInK\_1FW,$$

$$ie_{22} = \mathrm{fe}(ir_{22}),$$

$$cb_{11} = \begin{cases} 0, & ie_{21} - ie_{22} \le 0 \\ ie_{21} - ie_{22}, & ie_{21} - ie_{22} > 0 \end{cases},$$

$$me_{22} = 0.5 + (me_{19} + 0.5) \cdot 2^{cb_{11}},$$

$$ir_{23} = ir_{22} \cdot fltIntegGainFW,$$

$$me_{23} = 2 \cdot me_{22},$$

$$ie_{23} = \max(\mathrm{fe}(|fltIntegPartK\_1FW| + 0.5 \cdot \mathrm{ULP}(fltIntegPartK\_1FW)), \mathrm{fe}(|ir_{23}| + me_{23} \cdot \mathrm{ULP}(ir_{23}))),$$

$$ir_{24} = fltIntegPartK\_1FW + ir_{23},$$

$$ie_{24} = \mathrm{fe}(ir_{24}),$$

$$cb_{12} = \begin{cases} 0, & ie_{23} - ie_{24} \le 0 \\ ie_{23} - ie_{24}, & ie_{23} - ie_{24} > 0 \end{cases},$$

$$me_{24} = 0.5 + (me_{23} + 0.5) \cdot 2^{cb_{12}},$$

$$me_{25} = \begin{cases} 0, & ir_{24} - me_{24} \cdot \mathrm{ULP}(ir_{24}) > fltUpperLimitFW \\ 0, & ir_{24} + me_{24} \cdot \mathrm{ULP}(ir_{24}) < fltLowerLimitFW \\ me_{24} & otherwise \end{cases},$$

$$ir_{25} = \begin{cases} fltUpperLimitFW, & ir_{24} > fltUpperLimitFW \\ fltLowerLimitFW, & ir_{24} < fltLowerLimitFW \\ ir_{24} & otherwise \end{cases},$$

$$ir_{26} = ir_{19} \cdot fltPropGainFW,$$

$$me_{26} = 2 \cdot me_{19},$$

$$ie_{25} = \max(\mathrm{fe}(|ir_{25}| + me_{25} \cdot \mathrm{ULP}(ir_{25})), \mathrm{fe}(|ir_{26}| + me_{26} \cdot \mathrm{ULP}(ir_{26}))),$$

$$ir_{27} = ir_{25} + ir_{26},$$

$$ie_{26} = \mathrm{fe}(ir_{27}),$$

$$cb_{13} = \begin{cases} 0, & ie_{25} - ie_{26} \le 0 \\ ie_{25} - ie_{26}, & ie_{25} - ie_{26} > 0 \end{cases},$$

$$me_{27} = 0.5 + (me_{25} + me_{26}) \cdot 2^{cb_{13}},$$

$$me_{28} = \begin{cases} 0, & ir_{27} - me_{27} \cdot \mathrm{ULP}(ir_{24}) > fltUpperLimitFW \\ 0, & ir_{27} + me_{27} \cdot \mathrm{ULP}(ir_{24}) < fltLowerLimitFW \\ me_{27} & otherwise \end{cases},$$

$$ir_{28} = \begin{cases} fltUpperLimitFW, & ir_{27} > fltUpperLimitFW \\ fltLowerLimitFW, & ir_{27} < fltLowerLimitFW \\ ir_{27} & otherwise \end{cases},$$

$$ie_{27} = \max\left(\mathrm{fe}\left(|ir_{28}| + me_{28} \cdot \mathrm{ULP}(ir_{28})\right), \mathrm{fe}\left(\tfrac{\pi}{2} + 0.5 \cdot \mathrm{ULP}\left(\tfrac{\pi}{2}\right)\right)\right),$$

$$ir_{29} = \tfrac{\pi}{2} - ir_{28},$$

$$ie_{28} = \mathrm{fe}(ir_{29}),$$

$$cb_{14} = \begin{cases} 0, & ie_{27} - ie_{28} \leq 0 \\ ie_{27} - ie_{28}, & ie_{27} - ie_{28} > 0 \end{cases},$$

$$me_{29} = 0.5 + (me_{28} + 0.5) \cdot 2^{cb_{14}},$$

$$ir_{30} = \sin(ir_{29}),$$

$$me_{30} = 42 + 8 \cdot me_{29},$$

$$ir_{31} = \cos(ir_{29}),$$

$$me_{31} = 42 + 8 \cdot me_{29},$$

$$ir_{32} = ir_{31} \cdot \mathrm{abs}(ir_{13}),$$

$$me_{32} = 0.5 + 2 \cdot me_{31} + 2 \cdot me_{13},$$

$$ir_{33} = ir_{30} \cdot ir_{13},$$

$$me_{33} = 0.5 + 2 \cdot me_{30} + 2 \cdot me_{13},$$

then

Table 28. AMCLIB_FWSpeedLoop_FLT Worst-Case Error Bounds - pRamp.fltState output

Subset of input domain	Worst-case error bounds for pRamp.fltState output [ulp]	Allowed specific values (regardless the error bounds) for pRamp.fltState output
Any of the inputs is denormalized, NaN, or infinity, i.e. $\{X \mid X \cap D \neq \varnothing \vee X \cap M \neq \varnothing\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values beyond the allowed range, i.e. $\left\{ X \mid X \subset N \cup \{-0, +0\} \wedge \left(\begin{array}{c} fltLowerLimitFW < -\frac{\pi}{2} \vee \\ fltUpperLimitFW > 0 \vee \\ fltLowerLimitFW > fltUpperLimitFW \vee \\ fltLowerLimitQ > fltUpperLimitQ \vee \\ fltRampUp < 0 \vee \\ fltRampDown < 0 \vee \\ pUQLim < 0 \vee \\ ir_{29} \notin \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle \end{array} \right) \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Subset of input domain	Worst-case error bounds for pRamp.fltState output [ulp]	Allowed specific values (regardless the error bounds) for pRamp.fltState output
Normalized or zero input values which lead to normalized or zero results, i.e. $$\left\{\begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \\ ir \in (N \cup \{-0, +0\})^{33} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ fltLowerLimitQ \leq fltUpperLimitQ \wedge \\ fltRampUp \geq 0 \wedge \\ fltRampDown \geq 0 \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle \end{array}\right\}$$	$\langle -me_1, me_1 \rangle$	N/A
Normalized or zero input values which cause an underflow, i.e. $$\left\{\begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ fltLowerLimitQ \leq fltUpperLimitQ \wedge \\ fltRampUp \geq 0 \wedge \\ fltRampDown \geq 0 \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle, \\ \exists n : ir_n \neq \varnothing \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \end{array}\right\}$$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which cause an overflow, i.e. $$\left\{\begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ fltLowerLimitQ \leq fltUpperLimitQ \wedge \\ fltRampUp \geq 0 \wedge \\ fltRampDown \geq 0 \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle, \\ \exists n : ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \end{array}\right\}$$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Table 29. AMCLIB_FWSpeedLoop_FLT Worst-Case Error Bounds - pFilterW.fltAcc output

Subset of input domain	Worst-case error bounds for pFilterW.fltAcc output [ulp]	Allowed specific values (regardless the error bounds) for pFilterW.fltAcc output
Any of the inputs is denormalized, NaN, or infinity, i.e. $\{X \mid X \cap D \neq \varnothing \vee X \cap M \neq \varnothing\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values beyond the allowed range, i.e. $\left\{ X \,\middle|\, X \subset N \cup \{-0, +0\} \wedge \left(\begin{array}{c} fltLowerLimitFW < -\frac{\pi}{2} \vee \\ fltUpperLimitFW > 0 \vee \\ fltLowerLimitFW > fltUpperLimitFW \vee \\ fltLowerLimitQ > fltUpperLimitQ \vee \\ fltRampUp < 0 \vee \\ fltRampDown < 0 \vee \\ pUQLim < 0 \vee \\ ir_{29} \notin \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle \end{array} \right) \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{ \begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \\ ir \in (N \cup \{-0, +0\})^{33} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ fltLowerLimitQ \leq fltUpperLimitQ \wedge \\ fltRampUp \geq 0 \wedge \\ fltRampDown \geq 0 \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle \end{array} \right\}$	$\langle -me_5, me_5 \rangle$	N/A
Normalized or zero input values which cause an underflow, i.e. $\left\{ \begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ fltLowerLimitQ \leq fltUpperLimitQ \wedge \\ fltRampUp \geq 0 \wedge \\ fltRampDown \geq 0 \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle, \\ \exists n: ir_n \neq \varnothing \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \end{array} \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Subset of input domain	Worst-case error bounds for pFilterW.fltAcc output [ulp]	Allowed specific values (regardless the error bounds) for pFilterW.fltAcc output
Normalized or zero input values which cause an overflow, i.e. $$\left\{\begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ fltLowerLimitQ \leq fltUpperLimitQ \wedge \\ fltRampUp \geq 0 \wedge \\ fltRampDown \geq 0 \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle, \\ \exists n: ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \end{array}\right\}$$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Table 30. AMCLIB_FWSpeedLoop_FLT Worst-Case Error Bounds - pPIpAWQ.fltInK_1 output

Subset of input domain	Worst-case error bounds for pPIpAWQ.fltInK_1 output [ulp]	Allowed specific values (regardless the error bounds) for pPIpAWQ.fltInK_1 output
Any of the inputs is denormalized, NaN, or infinity, i.e. $$\{X \mid X \cap D \neq \varnothing \vee X \cap M \neq \varnothing\}$$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values beyond the allowed range, i.e. $$\left\{\begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \\ \left(\begin{array}{c} fltLowerLimitFW < -\frac{\pi}{2} \vee \\ fltUpperLimitFW > 0 \vee \\ fltLowerLimitFW > fltUpperLimitFW \vee \\ fltLowerLimitQ > fltUpperLimitQ \vee \\ fltRampUp < 0 \vee \\ fltRampDown < 0 \vee \\ pUQLim < 0 \vee \\ ir_{29} \notin \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle \end{array}\right) \end{array}\right\}$$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Subset of input domain	Worst-case error bounds for pPIpAWQ.fltInK_1 output [ulp]	Allowed specific values (regardless the error bounds) for pPIpAWQ.fltInK_1 output
Normalized or zero input values which lead to normalized or zero results, i.e. $\left(\begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \\ ir \in (N \cup \{-0, +0\})^{33} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ fltLowerLimitQ \leq fltUpperLimitQ \wedge \\ fltRampUp \geq 0 \wedge \\ fltRampDown \geq 0 \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle \end{array} \right)$	$\langle -me_6, me_6 \rangle$	N/A
Normalized or zero input values which cause an underflow, i.e. $\left(\begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ fltLowerLimitQ \leq fltUpperLimitQ \wedge \\ fltRampUp \geq 0 \wedge \\ fltRampDown \geq 0 \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle, \\ \exists n: ir_n \neq \varnothing \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \end{array} \right)$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which cause an overflow, i.e. $\left(\begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ fltLowerLimitQ \leq fltUpperLimitQ \wedge \\ fltRampUp \geq 0 \wedge \\ fltRampDown \geq 0 \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle, \\ \exists n: ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \end{array} \right)$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Table 31. AMCLIB_FWSpeedLoop_FLT Worst-Case Error Bounds - pPIpAWQ.fltIntegPartK_1 output

Subset of input domain	Worst-case error bounds for pPIpAWQ.fltIntegPartK_1 output [ulp]	Allowed specific values (regardless the error bounds) for pPIpAWQ.fltIntegPartK_1 output
Any of the inputs is denormalized, NaN, or infinity, i.e. $\{X \mid X \cap D \neq \varnothing \lor X \cap M \neq \varnothing\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values beyond the allowed range, i.e. $\left\{ X \mid X \subset N \cup \{-0, +0\} \land \left(\begin{array}{c} fltLowerLimitFW < -\frac{\pi}{2} \lor \\ fltUpperLimitFW > 0 \lor \\ fltLowerLimitFW > fltUpperLimitFW \lor \\ fltLowerLimitQ > fltUpperLimitQ \lor \\ fltRampUp < 0 \lor \\ fltRampDown < 0 \lor \\ pUQLim < 0 \lor \\ ir_{29} \notin \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle \end{array} \right) \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{ \begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \land \\ ir \in (N \cup \{-0, +0\})^{33} \land \\ fltLowerLimitFW \geq -\frac{\pi}{2} \land \\ fltUpperLimitFW \leq 0 \land \\ fltLowerLimitFW \leq fltUpperLimitFW \land \\ fltLowerLimitQ \leq fltUpperLimitQ \land \\ fltRampUp \geq 0 \land \\ fltRampDown \geq 0 \land \\ pUQLim \geq 0 \land \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle \end{array} \right\}$	$\langle -me_{10}, me_{10} \rangle$	N/A

Subset of input domain	Worst-case error bounds for pPIpAWQ.fltIntegPartK_1 output [ulp]	Allowed specific values (regardless the error bounds) for pPIpAWQ.fltIntegPartK_1 output
Normalized or zero input values which cause an underflow, i.e. $\left\{\begin{matrix} X \mid X \subset N \cup \{-0, +0\} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ fltLowerLimitQ \leq fltUpperLimitQ \wedge \\ fltRampUp \geq 0 \wedge \\ fltRampDown \geq 0 \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle, \\ \exists n : ir_n \neq \varnothing \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \end{matrix}\right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which cause an overflow, i.e. $\left\{\begin{matrix} X \mid X \subset N \cup \{-0, +0\} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ fltLowerLimitQ \leq fltUpperLimitQ \wedge \\ fltRampUp \geq 0 \wedge \\ fltRampDown \geq 0 \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle, \\ \exists n : ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \end{matrix}\right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Table 32. AMCLIB_FWSpeedLoop_FLT Worst-Case Error Bounds - pPIpAWFW.fltInK_1 output

Subset of input domain	Worst-case error bounds for pPIpAWFW.fltInK_1 output [ulp]	Allowed specific values (regardless the error bounds) for pPIpAWFW.fltInK_1 output
Any of the inputs is denormalized, NaN, or infinity, i.e. $\{X \mid X \cap D \neq \varnothing \vee X \cap M \neq \varnothing\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Subset of input domain	**Worst-case error bounds for pPIpAWFW.fltInK_1 output [ulp]**	**Allowed specific values (regardless the error bounds) for pPIpAWFW.fltInK_1 output**
Normalized or zero input values beyond the allowed range, i.e. $$\left\{ X \,\middle|\, \begin{array}{c} X \subset N \cup \{-0, +0\} \wedge \\ \left(\begin{array}{c} fltLowerLimitFW < -\frac{\pi}{2} \vee \\ fltUpperLimitFW > 0 \vee \\ fltLowerLimitFW > fltUpperLimitFW \vee \\ fltLowerLimitQ > fltUpperLimitQ \vee \\ fltRampUp < 0 \vee \\ fltRampDown < 0 \vee \\ pUQLim < 0 \vee \\ ir_{29} \notin \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle \end{array} \right) \end{array} \right\}$$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $$\left\{ X \,\middle|\, \begin{array}{c} X \subset N \cup \{-0, +0\} \wedge \\ ir \in (N \cup \{-0, +0\})^{33} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ fltLowerLimitQ \leq fltUpperLimitQ \wedge \\ fltRampUp \geq 0 \wedge \\ fltRampDown \geq 0 \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle \end{array} \right\}$$	$\langle -me_{19}, me_{19} \rangle$	N/A
Normalized or zero input values which cause an underflow, i.e. $$\left\{ X \,\middle|\, \begin{array}{c} X \subset N \cup \{-0, +0\} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ fltLowerLimitQ \leq fltUpperLimitQ \wedge \\ fltRampUp \geq 0 \wedge \\ fltRampDown \geq 0 \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle, \\ \exists n : ir_n \neq \varnothing \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \end{array} \right\}$$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Subset of input domain	Worst-case error bounds for pPIpAWFW.fltInK_1 output [ulp]	Allowed specific values (regardless the error bounds) for pPIpAWFW.fltInK_1 output
Normalized or zero input values which cause an overflow, i.e. $$\left\{\begin{matrix} X \mid X \subset N \cup \{-0, +0\} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ fltLowerLimitQ \leq fltUpperLimitQ \wedge \\ fltRampUp \geq 0 \wedge \\ fltRampDown \geq 0 \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle, \\ \exists n: ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \end{matrix}\right\}$$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Table 33. AMCLIB_FWSpeedLoop_FLT Worst-Case Error Bounds - pFilterFW.fltAcc output

Subset of input domain	Worst-case error bounds for pFilterFW.fltAcc output [ulp]	Allowed specific values (regardless the error bounds) for pFilterFW.fltAcc output
Any of the inputs is denormalized, NaN, or infinity, i.e. $$\{X \mid X \cap D \neq \varnothing \vee X \cap M \neq \varnothing\}$$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values beyond the allowed range, i.e. $$\left\{\begin{matrix} X \mid X \subset N \cup \{-0, +0\} \wedge \\ \left(\begin{matrix} fltLowerLimitFW < -\frac{\pi}{2} \vee \\ fltUpperLimitFW > 0 \vee \\ fltLowerLimitFW > fltUpperLimitFW \vee \\ fltLowerLimitQ > fltUpperLimitQ \vee \\ fltRampUp < 0 \vee \\ fltRampDown < 0 \vee \\ pUQLim < 0 \vee \\ ir_{29} \notin \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle \end{matrix}\right) \end{matrix}\right\}$$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Subset of input domain	Worst-case error bounds for pFilterFW.fltAcc output [ulp]	Allowed specific values (regardless the error bounds) for pFilterFW.fltAcc output
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{\begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \\ ir \in (N \cup \{-0, +0\})^{33} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ fltLowerLimitQ \leq fltUpperLimitQ \wedge \\ fltRampUp \geq 0 \wedge \\ fltRampDown \geq 0 \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle \end{array}\right\}$	$\langle -me_{21}, me_{21} \rangle$	N/A
Normalized or zero input values which cause an underflow, i.e. $\left\{\begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ fltLowerLimitQ \leq fltUpperLimitQ \wedge \\ fltRampUp \geq 0 \wedge \\ fltRampDown \geq 0 \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle, \\ \exists n : ir_n \neq \varnothing \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \end{array}\right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which cause an overflow, i.e. $\left\{\begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ fltLowerLimitQ \leq fltUpperLimitQ \wedge \\ fltRampUp \geq 0 \wedge \\ fltRampDown \geq 0 \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle, \\ \exists n : ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \end{array}\right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Table 34. AMCLIB_FWSpeedLoop_FLT Worst-Case Error Bounds - pPIpAWFW.fltIntegPartK_1 output

Subset of input domain	Worst-case error bounds for pPIpAWFW.fltIntegPartK_1 output [ulp]	Allowed specific values (regardless the error bounds) for pPIpAWFW.fltIntegPartK_1 output
Any of the inputs is denormalized, NaN, or infinity, i.e. $\{X \mid X \cap D \neq \varnothing \lor X \cap M \neq \varnothing\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values beyond the allowed range, i.e. $\left\{ X \mid X \subset N \cup \{-0, +0\} \land \left(\begin{array}{c} fltLowerLimitFW < -\frac{\pi}{2} \lor \\ fltUpperLimitFW > 0 \lor \\ fltLowerLimitFW > fltUpperLimitFW \lor \\ fltLowerLimitQ > fltUpperLimitQ \lor \\ fltRampUp < 0 \lor \\ fltRampDown < 0 \lor \\ pUQLim < 0 \lor \\ ir_{29} \notin \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle \end{array} \right) \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{ \begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \land \\ ir \in (N \cup \{-0, +0\})^{33} \land \\ fltLowerLimitFW \geq -\frac{\pi}{2} \land \\ fltUpperLimitFW \leq 0 \land \\ fltLowerLimitFW \leq fltUpperLimitFW \land \\ fltLowerLimitQ \leq fltUpperLimitQ \land \\ fltRampUp \geq 0 \land \\ fltRampDown \geq 0 \land \\ pUQLim \geq 0 \land \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle \end{array} \right\}$	$\langle -me_{25}, me_{25} \rangle$	N/A

Subset of input domain	Worst-case error bounds for pPIpAWFW.fltIntegPartK_1 output [ulp]	Allowed specific values (regardless the error bounds) for pPIpAWFW.fltIntegPartK_1 output
Normalized or zero input values which cause an underflow, i.e. $$\left\{\begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ fltLowerLimitQ \leq fltUpperLimitQ \wedge \\ fltRampUp \geq 0 \wedge \\ fltRampDown \geq 0 \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle, \\ \exists n: ir_n \neq \varnothing \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \end{array}\right\}$$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which cause an overflow, i.e. $$\left\{\begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ fltLowerLimitQ \leq fltUpperLimitQ \wedge \\ fltRampUp \geq 0 \wedge \\ fltRampDown \geq 0 \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle, \\ \exists n: ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \end{array}\right\}$$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Table 35. AMCLIB_FWSpeedLoop_FLT Worst-Case Error Bounds - pIDQReq.fltArg1 output

Subset of input domain	Worst-case error bounds for pIDQReq.fltArg1 output [ulp]	Allowed specific values (regardless the error bounds) for pIDQReq.fltArg1 output
Any of the inputs is denormalized, NaN, or infinity, i.e. $\{X \mid X \cap D \neq \varnothing \vee X \cap M \neq \varnothing\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Subset of input domain	Worst-case error bounds for pIDQReq.fltArg1 output [ulp]	Allowed specific values (regardless the error bounds) for pIDQReq.fltArg1 output
Normalized or zero input values beyond the allowed range, i.e. $$\left\{ \begin{matrix} X \mid X \subset N \cup \{-0, +0\} \wedge \\ \left(\begin{matrix} fltLowerLimitFW < -\frac{\pi}{2} \vee \\ fltUpperLimitFW > 0 \vee \\ fltLowerLimitFW > fltUpperLimitFW \vee \\ fltLowerLimitQ > fltUpperLimitQ \vee \\ fltRampUp < 0 \vee \\ fltRampDown < 0 \vee \\ pUQLim < 0 \vee \\ ir_{29} \notin \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle \end{matrix} \right) \end{matrix} \right\}$$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $$\left\{ \begin{matrix} X \mid X \subset N \cup \{-0, +0\} \wedge \\ ir \in (N \cup \{-0, +0\})^{33} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ fltLowerLimitQ \leq fltUpperLimitQ \wedge \\ fltRampUp \geq 0 \wedge \\ fltRampDown \geq 0 \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle \end{matrix} \right\}$$	$\langle -me_{32}, me_{32} \rangle$	N/A
Normalized or zero input values which cause an underflow, i.e. $$\left\{ \begin{matrix} X \mid X \subset N \cup \{-0, +0\} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ fltLowerLimitQ \leq fltUpperLimitQ \wedge \\ fltRampUp \geq 0 \wedge \\ fltRampDown \geq 0 \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle, \\ \exists n : ir_n \neq \varnothing \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \end{matrix} \right\}$$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Subset of input domain	Worst-case error bounds for pIDQReq.fltArg1 output [ulp]	Allowed specific values (regardless the error bounds) for pIDQReq.fltArg1 output
Normalized or zero input values which cause an overflow, i.e. $\left\{ \begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ fltLowerLimitQ \leq fltUpperLimitQ \wedge \\ fltRampUp \geq 0 \wedge \\ fltRampDown \geq 0 \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle, \\ \exists n: ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \end{array} \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Table 36. AMCLIB_FWSpeedLoop_FLT Worst-Case Error Bounds - pIDQReq.fltArg2 output

Subset of input domain	Worst-case error bounds for pIDQReq.fltArg2 output [ulp]	Allowed specific values (regardless the error bounds) for pIDQReq.fltArg2 output
Any of the inputs is denormalized, NaN, or infinity, i.e. $\{X \mid X \cap D \neq \varnothing \vee X \cap M \neq \varnothing\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values beyond the allowed range, i.e. $\left\{ \begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \\ \left(\begin{array}{c} fltLowerLimitFW < -\frac{\pi}{2} \vee \\ fltUpperLimitFW > 0 \vee \\ fltLowerLimitFW > fltUpperLimitFW \vee \\ fltLowerLimitQ > fltUpperLimitQ \vee \\ fltRampUp < 0 \vee \\ fltRampDown < 0 \vee \\ pUQLim < 0 \vee \\ ir_{29} \notin \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle \end{array} \right) \end{array} \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Subset of input domain	Worst-case error bounds for pIDQReq.fltArg2 output [ulp]	Allowed specific values (regardless the error bounds) for pIDQReq.fltArg2 output
Normalized or zero input values which lead to normalized or zero results, i.e. $\left(\begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \\ ir \in (N \cup \{-0, +0\})^{33} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ fltLowerLimitQ \leq fltUpperLimitQ \wedge \\ fltRampUp \geq 0 \wedge \\ fltRampDown \geq 0 \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle \end{array} \right)$	$\langle -me_{33}, me_{33} \rangle$	N/A
Normalized or zero input values which cause an underflow, i.e. $\left(\begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ fltLowerLimitQ \leq fltUpperLimitQ \wedge \\ fltRampUp \geq 0 \wedge \\ fltRampDown \geq 0 \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle, \\ \exists n: ir_n \neq \varnothing \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \end{array} \right)$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which cause an overflow, i.e. $\left(\begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \\ fltLowerLimitFW \geq -\frac{\pi}{2} \wedge \\ fltUpperLimitFW \leq 0 \wedge \\ fltLowerLimitFW \leq fltUpperLimitFW \wedge \\ fltLowerLimitQ \leq fltUpperLimitQ \wedge \\ fltRampUp \geq 0 \wedge \\ fltRampDown \geq 0 \wedge \\ pUQLim \geq 0 \wedge \\ ir_{29} \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle, \\ \exists n: ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \end{array} \right)$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

2.5 Function AMCLIB_SpeedLoop_FLT

Declaration

```
void AMCLIB_SpeedLoop_FLT(tFloat fltVelocityReq, tFloat
fltVelocityFbck, SWLIBS_2Syst_FLT *const pIDQReq,
AMCLIB_SPEED_LOOP_T_FLT *pCtrl);
```

Arguments

Table 37. AMCLIB_SpeedLoop_FLT arguments

Type	Name	Direction	Description
tFloat	fltVelocityReq	**input**	Required electrical angular velocity (setpoint).
tFloat	fltVelocityFbck	**input**	Actual electrical angular velocity from the feedback.
SWLIBS_2Syst_FLT *const	pIDQReq	**output**	Pointer to the structure with the required stator currents in the two-phase rotational orthogonal system (d-q). Only the q-axis component is written by the function.
AMCLIB_SPEED_LOOP_T_FLT *	pCtrl	**input, output**	Pointer to the structure with AMCLIB_SpeedLoop state.

Worst-Case Error Bounds

Let (*fltVelocityReq, fltVelocityFbck, fltState, fltIntegPartK_1Q, fltInK_1Q, fltAccW, fltRampUp, fltRampDown, fltLambdaW, fltPropGainQ, fltIntegGainQ, fltLowerLimitQ, fltUpperLimitQ*) ∊ *X* be a set of inputs to AMCLIB_SpeedLoop_FLT,

fltIntegPartK_1Q, fltInK_1Q, fltAccQ inputs represent real numbers with an error of max. ±0.5 ulp,

$ie_1 = |fltState| + 0.5 \cdot \mathrm{ULP}(fltState)$,

$ir_1 = \max(fltState - fltRampUp, \min(fltState + fltRampUp, fltVelocityReq))$,

$ie_2 = \mathrm{fe}(ir_1)$,

$$cb_1 = \begin{cases} 0, & ie_1 - ie_2 \le 0 \\ ie_1 - ie_2, & ie_1 - ie_2 > 0 \end{cases},$$

$me_1 = 1 + 0.5 \cdot 2^{cb_1}$,

$ir_2 = fltLambdaW \cdot fltVelocityFbck$,

$me_2 = 1$,

$ie_3 = \max(\mathrm{fe}(|ir_2| + me_2 \cdot \mathrm{ULP}(ir_2)), \mathrm{fe}(|fltAccW| + 0.5 \cdot \mathrm{ULP}(fltAccW)))$,

$ir_3 = ir_2 + fltAccW$,

$ie_4 = \mathrm{fe}(ir_3)$,

$$cb_2 = \begin{cases} 0, & ie_3 - ie_4 \le 0 \\ ie_3 - ie_4, & ie_3 - ie_4 > 0 \end{cases},$$

$me_3 = 0.5 + (me_2 + 0.5) \cdot 2^{cb_2}$,

$ir_4 = fltLambdaW \cdot ir_3$,

$me_4 = 2 \cdot me_3$,

$ie_5 = \max(\mathrm{fe}(|ir_4| + me_4 \cdot \mathrm{ULP}(ir_4)), \mathrm{fe}(|ir_3| + me_3 \cdot \mathrm{ULP}(ir_3)))$,

$ir_5 = ir_3 - ir_4$,

$ie_6 = \mathrm{fe}(ir_5)$,

$$cb_3 = \begin{cases} 0, & ie_5 - ie_6 \le 0 \\ ie_5 - ie_6, & ie_5 - ie_6 > 0 \end{cases},$$

$me_5 = 0.5 + (me_4 + me_3) \cdot 2^{cb_3}$,

$ie_7 = \max(\mathrm{fe}(|ir_3| + me_3 \cdot \mathrm{ULP}(ir_3)), \mathrm{fe}(|ir_1| + me_1 \cdot \mathrm{ULP}(ir_1)))$,

$ir_6 = ir_1 - ir_3$,

$ie_8 = \mathrm{fe}(ir_6)$,

$$cb_4 = \begin{cases} 0, & ie_7 - ie_8 \le 0 \\ ie_7 - ie_8, & ie_7 - ie_8 > 0 \end{cases},$$

$me_6 = 0.5 + (me_3 + me_1) \cdot 2^{cb_4}$,

$ie_9 = \max(\mathrm{fe}(|ir_6| + me_6 \cdot \mathrm{ULP}(ir_6)), \mathrm{fe}(|fltInK\_1Q| + 0.5 \cdot \mathrm{ULP}(fltInK\_1Q)))$,

$ir_7 = ir_6 + fltInK\_1Q$,

$ie_{10} = \mathrm{fe}(ir_7)$,

$$cb_5 = \begin{cases} 0, & ie_9 - ie_{10} \le 0 \\ ie_9 - ie_{10}, & ie_9 - ie_{10} > 0 \end{cases},$$

$me_7 = 0.5 + (me_6 + 0.5) \cdot 2^{cb_5}$,

$ir_8 = ir_7 \cdot fltIntegGainQ$,

$me_8 = 2 \cdot me_7$,

$ie_{11} = \max(\mathrm{fe}(|fltIntegPartK\_1Q| + 0.5 \cdot \mathrm{ULP}(fltIntegPartK\_1Q)), \mathrm{fe}(|ir_8| + me_8 \cdot \mathrm{ULP}(ir_8)))$,

$ir_9 = fltIntegPartK\_1Q + ir_8$,

$ie_{12} = \mathrm{fe}(ir_9)$,

$$cb_6 = \begin{cases} 0, & ie_{11} - ie_{12} \le 0 \\ ie_{11} - ie_{12}, & ie_{11} - ie_{12} > 0 \end{cases},$$

$me_9 = 0.5 + (0.5 + me_8) \cdot 2^{cb_6}$,

$$me_{10} = \begin{cases} 0, & ir_9 - me_9 \cdot \mathrm{ULP}(ir_9) > fltUpperLimitQ \\ 0, & ir_9 + me_9 \cdot \mathrm{ULP}(ir_9) < fltLowerLimitQ \\ me_9 & otherwise \end{cases},$$

$$ir_{10} = \begin{cases} fltUpperLimitQ, & ir_9 > fltUpperLimitQ \\ fltLowerLimitQ, & ir_9 < fltLowerLimitQ \\ ir_9 & otherwise \end{cases},$$

$ir_{11} = ir_6 \cdot fltPropGainQ$,

$$me_{11} = 2 \cdot me_6,$$

$$ie_{13} = \max(\mathrm{fe}(|ir_{10}| + me_{10} \cdot \mathrm{ULP}(ir_{10})), \mathrm{fe}(|ir_{11}| + me_{11} \cdot \mathrm{ULP}(ir_{11}))),$$

$$ir_{12} = ir_{10} + ir_{11},$$

$$ie_{14} = \mathrm{fe}(ir_{12}),$$

$$cb_7 = \begin{cases} 0, & ie_{13} - ie_{14} \le 0 \\ ie_{13} - ie_{14}, & ie_{13} - ie_{14} > 0 \end{cases},$$

$$me_{12} = 0.5 + (me_{10} + me_{11}) \cdot 2^{cb_7},$$

$$me_{13} = \begin{cases} 0, & ir_{12} - me_{12} \cdot \mathrm{ULP}(ir_{12}) > fltUpperLimitQ \\ 0, & ir_{12} + me_{12} \cdot \mathrm{ULP}(ir_{12}) < fltLowerLimitQ \\ me_{12} & otherwise \end{cases},$$

$$ir_{13} = \begin{cases} fltUpperLimitQ, & ir_{12} > fltUpperLimitQ \\ fltLowerLimitQ, & ir_{12} < fltLowerLimitQ \\ ir_{12} & otherwise \end{cases},$$

then

Table 38. AMCLIB_SpeedLoop_FLT Worst-Case Error Bounds - pRamp.fltState output

Subset of input domain	Worst-case error bounds for pRamp.fltState output [ulp]	Allowed specific values (regardless the error bounds) for pRamp.fltState output
Any of the inputs is denormalized, NaN, or infinity, i.e. $\{X \mid X \cap D \neq \varnothing \vee X \cap M \neq \varnothing\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values beyond the allowed range, i.e. $\left\{ X \mid X \subset N \cup \{-0, +0\} \wedge \left(\begin{array}{c} fltLowerLimitQ > fltUpperLimitQ \vee \\ fltRampUp < 0 \vee \\ fltRampDown < 0 \vee \end{array} \right) \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{ \begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \\ ir \in (N \cup \{-0, +0\})^{13} \wedge \\ fltLowerLimitQ \le fltUpperLimitQ \wedge \\ fltRampUp \ge 0 \wedge \\ fltRampDown \ge 0 \wedge \end{array} \right\}$	$\langle -me_1, me_1 \rangle$	N/A

Subset of input domain	Worst-case error bounds for pRamp.fltState output [ulp]	Allowed specific values (regardless the error bounds) for pRamp.fltState output
Normalized or zero input values which cause an underflow, i.e. $$\left\{\begin{matrix} X \mid X \subset N \cup \{-0, +0\} \wedge \\ fltLowerLimitQ \le fltUpperLimitQ \wedge \\ fltRampUp \ge 0 \wedge \\ fltRampDown \ge 0 \wedge \\ \exists n: ir_n \ne \varnothing \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \end{matrix}\right\}$$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which cause an overflow, i.e. $$\left\{\begin{matrix} X \mid X \subset N \cup \{-0, +0\} \wedge \\ fltLowerLimitQ \le fltUpperLimitQ \wedge \\ fltRampUp \ge 0 \wedge \\ fltRampDown \ge 0 \wedge \\ \exists n: ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \end{matrix}\right\}$$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Table 39. AMCLIB_SpeedLoop_FLT Worst-Case Error Bounds - pFilterW.fltAcc output

Subset of input domain	Worst-case error bounds for pFilterW.fltAcc output [ulp]	Allowed specific values (regardless the error bounds) for pFilterW.fltAcc output
Any of the inputs is denormalized, NaN, or infinity, i.e. $$\{X \mid X \cap D \ne \varnothing \vee X \cap M \ne \varnothing\}$$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values beyond the allowed range, i.e. $$\left\{\begin{matrix} X \mid X \subset N \cup \{-0, +0\} \wedge \\ \left(\begin{matrix} fltLowerLimitQ > fltUpperLimitQ \vee \\ fltRampUp < 0 \vee \\ fltRampDown < 0 \vee \end{matrix}\right) \end{matrix}\right\}$$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $$\left\{\begin{matrix} X \mid X \subset N \cup \{-0, +0\} \wedge \\ ir \in (N \cup \{-0, +0\})^{13} \wedge \\ fltLowerLimitQ \le fltUpperLimitQ \wedge \\ fltRampUp \ge 0 \wedge \\ fltRampDown \ge 0 \wedge \end{matrix}\right\}$$	$\langle -me_5, me_5 \rangle$	N/A

Subset of input domain	Worst-case error bounds for pFilterW.fltAcc output [ulp]	Allowed specific values (regardless the error bounds) for pFilterW.fltAcc output
Normalized or zero input values which cause an underflow, i.e. $$\left\{\begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \land \\ fltLowerLimitQ \le fltUpperLimitQ \land \\ fltRampUp \ge 0 \land \\ fltRampDown \ge 0 \land \\ \exists n: ir_n \ne \varnothing \land \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \end{array}\right\}$$	$\langle -Inf, Inf \rangle$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which cause an overflow, i.e. $$\left\{\begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \land \\ fltLowerLimitQ \le fltUpperLimitQ \land \\ fltRampUp \ge 0 \land \\ fltRampDown \ge 0 \land \\ \exists n: ir_n \in M \lor \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \end{array}\right\}$$	$\langle -Inf, Inf \rangle$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Table 40. AMCLIB_SpeedLoop_FLT Worst-Case Error Bounds - pPIpAWQ.fltInK_1 output

Subset of input domain	Worst-case error bounds for pPIpAWQ.fltInK_1 output [ulp]	Allowed specific values (regardless the error bounds) for pPIpAWQ.fltInK_1 output
Any of the inputs is denormalized, NaN, or infinity, i.e. $$\{X \mid X \cap D \ne \varnothing \lor X \cap M \ne \varnothing\}$$	$\langle -Inf, Inf \rangle$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values beyond the allowed range, i.e. $$\left\{\begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \land \\ \left(\begin{array}{c} fltLowerLimitQ > fltUpperLimitQ \lor \\ fltRampUp < 0 \lor \\ fltRampDown < 0 \lor \end{array}\right) \end{array}\right\}$$	$\langle -Inf, Inf \rangle$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $$\left\{\begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \land \\ ir \in (N \cup \{-0, +0\})^{13} \land \\ fltLowerLimitQ \le fltUpperLimitQ \land \\ fltRampUp \ge 0 \land \\ fltRampDown \ge 0 \land \end{array}\right\}$$	$\langle -me_6, me_6 \rangle$	N/A

Subset of input domain	Worst-case error bounds for pPIpAWQ.fltInK_1 output [ulp]	Allowed specific values (regardless the error bounds) for pPIpAWQ.fltInK_1 output
Normalized or zero input values which cause an underflow, i.e. $$\left\{\begin{matrix} X \mid X \subset N \cup \{-0, +0\} \wedge \\ fltLowerLimitQ \leq fltUpperLimitQ \wedge \\ fltRampUp \geq 0 \wedge \\ fltRampDown \geq 0 \wedge \\ \exists n: ir_n \neq \varnothing \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \end{matrix}\right\}$$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which cause an overflow, i.e. $$\left\{\begin{matrix} X \mid X \subset N \cup \{-0, +0\} \wedge \\ fltLowerLimitQ \leq fltUpperLimitQ \wedge \\ fltRampUp \geq 0 \wedge \\ fltRampDown \geq 0 \wedge \\ \exists n: ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \end{matrix}\right\}$$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Table 41. AMCLIB_SpeedLoop_FLT Worst-Case Error Bounds - pPIpAWQ.fltIntegPartK_1 output

Subset of input domain	Worst-case error bounds for pPIpAWQ.fltIntegPartK_1 output [ulp]	Allowed specific values (regardless the error bounds) for pPIpAWQ.fltIntegPartK_1 output
Any of the inputs is denormalized, NaN, or infinity, i.e. $$\{X \mid X \cap D \neq \varnothing \vee X \cap M \neq \varnothing\}$$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values beyond the allowed range, i.e. $$\left\{\begin{matrix} X \mid X \subset N \cup \{-0, +0\} \wedge \\ \left(\begin{matrix} fltLowerLimitQ > fltUpperLimitQ \vee \\ fltRampUp < 0 \vee \\ fltRampDown < 0 \vee \end{matrix}\right) \end{matrix}\right\}$$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $$\left\{\begin{matrix} X \mid X \subset N \cup \{-0, +0\} \wedge \\ ir \in (N \cup \{-0, +0\})^{13} \wedge \\ fltLowerLimitQ \leq fltUpperLimitQ \wedge \\ fltRampUp \geq 0 \wedge \\ fltRampDown \geq 0 \wedge \end{matrix}\right\}$$	$\langle -me_{10}, me_{10} \rangle$	N/A

Subset of input domain	Worst-case error bounds for pPIpAWQ.fltIntegPartK_1 output [ulp]	Allowed specific values (regardless the error bounds) for pPIpAWQ.fltIntegPartK_1 output
Normalized or zero input values which cause an underflow, i.e. $$\left\{\begin{matrix} X \mid X \subset N \cup \{-0, +0\} \wedge \\ fltLowerLimitQ \leq fltUpperLimitQ \wedge \\ fltRampUp \geq 0 \wedge \\ fltRampDown \geq 0 \wedge \\ \exists n: ir_n \neq \varnothing \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \end{matrix}\right\}$$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which cause an overflow, i.e. $$\left\{\begin{matrix} X \mid X \subset N \cup \{-0, +0\} \wedge \\ fltLowerLimitQ \leq fltUpperLimitQ \wedge \\ fltRampUp \geq 0 \wedge \\ fltRampDown \geq 0 \wedge \\ \exists n: ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \end{matrix}\right\}$$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Table 42. AMCLIB_SpeedLoop_FLT Worst-Case Error Bounds - pIDQReq.fltArg2 output

Subset of input domain	Worst-case error bounds for pIDQReq.fltArg2 output [ulp]	Allowed specific values (regardless the error bounds) for pIDQReq.fltArg2 output
Any of the inputs is denormalized, NaN, or infinity, i.e. $\{X \mid X \cap D \neq \varnothing \vee X \cap M \neq \varnothing\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values beyond the allowed range, i.e. $$\left\{\begin{matrix} X \mid X \subset N \cup \{-0, +0\} \wedge \\ \left(\begin{matrix} fltLowerLimitQ > fltUpperLimitQ \vee \\ fltRampUp < 0 \vee \\ fltRampDown < 0 \vee \end{matrix}\right) \end{matrix}\right\}$$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $$\left\{\begin{matrix} X \mid X \subset N \cup \{-0, +0\} \wedge \\ ir \in (N \cup \{-0, +0\})^{13} \wedge \\ fltLowerLimitQ \leq fltUpperLimitQ \wedge \\ fltRampUp \geq 0 \wedge \\ fltRampDown \geq 0 \wedge \end{matrix}\right\}$$	$\langle -me_{13}, me_{13} \rangle$	N/A

Subset of input domain	Worst-case error bounds for pIDQReq.fltArg2 output [ulp]	Allowed specific values (regardless the error bounds) for pIDQReq.fltArg2 output
Normalized or zero input values which cause an underflow, i.e. $\left\{\begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \\ fltLowerLimitQ \le fltUpperLimitQ \wedge \\ fltRampUp \ge 0 \wedge \\ fltRampDown \ge 0 \wedge \\ \exists n: ir_n \ne \varnothing \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \end{array}\right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which cause an overflow, i.e. $\left\{\begin{array}{c} X \mid X \subset N \cup \{-0, +0\} \wedge \\ fltLowerLimitQ \le fltUpperLimitQ \wedge \\ fltRampUp \ge 0 \wedge \\ fltRampDown \ge 0 \wedge \\ \exists n: ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \end{array}\right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

2.6 Function AMCLIB_TrackObsrv_FLT

Declaration

```
void AMCLIB_TrackObsrv_FLT(tFloat fltPhaseErr, tFloat *pPosEst,
tFloat *pVelocityEst, AMCLIB_TRACK_OBSRV_T_FLT *pCtrl);
```

Arguments

Table 43. AMCLIB_TrackObsrv_FLT arguments

Type	Name	Direction	Description
tFloat	fltPhaseErr	**input**	Input signal representing phase error of system to be estimated.
tFloat *	pPosEst	**output**	Estimated output position.
tFloat *	pVelocityEst	**output**	Estimated output velocity.
AMCLIB_TRACK_OBSRV_T_FLT *	pCtrl	**input, output**	Pointer to a tracking observer structure AMCLIB_TRACK_OBSRV_T_FLT, which contains algorithm coefficients.

Worst-Case Error Bounds

Let (*fltPhaseErr*, *fltCC1sc*, *fltCC2sc*, *fltAcc*, *fltInErrK1*, *fltUpperLimit*, *fltLowerLimit*, *fltState*, *fltInK1*, *fltC1*) $\in X$ be a set of inputs to AMCLIB_TrackObsrv_FLT,

fltAcc, *fltState*, *fltInK1* inputs represent real numbers with an error of max. ±0.5 ulp,

$ir_1 = fltPhaseErr \cdot fltCC1sc$,

$me_1 = 0$,

$ir_2 = fltInErrK1 \cdot fltCC2sc$,

$me_2 = 0$,

$ir_3 = ir_1 + ir_2$,

$me_3 = 1$,

$ie_1 = \max(\mathrm{fe}(|ir_3| + me_3 \cdot \mathrm{ULP}(ir_3)), \mathrm{fe}(|fltAcc| + 0.5 \cdot \mathrm{ULP}(fltAcc)))$,

$$ir_4 = \begin{cases} fltLowerLimit0, & ir_3 + fltAcc < fltLowerLimit \\ fltUpperLimit, & ir_3 + fltAcc > fltUpperLimit \\ ir_3 + fltAcc, & \text{otherwise} \end{cases},$$

$ie_2 = \mathrm{fe}(ir_4)$,

$$cb_1 = \begin{cases} 0, & ie_1 - ie_2 \le 0 \\ ie_1 - ie_2, & ie_1 - ie_2 > 0 \end{cases},$$

$$me_4 = \begin{cases} 0, & ir_4 + \left(0.5 + 1.5 \cdot 2^{cb_1}\right) \cdot \mathrm{ULP}(ir_4) < fltLowerLimit \\ 0, & ir_4 - \left(0.5 + 1.5 \cdot 2^{cb_1}\right) \cdot \mathrm{ULP}(ir_4) > fltUpperLimit \\ 0.5 + 1.5 \cdot 2^{cb_1}, & \text{otherwise} \end{cases},$$

$ie_3 = \max(\mathrm{fe}(|ir_4| + me_4 \cdot \mathrm{ULP}(ir_4)), \mathrm{fe}(|fltInK1| + 0.5 \cdot \mathrm{ULP}(fltInK1)))$,

$ir_5 = ir_4 + fltInK1$,

$ie_4 = \mathrm{fe}(ir_5)$,

$$cb_2 = \begin{cases} 0, & ie_3 - ie_4 \le 0 \\ ie_3 - ie_4, & ie_3 - ie_4 > 0 \end{cases},$$

$me_5 = 0.5 + (me_4 + 0.5) \cdot 2^{cb_2}$,

$ir_6 = ir_5 \cdot fltC1$,

$me_6 = 2 \cdot me_5$,

$ie_5 = \max(\mathrm{fe}(|ir_6| + me_6 \cdot \mathrm{ULP}(ir_6)), \mathrm{fe}(|fltState| + 0.5 \cdot \mathrm{ULP}(fltState)))$,

$ir_7 = ir_6 + fltState$,

$ie_6 = \mathrm{fe}(ir_7)$,

$$cb_3 = \begin{cases} 0, & ie_5 - ie_6 \le 0 \\ ie_5 - ie_6, & ie_5 - ie_6 > 0 \end{cases},$$

$me_7 = 0.5 + (me_6 + 0.5) \cdot 2^{cb_3}$,

then

Table 44. AMCLIB_TrackObsrv_FLT Worst-Case Error Bounds - pVelocityEst output

Subset of input domain	Worst-case error bounds for pVelocityEst output [ulp]	Allowed specific values (regardless the error bounds) for pVelocityEst output
Any of the inputs is denormalized, NaN, or infinity, i.e. $\{X \mid X \cap D \neq \varnothing \lor X \cap M \neq \varnothing\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values with pPhaseErr beyond the allowed range, i.e. $\{X \mid X \subset N \cup \{-0, +0\} \land \lvert pPhaseErr \rvert > \pi\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{ \begin{array}{l} X \mid X \subset N \cup \{-0, +0\} \land \lvert pPhaseErr \rvert \leq \pi, \\ \quad \boldsymbol{ir} \in (N \cup \{-0, +0\})^{42} \end{array} \right\}$	$\langle -me_4, me_4 \rangle$	N/A
Normalized or zero input values which cause an underflow, i.e. $\left\{ \begin{array}{l} X \mid X \subset N \cup \{-0, +0\} \land \lvert pPhaseErr \rvert \leq \pi, \\ \exists n: ir_n \neq \varnothing \land \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \end{array} \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which cause an overflow, i.e. $\left\{ \begin{array}{l} X \mid X \subset N \cup \{-0, +0\} \land \lvert pPhaseErr \rvert \leq \pi, \\ \exists n: ir_n \in M \lor \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \end{array} \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Table 45. AMCLIB_TrackObsrv_FLT Worst-Case Error Bounds - pParamPI.fltAcc output

Subset of input domain	Worst-case error bounds for pParamPI.fltAcc output [ulp]	Allowed specific values (regardless the error bounds) for pParamPI.fltAcc output
Any of the inputs is denormalized, NaN, or infinity, i.e. $\{X \mid X \cap D \neq \varnothing \lor X \cap M \neq \varnothing\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values with pPhaseErr beyond the allowed range, i.e. $\{X \mid X \subset N \cup \{-0, +0\} \land \lvert pPhaseErr \rvert > \pi\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Subset of input domain	Worst-case error bounds for pParamPI.fltAcc output [ulp]	Allowed specific values (regardless the error bounds) for pParamPI.fltAcc output
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{ X \;\middle|\; \begin{array}{c} X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \le \pi, \\ \boldsymbol{ir} \in (N \cup \{-0, +0\})^{42} \end{array} \right\}$	$\langle -me_4, me_4 \rangle$	N/A
Normalized or zero input values which cause an underflow, i.e. $\left\{ X \;\middle|\; \begin{array}{c} X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \le \pi, \\ \exists n: ir_n \ne \varnothing \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \end{array} \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which cause an overflow, i.e. $\left\{ X \;\middle|\; \begin{array}{c} X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \le \pi, \\ \exists n: ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \end{array} \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Table 46. AMCLIB_TrackObsrv_FLT Worst-Case Error Bounds - pParamPI.fltInErrK1 output

Subset of input domain	Worst-case error bounds for pParamPI.fltInErrK1 output [ulp]	Allowed specific values (regardless the error bounds) for pParamPI.fltInErrK1 output
Entire input domain	0	N/A

Table 47. AMCLIB_TrackObsrv_FLT Worst-Case Error Bounds - pPosEst output

Subset of input domain	Worst-case error bounds for pPosEst output [ulp]	Allowed specific values (regardless the error bounds) for pPosEst output
Any of the inputs is denormalized, NaN, or infinity, i.e. $\{X \mid X \cap D \ne \varnothing \vee X \cap M \ne \varnothing\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values with pPhaseErr beyond the allowed range, i.e. $\{X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert > \pi\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{ X \;\middle|\; \begin{array}{c} X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \le \pi, \\ \boldsymbol{ir} \in (N \cup \{-0, +0\})^{42} \end{array} \right\}$	$\langle -me_7, me_7 \rangle$	N/A

Subset of input domain	Worst-case error bounds for pPosEst output [ulp]	Allowed specific values (regardless the error bounds) for pPosEst output
Normalized or zero input values which lead to normalized or zero results with output wrap-around, i.e. $\left\{ X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \le \pi, \; ir \in (N \cup \{-0, +0\})^{42} \wedge \left(\begin{array}{c} \lvert ir_7 \rvert + me_7 \cdot \mathrm{ULP}(ir_7) > \pi \vee \\ \lvert ir_7 \rvert - me_7 \cdot \mathrm{ULP}(ir_7) < -\pi \end{array} \right) \right\}$	$(-Inf, Inf)$	N/A
Normalized or zero input values which cause an underflow, i.e. $\left\{ X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \le \pi, \; \exists n: ir_n \ne \varnothing \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which cause an overflow, i.e. $\left\{ X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \le \pi, \; \exists n: ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Table 48. AMCLIB_TrackObsrv_FLT Worst-Case Error Bounds - pParamInteg.fltState output

Subset of input domain	Worst-case error bounds for pParamInteg.fltState output [ulp]	Allowed specific values (regardless the error bounds) for pParamInteg.fltState output
Any of the inputs is denormalized, NaN, or infinity, i.e. $\{ X \mid X \cap D \ne \varnothing \vee X \cap M \ne \varnothing \}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values with pPhaseErr beyond the allowed range, i.e. $\{ X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert > \pi \}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{ X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \le \pi, \; \boldsymbol{ir} \in (N \cup \{-0, +0\})^{42} \right\}$	$\langle -me_7, me_7 \rangle$	N/A
Normalized or zero input values which cause an underflow, i.e. $\left\{ X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \le \pi, \; \exists n: ir_n \ne \varnothing \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Subset of input domain	Worst-case error bounds for pParamInteg.fltState output [ulp]	Allowed specific values (regardless the error bounds) for pParamInteg.fltState output
Normalized or zero input values which cause an overflow, i.e. $\left\{ \begin{array}{l} X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \le \pi, \\ \exists n : ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \end{array} \right\}$	$\langle -Inf, Inf \rangle$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Table 49. AMCLIB_TrackObsrv_FLT Worst-Case Error Bounds - pParamInteg.fltInK1 output

Subset of input domain	Worst-case error bounds for pParamInteg.fltInK1 output [ulp]	Allowed specific values (regardless the error bounds) for pParamInteg.fltInK1 output
Any of the inputs is denormalized, NaN, or infinity, i.e. $\{ X \mid X \cap D \ne \varnothing \vee X \cap M \ne \varnothing \}$	$\langle -Inf, Inf \rangle$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values with pPhaseErr beyond the allowed range, i.e. $\{ X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert > \pi \}$	$\langle -Inf, Inf \rangle$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{ \begin{array}{l} X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \le \pi, \\ \quad \boldsymbol{ir} \in (N \cup \{-0, +0\})^{42} \end{array} \right\}$	$\langle -me_4, me_4 \rangle$	N/A
Normalized or zero input values which cause an underflow, i.e. $\left\{ \begin{array}{l} X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \le \pi, \\ \exists n : ir_n \ne \varnothing \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \end{array} \right\}$	$\langle -Inf, Inf \rangle$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which cause an overflow, i.e. $\left\{ \begin{array}{l} X \mid X \subset N \cup \{-0, +0\} \wedge \lvert pPhaseErr \rvert \le \pi, \\ \exists n : ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \end{array} \right\}$	$\langle -Inf, Inf \rangle$	Arbitrary floating-point value (including Inf, -Inf, NaN)

2.7 Function AMCLIB_Windmilling_FLT

Declaration

```
AMCLIB_WINDMILLING_RET_T AMCLIB_Windmilling_FLT(const
SWLIBS_3Syst_FLT *pUabcIn, tFloat *pPosEst, tFloat *pVelocityEst,
AMCLIB_WINDMILLING_T_FLT *const pCtrl);
```

Arguments

Table 50. AMCLIB_Windmilling_FLT arguments

Type	Name	Direction	Description
const SWLIBS_3Syst_FLT *	pUabcIn	**input**	Pointer to the structure with the measured 3-phase A/B/C voltages.
tFloat *	pPosEst	**output**	Estimated rotor flux position in the interval <-π; π) radians.
tFloat *	pVelocityEst	**output**	Estimated electrical angular velocity of the rotor. The velocity estimates are noisy, especially for low speeds; therefore, it is recommended to use a GDFLIB_FilterMA_FLT to further filter the results. The filter should be engaged only after the AMCLIB_Windmilling has returned **SPINNING**; use GDFLIB_FilterMASetState_FLT to initialize the filter state with the first estimated velocity value.
AMCLIB_WINDMILLING_T_FLT *const	pCtrl	**input, output**	Pointer to the structure with AMCLIB_Windmilling parameters and state variables.

Worst-Case Error Bounds

The function internally normalizes the input voltages. If the inputs are near zero, the normalization causes significant amplification of intermediate rounding errors. Consequently, there is no practical upper bound for the possible output error. The function is implemented such that it achieves useful accuracy in all typical usage scenarios.

If any of the inputs is NaN, infinity, or a denormalized number, or if any of the intermediate results overflows or underflows, the output values are undefined.

2.8 Function GDFLIB_FilterFIR_FLT

Declaration

```
tFloat GDFLIB_FilterFIR_FLT(tFloat fltIn, const
GDFLIB_FILTERFIR_PARAM_T_FLT *const pParam,
GDFLIB_FILTERFIR_STATE_T_FLT *const pState);
```

Arguments

Table 51. GDFLIB_FilterFIR_FLT arguments

Type	Name	Direction	Description
tFloat	fltIn	**input**	Input sample.
const GDFLIB_FILTERFIR_PARAM_T_FLT *const	pParam	**input**	Pointer to a parameter structure.

Type	Name	Direction	Description
GDFLIB_FILTERFIR_STATE_T_FLT *const	pState	**input, output**	Pointer to a filter state structure.

Worst-Case Error Bounds

Let (*fltIn*, $\boldsymbol{CoefBuf}$, $\boldsymbol{InBuf}$) $\in X$ be a set of inputs to GDFLIB_FilterFIR_FLT,

$\boldsymbol{CoefBuf} = \left(CoefBuf_0, CoefBuf_1, \ldots, CoefBuf_{u32Order} \right)$,

$\boldsymbol{InBuf} = \left(fltIn_t, fltIn_{t-1}, \ldots, fltIn_{t-u32Order} \right)$, where *t* is the current time,

refResult be the theoretical exact result,

$\boldsymbol{mr} = \boldsymbol{CoefBuf} \odot \boldsymbol{InBuf}$, i.e. a vector of element-wise multiplication results of vectors $\boldsymbol{CoefBuf}$ and $\boldsymbol{InBuf}$,

$\boldsymbol{sr} = \left(sr_1, sr_2, \ldots, sr_{u32Order-1} \right), sr_k = \sum_{n=0}^{k} CoefBuf_n \cdot InBuf_n$, i.e. a vector of partial sums of element-wise multiplication results of vectors $\boldsymbol{CoefBuf}$ and $\boldsymbol{InBuf}$,

$ie_1 = \max_n \left(\mathrm{fe}\left(mr_n \right) \right)$,

$ie_2 = \mathrm{fe}\left(refResult \right)$,

$cb_1 = \begin{cases} 0, & ie_1 - ie_2 \le 0 \\ ie_1 - ie_2, & ie_1 - ie_2 > 0 \end{cases}$,

$me = 0.5 \cdot \left(u32Order + 1 \right) \cdot 2^{cb_1} + \sum_{n=1}^{\mathrm{ceil}\left(\frac{u32Order-2}{2}\right)} \mathrm{ceil}\left(\log_2\left(n+1 \right) \right) + \sum_{n=1}^{\mathrm{floor}\left(\frac{u32Order-2}{2}\right)} \mathrm{ceil}\left(\log_2\left(n+1 \right) \right)$,

then

Table 52. GDFLIB_FilterFIR_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Input values which contain at least one denormalized number while other inputs are normalized or zero, i.e. $\left\{ \left(fltIn, \boldsymbol{CoefBuf}, \boldsymbol{InBuf} \right) \in X \;\middle|\; X \cap M = \varnothing \wedge X \cap D \ne \varnothing \right\}$	$\left(-Inf, Inf \right)$	N/A
Input values which contain at least one NaN, Inf, or -Inf, i.e. $\left\{ \left(fltIn, \boldsymbol{CoefBuf}, \boldsymbol{InBuf} \right) \in X \;\middle|\; X \cap M \ne \varnothing \right\}$	N/A	Arbitrary floating-point value (including Inf, -Inf, NaN)

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Normalized or zero input values which lead to normalized or zero results, i.e. $$\left\{\begin{matrix} (fltIn, \boldsymbol{CoefBuf}, \boldsymbol{InBuf}) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ mr \in (N \cup \{-0, +0\})^{u32Order+1}, \\ sr \in (N \cup \{-0, +0\})^{u32Order-1}, \\ refResult = 0 \lor \\ \left(\begin{matrix} \lvert refResult \rvert - me \cdot \mathrm{ULP}(refResult) \notin D \land \\ \lvert refResult \rvert + me \cdot \mathrm{ULP}(refResult) \neq Inf \end{matrix}\right) \end{matrix}\right\}$$	$\langle -me, me \rangle$	N/A
Normalized or zero input values which cause result overflow, i.e. $$\left\{\begin{matrix} (fltIn, \boldsymbol{CoefBuf}, \boldsymbol{InBuf}) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ \lvert refResult \rvert + me \cdot \mathrm{ULP}(refResult) \in M \end{matrix}\right\}$$	$(-Inf, Inf)$	{Inf, -Inf, NaN}
Normalized or zero input values which cause result underflow, i.e. $$\left\{\begin{matrix} (fltIn, \boldsymbol{CoefBuf}, \boldsymbol{InBuf}) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ \lvert refResult \rvert - me \cdot \mathrm{ULP}(refResult) \in D \land \\ refResult \neq 0 \end{matrix}\right\}$$	$(-Inf, Inf)$	N/A
Normalized or zero input values which cause intermediate result overflow, i.e. $$\left\{\begin{matrix} (fltIn, \boldsymbol{CoefBuf}, \boldsymbol{InBuf}) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ \exists\, mr_n \in M \lor \\ \exists\, (\lvert sr_n \rvert + me \cdot \mathrm{ULP}(sr_n)) \in M \end{matrix}\right\}$$	$(-Inf, Inf)$	{Inf, -Inf, NaN}
Normalized or zero input values which cause intermediate result underflow, i.e. $$\left\{\begin{matrix} (fltIn, \boldsymbol{CoefBuf}, \boldsymbol{InBuf}) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ \exists\, mr_n \in D \lor \\ \exists\, (\lvert sr_n \rvert - me \cdot \mathrm{ULP}(sr_n)) \in D, sr \neq 0 \end{matrix}\right\}$$	$(-Inf, Inf)$	N/A

2.9 Function GDFLIB_FilterIIR1_FLT

Declaration

```
tFloat GDFLIB_FilterIIR1_FLT(tFloat fltIn,
GDFLIB_FILTER_IIR1_T_FLT *const pParam);
```

Arguments

Table 53. GDFLIB_FilterIIR1_FLT arguments

Type	Name	Direction	Description
tFloat	fltIn	**input**	Value of the input signal to be filtered in step (k). Input is a 32-bit number that contains a single precision floating point value.
GDFLIB_FILTER_IIR1_T_FLT *const	pParam	**input, output**	Pointer to a filter structure with a filter buffer and filter parameters. Arguments of the structure contain single precision floating point values.

Worst-Case Error Bounds

Let (*fltIn*, *fltB0*, *fltB1*, *flA1*, *fltFiltBufferX*, *fltFiltBufferY*) ∊ *X* be a set of inputs to GDFLIB_FilterIIR1_FLT,

refResult be the theoretical exact result,

$\boldsymbol{mr} = (fltIn, fltFiltBufferX, fltFiltBufferY) \odot (fltB0, fltB1, fltA1)$, i.e. a vector of element-wise multiplication results of vectors (*fltIn*, *fltFiltBufferX*, *fltFiltBufferY*) and (*fltB0*, *fltB1*, *fltA1*),

$sr = fltIn \cdot fltB0 + fltFiltBufferX \cdot fltB1$,

$ie_1 = \max_n(\mathrm{fe}(mr_n))$,

$ie_2 = \mathrm{fe}(refResult)$,

$$cb = \begin{cases} 0, & ie_1 - ie_2 \le 0 \\ ie_1 - ie_2, & ie_1 - ie_2 > 0 \end{cases},$$

$me = 0.5 + 2.5 \cdot 2^{cb}$,

the *fltFiltBufferY* input represents a real number with an error of max. ±0.5 ulp,

then

Table 54. GDFLIB_FilterIIR1_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Input values which contain at least one denormalized number while other inputs are normalized or zero, i.e. $\left\{ \begin{pmatrix} fltIn, fltB0, fltB1, fltA1, \\ fltFiltBufferX, fltFiltBufferY \end{pmatrix} \in X \middle\vert \begin{matrix} \\ X \cap M = \varnothing \wedge X \cap D \neq \varnothing \end{matrix} \right\}$	$(-Inf, Inf)$	N/A

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Input values which contain at least one NaN, Inf, or –Inf, i.e. $\left\{\left(\begin{matrix} fltIn,\ fltB0,\ fltB1,\ fltA1, \\ fltFiltBufferX,\ fltFiltBufferY \end{matrix}\right) \in X \;\middle|\; X \cap M \neq \varnothing \right\}$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{\left(\begin{matrix} fltIn,\ fltB0,\ fltB1,\ fltA1, \\ fltFiltBufferX,\ fltFiltBufferY \end{matrix}\right) \in X \;\middle|\; \begin{matrix} X \subset N \cup \{-0,\ +0\},\ \boldsymbol{mr} \in N^{u32Order+1}, \\ sr \in N \cup \{-0,\ +0\}, \\ refResult = 0 \vee \\ \left(\begin{matrix} \lvert refResult \rvert - me \cdot \mathrm{ULP}(refResult) \notin D \wedge \\ \lvert refResult \rvert + me \cdot \mathrm{ULP}(refResult) \neq Inf \end{matrix}\right) \end{matrix} \right\}$	$\langle -me,\ me \rangle$	N/A
Normalized or zero input values which cause result overflow, i.e. $\left\{\left(\begin{matrix} fltIn,\ fltB0,\ fltB1,\ fltA1, \\ fltFiltBufferX,\ fltFiltBufferY \end{matrix}\right) \in X \;\middle|\; \begin{matrix} X \subset N \cup \{-0,\ +0\}, \\ \lvert refResult \rvert + me \cdot \mathrm{ULP}(refResult) \in M \end{matrix} \right\}$	$(-Inf,\ Inf)$	{Inf, -Inf, NaN}
Normalized or zero input values which cause result underflow, i.e. $\left\{\left(\begin{matrix} fltIn,\ fltB0,\ fltB1,\ fltA1, \\ fltFiltBufferX,\ fltFiltBufferY \end{matrix}\right) \in X \;\middle|\; \begin{matrix} X \subset N \cup \{-0,\ +0\}, \\ \lvert refResult \rvert - me \cdot \mathrm{ULP}(refResult) \in D \wedge \\ refResult \neq 0 \end{matrix} \right\}$	$(-Inf,\ Inf)$	N/A
Normalized or zero input values which cause intermediate result overflow with normalized or zero reference output, i.e. $\left\{\left(\begin{matrix} fltIn,\ fltB0,\ fltB1,\ fltA1, \\ fltFiltBufferX,\ fltFiltBufferY \end{matrix}\right) \in X \;\middle|\; \begin{matrix} X \subset N \cup \{-0,\ +0\}, \\ \boldsymbol{mr} \in M^{u32Order+1} \vee \\ \lvert sr \rvert + me \cdot \mathrm{ULP}(sr) \in M \end{matrix} \right\}$	$(-Inf,\ Inf)$	{Inf, -Inf, NaN}

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Normalized or zero input values which cause intermediate result underflow with normalized or zero reference output, i.e. $\left\{ \begin{pmatrix} fltIn,\ fltB0,\ fltB1,\ fltA1, \\ fltFiltBufferX,\ fltFiltBufferY \end{pmatrix} \in X \middle\vert \begin{array}{c} X \subset N \cup \{-0,\ +0\}, \\ \boldsymbol{mr} \in D^{u32Order+1} \vee \\ \lvert sr \rvert - me \cdot \mathrm{ULP}(sr) \in D,\ sr \neq 0 \end{array} \right\}$	$(-Inf, Inf)$	{Inf, -Inf, NaN}

Table 55. GDFLIB_FilterIIR1_FLT Worst-Case Error Bounds - fltFiltBufferY Output

Subset of input domain	Worst-case error bounds for fltFiltBufferY output [ulp]	Allowed specific values (regardless the error bounds) for fltFiltBufferY output
Input values which contain at least one denormalized number while other inputs are normalized or zero, i.e. $\left\{ \begin{pmatrix} fltIn,\ fltB0,\ fltB1,\ fltA1, \\ fltFiltBufferX,\ fltFiltBufferY \end{pmatrix} \in X \middle\vert X \cap M = \varnothing \wedge X \cap D \neq \varnothing \right\}$	$(-Inf, Inf)$	N/A
Input values which contain at least one NaN, Inf, or –Inf, i.e. $\left\{ \begin{pmatrix} fltIn,\ fltB0,\ fltB1,\ fltA1, \\ fltFiltBufferX,\ fltFiltBufferY \end{pmatrix} \in X \middle\vert X \cap M \neq \varnothing \right\}$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{ \begin{pmatrix} fltIn,\ fltB0,\ fltB1,\ fltA1, \\ fltFiltBufferX,\ fltFiltBufferY \end{pmatrix} \in X \middle\vert \begin{array}{c} X \subset N \cup \{-0,\ +0\},\ \boldsymbol{mr} \in N^{u32Order+1}, \\ sr \in N \cup \{-0,\ +0\}, \\ refResult = 0 \vee \\ \begin{pmatrix} \lvert refResult \rvert - me \cdot \mathrm{ULP}(refResult) \notin D \wedge \\ \lvert refResult \rvert + me \cdot \mathrm{ULP}(refResult) \neq Inf \end{pmatrix} \end{array} \right\}$	$\langle -me, me \rangle$	N/A
Normalized or zero input values which cause result overflow, i.e. $\left\{ \begin{pmatrix} fltIn,\ fltB0,\ fltB1,\ fltA1, \\ fltFiltBufferX,\ fltFiltBufferY \end{pmatrix} \in X \middle\vert \begin{array}{c} X \subset N \cup \{-0,\ +0\}, \\ \lvert refResult \rvert + me \cdot \mathrm{ULP}(refResult) \in M \end{array} \right\}$	$(-Inf, Inf)$	{Inf, -Inf, NaN}

Subset of input domain	Worst-case error bounds for fltFiltBufferY output [ulp]	Allowed specific values (regardless the error bounds) for fltFiltBufferY output
Normalized or zero input values which cause result underflow, i.e. $$\left\{\begin{array}{c} \begin{pmatrix} fltIn, fltB0, fltB1, fltA1, \\ fltFiltBufferX, fltFiltBufferY \end{pmatrix} \in X \\ X \subset N \cup \{-0, +0\}, \\ \lvert refResult \rvert - me \cdot \mathrm{ULP}(refResult) \in D \wedge \\ refResult \neq 0 \end{array}\right\}$$	$(-Inf, Inf)$	N/A
Normalized or zero input values which cause intermediate result overflow with normalized or zero reference output, i.e. $$\left\{\begin{array}{c} \begin{pmatrix} fltIn, fltB0, fltB1, fltA1, \\ fltFiltBufferX, fltFiltBufferY \end{pmatrix} \in X \\ X \subset N \cup \{-0, +0\}, \\ \boldsymbol{mr} \in M^{u32Order+1} \vee \\ \lvert sr \rvert + me \cdot \mathrm{ULP}(sr) \in M \end{array}\right\}$$	$(-Inf, Inf)$	{Inf, -Inf, NaN}
Normalized or zero input values which cause intermediate result underflow with normalized or zero reference output, i.e. $$\left\{\begin{array}{c} \begin{pmatrix} fltIn, fltB0, fltB1, fltA1, \\ fltFiltBufferX, fltFiltBufferY \end{pmatrix} \in X \\ X \subset N \cup \{-0, +0\}, \\ \boldsymbol{mr} \in D^{u32Order+1} \vee \\ \lvert sr \rvert - me \cdot \mathrm{ULP}(sr) \in D, sr \neq 0 \end{array}\right\}$$	$(-Inf, Inf)$	{Inf, -Inf, NaN}

Table 56. GDFLIB_FilterIIR1_FLT Worst-Case Error Bounds - fltFiltBufferX Output

Subset of input domain	Worst-case error bounds for fltFiltBufferX output [ulp]	Allowed specific values (regardless the error bounds) for fltFiltBufferX output
Entire input domain	0	*fltIn*

2.10 Function GDFLIB_FilterIIR2_FLT

Declaration

```
tFloat GDFLIB_FilterIIR2_FLT(tFloat fltIn,
GDFLIB_FILTER_IIR2_T_FLT *const pParam);
```

Arguments

Table 57. GDFLIB_FilterIIR2_FLT arguments

Type	Name	Direction	Description
tFloat	fltIn	**input**	Value of the input signal to be filtered in step (k). Input is a 32-bit number that contains a single precision floating point value.
GDFLIB_FILTER_IIR2_T_FLT *const	pParam	**input, output**	Pointer to a filter structure with a filter buffer and filter parameters. Arguments of the structure contain single precision floating point values.

Worst-Case Error Bounds

Let (*fltIn*, *fltB0*, *fltB1*, *fltB2*, *flA1*, *flA2*, ***fltFiltBufferX***, ***fltFiltBufferY***) $\in X$ be a set of inputs to GDFLIB_FilterIIR2_FLT,

$\boldsymbol{fltFiltBufferX} = \left(fltFiltBufferX_0, fltFiltBufferX_1\right)$,

$\boldsymbol{fltFiltBufferY} = \left(fltFiltBufferY_0, fltFiltBufferY_1\right)$,

refResult be the theoretical exact result,

$\boldsymbol{mr} = \left(fltIn, fltFiltBufferX, fltFiltBufferY\right) \odot \left(fltB0, fltB1, fltB2, fltA1, fltA2\right)$, i.e. a vector of element-wise multiplication results of vectors (*fltIn*, ***fltFiltBufferX***, ***fltFiltBufferY***) and (*fltB0*, *fltB1*, *fltB2*, *flA1*, *flA2*),

$sr_1 = fltIn \cdot fltB_0 + fltFiltBufferX_0 \cdot fltB1$,

$sr_2 = sr_1 + fltFiltBufferX_1 \cdot fltB2$,

$sr_3 = sr_2 + fltFiltBufferY_0 \cdot fltA1$,

$\boldsymbol{sr} = \left(sr_1, sr_2, sr_3\right)$,

$ie_1 = \max_n\left(\mathrm{fe}\left(mr_n\right)\right)$,

$ie_2 = \mathrm{fe}\left(refResult\right)$,

$$cb = \begin{cases} 0, & ie_1 - ie_2 \le 0 \\ ie_1 - ie_2, & ie_1 - ie_2 > 0 \end{cases},$$

$me = 0.5 + 5 \cdot 2^{cb}$,

the *fltFiltBufferY* $_0$ input represents a real number with an error of max. ±0.5 ulp,

then

Table 58. GDFLIB_FilterIIR2_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Input values which contain at least one denormalized number while other inputs are normalized or zero, i.e. $$\left\{ \left(\begin{matrix} fltIn, fltB0, fltB1, fltB2, fltA1, fltA2, \\ fltFiltBufferX, fltFiltBufferY \end{matrix} \right) \in X \middle\vert \; X \cap M = \varnothing \wedge X \cap D \neq \varnothing \right\}$$	$(-Inf, Inf)$	N/A
Input values which contain at least one NaN, Inf, or –Inf, i.e. $$\left\{ \left(\begin{matrix} fltIn, fltB0, fltB1, fltB2, fltA1, fltA2, \\ fltFiltBufferX, fltFiltBufferY \end{matrix} \right) \in X \middle\vert \; X \cap M \neq \varnothing \right\}$$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $$\left\{ \left(\begin{matrix} fltIn, fltB0, fltB1, fltB2, fltA1, fltA2, \\ fltFiltBufferX, fltFiltBufferY \end{matrix} \right) \in X \middle\vert \begin{matrix} X \subset N \cup \{-0, +0\}, \\ \boldsymbol{mr} \in (N \cup \{-0, +0\})^{u32Order+1}, \\ \boldsymbol{sr} \in (N \cup \{-0, +0\})^{u32Order-1}, \\ refResult = 0 \vee \\ \left(\begin{matrix} \lvert refResult \rvert - me \cdot \mathrm{ULP}(refResult) \notin D \wedge \\ \lvert refResult \rvert + me \cdot \mathrm{ULP}(refResult) \neq Inf \end{matrix} \right) \end{matrix} \right\}$$	$\langle -me, me \rangle$	N/A
Normalized or zero input values which cause result overflow, i.e. $$\left\{ \left(\begin{matrix} fltIn, fltB0, fltB1, fltB2, fltA1, fltA2, \\ fltFiltBufferX, fltFiltBufferY \end{matrix} \right) \in X \middle\vert \begin{matrix} X \subset N \cup \{-0, +0\}, \\ \lvert refResult \rvert + me \cdot \mathrm{ULP}(refResult) \in M \end{matrix} \right\}$$	$(-Inf, Inf)$	{Inf, -Inf, NaN}
Normalized or zero input values which cause result underflow, i.e. $$\left\{ \left(\begin{matrix} fltIn, fltB0, fltB1, fltB2, fltA1, fltA2, \\ fltFiltBufferX, fltFiltBufferY \end{matrix} \right) \in X \middle\vert \begin{matrix} X \subset N \cup \{-0, +0\}, \\ \lvert refResult \rvert - me \cdot \mathrm{ULP}(refResult) \in D \wedge \\ refResult \neq 0 \end{matrix} \right\}$$	$(-Inf, Inf)$	N/A

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Normalized or zero input values which cause intermediate result overflow, i.e. $$\left\{ \begin{pmatrix} fltIn,\ fltB0,\ fltB1,\ fltB2,\ fltA1,\ fltA2, \\ fltFiltBufferX,\ fltFiltBufferY \end{pmatrix} \in X \middle\| \begin{matrix} X \subset N \cup \{-0,\ +0\}, \\ \exists\, mr_n \in M \vee \\ \exists\,(\lvert sr_n \rvert + me \cdot \mathrm{ULP}(sr_n)) \in M \end{matrix} \right\}$$	$(-Inf, Inf)$	{Inf, -Inf, NaN}
Normalized or zero input values which cause intermediate result underflow, i.e. $$\left\{ \begin{pmatrix} fltIn,\ fltB0,\ fltB1,\ fltB2,\ fltA1,\ fltA2, \\ fltFiltBufferX,\ fltFiltBufferY \end{pmatrix} \in X \middle\| \begin{matrix} X \subset N \cup \{-0,\ +0\}, \\ \exists\, mr_n \in D \vee \\ \exists\,(\lvert sr_n \rvert - me \cdot \mathrm{ULP}(sr_n)) \in D,\ sr \neq 0 \end{matrix} \right\}$$	$(-Inf, Inf)$	{Inf, -Inf, NaN}

Table 59. GDFLIB_FilterIIR2_FLT Worst-Case Error Bounds - $fltFiltBufferY_0$ Output

Subset of input domain	Worst-case error bounds for $fltFiltBufferY_0$ output [ulp]	Allowed specific values (regardless the error bounds) for $fltFiltBufferY_0$ output
Input values which contain at least one denormalized number while other inputs are normalized or zero, i.e. $$\left\{ \begin{pmatrix} fltIn,\ fltB0,\ fltB1,\ fltB2,\ fltA1,\ fltA2, \\ fltFiltBufferX,\ fltFiltBufferY \end{pmatrix} \in X \middle\| X \cap M = \varnothing \wedge X \cap D \neq \varnothing \right\}$$	$(-Inf, Inf)$	N/A
Input values which contain at least one NaN, Inf, or –Inf, i.e. $$\left\{ \begin{pmatrix} fltIn,\ fltB0,\ fltB1,\ fltB2,\ fltA1,\ fltA2, \\ fltFiltBufferX,\ fltFiltBufferY \end{pmatrix} \in X \middle\| X \cap M \neq \varnothing \right\}$$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)

Subset of input domain	Worst-case error bounds for fltFiltBufferY$_0$ output [ulp]	Allowed specific values (regardless the error bounds) for fltFiltBufferY$_0$ output
Normalized or zero input values which lead to normalized or zero results, i.e. $$\left\{\begin{matrix} \left(\begin{matrix} fltIn, fltB0, fltB1, fltB2, fltA1, fltA2, \\ fltFiltBufferX, fltFiltBufferY \end{matrix}\right) \in X \\ X \subset N \cup \{-0, +0\}, \\ \boldsymbol{mr} \in (N \cup \{-0, +0\})^{u32Order+1}, \\ \boldsymbol{sr} \in (N \cup \{-0, +0\})^{u32Order-1}, \\ refResult = 0 \vee \\ \left(\begin{matrix} \lvert refResult \rvert - me \cdot \mathrm{ULP}(refResult) \notin D \wedge \\ \lvert refResult \rvert + me \cdot \mathrm{ULP}(refResult) \neq Inf \end{matrix}\right) \end{matrix}\right\}$$	$\langle -me, me \rangle$	N/A
Normalized or zero input values which cause result overflow, i.e. $$\left\{\begin{matrix} \left(\begin{matrix} fltIn, fltB0, fltB1, fltB2, fltA1, fltA2, \\ fltFiltBufferX, fltFiltBufferY \end{matrix}\right) \in X \\ X \subset N \cup \{-0, +0\}, \\ \lvert refResult \rvert + me \cdot \mathrm{ULP}(refResult) \in M \end{matrix}\right\}$$	$(-Inf, Inf)$	{Inf, -Inf, NaN}
Normalized or zero input values which cause result underflow, i.e. $$\left\{\begin{matrix} \left(\begin{matrix} fltIn, fltB0, fltB1, fltB2, fltA1, fltA2, \\ fltFiltBufferX, fltFiltBufferY \end{matrix}\right) \in X \\ X \subset N \cup \{-0, +0\}, \\ \lvert refResult \rvert - me \cdot \mathrm{ULP}(refResult) \in D \wedge \\ refResult \neq 0 \end{matrix}\right\}$$	$(-Inf, Inf)$	N/A
Normalized or zero input values which cause intermediate result overflow, i.e. $$\left\{\begin{matrix} \left(\begin{matrix} fltIn, fltB0, fltB1, fltB2, fltA1, fltA2, \\ fltFiltBufferX, fltFiltBufferY \end{matrix}\right) \in X \\ X \subset N \cup \{-0, +0\}, \\ \exists\, mr_n \in M \vee \\ \exists\, (\lvert sr_n \rvert + me \cdot \mathrm{ULP}(sr_n)) \in M \end{matrix}\right\}$$	$(-Inf, Inf)$	{Inf, -Inf, NaN}
Normalized or zero input values which cause intermediate result underflow, i.e. $$\left\{\begin{matrix} \left(\begin{matrix} fltIn, fltB0, fltB1, fltB2, fltA1, fltA2, \\ fltFiltBufferX, fltFiltBufferY \end{matrix}\right) \in X \\ X \subset N \cup \{-0, +0\}, \\ \exists\, mr_n \in D \vee \\ \exists\, (\lvert sr_n \rvert - me \cdot \mathrm{ULP}(sr_n)) \in D, sr \neq 0 \end{matrix}\right\}$$	$(-Inf, Inf)$	{Inf, -Inf, NaN}

Table 60. GDFLIB_FilterIIR2_FLT Worst-Case Error Bounds - fltFiltBufferY_1 Output

Subset of input domain	Worst-case error bounds for fltFiltBufferY_1 output [ulp]	Allowed specific values (regardless the error bounds) for fltFiltBufferY_1 output
Entire input domain	0	*fltFiltBufferY* $_0$

Table 61. GDFLIB_FilterIIR2_FLT Worst-Case Error Bounds - fltFiltBufferX_0 Output

Subset of input domain	Worst-case error bounds for fltFiltBufferX_0 output [ulp]	Allowed specific values (regardless the error bounds) for fltFiltBufferX_0 output
Entire input domain	0	*fltIn*

Table 62. GDFLIB_FilterIIR2_FLT Worst-Case Error Bounds - fltFiltBufferX_1 Output

Subset of input domain	Worst-case error bounds for fltFiltBufferX_1 output [ulp]	Allowed specific values (regardless the error bounds) for fltFiltBufferX_1 output
Entire input domain	0	*fltFiltBufferX* $_0$

2.11 Function GDFLIB_FilterMA_FLT

Declaration

```
tFloat GDFLIB_FilterMA_FLT(tFloat fltIn, GDFLIB_FILTER_MA_T_FLT
*pParam);
```

Arguments

Table 63. GDFLIB_FilterMA_FLT arguments

Type	Name	Direction	Description
tFloat	fltIn	**input**	Value of the input signal to be filtered in step (k). The value is a single precision floating point data type.
GDFLIB_FILTER_MA_T_FLT *	pParam	**input, output**	Pointer to the filter structure with a filter accumulator and a smoothing factor.

Worst-Case Error Bounds

Let (*fltIn*, *fltAcc*, *fltLambda*) ∊ *X* be a set of inputs to GDFLIB_FilterMA_FLT,

refResult be the theoretical exact result,

$mr_1 = fltIn \cdot fltLambda$,

$mr_2 = refResult \cdot fltLambda$,

$ie_1 = \max(\mathrm{fe}(mr_1), \mathrm{fe}(fltAcc))$,

$ie_2 = \mathrm{fe}(refResult)$,

$$cb_1 = \begin{cases} 0, & ie_1 - ie_2 \le 0 \\ ie_1 - ie_2, & ie_1 - ie_2 > 0 \end{cases},$$

$me_1 = 0.5 + 0.5 \cdot 2^{cb_1}$,

$refState = refResult - mr_2$,

$ie_3 = \max(\mathrm{fe}(|mr_2| + 2 \cdot me_1 \cdot \mathrm{ULP}(mr_2)), \mathrm{fe}(|refResult| + me_1 \cdot \mathrm{ULP}(refResult)))$,

$ie_4 = \mathrm{fe}(refState)$,

$cb_2 = \begin{cases} 0, & ie_3 - ie_4 \le 0 \\ ie_3 - ie_4, & ie_3 - ie_4 > 0 \end{cases}$,

$me_2 = 0.5 + me_1 + (2 \cdot me_1) \cdot 2^{cb_2}$,

then

Table 64. GDFLIB_FilterMA_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Input values which contain at least one denormalized number while other inputs are normalized or zero, i.e. $\left\{ \begin{array}{c} (fltIn, fltAcc, fltLambda) \in X \mid \\ X \cap M = \varnothing \wedge X \cap D \ne \varnothing \end{array} \right\}$	$(-Inf, Inf)$	N/A
Input values which contain at least one NaN, Inf, or –Inf, i.e. $\{(fltIn, fltAcc, fltLambda) \in X \mid X \cap M \ne \varnothing\}$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)
Normalized or zero input values which lead to normalized or zero result, i.e. $\left\{ \begin{array}{c} (fltIn, fltAcc, fltLambda) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ mr_1 \in N \cup \{-0, +0\}, \\ refResult = 0 \vee \\ \left(\begin{array}{c} \lvert refResult \rvert - me_1 \cdot \mathrm{ULP}(refResult) \notin D \wedge \\ \lvert refResult \rvert + me_1 \cdot \mathrm{ULP}(refResult) \ne Inf \end{array} \right), \end{array} \right\}$	$\langle -me_1, me_1 \rangle$	N/A
Normalized or zero input values which cause result overflow, i.e. $\left\{ \begin{array}{c} (fltIn, fltAcc, fltLambda) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ \lvert refResult \rvert + me_1 \cdot \mathrm{ULP}(refResult) \in M \end{array} \right\}$	$(-Inf, Inf)$	{Inf, -Inf, NaN}
Normalized or zero input values which cause result underflow, i.e. $\left\{ \begin{array}{c} (fltIn, fltAcc, fltLambda) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ \lvert refResult \rvert - me_1 \cdot \mathrm{ULP}(refResult) \in D \wedge \\ refResult \ne 0 \end{array} \right\}$	$(-Inf, Inf)$	N/A

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Normalized or zero input values which cause intermediate result overflow, i.e. $\left\{\begin{array}{c}(fltIn,\ fltAcc,\ fltLambda) \in X \mid \\ X \subset N \cup \{-0,\ +0\}, \\ mr_1 \in \{Inf,\ -Inf\}\end{array}\right\}$	$(-Inf, Inf)$	{Inf, -Inf, NaN}
Normalized or zero input values which cause intermediate result underflow, i.e. $\left\{\begin{array}{c}(fltIn,\ fltAcc,\ fltLambda) \in X \mid \\ X \subset N \cup \{-0,\ +0\}, \\ mr_1 \in D\end{array}\right\}$	$(-Inf, Inf)$	N/A

Table 65. GDFLIB_FilterMA_FLT Worst-Case Error Bounds - fltAcc Output

Subset of input domain	Worst-case error bounds for fltAcc output [ulp]	Allowed specific values (regardless the error bounds) for fltAcc output
Input values which contain at least one denormalized number while other inputs are normalized or zero, i.e. $\left\{\begin{array}{c}(fltIn,\ fltAcc,\ fltLambda) \in X \mid \\ X \cap M = \varnothing \wedge X \cap D \neq \varnothing\end{array}\right\}$	$(-Inf, Inf)$	N/A
Input values which contain at least one NaN, Inf, or –Inf, i.e. $\{(fltIn,\ fltAcc,\ fltLambda) \in X \mid X \cap M \neq \varnothing\}$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)
Normalized or zero input values which lead to normalized or zero fltAcc output, i.e. $\left\{\begin{array}{c}(fltIn,\ fltAcc,\ fltLambda) \in X \mid \\ X \subset N \cup \{-0,\ +0\}, \\ mr_1 \in N \cup \{-0,\ +0\},\ mr_2 \in N \cup \{-0,\ +0\}, \\ refResult = 0 \vee \\ \left(\begin{array}{c}\lvert refResult\rvert - me_1 \cdot \mathrm{ULP}(refResult) \notin D \wedge \\ \lvert refResult\rvert + me_1 \cdot \mathrm{ULP}(refResult) \neq Inf\end{array}\right), \\ refState = 0 \vee \\ \left(\begin{array}{c}\lvert refState\rvert - me_2 \cdot \mathrm{ULP}(refState) \notin D \wedge \\ \lvert refState\rvert + me_2 \cdot \mathrm{ULP}(refState) \neq Inf\end{array}\right)\end{array}\right\}$	$\langle -me_2, me_2\rangle$	N/A

Subset of input domain	Worst-case error bounds for fltAcc output [ulp]	Allowed specific values (regardless the error bounds) for fltAcc output
Normalized or zero input values which cause *fltAcc* output overflow, i.e. $\left\{\begin{array}{c}(fltIn, fltAcc, fltLambda) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ \lvert refState \rvert + me_2 \cdot \mathrm{ULP}(refState) \in M\end{array}\right\}$	$(-Inf, Inf)$	{Inf, -Inf, NaN}
Normalized or zero input values which cause *fltAcc* output underflow, i.e. $\left\{\begin{array}{c}(fltIn, fltAcc, fltLambda) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ \lvert refState \rvert - me_2 \cdot \mathrm{ULP}(refState) \in D \wedge \\ refState \neq 0\end{array}\right\}$	$(-Inf, Inf)$	N/A
Normalized or zero input values which cause intermediate results overflow, i.e. $\left\{\begin{array}{c}(fltIn, fltAcc, fltLambda) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ mr_1 \in \{Inf, -Inf\}, \\ \lvert mr_2 \rvert + 2 \cdot me_1 \cdot \mathrm{ULP}(mr_2) = Inf\end{array}\right\}$	$(-Inf, Inf)$	{Inf, -Inf, NaN}
Normalized or zero input values which cause intermediate results underflow, i.e. $\left\{\begin{array}{c}(fltIn, fltAcc, fltLambda) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ mr_1 \in D \vee \\ \left(\begin{array}{c}refResult \neq 0 \wedge \\ \lvert refResult \rvert - me_1 \cdot \mathrm{ULP}(refResult) \in D\end{array}\right) \vee \\ (mr_2 \neq 0 \wedge \lvert mr_2 \rvert - 2 \cdot me_1 \cdot \mathrm{ULP}(mr_2) \in D)\end{array}\right\}$	$(-Inf, Inf)$	N/A

2.12 Function GFLIB_Acos_FLT

Declaration

```
tFloat GFLIB_Acos_FLT(tFloat fltIn, const GFLIB_ACOS_T_FLT *const
pParam);
```

Arguments

Table 66. GFLIB_Acos_FLT arguments

Type	Name	Direction	Description
tFloat	fltIn	**input**	Input argument is a 32-bit number that contains a single precision floating point value.
const GFLIB_ACOS_T_FLT *const	pParam	**input**	Pointer to an array of approximation coefficients. In case the default approximation coefficients are used, the &pParam must be replaced with GFLIB_ACOS_DEFAULT_FLT symbol.

Worst-Case Error Bounds

Only the default approximation coefficients are considered.

Let $fltIn \in X$ be an input to GFLIB_Acos_FLT,

then

Table 67. GFLIB_Acos_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Input NaN or infinity, i.e. $\{ fltIn \in X \mid fltIn \in M \}$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)
Input denormalized, normalized or zero, and within the allowed input interval, i.e. $\left\{ \begin{matrix} fltIn \in X \mid X \cap M = \emptyset, \\ -1 \leq fltIn \leq 1 \end{matrix} \right\}$	$\langle -130,130 \rangle$	N/A
Input normalized and beyond the allowed range, i.e. $\left\{ \begin{matrix} fltIn \in X \mid X \cap M = \emptyset, \\ fltIn < -1 \vee fltIn > 1 \end{matrix} \right\}$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)

2.13 Function GFLIB_Asin_FLT

Declaration

```
tFloat GFLIB_Asin_FLT(tFloat fltIn, const GFLIB_ASIN_T_FLT *const
pParam);
```

Arguments

Table 68. GFLIB_Asin_FLT arguments

Type	Name	Direction	Description
tFloat	fltIn	**input**	Input argument is a 32-bit number that contains a single precision floating point value.

Type	Name	Direction	Description
const GFLIB_ASIN_T_FLT *const	pParam	**input**	Pointer to an array of approximation coefficients. In case the default approximation coefficients are used, the &pParam must be replaced with GFLIB_ASIN_DEFAULT_FLT symbol.

Worst-Case Error Bounds

Only the default approximation coefficients are considered.

Let $fltIn \in X$ be an input to GFLIB_Asin_FLT,

then

Table 69. GFLIB_Asin_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Input NaN or infinity, i.e. $\{fltIn \in X \mid fltIn \in M\}$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)
Input denormalized, normalized or zero, and within the allowed input interval, i.e. $\left\{ fltIn \in X \mid X \cap M = \varnothing, -1 \le fltIn \le 1 \right\}$	$\langle -155, 155 \rangle$	N/A
Input normalized and beyond the allowed range, i.e. $\left\{ fltIn \in X \mid X \cap M = \varnothing, fltIn < -1 \vee fltIn > 1 \right\}$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)

2.14 Function GFLIB_Atan_FLT

Declaration

```
tFloat GFLIB_Atan_FLT(tFloat fltIn, const GFLIB_ATAN_T_FLT *const
pParam);
```

Arguments

Table 70. GFLIB_Atan_FLT arguments

Type	Name	Direction	Description
tFloat	fltIn	**input**	Input argument is a single precision floating point number between $(-2^{128}, 2^{128})$.
const GFLIB_ATAN_T_FLT *const	pParam	**input**	Pointer to an array of rational polynomial coefficients. In case the default approximation coefficients are used, the &pParam must be replaced with GFLIB_ATAN_DEFAULT_FLT symbol.

Worst-Case Error Bounds

Only the default approximation coefficients are considered.

Let *fltIn* ∊ *X* be a an input to GFLIB_Atan_FLT,

then

Table 71. GFLIB_Atan_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Input NaN, i.e. $\{fltIn \in X \mid fltIn = NaN\}$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)
Input not a NaN, i.e. $\{fltIn \in X \mid fltIn \neq NaN,\}$	⟨-3,3⟩	N/A

2.15 Function GFLIB_AtanYX_FLT

Declaration

```
tFloat GFLIB_AtanYX_FLT(tFloat fltInY, tFloat fltInX);
```

Arguments

Table 72. GFLIB_AtanYX_FLT arguments

Type	Name	Direction	Description
tFloat	fltInY	**input**	The ordinate of the input vector (y coordinate).
tFloat	fltInX	**input**	The abscissa of the input vector (x coordinate).

Worst-Case Error Bounds

Let (*fltInX*, *fltInY*) ∊ *X* be a set of inputs to GFLIB_AtanYX_FLT,

refResult be the theoretical exact result,

then

Table 73. GFLIB_AtanYX_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Any of the inputs is denormalized, NaN, or invinity, i.e. $\{(fltInY, fltInX) \in X \mid X \cap M \neq \emptyset \vee X \cap D \neq \emptyset\}$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Both inputs are normalized or zero, results normalized or zero, i.e. $$\left\{\begin{array}{c}(fltInY, fltInX) \in X \mid X \subset N \cup \{-0, +0\}, \\ \frac{fltInY}{fltInX} \in N \cup \{-0, +0\}, \\ refResult = 0 \vee \\ \left(\begin{array}{c}\lvert refResult\rvert - 3.5 \cdot \mathrm{ULP}(refResult) \notin D \wedge \\ \lvert refResult\rvert + 3.5 \cdot \mathrm{ULP}(refResult) \neq Inf\end{array}\right)\end{array}\right\}$$	$\langle -3.5, 3.5\rangle$	N/A
Both inputs are normalized or zero, result underflow, i.e. $$\left\{\begin{array}{c}(fltInY, fltInX) \in X \mid X \subset N \cup \{-0, +0\} \\ \lvert refResult\rvert - 3.5 \cdot \mathrm{ULP}(refResult) \in D \wedge \\ refResult \neq 0\end{array}\right\}$$	$(-Inf, Inf)$	N/A
Both inputs are normalized or zero, intermediate result overflow, i.e. $$\left\{\begin{array}{c}(fltInY, fltInX) \in X \mid X \subset N \cup \{-0, +0\} \\ \frac{fltInY}{fltInX} \in \{Inf, -Inf\}\end{array}\right\}$$	$(-Inf, Inf)$	{NaN, -Inf, Inf}

2.16 Function GFLIB_AtanYXShifted_FLT

Declaration

```
tFloat GFLIB_AtanYXShifted_FLT(tFloat fltInY, tFloat fltInX,
const GFLIB_ATANYXSHIFTED_T_FLT *pParam);
```

Arguments

Table 74. GFLIB_AtanYXShifted_FLT arguments

Type	Name	Direction	Description
tFloat	fltInY	**input**	The value of the first signal, assumed to be sin (θ).
tFloat	fltInX	**input**	The value of the second signal, assumed to be sin(θ + Δθ).
const GFLIB_ ATANYXSHIFTED_T_ FLT *	pParam	**input, output**	The parameters for the function.

Worst-Case Error Bounds

Let (*fltInX*, *fltInY*, *fltKx*, *fltKy*, *fltThetaAdj*) ∊ *X* be a set of inputs to GFLIB_AtanYXShifted_FLT,

$ir_1 = fltInY + fltInX$,

$ir_2 = ir_1 \cdot fltKy$,

$ir_3 = fltInX - fltInY$,

$ir_4 = ir_3 \cdot fltKx$,

$ir_6 = \mathrm{atan2}(ir_2, ir_4)$, where ir_2 is the *y* coordinate and ir_4 is the *x* coordinate and atan2(*y*, *x*) is the four-quadrant arctangent function,

$ir_7 = ir_6 - fltThetaAdj$,

$ie_1 = \max(\mathrm{fe}(ir_6 - 10 \cdot \mathrm{ULP}(ir_6)), \mathrm{fe}(ir_6 + 13.5 \cdot \mathrm{ULP}(ir_6)), \mathrm{fe}(fltThetaAdj))$,

$ie_2 = \mathrm{fe}(ir_7)$,

$$cb_1 = \begin{cases} 0, & ie_1 - ie_2 \le 0 \\ ie_1 - ie_2, & ie_1 - ie_2 > 0 \end{cases},$$

$me_1 = 0.5 + 13.5 \cdot 2^{cb_1}$,

$ie_3 = \max(\mathrm{fe}(ir_7 - me_1 \cdot \mathrm{ULP}(ir_7)), \mathrm{fe}(ir_7 + me_1 \cdot \mathrm{ULP}(ir_7)), \mathrm{fe}(2\pi))$,

$ie_4 = \mathrm{fe}(refResult)$,

$$cb_2 = \begin{cases} 0, & ie_3 - ie_4 \le 0 \\ ie_3 - ie_4, & ie_3 - ie_4 > 0 \end{cases},$$

$me_2 = 0.5 + (me_1 + 0.5) \cdot 2^{cb_2}$,

$$me_3 = \begin{cases} me_2, & (ir_7 + me_1 \cdot \mathrm{ULP}(ir_7) > \pi) \text{ or } (ir_7 - me_1 \cdot \mathrm{ULP}(ir_7) < -\pi) \\ me_1, & otherwise \end{cases},$$

refResult be the theoretical exact result,

then

Table 75. GFLIB_AtanYXShifted_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{ \begin{array}{c} (fltInX, fltInY, fltKx, fltKy, fltThetaAdj) \in X \\ X \subset N \cup \{-0, +0\}, \\ \{ir_1, ir_2, ir_3, ir_4, ir_5, ir_6, ir_7\} \subset N \cup \{-0, +0\}, \\ refResult = 0 \vee \\ \left(\begin{array}{c} \lvert refResult \rvert - me_3 \cdot \mathrm{ULP}(refResult) \notin D \wedge \\ \lvert refResult \rvert + me_3 \cdot \mathrm{ULP}(refResult) \ne Inf \end{array} \right) \end{array} \right\vert \left. \right\}$	$\langle -me_3, me_3 \rangle$	N/A
Input values which contain at least one NaN, Inf, or -Inf, i.e. $\left\{ \begin{array}{c} (fltInX, fltInY, fltKx, fltKy, fltThetaAdj) \in X \\ X \cap M \ne \varnothing \end{array} \right\vert \left. \right\}$	N/A	Arbitrary floating-point value (including Inf, -Inf, NaN)

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Input values which contain at least one denormalized number while other inputs are normalized or zero, i.e. $$\left\{ (fltInX, fltInY, fltKx, fltKy, fltThetaAdj) \in X \;\middle|\; X \cap M = \varnothing \wedge X \cap D \neq \varnothing \right\}$$	N/A	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which cause result underflow, i.e. $$\left\{ (fltInX, fltInY, fltKx, fltKy, fltThetaAdj) \in X \;\middle|\; \begin{array}{c} X \subset N \cup \{-0, +0\}, \\ \lvert refResult \rvert - me_3 \cdot \mathrm{ULP}(refResult) \in D \wedge \\ refResult \neq 0 \end{array} \right\}$$	$(-Inf, Inf)$	N/A
Normalized or zero input values which cause intermediate result overflow, i.e. $$\left\{ (fltInX, fltInY, fltKx, fltKy, fltThetaAdj) \in X \;\middle|\; \begin{array}{c} X \subset N \cup \{-0, +0\}, \\ \left\{ \begin{array}{c} ir_1, \lvert ir_2 \rvert + 1.5 \cdot \mathrm{ULP}(ir_2), \\ ir_3, \lvert ir_4 \rvert + 1.5 \cdot \mathrm{ULP}(ir_4), \\ \frac{\lvert ir_2 \rvert + 1.5 \cdot \mathrm{ULP}(ir_2)}{\lvert ir_4 \rvert - 1.5 \cdot \mathrm{ULP}(ir_4)} \end{array} \right\} \cap M \neq \varnothing \end{array} \right\}$$	$(-Inf, Inf)$	{Inf, -Inf, NaN}
Normalized or zero input values which cause intermediate result underflow, i.e. $$\left\{ (fltInX, fltInY, fltKx, fltKy, fltThetaAdj) \in X \;\middle|\; \begin{array}{c} X \subset N \cup \{-0, +0\}, \\ \left\{ \begin{array}{c} ir_1, \lvert ir_2 \rvert - 1.5 \cdot \mathrm{ULP}(ir_2), \\ ir_3, \lvert ir_4 \rvert - 1.5 \cdot \mathrm{ULP}(ir_4), \\ \frac{\lvert ir_2 \rvert - 1.5 \cdot \mathrm{ULP}(ir_2)}{\lvert ir_4 \rvert + 1.5 \cdot \mathrm{ULP}(ir_4)}, \\ \lvert ir_6 \rvert - 13.5 \cdot \mathrm{ULP}(ir_6), \\ \lvert ir_7 \rvert - me_1 \cdot \mathrm{ULP}(ir_7), \end{array} \right\} \cap D \neq \varnothing, \\ ir_2 \neq 0, ir_4 \neq 0, ir_5 \neq 0, ir_6 \neq 0, ir_7 \neq 0 \end{array} \right\}$$	$(-Inf, Inf)$	{Inf, -Inf, NaN}

2.17 Function GFLIB_ControllerPIDpAW_FLT

Declaration

```
tFloat GFLIB_ControllerPIDpAW_FLT(tFloat fltInErr,
GFLIB_CONTROLLER_PID_P_AW_T_FLT *const pParam);
```

Arguments

Table 76. GFLIB_ControllerPIDpAW_FLT arguments

Type	Name	Direction	Description
tFloat	fltInErr	**input**	Input error signal to the controller in single precision floating format.
GFLIB_CONTROLLER_PID_P_AW_T_FLT *const	pParam	**input, output**	Pointer to the controller parameters structure.

Worst-Case Error Bounds

Let (*fltInErr*, *fltPropGain*, *fltIntegGain*, *fltDerivGain*, *fltFiltCoef*, *fltLowerLimit*, *fltUpperLimit*, *fltIntegPartK_1*, *fltDerivPartK_1*, *fltInK_1*) ∈ *X* be a set of inputs to GFLIB_ControllerPIDpAW_FLT,

fltIntegPartK_1 input represents a real number with an error of max. ±0.5 ulp,

fltDerivPartK_1 input represents a real number with an error of max. ±0.5 ulp,

refResult be the theoretical exact result,

$$ir_1 = (fltInErr + fltInK\_1) \cdot fltIntegGain,$$

$$ie_1 = \max(\mathrm{fe}(|ir_1| + \mathrm{ULP}(ir_1)), \mathrm{fe}(|fltIntegPartK\_1| + 0.5 \cdot \mathrm{ULP}(fltIntegPartK\_1))),$$

$$refInteg = fltIntegPartK_1 + ir_1,$$

$$ie_2 = fe(refInteg),$$

$$cb_1 = \begin{cases} 0, & ie_1 - ie_2 \le 0 \\ ie_1 - ie_2, & ie_1 - ie_2 > 0 \end{cases}$$

$$me_1 = \begin{cases} 0, & refInteg + (0.5 + 1.5 \cdot 2^{cb_1}) \cdot \mathrm{ULP}(refInteg) < fltLowerLimit \\ 0, & refInteg - (0.5 + 1.5 \cdot 2^{cb_1}) \cdot \mathrm{ULP}(refInteg) > fltUpperLimit \\ 0.5 + 1.5 \cdot 2^{cb_1}, & \text{otherwise} \end{cases}$$

$$ir_2 = fltInErr \cdot fltDerivGain,$$

$$ir_3 = fltInK\_1 \cdot fltDerivGain,$$

$$ie_3 = \max(\mathrm{fe}(|ir_2| + 0.5 \cdot \mathrm{ULP}(ir_2)), \mathrm{fe}(|ir_3| + 1 \cdot \mathrm{ULP}(ir_3))),$$

$$ir_4 = ir_2 - ir_3,$$

$$ie_4 = fe(ir_4),$$

$$cb_2 = \begin{cases} 0, & ie_3 - ie_4 \le 0 \\ ie_3 - ie_4, & ie_3 - ie_4 > 0 \end{cases},$$

$$me_2 = 0.5 + 1.5 \cdot 2^{cb_2},$$

$$ir_5 = fltDerivPartK_1 \cdot fltFiltCoef,$$

$$ie_5 = \max(\mathrm{fe}(|ir_4| + me_2 \cdot \mathrm{ULP}(ir_4)), \mathrm{fe}(|ir_5| + 1 \cdot \mathrm{ULP}(ir_5))),$$

$$refDeriv = ir_4 + ir_5,$$

$$ie_6 = fe(refDeriv),$$

$$cb_3 = \begin{cases} 0, & ie_5 - ie_6 \le 0 \\ ie_5 - ie_6, & ie_5 - ie_6 > 0 \end{cases},$$

$$me_3 = 0.5 + (me_2 + 1) \cdot 2^{cb_3},$$

$$ir_6 = fltInErr \cdot fltPropGain,$$

$$ie_7 = \max(\mathrm{fe}(|refInteg| + me_1 \cdot \mathrm{ULP}(refInteg)), \mathrm{fe}(|ir_6| + 0.5 \cdot \mathrm{ULP}(ir_6))),$$

$$ir_7 = refInteg + ir_6,$$

$$ie_8 = fe(ir_7),$$

$$cb_4 = \begin{cases} 0, & ie_7 - ie_8 \le 0 \\ ie_7 - ie_8, & ie_7 - ie_8 > 0 \end{cases},$$

$$me_4 = 0.5 + (me_1 + 0.5) \cdot 2^{cb_4},$$

$$ie_8 = \max(\mathrm{fe}(|refDeriv| + me_3 \cdot \mathrm{ULP}(refDeriv)), \mathrm{fe}(|ir_7| + me_4 \cdot \mathrm{ULP}(ir_7))),$$

$$ie_9 = fe(refResult),$$

$$cb_5 = \begin{cases} 0, & ie_8 - ie_9 \le 0 \\ ie_8 - ie_9, & ie_8 - ie_9 > 0 \end{cases},$$

$$me_5 = \begin{cases} 0, & refResult + \left(0.5 + (me_3 + me_4) \cdot 2^{cb_5}\right) \cdot \mathrm{ULP}(refResult) < fltLowerLimit \\ 0, & refResult - \left(0.5 + (me_3 + me_4) \cdot 2^{cb_5}\right) \cdot \mathrm{ULP}(refResult) > fltUpperLimit \\ 0.5 + (me_3 + me_4) \cdot 2^{cb_5}, & \text{otherwise} \end{cases}$$

then

Table 77. GFLIB_ControllerPIDpAW_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Any of the inputs is denormalized, others are normalized or zero, i.e. $\left\{ \begin{pmatrix} fltInErr, fltPropGain, fltIntegGain, \\ fltDerivGain, \; fltFiltCoef, \\ fltLowerLimit, \; fltUpperLimit, \\ fltIntegPartK\_1, fltDerivPartK\_1 \end{pmatrix} \in X \;\middle|\; X \cap D \ne \varnothing \wedge X \cap M = \varnothing \right\}$	$(-Inf, Inf)$	N/A
Any of the inputs is NaN or infinity, i.e. $\left\{ \begin{pmatrix} fltInErr, fltPropGain, fltIntegGain, \\ fltDerivGain, \; fltFiltCoef, \\ fltLowerLimit, \; fltUpperLimit, \\ fltIntegPartK\_1, fltDerivPartK\_1 \end{pmatrix} \in X \;\middle|\; X \cap M \ne \varnothing \right\}$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{ \begin{array}{c} \left. \begin{pmatrix} fltInErr, fltPropGain, fltIntegGain, \\ fltDerivGain, \quad fltFiltCoef, \\ fltLowerLimit, \quad fltUpperLimit, \\ fltIntegPartK\_1, fltDerivPartK\_1 \end{pmatrix} \in X \right\vert \\ X \subset N \cup \{-0, +0\}, \\ \{ir_1, ir_2, ir_3, ir_4, ir_5, ir_6, ir_7\} \subset N \cup \{-0, +0\}, \\ \{refInteg, refDeriv\} \subset N \cup \{-0, +0\}, \\ refResult = 0 \vee \\ \begin{pmatrix} \lvert refResult \rvert - me_5 \cdot \mathrm{ULP}(refResult) \notin D \wedge \\ \lvert refResult \rvert + me_5 \cdot \mathrm{ULP}(refResult) \neq Inf \end{pmatrix} \end{array} \right\}$	$\langle -me_5, me_5 \rangle$	N/A
Normalized or zero input values which cause result underflow, i.e. $\left\{ \begin{array}{c} \left. \begin{pmatrix} fltInErr, fltPropGain, fltIntegGain, \\ fltDerivGain, \quad fltFiltCoef, \\ fltLowerLimit, \quad fltUpperLimit, \\ fltIntegPartK\_1, fltDerivPartK\_1 \end{pmatrix} \in X \right\vert \\ X \subset N \cup \{-0, +0\}, \\ \lvert refResult \rvert - me_5 \cdot \mathrm{ULP}(refResult) \notin D \wedge \\ refResult \neq 0 \end{array} \right\}$	$(-Inf, Inf)$	N/A
Normalized or zero input values which cause result overflow, i.e. $\left\{ \begin{array}{c} \left. \begin{pmatrix} fltInErr, fltPropGain, fltIntegGain, \\ fltDerivGain, \quad fltFiltCoef, \\ fltLowerLimit, \quad fltUpperLimit, \\ fltIntegPartK\_1, fltDerivPartK\_1 \end{pmatrix} \in X \right\vert \\ X \subset N \cup \{-0, +0\}, \\ \lvert refResult \rvert + me_5 \cdot \mathrm{ULP}(refResult) = Inf \end{array} \right\}$	$(-Inf, Inf)$	{Inf, –Inf, NaN}

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Normalized or zero input values which cause intermediate result underflow, i.e. $$\left\{ \left. \begin{pmatrix} fltInErr,\ fltPropGain,\ fltIntegGain, \\ fltDerivGain,\ \ fltFiltCoef, \\ fltLowerLimit,\ \ fltUpperLimit, \\ fltIntegPartK\_1,\ fltDerivPartK\_1 \end{pmatrix} \in X \right\vert \begin{matrix} X \subset N \cup \{-0,\ +0\}, \\ \left\{ \begin{matrix} \lvert ir_1 \rvert - 0.5 \cdot \mathrm{ULP}(ir_1), \\ \lvert ir_2 \rvert - 0.5 \cdot \mathrm{ULP}(ir_2), \\ \lvert ir_3 \rvert - 1 \cdot \mathrm{ULP}(ir_3), \\ \lvert refInteg \rvert - me_1 \cdot \mathrm{ULP}(refInteg), \\ \lvert ir_4 \rvert - me_2 \cdot \mathrm{ULP}(ir_4), \\ \lvert ir_5 \rvert - 1 \cdot \mathrm{ULP}(ir_5), \\ \lvert refDeriv \rvert - me_3 \cdot \mathrm{ULP}(refDeriv), \\ \lvert ir_6 \rvert - 0.5 \cdot \mathrm{ULP}(ir_6), \\ \lvert ir_7 \rvert - me_4 \cdot \mathrm{ULP}(ir_7), \end{matrix} \right\} \cap D \neq \varnothing \wedge \\ \{ir_1, ir_2, ir_3, ir_4, ir_5, ir_6, ir_7, refInteg, refDeriv\} \notin \{-0,\ +0\} \end{matrix} \right\}$$	$(-Inf, Inf)$	{Inf, –Inf, NaN}
Normalized or zero input values which cause intermediate result overflow, i.e. $$\left\{ \left. \begin{pmatrix} fltInErr,\ fltPropGain,\ fltIntegGain, \\ fltDerivGain,\ \ fltFiltCoef, \\ fltLowerLimit,\ \ fltUpperLimit, \\ fltIntegPartK\_1,\ fltDerivPartK\_1 \end{pmatrix} \in X \right\vert \begin{matrix} X \subset N \cup \{-0,\ +0\}, \\ \left\{ \begin{matrix} \lvert ir_1 \rvert + 0.5 \cdot \mathrm{ULP}(ir_1), \\ \lvert ir_2 \rvert + 0.5 \cdot \mathrm{ULP}(ir_2), \\ \lvert ir_3 \rvert + 1 \cdot \mathrm{ULP}(ir_3), \\ \lvert refInteg \rvert + me_1 \cdot \mathrm{ULP}(refInteg), \\ \lvert ir_4 \rvert + me_2 \cdot \mathrm{ULP}(ir_4), \\ \lvert ir_5 \rvert + 1 \cdot \mathrm{ULP}(ir_5), \\ \lvert refDeriv \rvert + me_3 \cdot \mathrm{ULP}(refDeriv), \\ \lvert ir_6 \rvert + 0.5 \cdot \mathrm{ULP}(ir_6), \\ \lvert ir_7 \rvert + me_4 \cdot \mathrm{ULP}(ir_7), \end{matrix} \right\} \cap M \neq \varnothing \end{matrix} \right.$$	$(-Inf, Inf)$	{Inf, –Inf, NaN}

Table 78. GFLIB_ControllerPIDpAW_FLT Worst-Case Error Bounds - fltIntegPartK_1 Output

Subset of input domain	Worst-case error bounds for fltIntegPartK_1 output [ulp]	Allowed specific values (regardless the error bounds) for fltIntegPartK_1 output
Any of the inputs is denormalized, others are normalized or zero, i.e. $$\left\{\left.\begin{pmatrix} fltInErr, fltPropGain, fltIntegGain, \\ fltDerivGain, \ fltFiltCoef, \\ fltLowerLimit, \ fltUpperLimit, \\ fltIntegPartK\_1, fltDerivPartK\_1 \end{pmatrix} \in X \right\| \begin{array}{c} \\ X \cap D \neq \varnothing \wedge X \cap M = \varnothing \end{array}\right\}$$	$(-Inf, Inf)$	N/A
Any of the inputs is NaN or infinity, i.e. $$\left\{\left.\begin{pmatrix} fltInErr, fltPropGain, fltIntegGain, \\ fltDerivGain, \ fltFiltCoef, \\ fltLowerLimit, \ fltUpperLimit, \\ fltIntegPartK\_1, fltDerivPartK\_1 \end{pmatrix} \in X \right\| \begin{array}{c} \\ X \cap M \neq \varnothing \end{array}\right\}$$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $$\left\{\left.\begin{pmatrix} fltInErr, fltPropGain, fltIntegGain, \\ fltDerivGain, \ fltFiltCoef, \\ fltLowerLimit, \ fltUpperLimit, \\ fltIntegPartK\_1, fltDerivPartK\_1 \end{pmatrix} \in X \right\| \begin{array}{c} X \subset N \cup \{-0, +0\}, \\ ir_1 \in N \cup \{-0, +0\}, \\ refInteg = 0 \vee \\ \begin{pmatrix} \lvert refInteg \rvert - me_1 \cdot \mathrm{ULP}(refInteg) \notin D \wedge \\ \lvert refInteg \rvert + me_1 \cdot \mathrm{ULP}(refInteg) \neq Inf \end{pmatrix} \end{array}\right\}$$	$\langle -me_1, me_1 \rangle$	N/A
Normalized or zero input values which cause *fltIntegPartK_1* output underflow, i.e. $$\left\{\left.\begin{pmatrix} fltInErr, fltPropGain, fltIntegGain, \\ fltDerivGain, \ fltFiltCoef, \\ fltLowerLimit, \ fltUpperLimit, \\ fltIntegPartK\_1, fltDerivPartK\_1 \end{pmatrix} \in X \right\| \begin{array}{c} X \subset N \cup \{-0, +0\}, \\ \lvert refInteg \rvert - me_1 \cdot \mathrm{ULP}(refInteg) \notin D \wedge \\ refInteg \neq 0 \end{array}\right\}$$	$(-Inf, Inf)$	N/A

Subset of input domain	Worst-case error bounds for fltIntegPartK_1 output [ulp]	Allowed specific values (regardless the error bounds) for fltIntegPartK_1 output
Normalized or zero input values which cause *fltIntegPartK_1* output overflow, i.e. $$\left\{ \begin{pmatrix} fltInErr, fltPropGain, fltIntegGain, \\ fltDerivGain, \ fltFiltCoef, \\ fltLowerLimit, \ fltUpperLimit, \\ fltIntegPartK\_1, fltDerivPartK\_1 \end{pmatrix} \in X \middle\vert \begin{array}{c} X \subset N \cup \{-0, +0\}, \\ \lvert refInteg \rvert + me_1 \cdot \mathrm{ULP}(refInteg) \neq Inf \end{array} \right\}$$	$(-Inf, Inf)$	{Inf, –Inf, NaN}
Normalized or zero input values which cause intermediate result underflow, i.e. $$\left\{ \begin{pmatrix} fltInErr, fltPropGain, fltIntegGain, \\ fltDerivGain, \ fltFiltCoef, \\ fltLowerLimit, \ fltUpperLimit, \\ fltIntegPartK\_1, fltDerivPartK\_1 \end{pmatrix} \in X \middle\vert \begin{array}{c} X \subset N \cup \{-0, +0\}, \\ \{ \lvert ir_1 \rvert - 0.5 \cdot \mathrm{ULP}(ir_1) \} \cap D \neq \varnothing \wedge \\ ir_1 \notin \{-0, +0\} \end{array} \right\}$$	$(-Inf, Inf)$	{Inf, –Inf, NaN}
Normalized or zero input values which cause intermediate result overflow, i.e. $$\left\{ \begin{pmatrix} fltInErr, fltPropGain, fltIntegGain, \\ fltDerivGain, \ fltFiltCoef, \\ fltLowerLimit, \ fltUpperLimit, \\ fltIntegPartK\_1, fltDerivPartK\_1 \end{pmatrix} \in X \middle\vert \begin{array}{c} X \subset N \cup \{-0, +0\}, \\ \{ \lvert ir_1 \rvert - 0.5 \cdot \mathrm{ULP}(ir_1) \} \cap M \neq \varnothing \end{array} \right\}$$	$(-Inf, Inf)$	{Inf, –Inf, NaN}

Table 79. GFLIB_ControllerPIDpAW_FLT Worst-Case Error Bounds - fltDerivPartK_1 Output

Subset of input domain	Worst-case error bounds for fltDerivPartK_1 output [ulp]	Allowed specific values (regardless the error bounds) for fltDerivPartK_1 output
Any of the inputs is denormalized, others are normalized or zero, i.e. $$\left\{ \begin{pmatrix} fltInErr, fltPropGain, fltIntegGain, \\ fltDerivGain, \ fltFiltCoef, \\ fltLowerLimit, \ fltUpperLimit, \\ fltIntegPartK\_1, fltDerivPartK\_1 \end{pmatrix} \in X \middle\vert X \cap D \neq \varnothing \wedge X \cap M = \varnothing \right\}$$	$(-Inf, Inf)$	N/A

Subset of input domain	Worst-case error bounds for fltDerivPartK_1 output [ulp]	Allowed specific values (regardless the error bounds) for fltDerivPartK_1 output
Any of the inputs is NaN or infinity, i.e. $$\left\{ \left(\begin{matrix} fltInErr,\ fltPropGain,\ fltIntegGain, \\ fltDerivGain,\ \ fltFiltCoef, \\ fltLowerLimit,\ \ fltUpperLimit, \\ fltIntegPartK\_1,\ fltDerivPartK\_1 \end{matrix} \right) \in X \ \middle|\ X \cap M \neq \varnothing \right\}$$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $$\left\{ \left(\begin{matrix} fltInErr,\ fltPropGain,\ fltIntegGain, \\ fltDerivGain,\ \ fltFiltCoef, \\ fltLowerLimit,\ \ fltUpperLimit, \\ fltIntegPartK\_1,\ fltDerivPartK\_1 \end{matrix} \right) \in X \ \middle|\ \begin{matrix} X \subset N \cup \{-0,\ +0\}, \\ \{ir_2, ir_3, ir_4, ir_5\} \subset N \cup \{-0,\ +0\}, \\ refInteg = 0 \vee \\ \left(\begin{matrix} \lvert refDeriv \rvert - me_3 \cdot \mathrm{ULP}(refDeriv) \notin D \wedge \\ \lvert refDeriv \rvert + me_3 \cdot \mathrm{ULP}(refDeriv) \neq Inf \end{matrix} \right) \end{matrix} \right\}$$	$\langle -me_1, me_1 \rangle$	N/A
Normalized or zero input values which cause *fltDerivPartK_1* output underflow, i.e. $$\left\{ \left(\begin{matrix} fltInErr,\ fltPropGain,\ fltIntegGain, \\ fltDerivGain,\ \ fltFiltCoef, \\ fltLowerLimit,\ \ fltUpperLimit, \\ fltIntegPartK\_1,\ fltDerivPartK\_1 \end{matrix} \right) \in X \ \middle|\ \begin{matrix} X \subset N \cup \{-0,\ +0\}, \\ \lvert refDeriv \rvert - me_3 \cdot \mathrm{ULP}(refDeriv) \notin D \wedge \\ refDeriv \neq 0 \end{matrix} \right\}$$	$(-Inf, Inf)$	N/A
Normalized or zero input values which cause *fltDerivPartK_1* output overflow, i.e. $$\left\{ \left(\begin{matrix} fltInErr,\ fltPropGain,\ fltIntegGain, \\ fltDerivGain,\ \ fltFiltCoef, \\ fltLowerLimit,\ \ fltUpperLimit, \\ fltIntegPartK\_1,\ fltDerivPartK\_1 \end{matrix} \right) \in X \ \middle|\ \begin{matrix} X \subset N \cup \{-0,\ +0\}, \\ \lvert refDeriv \rvert + me_3 \cdot \mathrm{ULP}(refDeriv) \neq Inf \end{matrix} \right\}$$	$(-Inf, Inf)$	{Inf, –Inf, NaN}

Subset of input domain	Worst-case error bounds for fltDerivPartK_1 output [ulp]	Allowed specific values (regardless the error bounds) for fltDerivPartK_1 output
Normalized or zero input values which cause intermediate result underflow, i.e. $$\left(\begin{array}{c} \left(\begin{array}{c} fltInErr, fltPropGain, fltIntegGain, \\ fltDerivGain, \; fltFiltCoef, \\ fltLowerLimit, \; fltUpperLimit, \\ fltIntegPartK\_1, fltDerivPartK\_1 \end{array} \right) \in X \\ X \subset N \cup \{-0, +0\}, \\ \left\{ \begin{array}{c} \lvert ir_2 \rvert - 0.5 \cdot \mathrm{ULP}(ir_2), \\ \lvert ir_3 \rvert - 1 \cdot \mathrm{ULP}(ir_3), \\ \lvert ir_4 \rvert - me_2 \cdot \mathrm{ULP}(ir_4), \\ \lvert ir_5 \rvert - 1 \cdot \mathrm{ULP}(ir_5), \end{array} \right\} \cap D \neq \varnothing \wedge \\ \{ir_2, ir_3, ir_4, ir_5\} \notin \{-0, +0\} \end{array} \right)$$	$(-Inf, Inf)$	{Inf, –Inf, NaN}
Normalized or zero input values which cause intermediate result overflow, i.e. $$\left(\begin{array}{c} \left(\begin{array}{c} fltInErr, fltPropGain, fltIntegGain, \\ fltDerivGain, \; fltFiltCoef, \\ fltLowerLimit, \; fltUpperLimit, \\ fltIntegPartK\_1, fltDerivPartK\_1 \end{array} \right) \in X \\ X \subset N \cup \{-0, +0\}, \\ \left\{ \begin{array}{c} \lvert ir_2 \rvert - 0.5 \cdot \mathrm{ULP}(ir_2), \\ \lvert ir_3 \rvert - 1 \cdot \mathrm{ULP}(ir_3), \\ \lvert ir_4 \rvert - me_2 \cdot \mathrm{ULP}(ir_4), \\ \lvert ir_5 \rvert - 1 \cdot \mathrm{ULP}(ir_5), \end{array} \right\} \cap M \neq \varnothing \end{array} \right)$$	$(-Inf, Inf)$	{Inf, –Inf, NaN}

Table 80. GFLIB_ControllerPIDpAW_FLT Worst-Case Error Bounds - fltInK_1 Output

Subset of input domain	Worst-case error bounds for fltInK_1 output [ulp]	Allowed specific values (regardless the error bounds) for fltInK_1 output
Entire input domain	0	*fltInErr*

2.18 Function GFLIB_ControllerPIp_FLT

Declaration

```
tFloat GFLIB_ControllerPIp_FLT(tFloat fltInErr,
GFLIB_CONTROLLER_PI_P_T_FLT *const pParam);
```

Arguments

Table 81. GFLIB_ControllerPIp_FLT arguments

Type	Name	Direction	Description
tFloat	fltInErr	**input**	Input error signal to the controller in single precision floating format.
GFLIB_CONTROLLER_PI_P_T_FLT *const	pParam	**input, output**	Pointer to the controller parameters structure.

Worst-Case Error Bounds

Let (*fltInErr*, *fltPropGain*, *fltIntegGain*, *fltIntegPartK_1*, *fltInK_1*) $\in X$ be a set of inputs to GFLIB_ControllerPIp_FLT,

fltIntegPartK_1 input represents a real number with an error of max. ±0.5 ulp,

refResult be the theoretical exact result,

$ir_1 = fltInErr + fltInK\_1$,

$ir_2 = ir_1 \cdot fltIntegGain$,

$ie_1 = \max(\mathrm{fe}(|ir_2| + \mathrm{ULP}(ir_2)), \mathrm{fe}(|fltIntegPartK\_1| + 0.5 \cdot \mathrm{ULP}(fltIntegPartK\_1)))$,

$refInteg = fltIntegPartK\_1 + ir_2$,

$ie_2 = \mathrm{fe}(refInteg)$,

$$cb_1 = \begin{cases} 0, & ie_1 - ie_2 \leq 0 \\ ie_1 - ie_2, & ie_1 - ie_2 > 0 \end{cases},$$

$me_1 = 0.5 + 1.5 \cdot 2^{cb_1}$,

$ir_3 = fltInErr \cdot fltPropGain$,

$ie_3 = \max(\mathrm{fe}(ir_3), \mathrm{fe}(|refInteg| + me_1 \cdot \mathrm{ULP}(refInteg)))$,

$ie_4 = \mathrm{fe}(refResult)$,

$$cb_2 = \begin{cases} 0, & ie_3 - ie_4 \leq 0 \\ ie_3 - ie_4, & ie_3 - ie_4 > 0 \end{cases},$$

$me_2 = 0.5 + me_1 \cdot 2^{cb_2}$,

then

Table 82. GFLIB_ControllerPIp_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Any of the inputs is denormalized, others are normalized or zero, i.e. $\left\{ \left(\begin{matrix} fltInErr, fltPropGain, fltIntegGain, \\ fltIntegPartK\_1, fltInK\_1 \end{matrix} \right) \in X \;\middle|\; X \cap D \neq \varnothing \wedge X \cap M = \varnothing \right\}$	$(-Inf, Inf)$	N/A

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Any of the inputs is NaN or infinity, i.e. $$\left\{ \begin{pmatrix} fltInErr,\ fltPropGain,\ fltIntegGain, \\ fltIntegPartK\_1,\ fltInK\_1 \end{pmatrix} \in X \;\middle|\; X \cap M \neq \varnothing \right\}$$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $$\left\{ \begin{pmatrix} fltInErr,\ fltPropGain,\ fltIntegGain, \\ fltIntegPartK\_1,\ fltInK\_1 \end{pmatrix} \in X \;\middle|\; \begin{matrix} X \subset N \cup \{-0,\ +0\}, \\ \{ir_1, ir_2, ir_3\} \subset N \cup \{-0,\ +0\}, \\ refInteg \in N \cup \{-0,\ +0\}, \\ refResult = 0 \vee \\ \begin{pmatrix} \lvert refResult \rvert - me_2 \cdot \mathrm{ULP}(refResult) \notin D \wedge \\ \lvert refResult \rvert + me_2 \cdot \mathrm{ULP}(refResult) \neq Inf \end{pmatrix} \end{matrix} \right\}$$	$\langle -me_2,\ me_2 \rangle$	N/A
Normalized or zero input values which cause result underflow, i.e. $$\left\{ \begin{pmatrix} fltInErr,\ fltPropGain,\ fltIntegGain, \\ fltIntegPartK\_1,\ fltInK\_1 \end{pmatrix} \in X \;\middle|\; \begin{matrix} X \subset N \cup \{-0,\ +0\}, \\ \lvert refResult \rvert - me_2 \cdot \mathrm{ULP}(refResult) \in D \wedge \\ refResult \neq 0 \end{matrix} \right\}$$	$(-Inf,\ Inf)$	N/A
Normalized or zero input values which cause result overflow, i.e. $$\left\{ \begin{pmatrix} fltInErr,\ fltPropGain,\ fltIntegGain, \\ fltIntegPartK\_1,\ fltInK\_1 \end{pmatrix} \in X \;\middle|\; \begin{matrix} X \subset N \cup \{-0,\ +0\}, \\ \lvert refResult \rvert + me_2 \cdot \mathrm{ULP}(refResult) = Inf \end{matrix} \right\}$$	$(-Inf,\ Inf)$	{Inf, –Inf, NaN}
Normalized or zero input values which cause intermediate result underflow, i.e. $$\left\{ \begin{pmatrix} fltInErr,\ fltPropGain,\ fltIntegGain, \\ fltIntegPartK\_1,\ fltInK\_1 \end{pmatrix} \in X \;\middle|\; \begin{matrix} X \subset N \cup \{-0,\ +0\}, \\ \left\{ \begin{matrix} \lvert ir_1 \rvert - 0.5 \cdot \mathrm{ULP}(ir_1), \\ \lvert ir_2 \rvert - \mathrm{ULP}(ir_2), \\ \lvert refInteg \rvert - me_1 \cdot \mathrm{ULP}(refInteg), \\ ir_3 \end{matrix} \right\} \cap D \neq \varnothing \wedge \\ \{ir_1, ir_2, ir_3, refInteg\} \notin \{-0,\ +0\} \end{matrix} \right\}$$	$(-Inf,\ Inf)$	{Inf, –Inf, NaN}

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Normalized or zero input values which cause intermediate result overflow, i.e. $$\left\{ \left(\begin{matrix} fltInErr, fltPropGain, fltIntegGain, \\ fltIntegPartK\_1, fltInK\_1 \end{matrix} \right) \in X \;\middle|\; \begin{matrix} X \subset N \cup \{-0, +0\}, \\ \left\{ \begin{matrix} \lvert ir_1 \rvert + 0.5 \cdot \mathrm{ULP}(ir_1), \\ \lvert ir_2 \rvert + \mathrm{ULP}(ir_2), \\ \lvert refInteg \rvert + me_1 \cdot \mathrm{ULP}(refInteg), \\ ir_3 \end{matrix} \right\} \cap M \neq \varnothing \end{matrix} \right\}$$	$(-Inf, Inf)$	{Inf, –Inf, NaN}

Table 83. GFLIB_ControllerPIp_FLT Worst-Case Error Bounds - fltIntegPartK_1 Output

Subset of input domain	Worst-case error bounds for fltIntegPartK_1 output [ulp]	Allowed specific values (regardless the error bounds) for fltIntegPartK_1 output
Any of the inputs is denormalized, others are normalized or zero, i.e. $$\left\{ \left(\begin{matrix} fltInErr, fltPropGain, fltIntegGain, \\ fltIntegPartK\_1, fltInK\_1 \end{matrix} \right) \in X \;\middle|\; X \cap D \neq \varnothing \wedge X \cap M = \varnothing \right\}$$	$(-Inf, Inf)$	N/A
Any of the inputs is NaN or infinity, i.e. $$\left\{ \left(\begin{matrix} fltInErr, fltPropGain, fltIntegGain, \\ fltIntegPartK\_1, fltInK\_1 \end{matrix} \right) \in X \;\middle|\; X \cap M \neq \varnothing \right\}$$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $$\left\{ \left(\begin{matrix} fltInErr, fltPropGain, fltIntegGain, \\ fltIntegPartK\_1, fltInK\_1 \end{matrix} \right) \in X \;\middle|\; \begin{matrix} X \subset N \cup \{-0, +0\}, \\ \{ir_1, ir_2\} \subset N \cup \{-0, +0\}, \\ refInteg = 0 \vee \\ \left(\begin{matrix} \lvert refInteg \rvert - me_1 \cdot \mathrm{ULP}(refInteg) \notin D \wedge \\ \lvert refInteg \rvert + me_1 \cdot \mathrm{ULP}(refInteg) \neq Inf \end{matrix} \right) \end{matrix} \right\}$$	$\langle -me_1, me_1 \rangle$	N/A

Subset of input domain	Worst-case error bounds for fltIntegPartK_1 output [ulp]	Allowed specific values (regardless the error bounds) for fltIntegPartK_1 output
Normalized or zero input values which cause *fltIntegPartK_1* output underflow, i.e. $$\left\{ \begin{array}{c} \begin{pmatrix} fltInErr,\ fltPropGain,\ fltIntegGain, \\ fltIntegPartK\_1,\ fltInK\_1 \end{pmatrix} \in X \\ X \subset N \cup \{-0, +0\}, \\ \lvert refInteg\rvert - me_1 \cdot \mathrm{ULP}(refInteg) \in D \wedge \\ refInteg \neq 0 \end{array} \right\}$$	$(-Inf, Inf)$	N/A
Normalized or zero input values which cause *fltIntegPartK_1* output overflow, i.e. $$\left\{ \begin{array}{c} \begin{pmatrix} fltInErr,\ fltPropGain,\ fltIntegGain, \\ fltIntegPartK\_1,\ fltInK\_1 \end{pmatrix} \in X \\ X \subset N \cup \{-0, +0\}, \\ \lvert refInteg\rvert + me_1 \cdot \mathrm{ULP}(refInteg) = Inf \end{array} \right\}$$	$(-Inf, Inf)$	{Inf, –Inf, NaN}
Normalized or zero input values which cause intermediate result underflow, i.e. $$\left\{ \begin{array}{c} \begin{pmatrix} fltInErr,\ fltPropGain,\ fltIntegGain, \\ fltIntegPartK\_1,\ fltInK\_1 \end{pmatrix} \in X \\ X \subset N \cup \{-0, +0\}, \\ \left\{ \begin{array}{c} \lvert ir_1\rvert - 0.5 \cdot \mathrm{ULP}(ir_1), \\ \lvert ir_2\rvert - \mathrm{ULP}(ir_2), \end{array} \right\} \cap D \neq \varnothing \wedge \\ \{ir_1, ir_2\} \notin \{-0, +0\} \end{array} \right\}$$	$(-Inf, Inf)$	{Inf, –Inf, NaN}
Normalized or zero input values which cause intermediate result overflow, i.e. $$\left\{ \begin{array}{c} \begin{pmatrix} fltInErr,\ fltPropGain,\ fltIntegGain, \\ fltIntegPartK\_1,\ fltInK\_1 \end{pmatrix} \in X \\ X \subset N \cup \{-0, +0\}, \\ \left\{ \begin{array}{c} \lvert ir_1\rvert + 0.5 \cdot \mathrm{ULP}(ir_1), \\ \lvert ir_2\rvert + \mathrm{ULP}(ir_2), \end{array} \right\} \cap M \neq \varnothing \end{array} \right\}$$	$(-Inf, Inf)$	{Inf, –Inf, NaN}

Table 84. GFLIB_ControllerPIp_FLT Worst-Case Error Bounds - fltInK_1 Output

Subset of input domain	Worst-case error bounds for fltInK_1 output [ulp]	Allowed specific values (regardless the error bounds) for fltInK_1 output
Entire input domain	0	*fltInErr*

2.19 Function GFLIB_ControllerPIpAW_FLT

Declaration

```
tFloat GFLIB_ControllerPIpAW_FLT(tFloat fltInErr,
GFLIB_CONTROLLER_PIAW_P_T_FLT *const pParam);
```

Arguments

Table 85. GFLIB_ControllerPIpAW_FLT arguments

Type	Name	Direction	Description
tFloat	fltInErr	**input**	Input error signal to the controller is a single precision floating point data type.
GFLIB_ CONTROLLER_ PIAW_P_T_FLT *const	pParam	**input, output**	Pointer to the controller parameters structure.

Worst-Case Error Bounds

Let (*fltInErr*, *fltPropGain*, *fltIntegGain*, *fltLowerLimit*, *fltUpperLimit*, *fltIntegPartK_1*, *fltInK_1*) $\in X$ be a set of inputs to GFLIB_ControllerPIpAW_FLT,

fltIntegPartK_1 input represents a real number with an error of max. ±0.5 ulp,

refResult be the theoretical exact result,

$$ir_1 = fltInErr + fltInK\_1,$$

$$ir_2 = ir_1 \cdot fltIntegGain,$$

$$ie_1 = \max(\mathrm{fe}(|ir_2| + \mathrm{ULP}(ir_2)), \mathrm{fe}(|fltIntegPartK\_1| + 0.5 \cdot \mathrm{ULP}(fltIntegPartK\_1))),$$

$$refInteg = fltIntegPartK\_1 + ir_2,$$

$$ie_2 = \mathrm{fe}(refInteg),$$

$$cb_1 = \begin{cases} 0, & ie_1 - ie_2 \le 0 \\ ie_1 - ie_2, & ie_1 - ie_2 > 0 \end{cases},$$

$$me_1 = \begin{cases} 0, & refInteg + \left(0.5 + 1.5 \cdot 2^{cb_1}\right) \cdot \mathrm{ULP}(refInteg) < fltLowerLimit \\ 0, & refInteg - \left(0.5 + 1.5 \cdot 2^{cb_1}\right) \cdot \mathrm{ULP}(refInteg) > fltUpperLimit \\ 0.5 + 1.5 \cdot 2^{cb_1}, & \text{otherwise} \end{cases},$$

$$ir_3 = fltInErr \cdot fltPropGain,$$

$$ie_3 = \max(\mathrm{fe}(ir_3), \mathrm{fe}(|refInteg| + me_1 \cdot \mathrm{ULP}(refInteg))),$$

$$ie_4 = \mathrm{fe}(refResult),$$

$$cb_2 = \begin{cases} 0, & ie_3 - ie_4 \le 0 \\ ie_3 - ie_4, & ie_3 - ie_4 > 0 \end{cases},$$

$$me_2 = 0.5 + me_1 \cdot 2^{cb_2},$$

then

Table 86. GFLIB_ControllerPIpAW_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Any of the inputs is denormalized, others are normalized or zero, i.e. $\left\{ \left(\begin{matrix} fltInErr,\ fltPropGain,\ fltIntegGain, \\ fltLowerLimit,\ fltUpperLimit, \\ fltIntegPartK\_1,\ fltInK\_1 \end{matrix} \right) \in X \middle\vert\; X \cap D \neq \varnothing \wedge X \cap M = \varnothing \right\}$	$(-Inf, Inf)$	N/A
Any of the inputs is NaN or infinity, i.e. $\left\{ \left(\begin{matrix} fltInErr,\ fltPropGain,\ fltIntegGain, \\ fltLowerLimit,\ fltUpperLimit, \\ fltIntegPartK\_1,\ fltInK\_1 \end{matrix} \right) \in X \middle\vert\; X \cap M \neq \varnothing \right\}$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{ \left(\begin{matrix} fltInErr,\ fltPropGain,\ fltIntegGain, \\ fltLowerLimit,\ fltUpperLimit, \\ fltIntegPartK\_1,\ fltInK\_1 \end{matrix} \right) \in X \middle\vert\; \begin{matrix} X \subset N \cup \{-0, +0\}, \\ \{ir_1, ir_2, ir_3\} \subset N \cup \{-0, +0\}, \\ refInteg \in N \cup \{-0, +0\}, \\ refResult = 0 \vee \\ \left(\begin{matrix} \lvert refResult \rvert - me_2 \cdot \mathrm{ULP}(refResult) \notin D \wedge \\ \lvert refResult \rvert + me_2 \cdot \mathrm{ULP}(refResult) \neq Inf \end{matrix} \right) \end{matrix} \right\}$	$\langle -me_2, me_2 \rangle$	N/A
Normalized or zero input values which cause result underflow, i.e. $\left\{ \left(\begin{matrix} fltInErr,\ fltPropGain,\ fltIntegGain, \\ fltLowerLimit,\ fltUpperLimit, \\ fltIntegPartK\_1,\ fltInK\_1 \end{matrix} \right) \in X \middle\vert\; \begin{matrix} X \subset N \cup \{-0, +0\}, \\ \lvert refResult \rvert - me_2 \cdot \mathrm{ULP}(refResult) \in D \wedge \\ refResult \neq 0 \end{matrix} \right\}$	$(-Inf, Inf)$	N/A
Normalized or zero input values which cause result overflow, i.e. $\left\{ \left(\begin{matrix} fltInErr,\ fltPropGain,\ fltIntegGain, \\ fltLowerLimit,\ fltUpperLimit, \\ fltIntegPartK\_1,\ fltInK\_1 \end{matrix} \right) \in X \middle\vert\; \begin{matrix} X \subset N \cup \{-0, +0\}, \\ \lvert refResult \rvert + me_2 \cdot \mathrm{ULP}(refResult) = Inf \end{matrix} \right\}$	$(-Inf, Inf)$	{Inf, –Inf, NaN}

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Normalized or zero input values which cause intermediate result underflow, i.e. $$\left\{ \begin{pmatrix} fltInErr, fltPropGain, fltIntegGain, \\ fltLowerLimit, fltUpperLimit, \\ fltIntegPartK\_1, fltInK\_1 \end{pmatrix} \in X \;\middle|\; \begin{array}{c} X \subset N \cup \{-0, +0\}, \\ \left\{ \begin{array}{c} \lvert ir_1 \rvert - 0.5 \cdot \mathrm{ULP}(ir_1), \\ \lvert ir_2 \rvert - \mathrm{ULP}(ir_2), \\ \lvert refInteg \rvert - me_1 \cdot \mathrm{ULP}(refInteg), \\ ir_3 \end{array} \right\} \cap D \neq \varnothing \wedge \\ \{ir_1, ir_2, ir_3, refInteg\} \notin \{-0, +0\} \end{array} \right\}$$	$(-Inf, Inf)$	{Inf, –Inf, NaN}
Normalized or zero input values which cause intermediate result overflow, i.e. $$\left\{ \begin{pmatrix} fltInErr, fltPropGain, fltIntegGain, \\ fltLowerLimit, fltUpperLimit, \\ fltIntegPartK\_1, fltInK\_1 \end{pmatrix} \in X \;\middle|\; \begin{array}{c} X \subset N \cup \{-0, +0\}, \\ \left\{ \begin{array}{c} \lvert ir_1 \rvert + 0.5 \cdot \mathrm{ULP}(ir_1), \\ \lvert ir_2 \rvert + \mathrm{ULP}(ir_2), \\ \lvert refInteg \rvert + me_1 \cdot \mathrm{ULP}(refInteg), \\ ir_3 \end{array} \right\} \cap M \neq \varnothing \end{array} \right\}$$	$(-Inf, Inf)$	{Inf, –Inf, NaN}

Table 87. GFLIB_ControllerPIpAW_FLT Worst-Case Error Bounds - fltIntegPartK_1 Output

Subset of input domain	Worst-case error bounds for fltIntegPartK_1 output [ulp]	Allowed specific values (regardless the error bounds) for fltIntegPartK_1 output
Any of the inputs is denormalized, others are normalized or zero, i.e. $$\left\{ \begin{pmatrix} fltInErr, fltPropGain, fltIntegGain, \\ fltLowerLimit, fltUpperLimit, \\ fltIntegPartK\_1, fltInK\_1 \end{pmatrix} \in X \;\middle|\; X \cap D \neq \varnothing \wedge X \cap M = \varnothing \right\}$$	$(-Inf, Inf)$	N/A
Any of the inputs is NaN or infinity, i.e. $$\left\{ \begin{pmatrix} fltInErr, fltPropGain, fltIntegGain, \\ fltLowerLimit, fltUpperLimit, \\ fltIntegPartK\_1, fltInK\_1 \end{pmatrix} \in X \;\middle|\; X \cap M \neq \varnothing \right\}$$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)

Subset of input domain	Worst-case error bounds for fltIntegPartK_1 output [ulp]	Allowed specific values (regardless the error bounds) for fltIntegPartK_1 output
Normalized or zero input values which lead to normalized or zero results, i.e. $$\left\{ \begin{array}{c} \left(\begin{array}{c} fltInErr,\ fltPropGain,\ fltIntegGain, \\ fltLowerLimit,\ fltUpperLimit, \\ fltIntegPartK\_1,\ fltInK\_1 \end{array} \right) \in X \\ X \subset N \cup \{-0, +0\}, \\ \{ir_1, ir_2\} \subset N \cup \{-0, +0\}, \\ refInteg = 0 \vee \\ \left(\begin{array}{c} \lvert refInteg \rvert - me_1 \cdot \mathrm{ULP}(refInteg) \notin D \wedge \\ \lvert refInteg \rvert + me_1 \cdot \mathrm{ULP}(refInteg) \neq Inf \end{array} \right) \end{array} \right\}$$	$\langle -me_1, me_1 \rangle$	N/A
Normalized or zero input values which cause *fltIntegPartK_1* output underflow, i.e. $$\left\{ \begin{array}{c} \left(\begin{array}{c} fltInErr,\ fltPropGain,\ fltIntegGain, \\ fltLowerLimit,\ fltUpperLimit, \\ fltIntegPartK\_1,\ fltInK\_1 \end{array} \right) \in X \\ X \subset N \cup \{-0, +0\}, \\ \lvert refInteg \rvert - me_1 \cdot \mathrm{ULP}(refInteg) \in D \wedge \\ refInteg \neq 0 \end{array} \right\}$$	$(-Inf, Inf)$	N/A
Normalized or zero input values which cause *fltIntegPartK_1* output overflow, i.e. $$\left\{ \begin{array}{c} \left(\begin{array}{c} fltInErr,\ fltPropGain,\ fltIntegGain, \\ fltLowerLimit,\ fltUpperLimit, \\ fltIntegPartK\_1,\ fltInK\_1 \end{array} \right) \in X \\ X \subset N \cup \{-0, +0\}, \\ \lvert refInteg \rvert + me_1 \cdot \mathrm{ULP}(refInteg) = Inf \end{array} \right\}$$	$(-Inf, Inf)$	{Inf, –Inf, NaN}
Normalized or zero input values which cause intermediate result underflow, i.e. $$\left\{ \begin{array}{c} \left(\begin{array}{c} fltInErr,\ fltPropGain,\ fltIntegGain, \\ fltLowerLimit,\ fltUpperLimit, \\ fltIntegPartK\_1,\ fltInK\_1 \end{array} \right) \in X \\ X \subset N \cup \{-0, +0\}, \\ \left\{ \begin{array}{c} \lvert ir_1 \rvert - 0.5 \cdot \mathrm{ULP}(ir_1), \\ \lvert ir_2 \rvert - \mathrm{ULP}(ir_2), \end{array} \right\} \cap D \neq \varnothing \wedge \\ \{ir_1, ir_2\} \notin \{-0, +0\} \end{array} \right\}$$	$(-Inf, Inf)$	{Inf, –Inf, NaN}

Subset of input domain	Worst-case error bounds for fltIntegPartK_1 output [ulp]	Allowed specific values (regardless the error bounds) for fltIntegPartK_1 output
Normalized or zero input values which cause intermediate result overflow, i.e. $\left\{\left(\begin{matrix} fltInErr, fltPropGain, fltIntegGain, \\ fltLowerLimit, fltUpperLimit, \\ fltIntegPartK\_1, fltInK\_1 \end{matrix}\right) \in X \left\| \begin{matrix} X \subset N \cup \{-0, +0\}, \\ \left\{\begin{matrix} \lvert ir_1 \rvert + 0.5 \cdot \mathrm{ULP}(ir_1), \\ \lvert ir_2 \rvert + \mathrm{ULP}(ir_2), \end{matrix}\right\} \cap M \neq \varnothing \end{matrix} \right.\right\}$	$(-Inf, Inf)$	{Inf, –Inf, NaN}

Table 88. GFLIB_ControllerPIpAW_FLT Worst-Case Error Bounds - fltInK_1 Output

Subset of input domain	Worst-case error bounds for fltInK_1 output [ulp]	Allowed specific values (regardless the error bounds) for fltInK_1 output
Entire input domain	0	*fltInErr*

2.20 Function GFLIB_ControllerPIr_FLT

Declaration

```
tFloat GFLIB_ControllerPIr_FLT(tFloat fltInErr,
GFLIB_CONTROLLER_PI_R_T_FLT *const pParam);
```

Arguments

Table 89. GFLIB_ControllerPIr_FLT arguments

Type	Name	Direction	Description
tFloat	fltInErr	**input**	Input error signal to the controller as a single precision floating point value.
GFLIB_ CONTROLLER_PI_R_ T_FLT *const	pParam	**input, output**	Pointer to the controller parameters structure.

Worst-Case Error Bounds

Let (*fltInErr*, *fltCC1sc*, *fltCC2sc*, *fltAcc*, *fltInErrK1*) ∊ *X* be a set of inputs to GFLIB_ControllerPIr_FLT,

fltAcc input represents a real number with an error of max. ±0.5 ulp,

refResult be the theoretical exact result,

$ir_1 = fltInErr \cdot fltCC1sc$,

$ir_2 = fltInErrK1 \cdot fltCC2sc$,

$ir_3 = ir_1 + ir_2$,

$$ie_1 = \max(\mathrm{fe}(|ir_3| + \mathrm{ULP}(ir_3)), \mathrm{fe}(|fltAcc| + 0.5 \cdot \mathrm{ULP}(fltAcc))),$$

$$ie_2 = \mathrm{fe}(refResult),$$

$$cb = \begin{cases} 0, & ie_1 - ie_2 \le 0 \\ ie_1 - ie_2, & ie_1 - ie_2 > 0 \end{cases},$$

$$me = 0.5 + 1.5 \cdot 2^{cb},$$

then

Table 90. GFLIB_ControllerPIr_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Any of the inputs is denormalized, others are normalized or zero, i.e. $\left\{ \begin{pmatrix} fltInErr, fltCC1sc, fltCC2sc, \\ fltAcc, fltInErrK1 \end{pmatrix} \in X \;\middle|\; X \cap D \ne \varnothing \wedge X \cap M = \varnothing \right\}$	$(-Inf, Inf)$	N/A
Any of the inputs is NaN or infinity, i.e. $\left\{ \begin{pmatrix} fltInErr, fltCC1sc, fltCC2sc, \\ fltAcc, fltInErrK1 \end{pmatrix} \in X \;\middle|\; X \cap M \ne \varnothing \right\}$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{ \begin{pmatrix} fltInErr, fltCC1sc, fltCC2sc, \\ fltAcc, fltInErrK1 \end{pmatrix} \in X \;\middle|\; \begin{matrix} X \subset N \cup \{-0, +0\}, \\ \{ir_1, ir_2, ir_3\} \subset N \cup \{-0, +0\}, \\ refResult = 0 \vee \\ \left(\begin{matrix} \lvert refResult \rvert - me \cdot \mathrm{ULP}(refResult) \notin D \wedge \\ \lvert refResult \rvert + me \cdot \mathrm{ULP}(refResult) \ne Inf \end{matrix} \right) \end{matrix} \right\}$	$\langle -me, me \rangle$	N/A
Normalized or zero input values which cause result underflow, i.e. $\left\{ \begin{pmatrix} fltInErr, fltCC1sc, fltCC2sc, \\ fltAcc, fltInErrK1 \end{pmatrix} \in X \;\middle|\; \begin{matrix} X \subset N \cup \{-0, +0\}, \\ \lvert refResult \rvert - me \cdot \mathrm{ULP}(refResult) \in D \wedge \\ refResult \ne 0 \end{matrix} \right\}$	$(-Inf, Inf)$	N/A

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Normalized or zero input values which cause result overflow, i.e. $$\left\{ \begin{matrix} \begin{pmatrix} fltInErr, fltCC1sc, fltCC2sc, \\ fltAcc, fltInErrK1 \end{pmatrix} \in X \\ X \subset N \cup \{-0, +0\}, \\ \lvert refResult \rvert + me \cdot \mathrm{ULP}(refResult) = Inf \end{matrix} \right\}$$	$(-Inf, Inf)$	{Inf, –Inf, NaN}
Normalized or zero input values which cause intermediate result underflow, i.e. $$\left\{ \begin{matrix} \begin{pmatrix} fltInErr, fltCC1sc, fltCC2sc, \\ fltAcc, fltInErrK1 \end{pmatrix} \in X \\ X \subset N \cup \{-0, +0\}, \\ \{ir_1, ir_2\} \cap D \neq \varnothing \vee \\ (\lvert ir_3 \rvert - \mathrm{ULP}(ir_3) \in D \wedge ir_3 \neq 0) \end{matrix} \right\}$$	$(-Inf, Inf)$	{Inf, –Inf, NaN}
Normalized or zero input values which cause intermediate result overflow, i.e. $$\left\{ \begin{matrix} \begin{pmatrix} fltInErr, fltCC1sc, fltCC2sc, \\ fltAcc, fltInErrK1 \end{pmatrix} \in X \\ X \subset N \cup \{-0, +0\}, \\ \{ir_1, ir_2, \lvert ir_3 \rvert + \mathrm{ULP}(ir_3)\} \cap M \neq \varnothing \end{matrix} \right\}$$	$(-Inf, Inf)$	{Inf, –Inf, NaN}

Table 91. GFLIB_ControllerPIr_FLT Worst-Case Error Bounds - fltAcc Output

Subset of input domain	Worst-case error bounds for fltAcc output [ulp]	Allowed specific values (regardless the error bounds) for fltAcc output
Any of the inputs is denormalized, others are normalized or zero, i.e. $$\left\{ \begin{matrix} \begin{pmatrix} fltInErr, fltCC1sc, fltCC2sc, \\ fltAcc, fltInErrK1 \end{pmatrix} \in X \\ X \cap D \neq \varnothing \wedge X \cap M = \varnothing \end{matrix} \right\}$$	$(-Inf, Inf)$	N/A
Any of the inputs is NaN or infinity, i.e. $$\left\{ \begin{matrix} \begin{pmatrix} fltInErr, fltCC1sc, fltCC2sc, \\ fltAcc, fltInErrK1 \end{pmatrix} \in X \\ X \cap M \neq \varnothing \end{matrix} \right\}$$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)

Subset of input domain	Worst-case error bounds for fltAcc output [ulp]	Allowed specific values (regardless the error bounds) for fltAcc output
Normalized or zero input values which lead to normalized or zero results, i.e. $$\left\{ \begin{array}{c} \left(\begin{array}{c} fltInErr,\ fltCC1sc,\ fltCC2sc, \\ fltAcc,\ fltInErrK1 \end{array} \right) \in X \\ X \subset N \cup \{-0,\ +0\}, \\ \{ir_1, ir_2, ir_3\} \subset N \cup \{-0,\ +0\}, \\ refResult = 0 \vee \\ \left(\begin{array}{c} \lvert refResult \rvert - me \cdot \mathrm{ULP}(refResult) \notin D \wedge \\ \lvert refResult \rvert + me \cdot \mathrm{ULP}(refResult) \neq Inf \end{array} \right) \end{array} \right\}$$	$\langle -me, me \rangle$	N/A
Normalized or zero input values which cause *fltAcc* output underflow, i.e. $$\left\{ \begin{array}{c} \left(\begin{array}{c} fltInErr,\ fltCC1sc,\ fltCC2sc, \\ fltAcc,\ fltInErrK1 \end{array} \right) \in X \\ X \subset N \cup \{-0,\ +0\}, \\ \lvert refResult \rvert - me \cdot \mathrm{ULP}(refResult) \in D \wedge \\ refResult \neq 0 \end{array} \right\}$$	$(-Inf, Inf)$	N/A
Normalized or zero input values which cause *fltAcc* output overflow, i.e. $$\left\{ \begin{array}{c} \left(\begin{array}{c} fltInErr,\ fltCC1sc,\ fltCC2sc, \\ fltAcc,\ fltInErrK1 \end{array} \right) \in X \\ X \subset N \cup \{-0,\ +0\}, \\ \lvert refResult \rvert + me \cdot \mathrm{ULP}(refResult) = Inf \end{array} \right\}$$	$(-Inf, Inf)$	{Inf, –Inf, NaN}
Normalized or zero input values which cause intermediate result underflow, i.e. $$\left\{ \begin{array}{c} \left(\begin{array}{c} fltInErr,\ fltCC1sc,\ fltCC2sc, \\ fltAcc,\ fltInErrK1 \end{array} \right) \in X \\ X \subset N \cup \{-0,\ +0\}, \\ \{ir_1, ir_2\} \cap D \neq \varnothing \vee \\ (\lvert ir_3 \rvert - \mathrm{ULP}(ir_3) \in D \wedge ir_3 \neq 0) \end{array} \right\}$$	$(-Inf, Inf)$	{Inf, –Inf, NaN}
Normalized or zero input values which cause intermediate result overflow, i.e. $$\left\{ \begin{array}{c} \left(\begin{array}{c} fltInErr,\ fltCC1sc,\ fltCC2sc, \\ fltAcc,\ fltInErrK1 \end{array} \right) \in X \\ X \subset N \cup \{-0,\ +0\}, \\ \{ir_1, ir_2, \lvert ir_3 \rvert + \mathrm{ULP}(ir_3)\} \cap M \neq \varnothing \end{array} \right\}$$	$(-Inf, Inf)$	{Inf, –Inf, NaN}

Table 92. GFLIB_ControllerPIr_FLT Worst-Case Error Bounds - fltInErrK1 Output

Subset of input domain	Worst-case error bounds for fltInErrK1 output [ulp]	Allowed specific values (regardless the error bounds) for fltInErrK1 output
Entire input domain	0	*fltInErr*

2.21 Function GFLIB_ControllerPIrAW_FLT

Declaration

```
tFloat GFLIB_ControllerPIrAW_FLT(tFloat fltInErr,
GFLIB_CONTROLLER_PIAW_R_T_FLT *const pParam);
```

Arguments

Table 93. GFLIB_ControllerPIrAW_FLT arguments

Type	Name	Direction	Description
tFloat	fltInErr	**input**	Input error signal to the controller in single precision floating point data format.
GFLIB_ CONTROLLER_ PIAW_R_T_FLT *const	pParam	**input, output**	Pointer to the controller parameters structure.

Worst-Case Error Bounds

Let (*fltInErr*, *fltCC1sc*, *fltCC2sc*, *fltAcc*, *fltInErrK1*, *fltUpperLimit*, *fltLowerLimit*) ∊ *X* be a set of inputs to GFLIB_ControllerPIrAW_FLT,

fltAcc input represents a real number with an error of max. ±0.5 ulp,

refResult be the theoretical exact result,

$ir_1 = fltInErr \cdot fltCC1s$,

$ir_2 = fltInErrK1 \cdot fltCC2sc$,

$ir_3 = ir_1 + ir_2$,

$ie_1 = \max(\mathrm{fe}(|ir_3| + \mathrm{ULP}(ir_3)), \mathrm{fe}(|fltAcc| + 0.5 \cdot \mathrm{ULP}(fltAcc)))$,

$ie_2 = \mathrm{fe}(refResult)$,

$$cb = \begin{cases} 0, & ie_1 - ie_2 \le 0 \\ ie_1 - ie_2, & ie_1 - ie_2 > 0 \end{cases},$$

$me = 0.5 + 1.5 \cdot 2^{cb}$,

then

Table 94. GFLIB_ControllerPIrAW_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Any of the inputs is denormalized, others are normalized or zero, i.e. $\left\{\begin{pmatrix} fltInErr, fltCC1sc, fltCC2sc, \\ fltAccfltInErrK1, \\ fltUpperLimit, fltLowerLimit \end{pmatrix} \in X \;\middle\|\; X \cap D \neq \varnothing \wedge X \cap M = \varnothing \right\}$	$\left(-Inf, Inf\right)$	N/A
Any of the inputs is NaN or infinity, i.e. $\left\{\begin{pmatrix} fltInErr, fltCC1sc, fltCC2sc, \\ fltAccfltInErrK1, \\ fltUpperLimit, fltLowerLimit \end{pmatrix} \in X \;\middle\|\; X \cap M \neq \varnothing \right\}$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{\begin{pmatrix} fltInErr, fltCC1sc, fltCC2sc, \\ fltAccfltInErrK1, \\ fltUpperLimit, fltLowerLimit \end{pmatrix} \in X \;\middle\|\; \begin{array}{c} X \subset N \cup \{-0, +0\}, \\ \{ir_1, ir_2, ir_3\} \subset N \cup \{-0, +0\}, \\ refResult = 0 \vee \\ \begin{pmatrix} \|refResult\| - me \cdot \mathrm{ULP}(refResult) \notin D \wedge \\ \|refResult\| + me \cdot \mathrm{ULP}(refResult) \neq Inf \end{pmatrix} \end{array} \right\}$	$\langle -me, me \rangle$	N/A
Normalized or zero input values which cause result underflow, i.e. $\left\{\begin{pmatrix} fltInErr, fltCC1sc, fltCC2sc, \\ fltAccfltInErrK1, \\ fltUpperLimit, fltLowerLimit \end{pmatrix} \in X \;\middle\|\; \begin{array}{c} X \subset N \cup \{-0, +0\}, \\ \|refResult\| - me \cdot \mathrm{ULP}(refResult) \in D \wedge \\ refResult \neq 0 \end{array} \right\}$	$\left(-Inf, Inf\right)$	N/A
Normalized or zero input values which cause result overflow, i.e. $\left\{\begin{pmatrix} fltInErr, fltCC1sc, fltCC2sc, \\ fltAccfltInErrK1, \\ fltUpperLimit, fltLowerLimit \end{pmatrix} \in X \;\middle\|\; \begin{array}{c} X \subset N \cup \{-0, +0\}, \\ \|refResult\| + me \cdot \mathrm{ULP}(refResult) = Inf \end{array} \right\}$	$\left(-Inf, Inf\right)$	{Inf, –Inf, NaN}

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Normalized or zero input values which cause intermediate result underflow, i.e. $\left\{ \left(\begin{matrix} fltInErr, fltCC1sc, fltCC2sc, \\ fltAccfltInErrK1, \\ fltUpperLimit, fltLowerLimit \end{matrix} \right) \in X \middle\| \begin{matrix} X \subset N \cup \{-0, +0\}, \\ \{ir_1, ir_2\} \cap D \neq \varnothing \vee \\ (\|ir_3\| - \mathrm{ULP}(ir_3) \in D \wedge ir_3 \neq 0) \end{matrix} \right\}$	$(-Inf, Inf)$	{Inf, –Inf, NaN}
Normalized or zero input values which cause intermediate result overflow, i.e. $\left\{ \left(\begin{matrix} fltInErr, fltCC1sc, fltCC2sc, \\ fltAccfltInErrK1, \\ fltUpperLimit, fltLowerLimit \end{matrix} \right) \in X \middle\| \begin{matrix} X \subset N \cup \{-0, +0\}, \\ \{ir_1, ir_2, \|ir_3\| + \mathrm{ULP}(ir_3)\} \cap M \neq \varnothing \end{matrix} \right\}$	$(-Inf, Inf)$	{Inf, –Inf, NaN}

Table 95. GFLIB_ControllerPIrAW_FLT Worst-Case Error Bounds - fltAcc Output

Subset of input domain	Worst-case error bounds for fltAcc output [ulp]	Allowed specific values (regardless the error bounds) for fltAcc output
Any of the inputs is denormalized, others are normalized or zero, i.e. $\left\{ \left(\begin{matrix} fltInErr, fltCC1sc, fltCC2sc, \\ fltAccfltInErrK1, \\ fltUpperLimit, fltLowerLimit \end{matrix} \right) \in X \middle\| X \cap D \neq \varnothing \wedge X \cap M = \varnothing \right\}$	$(-Inf, Inf)$	N/A
Any of the inputs is NaN or infinity, i.e. $\left\{ \left(\begin{matrix} fltInErr, fltCC1sc, fltCC2sc, \\ fltAccfltInErrK1, \\ fltUpperLimit, fltLowerLimit \end{matrix} \right) \in X \middle\| X \cap M \neq \varnothing \right\}$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)

Subset of input domain	Worst-case error bounds for fltAcc output [ulp]	Allowed specific values (regardless the error bounds) for fltAcc output
Normalized or zero input values which lead to normalized or zero results, i.e. $$\left\{ \begin{array}{c} \begin{pmatrix} fltInErr,\ fltCC1sc,\ fltCC2sc, \\ fltAcc fltInErrK1, \\ fltUpperLimit,\ fltLowerLimit \end{pmatrix} \in X \ \Bigg\vert \\ X \subset N \cup \{-0,\ +0\}, \\ \{ir_1,\ ir_2,\ ir_3\} \subset N \cup \{-0,\ +0\}, \\ refResult = 0 \vee \\ \begin{pmatrix} \lvert refResult \rvert - me \cdot \mathrm{ULP}(refResult) \notin D \wedge \\ \lvert refResult \rvert + me \cdot \mathrm{ULP}(refResult) \neq Inf \end{pmatrix} \end{array} \right\}$$	$\langle -me,\ me \rangle$	N/A
Normalized or zero input values which cause *fltAcc* output underflow, i.e. $$\left\{ \begin{array}{c} \begin{pmatrix} fltInErr,\ fltCC1sc,\ fltCC2sc, \\ fltAcc fltInErrK1, \\ fltUpperLimit,\ fltLowerLimit \end{pmatrix} \in X \ \Bigg\vert \\ X \subset N \cup \{-0,\ +0\}, \\ \lvert refResult \rvert - me \cdot \mathrm{ULP}(refResult) \in D \wedge \\ refResult \neq 0 \end{array} \right\}$$	$(-Inf,\ Inf)$	N/A
Normalized or zero input values which cause *fltAcc* output overflow, i.e. $$\left\{ \begin{array}{c} \begin{pmatrix} fltInErr,\ fltCC1sc,\ fltCC2sc, \\ fltAcc fltInErrK1, \\ fltUpperLimit,\ fltLowerLimit \end{pmatrix} \in X \ \Bigg\vert \\ X \subset N \cup \{-0,\ +0\}, \\ \lvert refResult \rvert + me \cdot \mathrm{ULP}(refResult) = Inf \end{array} \right\}$$	$(-Inf,\ Inf)$	{Inf, –Inf, NaN}
Normalized or zero input values which cause intermediate result underflow, i.e. $$\left\{ \begin{array}{c} \begin{pmatrix} fltInErr,\ fltCC1sc,\ fltCC2sc, \\ fltAcc fltInErrK1, \\ fltUpperLimit,\ fltLowerLimit \end{pmatrix} \in X \ \Bigg\vert \\ X \subset N \cup \{-0,\ +0\}, \\ \{ir_1,\ ir_2\} \cap D \neq \varnothing \vee \\ (\lvert ir_3 \rvert - \mathrm{ULP}(ir_3) \in D \wedge ir_3 \neq 0) \end{array} \right\}$$	$(-Inf,\ Inf)$	{Inf, –Inf, NaN}

Subset of input domain	Worst-case error bounds for fltAcc output [ulp]	Allowed specific values (regardless the error bounds) for fltAcc output
Normalized or zero input values which cause intermediate result overflow, i.e. $\left\{\left(\begin{matrix} fltInErr, fltCC1sc, fltCC2sc, \\ fltAcc\, fltInErrK1, \\ fltUpperLimit, fltLowerLimit \end{matrix}\right) \in X \;\middle|\; \begin{matrix} X \subset N \cup \{-0, +0\}, \\ \{ir_1, ir_2, \|ir_3\| + \mathrm{ULP}(ir_3)\} \cap M \neq \varnothing \end{matrix}\right\}$	$(-Inf, Inf)$	{Inf, –Inf, NaN}

Table 96. GFLIB_ControllerPIrAW_FLT Worst-Case Error Bounds - fltInErrK1 Output

Subset of input domain	Worst-case error bounds for fltAcc output [ulp]	Allowed specific values (regardless the error bounds) for fltAcc output
Entire input domain	0	*fltInErr*

2.22 Function GFLIB_Cos_FLT

Declaration

```
tFloat GFLIB_Cos_FLT(tFloat fltIn, const GFLIB_COS_T_FLT *const
pParam);
```

Arguments

Table 97. GFLIB_Cos_FLT arguments

Type	Name	Direction	Description
tFloat	fltIn	**input**	Input argument is a single precision floating point number that contains an angle in radians from interval [- π, π].
const GFLIB_COS_T_FLT *const	pParam	**input**	Pointer to an array of approximation coefficients. In case the default approximation coefficients are used, the &pParam must be replaced with GFLIB_COS_DEFAULT_FLT symbol.

Worst-Case Error Bounds

Only the default approximation coefficients are considered.

Let $fltIn \in X$ be an input to GFLIB_Cos_FLT,

then

Table 98. GFLIB_Cos_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Input NaN or infinity, i.e. $\{fltIn \in X \mid fltIn \in M\}$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)
Input denormalized, normalized or zero, and within the allowed input interval, i.e. $\left\{ \begin{matrix} fltIn \in X \mid X \cap M = \varnothing, \\ -\pi \leq fltIn \leq \pi \end{matrix} \right\}$	$\langle -42, 42 \rangle$	N/A
Input normalized and beyond the allowed range, i.e. $\left\{ \begin{matrix} fltIn \in X \mid X \cap M = \varnothing, \\ fltIn < -\pi \vee fltIn > \pi \end{matrix} \right\}$	$(-Inf, Inf)$	{NaN, -Inf, Inf}

2.23 Function GFLIB_Hyst_FLT

Declaration

```
tFloat GFLIB_Hyst_FLT(tFloat fltIn, GFLIB_HYST_T_FLT *const
pParam);
```

Arguments

Table 99. GFLIB_Hyst_FLT arguments

Type	Name	Direction	Description
tFloat	fltIn	**input**	Input value, in single precision floating point data format.
GFLIB_HYST_T_FLT *const	pParam	**input, output**	Pointer to the structure with parameters and states of the hysteresis function. Arguments of the structure contain a single precision floating point values.

Worst-Case Error Bounds

Let (*fltIn*, *fltHystOn*, *fltHystOff*, *fltOutValOn*, *fltOutValOff*) ∊ *X* be a set of inputs to GFLIB_Hyst_FLT,

then

Table 100. GFLIB_Hyst_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
All inputs are normalized, denormalized, or zero, and *fltHystOn* is greater than *fltHystOff*, i.e. $\left\{ \begin{array}{c} \left(\begin{array}{c} fltIn, fltHystOn, fltHystOff, \\ fltOutValOn, fltOutValOff \end{array} \right) \in X \\ X \cap M = \varnothing \wedge \\ fltHystOff < fltHystOn \end{array} \right\}$	0	N/A
At least one of the inputs is NaN or infinite, or *fltHystOn* is not greater than *fltHystOff*, i.e. $\left\{ \begin{array}{c} \left(\begin{array}{c} fltIn, fltHystOn, fltHystOff, \\ fltOutValOn, fltOutValOff \end{array} \right) \in X \\ X \cap M \neq \varnothing \vee \\ fltHystOff \geq fltHystOn \end{array} \right\}$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)

2.24 Function GFLIB_IntegratorTR_FLT

Declaration

```
tFloat GFLIB_IntegratorTR_FLT(tFloat fltIn,
GFLIB_INTEGRATOR_TR_T_FLT *const pParam);
```

Arguments

Table 101. GFLIB_IntegratorTR_FLT arguments

Type	Name	Direction	Description
tFloat	fltIn	**input**	Input argument to be integrated.
GFLIB_ INTEGRATOR_TR_T_ FLT *const	pParam	**input, output**	Pointer to the integrator parameters structure.

Worst-Case Error Bounds

Let (*fltIn*, *fltState*, *fltInK1*, *fltC1*) $\in X$ be a set of inputs to GFLIB_IntegratorTR_FLT,

fltState input represents a real number with an error of max. ±0.5 ulp,

refResult be the theoretical exact result,

$ir_1 = fltIn + fltInK1$,

$ir_2 = ir_1 \cdot fltC1$,

$ie_1 = \max(\mathrm{fe}(|ir_2| + \mathrm{ULP}(ir_2)), \mathrm{fe}(|fltState| + 0.5 \cdot \mathrm{ULP}(fltState)))$,

$ie_2 = \mathrm{fe}(refResult)$,

$$cb = \begin{cases} 0, & ie_1 - ie_2 \leq 0 \\ ie_1 - ie_2, & ie_1 - ie_2 > 0 \end{cases},$$

$me = 0.5 + 1.5 \cdot 2^{cb}$,

then

Table 102. GFLIB_IntegratorTR_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Any of the inputs is denormalized, others are normalized or zero, i.e. $\left\{ \begin{array}{c} (fltIn, fltState, fltInK1, fltC1) \in X \mid \\ X \cap D \neq \varnothing \wedge X \cap M = \varnothing \end{array} \right\}$	$(-Inf, Inf)$	N/A
Any of the inputs is NaN or infinity, i.e. $\left\{ \begin{array}{c} (fltIn, fltState, fltInK1, fltC1) \in X \mid \\ X \cap M \neq \varnothing \end{array} \right\}$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{ \begin{array}{c} (fltIn, fltState, fltInK1, fltC1) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ \{ir_1, ir_2\} \subset N \cup \{-0, +0\}, \\ refResult = 0 \vee \\ \left(\begin{array}{c} \lvert refResult \rvert - me \cdot \mathrm{ULP}(refResult) \notin D \wedge \\ \lvert refResult \rvert + me \cdot \mathrm{ULP}(refResult) \neq Inf \end{array} \right) \end{array} \right\}$	$\langle -me, me \rangle$	N/A
Normalized or zero input values which cause result underflow, i.e. $\left\{ \begin{array}{c} (fltIn, fltState, fltInK1, fltC1) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ \lvert refResult \rvert - me \cdot \mathrm{ULP}(refResult) \in D \wedge \\ refResult \neq 0 \end{array} \right\}$	$(-Inf, Inf)$	N/A
Normalized or zero input values which cause result overflow, i.e. $\left\{ \begin{array}{c} (fltIn, fltState, fltInK1, fltC1) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ \lvert refResult \rvert + me \cdot \mathrm{ULP}(refResult) = Inf \end{array} \right\}$	$(-Inf, Inf)$	{Inf, –Inf, NaN}

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Normalized or zero input values which cause intermediate result underflow, i.e. $$\left\{\begin{array}{c}(fltIn, fltState, fltInK1, fltC1) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ \left\{\begin{array}{c}(\lvert ir_1\rvert - 0.5 \cdot \mathrm{ULP}(ir_1)), \\ (\lvert ir_2\rvert - \mathrm{ULP}(ir_2))\end{array}\right\} \cap D \neq \varnothing \vee \\ ir_1 \neq 0 \vee ir_2 \neq 0\end{array}\right\}$$	$(-Inf, Inf)$	{Inf, –Inf, NaN}
Normalized or zero input values which cause intermediate result overflow, i.e. $$\left\{\begin{array}{c}(fltIn, fltState, fltInK1, fltC1) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ \left\{\begin{array}{c}(\lvert ir_1\rvert + 0.5 \cdot \mathrm{ULP}(ir_1)), \\ (\lvert ir_2\rvert + \mathrm{ULP}(ir_2))\end{array}\right\} \cap M \neq \varnothing\end{array}\right\}$$	$(-Inf, Inf)$	{Inf, –Inf, NaN}

Table 103. GFLIB_IntegratorTR_FLT Worst-Case Error Bounds - fltState Output

Subset of input domain	Worst-case error bounds for fltState output [ulp]	Allowed specific values (regardless the error bounds) for fltState output
Any of the inputs is denormalized, others are normalized or zero, i.e. $$\left\{\begin{array}{c}(fltIn, fltState, fltInK1, fltC1) \in X \mid \\ X \cap D \neq \varnothing \wedge X \cap M = \varnothing\end{array}\right\}$$	$(-Inf, Inf)$	N/A
Any of the inputs is NaN or infinity, i.e. $$\left\{\begin{array}{c}(fltIn, fltState, fltInK1, fltC1) \in X \mid \\ X \cap M \neq \varnothing\end{array}\right\}$$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $$\left\{\begin{array}{c}(fltIn, fltState, fltInK1, fltC1) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ \{ir_1, ir_2\} \subset N \cup \{-0, +0\}, \\ refResult = 0 \vee \\ \left(\begin{array}{c}\lvert refResult\rvert - me \cdot \mathrm{ULP}(refResult) \notin D \wedge \\ \lvert refResult\rvert + me \cdot \mathrm{ULP}(refResult) \neq Inf\end{array}\right)\end{array}\right\}$$	$\langle -me, me\rangle$	N/A

Subset of input domain	Worst-case error bounds for fltState output [ulp]	Allowed specific values (regardless the error bounds) for fltState output
Normalized or zero input values which cause *fltState* output underflow, i.e. $\left\{\begin{array}{c} (fltIn, fltState, fltInK1, fltC1) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ \lvert refResult \rvert - me \cdot \mathrm{ULP}(refResult) \in D \wedge \\ refResult \neq 0 \end{array}\right\}$	$(-Inf, Inf)$	N/A
Normalized or zero input values which cause *fltState* output overflow, i.e. $\left\{\begin{array}{c} (fltIn, fltState, fltInK1, fltC1) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ \lvert refResult \rvert + me \cdot \mathrm{ULP}(refResult) = Inf \end{array}\right\}$	$(-Inf, Inf)$	{Inf, –Inf, NaN}
Normalized or zero input values which cause intermediate result underflow, i.e. $\left\{\begin{array}{c} (fltIn, fltState, fltInK1, fltC1) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ \left\{\begin{array}{c} (\lvert ir_1 \rvert - 0.5 \cdot \mathrm{ULP}(ir_1)), \\ (\lvert ir_2 \rvert - \mathrm{ULP}(ir_2)) \end{array}\right\} \cap D \neq \varnothing \vee \\ ir_1 \neq 0 \vee ir_2 \neq 0 \end{array}\right\}$	$(-Inf, Inf)$	{Inf, –Inf, NaN}
Normalized or zero input values which cause intermediate result overflow, i.e. $\left\{\begin{array}{c} (fltIn, fltState, fltInK1, fltC1) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ \left\{\begin{array}{c} (\lvert ir_1 \rvert + 0.5 \cdot \mathrm{ULP}(ir_1)), \\ (\lvert ir_2 \rvert + \mathrm{ULP}(ir_2)) \end{array}\right\} \cap M \neq \varnothing \end{array}\right\}$	$(-Inf, Inf)$	{Inf, –Inf, NaN}

Table 104. GFLIB_IntegratorTR_FLT Worst-Case Error Bounds - fltInK1 Output

Subset of input domain	Worst-case error bounds for fltInK1 output [ulp]	Allowed specific values (regardless the error bounds) for fltInK1 output
Entire input domain	0	*fltIn*

2.25 Function GFLIB_Limit_FLT

Declaration

```
tFloat GFLIB_Limit_FLT(tFloat fltIn, const GFLIB_LIMIT_T_FLT
*const pParam);
```

Arguments

Table 105. GFLIB_Limit_FLT arguments

Type	Name	Direction	Description
tFloat	fltIn	**input**	Input value.
const GFLIB_LIMIT_T_ FLT *const	pParam	**input**	Pointer to the limits structure.

Worst-Case Error Bounds

Let (*fltIn*, *fltLowerLimit*, *fltUpperLimit*) ∊ *X* be a set of inputs to GFLIB_Limit_FLT, then

Table 106. GFLIB_Limit_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
All inputs are normalized, denormalized, or zero, and *fltUpperLimit* is greater than *fltLowerLimit*, i.e. $\left\{ \begin{array}{c} (fltIn, fltLowerLimit, fltUpperLimit) \in X \\ X \cap M = \varnothing \wedge \\ fltLowerLimit < fltUpperLimit \end{array} \right\}$	0	N/A
At least one of the inputs is NaN or infinite, or *fltUpperLimit* is not greater than *fltLowerLimit*, i.e. $\left\{ \begin{array}{c} (fltIn, fltLowerLimit, fltUpperLimit) \in X \\ X \cap M \neq \varnothing \vee \\ fltLowerLimit \geq fltUpperLimit \end{array} \right\}$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)

2.26 Function GFLIB_Log10_FLT

Declaration

```
tFloat GFLIB_Log10_FLT(tFloat fltIn, const GFLIB_LOG10_T_FLT
*const pParam);
```

Arguments

Table 107. GFLIB_Log10_FLT arguments

Type	Name	Direction	Description
tFloat	fltIn	**input**	Input argument is a 32-bit number that contains a single precision floating point value.
const GFLIB_LOG10_ T_FLT *const	pParam	**input**	Pointer to an array of approximation coefficients.

Worst-Case Error Bounds

Only the default approximation coefficients are considered.

Let *fltIn* ∊ *X* be an input to GFLIB_Log10_FLT,

then

Table 108. GFLIB_Log10_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Input not normalized, i.e. $\{ fltIn \in X \mid fltIn \notin N \}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, –Inf, NaN)
Input normalized, i.e. $\{ fltIn \in X \mid fltIn \in N \}$	$\langle -760, 760 \rangle$	N/A

2.27 Function GFLIB_LowerLimit_FLT

Declaration

```
tFloat GFLIB_LowerLimit_FLT(tFloat fltIn, const
GFLIB_LOWERLIMIT_T_FLT *const pParam);
```

Arguments

Table 109. GFLIB_LowerLimit_FLT arguments

Type	Name	Direction	Description
tFloat	fltIn	**input**	Input value.
const GFLIB_ LOWERLIMIT_T_FLT *const	pParam	**input**	Pointer to the limits structure.

Worst-Case Error Bounds

Let (*fltIn*, *fltLowerLimit*) ∊ *X* be a set of inputs to GFLIB_LowerLimit_FLT,

then

Table 110. GFLIB_LowerLimit_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
All inputs are normalized, denormalized, or zero, i.e. $\left\{ (fltIn, fltLowerLimit) \in X \,\middle|\, X \cap M = \varnothing \right\}$	0	N/A
At least one of the inputs is NaN or infinite, i.e. $\left\{ (fltIn, fltLowerLimit) \in X \,\middle|\, X \cap M \neq \varnothing \right\}$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)

2.28 Function GFLIB_Lut1D_FLT

Declaration

```
tFloat GFLIB_Lut1D_FLT(tFloat fltIn, const GFLIB_LUT1D_T_FLT
*const pParam);
```

Arguments

Table 111. GFLIB_Lut1D_FLT arguments

Type	Name	Direction	Description
tFloat	fltIn	**input**	The abscissa for which 1D interpolation is performed.
const GFLIB_LUT1D_T_FLT *const	pParam	**input**	Pointer to the parameters structure with parameters of the look-up table function.

Worst-Case Error Bounds

Let (*fltIn*, *u32ShamOffset*, ***fltTable***) $\in X$ be a set of inputs to GFLIB_Lut1D_FLT, *refResult* be the theoretical exact result,

$$k = \begin{cases} fltIn \cdot 2^{u32ShamOffset} - \mathrm{fix}\left(fltIn \cdot 2^{u32ShamOffset}\right), & fltIn \geq 0 \\ fltIn \cdot 2^{u32ShamOffset} - \mathrm{fix}\left(fltIn \cdot 2^{u32ShamOffset}\right) + 1, & fltIn < 0 \end{cases},$$

$$mr_n = k \cdot \left(fltTable_{n+1} - fltTable_n\right),$$

$$ie = \max_n\left(\max\left(\mathrm{fe}\left(|mr_n| + 2.5 \cdot \mathrm{ULP}(mr_n)\right), \mathrm{fe}\left(fltTable_n\right)\right) - \mathrm{fe}\left(mr_n + fltTable_n\right)\right),$$

$$cb = \begin{cases} 0, & ie \leq 0 \\ ie, & ie > 0 \end{cases},$$

$$me = 0.5 + 2.5 \cdot 2^{cb},$$

then

Table 112. GFLIB_Lut1D_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Any of the inputs is denormalized, others are normalized or zero, i.e. $\left\{ (fltIn, u32ShamOffset, \boldsymbol{fltTable}) \in X \;\middle|\; X \cap D \neq \varnothing \wedge X \cap M = \varnothing \right\}$	$(-Inf, Inf)$	N/A
Any of the inputs is NaN or infinity, or the input is beyond allowed range, i.e. $\left\{ (fltIn, u32ShamOffset, \boldsymbol{fltTable}) \in X \;\middle|\; X \cap M \neq \varnothing \vee \lvert fltIn \rvert \geq 1 \right\}$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Normalized or zero input values which lead to normalized or zero results, input within allowed range, i.e. $$\left\{ \begin{array}{c} (fltIn, u32ShamOffset, \boldsymbol{fltTable}) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ fltTable \subset N \cup \{-0, +0\} \\ \lvert fltIn \rvert < 1, \\ \max_n(\lvert mr_n \rvert) + 2.5 \cdot \mathrm{ULP}(\max_n(mr_n)) \neq Inf, \\ \bigvee mr_n = 0 \vee \lvert mr_n \rvert - 2.5 \cdot \mathrm{ULP}(mr_n) \notin D, \\ refResult = 0 \vee \\ \left(\begin{array}{c} \lvert refResult \rvert - me_2 \cdot \mathrm{ULP}(refResult) \notin D \wedge \\ \lvert refResult \rvert + me_2 \cdot \mathrm{ULP}(refResult) \neq Inf \end{array} \right) \end{array} \right\}$$	$\langle -me, me \rangle$	N/A
Normalized or zero input values which cause result underflow, i.e. $$\left\{ \begin{array}{c} (fltIn, u32ShamOffset, \boldsymbol{fltTable}) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ \lvert refResult \rvert - me \cdot \mathrm{ULP}(refResult) \in D \wedge \\ refResult \neq 0 \end{array} \right\}$$	$(-Inf, Inf)$	N/A
Normalized or zero input values which cause intermediate result underflow, i.e. $$\left\{ \begin{array}{c} (fltIn, u32ShamOffset, \boldsymbol{fltTable}) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ \exists \lvert mr_n \rvert - 2.5 \cdot \mathrm{ULP}(mr_n) \in D \wedge mr_n \neq 0 \end{array} \right\}$$	$(-Inf, Inf)$	{Inf, –Inf, NaN}

2.29 Function GFLIB_Lut2D_FLT

Declaration

```
tFloat GFLIB_Lut2D_FLT(tFloat fltIn1, tFloat fltIn2, const
GFLIB_LUT2D_T_FLT *const pParam);
```

Arguments

Table 113. GFLIB_Lut2D_FLT arguments

Type	Name	Direction	Description
tFloat	fltIn1	**input**	First input variable for which 2D interpolation is performed. Input value is in single precision floating data format.
tFloat	fltIn2	**input**	Second input variable for which 2D interpolation is performed. Input value is in single precision floating data format.
const GFLIB_LUT2D_T_FLT *const	pParam	**input**	Pointer to the parameters structure with parameters of the two dimensional look-up table function.

Worst-Case Error Bounds

Let (*fltIn1*, *fltIn2*, *u32ShamOffset1*, *u32ShamOffset2*, ***fltTable***) ∈ *X* be a set of inputs to GFLIB_Lut2D_FLT,

refResult be the theoretical exact result,

$$kx = \begin{cases} fltIn1 \cdot 2^{u32ShamOffset1} - \mathrm{fix}\left(fltIn1 \cdot 2^{u32ShamOffset1}\right), & fltIn1 \geq 0 \\ fltIn1 \cdot 2^{u32ShamOffset1} - \mathrm{fix}\left(fltIn1 \cdot 2^{u32ShamOffset1}\right) + 1, & fltIn1 < 0 \end{cases},$$

$$ky = \begin{cases} fltIn2 \cdot 2^{u32ShamOffset2} - \mathrm{fix}\left(fltIn2 \cdot 2^{u32ShamOffset2}\right), & fltIn2 \geq 0 \\ fltIn2 \cdot 2^{u32ShamOffset2} - \mathrm{fix}\left(fltIn2 \cdot 2^{u32ShamOffset2}\right) + 1, & fltIn2 < 0 \end{cases},$$

$$yr = 2^{u32ShamOffset2} + 1,$$

$$z11_n = fltTable_n,$$

$$z21_n = fltTable_{n+yr},$$

$$z12_n = fltTable_{n+1},$$

$$z22_n = fltTable_{n+1+yr},$$

$$mra_n = kx \cdot (z21_n - z11_n),$$

$$sra = \max_n\left(\max\left(\mathrm{fe}\left(|mra_n| + 2.5 \cdot \mathrm{ULP}(mra_n)\right), \mathrm{fe}(z11_n)\right) - \mathrm{fe}(mra_n + z11_n)\right),$$

$$cb_1 = \begin{cases} 0, & sra \leq 0 \\ sra, & sra > 0 \end{cases},$$

$$me_1 = 0.5 + 2.5 \cdot 2^{cb_1},$$

$$mrb_n = kx \cdot (z22_n - z12_n),$$

$$srb = \max_n\left(\max\left(\mathrm{fe}\left(|mrb_n| + 2.5 \cdot \mathrm{ULP}(mrb_n)\right), \mathrm{fe}(z12_n)\right) - \mathrm{fe}(mrb_n + z12_n)\right),$$

$$cb_2 = \begin{cases} 0, & srb \leq 0 \\ srb, & srb > 0 \end{cases},$$

$$me_2 = 0.5 + 2.5 \cdot 2^{cb_2},$$

$$mrc_n = ky \cdot \left((mrb_n + z12_n) - (mra_n + z11_n)\right),$$

$$mec = \left(2 \cdot (me_1 + me_2 + 0.5) + 0.5\right) \cdot \mathrm{ULP}(mrc_n),$$

$$src = \max_n\left(\max\left(\mathrm{fe}\left(|mrc_n| + mec\right), \mathrm{fe}(mra_n + z11_n)\right) - \mathrm{fe}\left(mrc_n + (mra_n + z11_n)\right)\right),$$

$$cb_3 = \begin{cases} 0, & src \leq 0 \\ src, & src > 0 \end{cases},$$

$$me_3 = 0.5 + \left(2 \cdot (me_1 + me_2 + 0.5) + 0.5\right) \cdot 2^{cb_3},$$

then

Table 114. GFLIB_Lut2D_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Any of the inputs is denormalized, others are normalized or zero, i.e. $$\left\{ \left(\begin{matrix} fltIn1, fltIn2, u32ShamOffset1, \\ u32ShamOffset2, \boldsymbol{fltTable} \end{matrix} \right) \in X \middle\vert\ \begin{matrix} \\ X \cap D \neq \varnothing \wedge X \cap M = \varnothing \end{matrix} \right\}$$	$\langle -Inf, Inf \rangle$	N/A
Any of the inputs is NaN or infinity, or an input is beyond allowed range, i.e. $$\left\{ \left(\begin{matrix} fltIn1, fltIn2, u32ShamOffset1, \\ u32ShamOffset2, \boldsymbol{fltTable} \end{matrix} \right) \in X \middle\vert\ \begin{matrix} \\ X \cap M \neq \varnothing \vee \lvert fltIn \rvert \geq 1 \vee \lvert fltIn \rvert \geq 1 \end{matrix} \right\}$$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, inputs within allowed range, i.e. $$\left\{ \left(\begin{matrix} fltIn1, fltIn2, u32ShamOffset1, \\ u32ShamOffset2, \boldsymbol{fltTable} \end{matrix} \right) \in X \middle\vert\ \begin{matrix} X \subset N \cup \{-0, +0\}, \\ \boldsymbol{fltTable} \subset N \cup \{-0, +0\} \\ \lvert fltIn1 \rvert < 1, \\ \lvert fltIn2 \rvert < 1, \\ \max_n(\lvert mra_n \rvert) + 2.5 \cdot \mathrm{ULP}(\max_n(mra_n)) \neq Inf, \\ \bigvee mra_n = 0 \vee \lvert mra_n \rvert - 2.5 \cdot \mathrm{ULP}(mra_n) \notin D, \\ \max_n(\lvert sra_n \rvert) + 2.5 \cdot \mathrm{ULP}(\max_n(sra_n)) \neq Inf, \\ \bigvee sra_n = 0 \vee \lvert sra_n \rvert - 2.5 \cdot \mathrm{ULP}(sra_n) \notin D, \\ \max_n(\lvert mrb_n \rvert) + 2.5 \cdot \mathrm{ULP}(\max_n(mrb_n)) \neq Inf, \\ \bigvee mrb_n = 0 \vee \lvert mrb_n \rvert - 2.5 \cdot \mathrm{ULP}(mrb_n) \notin D, \\ \max_n(\lvert srb_n \rvert) + 2.5 \cdot \mathrm{ULP}(\max_n(srb_n)) \neq Inf, \\ \bigvee srb_n = 0 \vee \lvert srb_n \rvert - 2.5 \cdot \mathrm{ULP}(srb_n) \notin D, \\ \max_n(\lvert mrc_n \rvert) + 2.5 \cdot \mathrm{ULP}(\max_n(mrc_n)) \neq Inf, \\ \bigvee mrc_n = 0 \vee \lvert mrc_n \rvert - 2.5 \cdot \mathrm{ULP}(mrc_n) \notin D, \\ refResult = 0 \vee \\ \left(\begin{matrix} \lvert refResult \rvert - me_3 \cdot \mathrm{ULP}(refResult) \notin D \wedge \\ \lvert refResult \rvert + me_3 \cdot \mathrm{ULP}(refResult) \neq Inf \end{matrix} \right) \end{matrix} \right\}$$	$\langle -me_3, me_3 \rangle$	N/A

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Normalized or zero input values which cause result underflow, i.e. $\left\{ \begin{array}{c} \begin{pmatrix} fltIn1,\ fltIn2,\ u32ShamOffset1, \\ u32ShamOffset2,\ \boldsymbol{fltTable} \end{pmatrix} \in X \\ X \subset N \cup \{-0,\ +0\}, \\ \lvert refResult \rvert - me_3 \cdot \mathrm{ULP}(refResult) \in D \wedge \\ refResult \neq 0 \end{array} \right\}$	$(-Inf, Inf)$	N/A
Normalized or zero input values which cause intermediate result underflow, i.e. $\left\{ \begin{array}{c} \begin{pmatrix} fltIn1,\ fltIn2,\ u32ShamOffset1, \\ u32ShamOffset2,\ \boldsymbol{fltTable} \end{pmatrix} \in X \\ X \subset N \cup \{-0,\ +0\}, \\ \exists \lvert mra_n \rvert - 2.5 \cdot \mathrm{ULP}(mra_n) \in D \wedge mra_n \neq 0 \vee \\ \exists \lvert sra_n \rvert - 2.5 \cdot \mathrm{ULP}(sra_n) \in D \wedge sra_n \neq 0 \vee \\ \exists \lvert mrb_n \rvert - 2.5 \cdot \mathrm{ULP}(mrb_n) \in D \wedge mrb_n \neq 0 \vee \\ \exists \lvert srb_n \rvert - 2.5 \cdot \mathrm{ULP}(srb_n) \in D \wedge srb_n \neq 0 \vee \\ \exists \lvert mrc_n \rvert - 2.5 \cdot \mathrm{ULP}(mrc_n) \in D \wedge mrc_n \neq 0 \vee \end{array} \right\}$	$(-Inf, Inf)$	{Inf, –Inf, NaN}

2.30 Function GFLIB_Ramp_FLT

Declaration

```
tFloat GFLIB_Ramp_FLT(tFloat fltIn, GFLIB_RAMP_T_FLT *const
pParam);
```

Arguments

Table 115. GFLIB_Ramp_FLT arguments

Type	Name	Direction	Description
tFloat	fltIn	**input**	Input argument representing the desired output value. Input value is in single precision floating data format.
GFLIB_RAMP_T_FLT *const	pParam	**input, output**	Pointer to the ramp parameters structure. Arguments of the structure contain single precision floating point values.

Worst-Case Error Bounds

Let (*fltIn*, *fltState*, *fltRampUp*, *fltRampDown*) ∊ *X* be a set of inputs to GFLIB_Ramp_FLT,

fltState input represents a real number with an error of max. ±0.5 ulp,

refResult be the theoretical exact result,

$ie_1 = \mathrm{fe}(\lvert fltState \rvert + 0.5 \cdot \mathrm{ULP}(fltState))$,

$ie_2 = \mathrm{fe}(refResult)$,

$$cb = \begin{cases} 0, & ie_1 - ie_2 \le 0 \\ ie_1 - ie_2, & ie_1 - ie_2 > 0 \end{cases},$$

$$me = 0.5 + 0.5 \cdot 2^{cb},$$

then

Table 116. GFLIB_Ramp_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Any of the inputs is denormalized, others are normalized or zero, i.e. $\left\{ \begin{pmatrix} fltIn,\ fltState, \\ fltRampUp,\ fltRampDown \end{pmatrix} \in X \;\middle\vert\; X \cap D \neq \varnothing \wedge X \cap M = \varnothing \right\}$	$\langle -Inf, Inf \rangle$	N/A
Any of the inputs is NaN or infinity, i.e. $\left\{ \begin{pmatrix} fltIn,\ fltState, \\ fltRampUp,\ fltRampDown \end{pmatrix} \in X \;\middle\vert\; X \cap M \neq \varnothing \right\}$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{ \begin{matrix} \begin{pmatrix} fltIn,\ fltState, \\ fltRampUp,\ fltRampDown \end{pmatrix} \in X \;\middle\vert \\ X \subset N \cup \{-0,\ +0\}, \\ refResult = 0 \vee \\ \begin{pmatrix} \lvert refResult \rvert - me \cdot \mathrm{ULP}(refResult) \notin D \wedge \\ \lvert refResult \rvert + me \cdot \mathrm{ULP}(refResult) \neq Inf \end{pmatrix} \end{matrix} \right\}$	$\langle -me, me \rangle$	N/A
Normalized or zero input values which cause result underflow, i.e. $\left\{ \begin{matrix} \begin{pmatrix} fltIn,\ fltState, \\ fltRampUp,\ fltRampDown \end{pmatrix} \in X \;\middle\vert \\ X \subset N \cup \{-0,\ +0\}, \\ \lvert refResult \rvert - me \cdot \mathrm{ULP}(refResult) \in D \wedge \\ refResult \neq 0 \end{matrix} \right\}$	$\langle -Inf, Inf \rangle$	N/A

Table 117. GFLIB_Ramp_FLT Worst-Case Error Bounds - fltState Output

Subset of input domain	Worst-case error bounds for fltState output [ulp]	Allowed specific values (regardless the error bounds) for fltState output
Any of the inputs is denormalized, others are normalized or zero, i.e. $\left\{ \begin{pmatrix} fltIn, fltState, \\ fltRampUp, fltRampDown \end{pmatrix} \in X \;\middle|\; X \cap D \neq \varnothing \wedge X \cap M = \varnothing \right\}$	$(-Inf, Inf)$	N/A
Any of the inputs is NaN or infinity, i.e. $\left\{ \begin{pmatrix} fltIn, fltState, \\ fltRampUp, fltRampDown \end{pmatrix} \in X \;\middle|\; X \cap M \neq \varnothing \right\}$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{ \begin{pmatrix} fltIn, fltState, \\ fltRampUp, fltRampDown \end{pmatrix} \in X \;\middle|\; \begin{array}{c} X \subset N \cup \{-0, +0\}, \\ refResult = 0 \vee \\ \begin{pmatrix} \lvert refResult \rvert - me \cdot \mathrm{ULP}(refResult) \notin D \wedge \\ \lvert refResult \rvert + me \cdot \mathrm{ULP}(refResult) \neq Inf \end{pmatrix} \end{array} \right\}$	$\langle -me, me \rangle$	N/A
Normalized or zero input values which cause result underflow, i.e. $\left\{ \begin{pmatrix} fltIn, fltState, \\ fltRampUp, fltRampDown \end{pmatrix} \in X \;\middle|\; \begin{array}{c} X \subset N \cup \{-0, +0\}, \\ \lvert refResult \rvert - me \cdot \mathrm{ULP}(refResult) \in D \wedge \\ refResult \neq 0 \end{array} \right\}$	$(-Inf, Inf)$	N/A

Table 118. GFLIB_Ramp_FLT Worst-Case Error Bounds - fltInK1 Output

Subset of input domain	Worst-case error bounds for fltInK1 output [ulp]	Allowed specific values (regardless the error bounds) for fltInK1 output
Entire input domain	0	*fltIn*

2.31 Function GFLIB_Sign_FLT

Declaration

```
tFloat GFLIB_Sign_FLT(tFloat fltIn);
```

Arguments

Table 119. GFLIB_Sign_FLT arguments

Type	Name	Direction	Description
tFloat	fltIn	**input**	Input argument.

Worst-Case Error Bounds

Let *fltIn* ∈ *X* be an input to GFLIB_Sign_FLT,

then

Table 120. GFLIB_Sign_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Input NaN, i.e. $\{fltIn \in X \mid fltIn = NaN\}$	N/A	{NaN, *pmax*, *nmax*, 0, -0}
Normalized, denormalized, infinite, or zero input, i.e. $\{fltIn \in X \mid fltIn \neq NaN\}$	0	N/A

2.32 Function GFLIB_Sin_FLT

Declaration

```
tFloat GFLIB_Sin_FLT(tFloat fltIn, const GFLIB_SIN_T_FLT *const
pParam);
```

Arguments

Table 121. GFLIB_Sin_FLT arguments

Type	Name	Direction	Description
tFloat	fltIn	**input**	Input argument is a single precision floating point number that contains an angle in radians from interval [- π, π].
const GFLIB_SIN_T_ FLT *const	pParam	**input**	Pointer to an array of approximation coefficients. In case the default approximation coefficients are used, the &pParam must be replaced with GFLIB_SIN_DEFAULT_FLT symbol.

Worst-Case Error Bounds

Only the default approximation coefficients are considered.

Let (*fltIn*) ∈ *X* be an input to GFLIB_Sin_FLT,

π_{SP} be the single-precision representation of π,

then

Table 122. GFLIB_Sin_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Input infinite, i.e. $\{fltIn \in X \mid fltIn \in \{Inf, -Inf\}\}$	$(-Inf, Inf)$	{Inf, -Inf, NaN}
Input NaN, i.e. $\{fltIn \in X \mid fltIn = NaN\}$	$(-Inf, Inf)$	{NaN, pmax}
Normalized, denormalized, or zero input within guaranteed range, i.e. $\{fltIn \in X \mid fltIn \notin M, \lvert fltIn \rvert \leq \pi_{SP}\}$	$\langle -42, 42 \rangle$	N/A
Normalized input beyond the guaranteed range, i.e. $\{fltIn \in X \mid fltIn \notin M, \lvert fltIn \rvert > \pi_{SP}\}$	$(-Inf, Inf)$	N/A

2.33 Function GFLIB_SinCos_FLT

Declaration

```
void GFLIB_SinCos_FLT(tFloat fltIn, SWLIBS_2Syst_FLT *pOut, const
GFLIB_SINCOS_T_FLT *const pParam);
```

Arguments

Table 123. GFLIB_SinCos_FLT arguments

Type	Name	Direction	Description
tFloat	fltIn	**input**	Input argument is a single precision floating point number that contains an angle in radians from interval [- π, π].
SWLIBS_2Syst_FLT *	pOut	**output**	Pointer to the structure where the values of the sine and cosine of the input angle are stored. The function returns the sine and cosine of the input argument as a single precision floating point number. The *sine* of input angle is returned in first item of the structure and the *cosine* of input angle is returned in second item of the structure.
const GFLIB_SINCOS_T_FLT *const	pParam	**input**	Pointer to an array of approximation coefficients. In case the default approximation coefficients are used, the &pParam must be replaced with GFLIB_SINCOS_DEFAULT_FLT symbol.

Worst-Case Error Bounds

Only the default approximation coefficients are considered.

Let $(fltIn) \in X$ be an input to GFLIB_SinCos_FLT,

π_{SP} be the single-precision representation of π,

then

Table 124. GFLIB_SinCos_FLT Worst-Case Error Bounds - fltArg1 Output

Subset of input domain	Worst-case error bounds for fltArg1 output [ulp]	Allowed specific values (regardless the error bounds) for fltArg1 output
Input infinite, i.e. $\{ fltIn \in X \mid fltIn \in \{ Inf, -Inf \} \}$	$(-Inf, Inf)$	{Inf, -Inf, NaN}
Input NaN, i.e. $\{ fltIn \in X \mid fltIn = NaN \}$	$(-Inf, Inf)$	{NaN, pmax}
Normalized, denormalized, or zero input within guaranteed range, i.e. $\{ fltIn \in X \mid fltIn \notin M, \lvert fltIn \rvert \leq \pi_{SP} \}$	$\langle -42, 42 \rangle$	N/A
Normalized input beyond the guaranteed range, i.e. $\{ fltIn \in X \mid fltIn \notin M, \lvert fltIn \rvert > \pi_{SP} \}$	$(-Inf, Inf)$	N/A

Table 125. GFLIB_SinCos_FLT Worst-Case Error Bounds - fltArg2 Output

Subset of input domain	Worst-case error bounds for fltArg2 output [ulp]	Allowed specific values (regardless the error bounds) for fltArg2 output
Input NaN or infinity, i.e. $\{ fltIn \in X \mid fltIn \in M \}$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)
Input denormalized, normalized or zero, and within the allowed input interval, i.e. $\left\{ \begin{matrix} fltIn \in X \mid X \cap M = \varnothing, \\ -\pi \leq fltIn \leq \pi \end{matrix} \right\}$	$\langle -42, 42 \rangle$	N/A
Input normalized and beyond the allowed range, i.e. $\left\{ \begin{matrix} fltIn \in X \mid X \cap M = \varnothing, \\ fltIn < -\pi \vee fltIn > \pi \end{matrix} \right\}$	$(-Inf, Inf)$	{NaN, -Inf, Inf}

2.34 Function GFLIB_Sqrt_FLT

Declaration

```
tFloat GFLIB_Sqrt_FLT(tFloat fltIn);
```

Arguments

Table 126. GFLIB_Sqrt_FLT arguments

Type	Name	Direction	Description
tFloat	fltIn	**input**	The input value.

Worst-Case Error Bounds

Let *fltIn* $\in X$ be an input to GFLIB_Sqrt_FLT,

then

Table 127. GFLIB_Sqrt_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Input positive infinity, i.e. $\{fltIn \in X \mid fltIn = Inf\}$	$(-Inf, Inf)$	{NaN, Inf, -Inf, *pmax*, 0}
Input NaN, i.e. $\{fltIn \in X \mid fltIn = NaN\}$	$(-Inf, Inf)$	{0, -0, NaN}
Negative input, i.e. $\{fltIn \in X \mid fltIn < 0\}$	N/A	{-0, NaN}
Positive denormalized input, i.e. $\{fltIn \in X \mid fltIn \in D \wedge fltIn > 0\}$	$(-Inf, Inf)$	N/A
Positive normalized input, i.e. $\{fltIn \in X \mid fltIn \in N \wedge fltIn > 0\}$	$\langle -0.5, 0.5\rangle$	N/A
Positive zero input, i.e. $\{fltIn \in X \mid fltIn = 0\}$	N/A	0
Negative zero input, i.e. $\{fltIn \in X \mid fltIn = -0\}$	N/A	-0

2.35 Function GFLIB_Tan_FLT

Declaration

```
tFloat GFLIB_Tan_FLT(tFloat fltIn, const GFLIB_TAN_T_FLT *const
pParam);
```

Arguments

Table 128. GFLIB_Tan_FLT arguments

Type	Name	Direction	Description
tFloat	fltIn	**input**	Input argument is a single precision floating point number that contains an angle in radians from interval (- π, π).
const GFLIB_TAN_T_FLT *const	pParam	**input**	Pointer to an array of approximation coefficients. In case the default approximation coefficients are used, the &pParam must be replaced with GFLIB_TAN_DEFAULT_FLT symbol.

Worst-Case Error Bounds

Only the default approximation coefficients are considered.

Let $fltIn \in X$ be an input to GFLIB_Tan_FLT,

π_{SP} be the single-precision representation of π,

then

Table 129. GFLIB_Tan_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Input infinite, i.e. $\{fltIn \in X \mid fltIn \in \{Inf, -Inf\}\}$	$(-Inf, Inf)$	{Inf, -Inf, NaN}
Input NaN, i.e. $\{fltIn \in X \mid fltIn = NaN\}$	$(-Inf, Inf)$	NaN
Normalized, denormalized, or zero input within guaranteed range, i.e. $\{fltIn \in X \mid fltIn \notin M, \lvert fltIn \rvert \le \pi_{SP}\}$	$\langle -13, 13 \rangle$	N/A
Normalized input beyond the guaranteed range, i.e. $\{fltIn \in X \mid fltIn \notin M, \lvert fltIn \rvert > \pi_{SP}\}$	$(-Inf, Inf)$	N/A

2.36 Function GFLIB_UpperLimit_FLT

Declaration

```
tFloat GFLIB_UpperLimit_FLT(tFloat fltIn, const
GFLIB_UPPERLIMIT_T_FLT *const pParam);
```

Arguments

Table 130. GFLIB_UpperLimit_FLT arguments

Type	Name	Direction	Description
tFloat	fltIn	**input**	Input value.
const GFLIB_ UPPERLIMIT_T_FLT *const	pParam	**input**	Pointer to the limits structure.

Worst-Case Error Bounds

Let (*fltIn*, *fltUpperLimit*) ∊ *X* be a set of inputs to GFLIB_UpperLimit_FLT,

then

Table 131. GFLIB_UpperLimit_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
All inputs are normalized, denormalized, i.e. $\left\{ (fltIn, fltUpperLimit) \in X \;\middle|\; X \cap M = \varnothing \right\}$	0	N/A
At least one of the inputs is NaN or infinite, i.e. $\left\{ (fltIn, fltUpperLimit) \in X \;\middle|\; X \cap M \neq \varnothing \vee \right\}$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)

2.37 Function GFLIB_VectorLimit_FLT

Declaration

```
tBool GFLIB_VectorLimit_FLT(SWLIBS_2Syst_FLT *const pOut, const
SWLIBS_2Syst_FLT *const pIn, const GFLIB_VECTORLIMIT_T_FLT *const
pParam);
```

Arguments

Table 132. GFLIB_VectorLimit_FLT arguments

Type	Name	Direction	Description
const SWLIBS_2Syst_ FLT *const	pIn	**input**	Pointer to the structure of the input vector.
SWLIBS_2Syst_FLT *const	pOut	**output**	Pointer to the structure of the limited output vector.

Type	Name	Direction	Description
const GFLIB_ VECTORLIMIT_T_FLT *const	pParam	**input**	Pointer to the parameters structure.

Worst-Case Error Bounds

Let (*fltArg1*, *fltArg2*, *fltLimit*) ∈ X be a set of inputs to GFLIB_VectorLimit_FLT,

reffltArg1, *reffltArg2* be the theoretical exact results for outputs *fltArg1* and *fltArg2*, respectively,

$ir_1 = fltArg1 \cdot fltArg1$,

$ir_2 = fltArg2 \cdot fltArg2$,

$ir_3 = ir_1 + ir_2$,

$ir_4 = \sqrt{ir_3}$,

$ir_5 = \frac{fltLimit}{ir_4}$,

$ir_6 = fltArg1 \cdot ir_5$,

$ir_7 = fltArg2 \cdot ir_5$,

then

Table 133. GFLIB_VectorLimit_FLT Return Value

Subset of input domain	Meaningful Return Value
Any of the inputs is denormalized, others are normalized or zero, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2, fltLimit) \in X \; \vert \\ X \cap D \neq \varnothing \wedge X \cap M = \varnothing \end{array} \right\}$	No
Any of the inputs is NaN or infinity, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2, fltLimit) \in X \; \vert \\ X \cap M \neq \varnothing \end{array} \right\}$	No
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2, fltLimit) \in X \; \vert \\ X \subset N \cup \{-0, +0\}, \\ \left\{ \begin{array}{c} ref fltArg1, ref fltArg2, \\ ir_1, ir_2, ir_3, ir_4, ir_5, ir_6, ir_7 \end{array} \right\} \subset N \cup \{-0, +0\} \end{array} \right\}$	Yes

Subset of input domain	Meaningful Return Value
Normalized or zero input values which cause an output underflow, i.e. $$\left\{\begin{matrix} (fltArg1, fltArg2, fltLimit) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ \{reffltArg1, reffltArg2\} \cap M \neq \varnothing \\ \left(\begin{matrix}\lvert reffltArg1\rvert - 276 \cdot \mathrm{ULP}(reffltArg1) \in D \wedge \\ reffltArg1 \neq 0\end{matrix}\right) \vee \\ \left(\begin{matrix}\lvert reffltArg2\rvert - 276 \cdot \mathrm{ULP}(reffltArg2) \in D \wedge \\ reffltArg2 \neq 0\end{matrix}\right)\end{matrix}\right\}$$	No
Normalized or zero input values which cause an output overflow, i.e. $$\left\{\begin{matrix} (fltArg1, fltArg2, fltLimit) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ (\lvert reffltArg1\rvert + 276 \cdot \mathrm{ULP}(reffltArg1) \in M \wedge) \vee \\ (\lvert reffltArg2\rvert + 276 \cdot \mathrm{ULP}(reffltArg2) \in M \wedge) \end{matrix}\right\}$$	No
Normalized or zero input values which cause intermediate results underflow, i.e. $$\left\{\begin{matrix} \left(\begin{matrix} fltInErr, fltPropGain, fltIntegGain, \\ fltIntegPartK\_1, fltInK\_1 \end{matrix}\right) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ (\lvert ir_1\rvert - 0.5 \cdot \mathrm{ULP}(ir_1) \in D \wedge ir_1 \neq 0) \vee \\ (\lvert ir_2\rvert - 0.5 \cdot \mathrm{ULP}(ir_2) \in D \wedge ir_2 \neq 0) \vee \\ (\lvert ir_3\rvert - \mathrm{ULP}(ir_3) \in D \wedge ir_3 \neq 0) \vee \\ (\lvert ir_4\rvert - 276 \cdot \mathrm{ULP}(ir_4) \in D \wedge ir_4 \neq 0) \vee \\ (\lvert ir_5\rvert - 276 \cdot \mathrm{ULP}(ir_5) \in D \wedge ir_5 \neq 0) \vee \\ (\lvert ir_6\rvert - 276 \cdot \mathrm{ULP}(ir_6) \in D \wedge ir_6 \neq 0) \vee \\ (\lvert ir_7\rvert - 276 \cdot \mathrm{ULP}(ir_7) \in D \wedge ir_7 \neq 0), \\ \{ir_1, ir_2, ir_3, ir_4, ir_5, ir_6, ir_7\} \cap M \neq \varnothing \end{matrix}\right\}$$	No
Normalized or zero input values which cause intermediate results overflow, i.e. $$\left\{\begin{matrix} \left(\begin{matrix} fltInErr, fltPropGain, fltIntegGain, \\ fltIntegPartK\_1, fltInK\_1 \end{matrix}\right) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ (\lvert ir_1\rvert + 0.5 \cdot \mathrm{ULP}(ir_1) \in M) \vee \\ (\lvert ir_2\rvert + 0.5 \cdot \mathrm{ULP}(ir_2) \in M) \vee \\ (\lvert ir_3\rvert + \mathrm{ULP}(ir_3) \in M) \vee \\ (\lvert ir_4\rvert + 276 \cdot \mathrm{ULP}(ir_4) \in M) \vee \\ (\lvert ir_5\rvert + 276 \cdot \mathrm{ULP}(ir_5) \in M) \vee \\ (\lvert ir_6\rvert + 276 \cdot \mathrm{ULP}(ir_6) \in M) \vee \\ (\lvert ir_7\rvert + 276 \cdot \mathrm{ULP}(ir_7) \in M) \end{matrix}\right\}$$	No

Table 134. GFLIB_VectorLimit_FLT Worst-Case Error Bounds - fltArg1 Output

Subset of input domain	Worst-case error bounds for fltArg1 output [ulp]	Allowed specific values (regardless the error bounds) for fltArg1 output
Any of the inputs is denormalized, others are normalized or zero, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2, fltLimit) \in X \mid \\ X \cap D \neq \varnothing \wedge X \cap M = \varnothing \end{array} \right\}$	$(-Inf, Inf)$	N/A
Any of the inputs is NaN or infinity, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2, fltLimit) \in X \mid \\ X \cap M \neq \varnothing \end{array} \right\}$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2, fltLimit) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ \left\{ \begin{array}{c} reffltArg1, reffltArg2, \\ ir_1, ir_2, ir_3, ir_4, ir_5, ir_6, ir_7 \end{array} \right\} \subset N \cup \{-0, +0\} \end{array} \right\}$	$\langle -276, 276 \rangle$	N/A
Normalized or zero input values which cause an output underflow, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2, fltLimit) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ \{reffltArg1, reffltArg2\} \cap M \neq \varnothing \\ \left(\begin{array}{c} \lvert reffltArg1 \rvert - 276 \cdot \mathrm{ULP}(reffltArg1) \in D \wedge \\ reffltArg1 \neq 0 \end{array} \right) \vee \\ \left(\begin{array}{c} \lvert reffltArg2 \rvert - 276 \cdot \mathrm{ULP}(reffltArg2) \in D \wedge \\ reffltArg2 \neq 0 \end{array} \right) \end{array} \right\}$	$(-Inf, Inf)$	N/A
Normalized or zero input values which cause an output overflow, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2, fltLimit) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ (\lvert reffltArg1 \rvert + 276 \cdot \mathrm{ULP}(reffltArg1) \in M \wedge) \vee \\ (\lvert reffltArg2 \rvert + 276 \cdot \mathrm{ULP}(reffltArg2) \in M \wedge) \end{array} \right\}$	$(-Inf, Inf)$	{Inf, –Inf, NaN}

Subset of input domain	Worst-case error bounds for fltArg1 output [ulp]	Allowed specific values (regardless the error bounds) for fltArg1 output
Normalized or zero input values which cause intermediate results underflow, i.e. $$\left\{\begin{array}{c} \left(\begin{array}{c} fltInErr,\ fltPropGain,\ fltIntegGain, \\ fltIntegPartK\_1,\ fltInK\_1 \end{array}\right) \in X \\ X \subset N \cup \{-0,\ +0\}, \\ (\lvert ir_1 \rvert - 0.5 \cdot \mathrm{ULP}(ir_1) \in D \wedge ir_1 \neq 0) \vee \\ (\lvert ir_2 \rvert - 0.5 \cdot \mathrm{ULP}(ir_2) \in D \wedge ir_2 \neq 0) \vee \\ (\lvert ir_3 \rvert - \mathrm{ULP}(ir_3) \in D \wedge ir_3 \neq 0) \vee \\ (\lvert ir_4 \rvert - 276 \cdot \mathrm{ULP}(ir_4) \in D \wedge ir_4 \neq 0) \vee \\ (\lvert ir_5 \rvert - 276 \cdot \mathrm{ULP}(ir_5) \in D \wedge ir_5 \neq 0) \vee \\ (\lvert ir_6 \rvert - 276 \cdot \mathrm{ULP}(ir_6) \in D \wedge ir_6 \neq 0) \vee \\ (\lvert ir_7 \rvert - 276 \cdot \mathrm{ULP}(ir_7) \in D \wedge ir_7 \neq 0), \\ \{ir_1, ir_2, ir_3, ir_4, ir_5, ir_6, ir_7\} \cap M \neq \varnothing \end{array}\right\}$$	$(-Inf, Inf)$	{Inf, –Inf, NaN}
Normalized or zero input values which cause intermediate results overflow, i.e. $$\left\{\begin{array}{c} \left(\begin{array}{c} fltInErr,\ fltPropGain,\ fltIntegGain, \\ fltIntegPartK\_1,\ fltInK\_1 \end{array}\right) \in X \\ X \subset N \cup \{-0,\ +0\}, \\ (\lvert ir_1 \rvert + 0.5 \cdot \mathrm{ULP}(ir_1) \in M) \vee \\ (\lvert ir_2 \rvert + 0.5 \cdot \mathrm{ULP}(ir_2) \in M) \vee \\ (\lvert ir_3 \rvert + \mathrm{ULP}(ir_3) \in M) \vee \\ (\lvert ir_4 \rvert + 276 \cdot \mathrm{ULP}(ir_4) \in M) \vee \\ (\lvert ir_5 \rvert + 276 \cdot \mathrm{ULP}(ir_5) \in M) \vee \\ (\lvert ir_6 \rvert + 276 \cdot \mathrm{ULP}(ir_6) \in M) \vee \\ (\lvert ir_7 \rvert + 276 \cdot \mathrm{ULP}(ir_7) \in M) \end{array}\right\}$$	$(-Inf, Inf)$	{Inf, –Inf, NaN}

Table 135. GFLIB_VectorLimit_FLT Worst-Case Error Bounds - fltArg2 Output

Subset of input domain	Worst-case error bounds for fltArg2 output [ulp]	Allowed specific values (regardless the error bounds) for fltArg2 output
Any of the inputs is denormalized, others are normalized or zero, i.e. $$\left\{\begin{array}{c} (fltArg1,\ fltArg2,\ fltLimit) \in X \\ X \cap D \neq \varnothing \wedge X \cap M = \varnothing \end{array}\right\}$$	$(-Inf, Inf)$	N/A

Subset of input domain	Worst-case error bounds for fltArg2 output [ulp]	Allowed specific values (regardless the error bounds) for fltArg2 output
Any of the inputs is NaN or infinity, i.e. $$\left\{ \begin{matrix} (fltArg1, fltArg2, fltLimit) \in X \mid \\ X \cap M \neq \varnothing \end{matrix} \right\}$$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)
Normalized or zero input values which lead to normalized or zero results, i.e. $$\left\{ \begin{matrix} (fltArg1, fltArg2, fltLimit) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ \left\{ \begin{matrix} ref\,fltArg1, ref\,fltArg2, \\ ir_1, ir_2, ir_3, ir_4, ir_5, ir_6, ir_7 \end{matrix} \right\} \subset N \cup \{-0, +0\} \end{matrix} \right\}$$	$\langle -276, 276 \rangle$	N/A
Normalized or zero input values which cause an output underflow, i.e. $$\left\{ \begin{matrix} (fltArg1, fltArg2, fltLimit) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ \{ref\,fltArg1, ref\,fltArg2\} \cap M \neq \varnothing \\ \left(\begin{matrix} \lvert ref\,fltArg1 \rvert - 276 \cdot \mathrm{ULP}(ref\,fltArg1) \in D \wedge \\ ref\,fltArg1 \neq 0 \end{matrix} \right) \vee \\ \left(\begin{matrix} \lvert ref\,fltArg2 \rvert - 276 \cdot \mathrm{ULP}(ref\,fltArg2) \in D \wedge \\ ref\,fltArg2 \neq 0 \end{matrix} \right) \end{matrix} \right\}$$	$(-Inf, Inf)$	N/A
Normalized or zero input values which cause an output overflow, i.e. $$\left\{ \begin{matrix} (fltArg1, fltArg2, fltLimit) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ (\lvert ref\,fltArg1 \rvert + 276 \cdot \mathrm{ULP}(ref\,fltArg1) \in M \wedge) \vee \\ (\lvert ref\,fltArg2 \rvert + 276 \cdot \mathrm{ULP}(ref\,fltArg2) \in M \wedge) \end{matrix} \right\}$$	$(-Inf, Inf)$	{Inf, –Inf, NaN}

Subset of input domain	Worst-case error bounds for fltArg2 output [ulp]	Allowed specific values (regardless the error bounds) for fltArg2 output
Normalized or zero input values which cause intermediate results underflow, i.e. $$\left\{ \begin{pmatrix} fltInErr, fltPropGain, fltIntegGain, \\ fltIntegPartK\_1, fltInK\_1 \end{pmatrix} \in X \;\middle\|\; \begin{array}{c} X \subset N \cup \{-0, +0\}, \\ (\lvert ir_1 \rvert - 0.5 \cdot \mathrm{ULP}(ir_1) \in D \wedge ir_1 \neq 0) \vee \\ (\lvert ir_2 \rvert - 0.5 \cdot \mathrm{ULP}(ir_2) \in D \wedge ir_2 \neq 0) \vee \\ (\lvert ir_3 \rvert - \mathrm{ULP}(ir_3) \in D \wedge ir_3 \neq 0) \vee \\ (\lvert ir_4 \rvert - 276 \cdot \mathrm{ULP}(ir_4) \in D \wedge ir_4 \neq 0) \vee \\ (\lvert ir_5 \rvert - 276 \cdot \mathrm{ULP}(ir_5) \in D \wedge ir_5 \neq 0) \vee \\ (\lvert ir_6 \rvert - 276 \cdot \mathrm{ULP}(ir_6) \in D \wedge ir_6 \neq 0) \vee \\ (\lvert ir_7 \rvert - 276 \cdot \mathrm{ULP}(ir_7) \in D \wedge ir_7 \neq 0), \\ \{ir_1, ir_2, ir_3, ir_4, ir_5, ir_6, ir_7\} \cap M \neq \varnothing \end{array} \right\}$$	$(-Inf, Inf)$	{Inf, –Inf, NaN}
Normalized or zero input values which cause intermediate results overflow, i.e. $$\left\{ \begin{pmatrix} fltInErr, fltPropGain, fltIntegGain, \\ fltIntegPartK\_1, fltInK\_1 \end{pmatrix} \in X \;\middle\|\; \begin{array}{c} X \subset N \cup \{-0, +0\}, \\ (\lvert ir_1 \rvert + 0.5 \cdot \mathrm{ULP}(ir_1) \in M) \vee \\ (\lvert ir_2 \rvert + 0.5 \cdot \mathrm{ULP}(ir_2) \in M) \vee \\ (\lvert ir_3 \rvert + \mathrm{ULP}(ir_3) \in M) \vee \\ (\lvert ir_4 \rvert + 276 \cdot \mathrm{ULP}(ir_4) \in M) \vee \\ (\lvert ir_5 \rvert + 276 \cdot \mathrm{ULP}(ir_5) \in M) \vee \\ (\lvert ir_6 \rvert + 276 \cdot \mathrm{ULP}(ir_6) \in M) \vee \\ (\lvert ir_7 \rvert + 276 \cdot \mathrm{ULP}(ir_7) \in M) \end{array} \right\}$$	$(-Inf, Inf)$	{Inf, –Inf, NaN}

2.38 Function GFLIB_VLog10_FLT

Declaration

```
void GFLIB_VLog10_FLT(tFloat *pInOut, tU32 u32N, const
GFLIB_VLOG10_T_FLT *const pParam);
```

Arguments

Table 136. GFLIB_VLog10_FLT arguments

Type	Name	Direction	Description
tFloat *	pInOut	**input, output**	Pointer to the floating-point input/output data array. Must be aligned to a double-word boundary.
tU32	u32N	**input**	Array length. Must be divisible by 8 (i.e. 8, 16, 24, ...).

Type	Name	Direction	Description
const GFLIB_ VLOG10_T_FLT *const	pParam	**input**	Pointer to an array of approximation coefficients.

Worst-Case Error Bounds

Only the default approximation coefficients are considered.

Let *fltIn* $\in X$ be an input to GFLIB_VLog10_FLT,

then

Table 137. GFLIB_VLog10_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case output value error bounds [ulp]	Allowed specific output values (regardless the error bounds)
Input not normalized, i.e. $\{fltIn \in X \mid fltIn \notin N\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, –Inf, NaN)
Input normalized, i.e. $\{fltIn \in X \mid fltIn \in N\}$	$\langle -760, 760 \rangle$	N/A

2.39 Function GFLIB_VMin_FLT

Declaration

```
tU32 GFLIB_VMin_FLT(const tFloat *pIn, tU32 u32N);
```

Arguments

Table 138. GFLIB_VMin_FLT arguments

Type	Name	Direction	Description
const tFloat *	pIn	**input**	Pointer to an array of single precision floating-point input values.
tU32	u32N	**input**	Length of the input array.

Worst-Case Error Bounds

The return value is exact if all inputs are normalized or zero. The return value is undefined if any of the inputs are denormalized, infinite, or not a number.

2.40 Function GMCLIB_BetaProjection_FLT

Declaration

```
void GMCLIB_BetaProjection_FLT(SWLIBS_2Syst_FLT *const pOut,
const SWLIBS_3Syst_FLT *const pIn);
```

Arguments

Table 139. GMCLIB_BetaProjection_FLT arguments

Type	Name	Direction	Description
const SWLIBS_3Syst_FLT *const	pIn	**input**	Pointer to the structure containing data of the three-phase stationary system (fltA-fltB-fltC). Arguments of the structure contain single precision floating point values.
SWLIBS_2Syst_FLT *const	pOut	**output**	Pointer to the structure containing data of the two-phase stationary orthogonal system (α-β). Arguments of the structure contain single precision floating point values.

Worst-Case Error Bounds

Let (*fltArg1*, *fltArg2*, *fltArg3*) ∈ *X* be a set of inputs to GMCLIB_BetaProjection_FLT,

$ir_1 = fltArg2 + fltArg3$,

$ir_2 = 2 \cdot fltArg1$,

$ir_3 = ir_1 + ir_2$,

$ie_1 = \max(\mathrm{fe}(|ir_1| + 0.5 \cdot \mathrm{ULP}(ir_1)), \mathrm{fe}(|ir_2|))$,

$ie_2 = \mathrm{fe}(ir_3)$,

$cb = \begin{cases} 0, & ie_1 - ie_2 \le 0 \\ ie_1 - ie_2, & ie_1 - ie_2 > 0 \end{cases}$,

$me_1 = 0.5 + 0.5 \cdot 2^{cb}$,

$ir_4 = \frac{ir_3}{3}$,

$me_2 = 1.5 + 2 \cdot me_1$,

$ir_5 = fltArg2 - fltArg3$,

$ir_6 = \frac{ir_5}{\sqrt{3}}$,

then

Table 140. GMCLIB_BetaProjection_FLT Worst-Case Error Bounds - fltArg1 Output

Subset of input domain	Worst-case error bounds for fltArg1 output [ulp]	Allowed specific values (regardless the error bounds) for fltArg1 output
Any of the inputs is NaN or infinity, i.e. $\left\{ (fltArg1, fltArg2, fltArg3) \in X \;\middle|\; X \cap M \neq \varnothing \right\}$	$(-Inf, Inf)$	{Inf, -Inf, NaN}
Any of the inputs is denormalized, others are normalized or zero, i.e. $\left\{ (fltArg1, fltArg2, fltArg3) \in X \;\middle|\; X \cap D \neq \varnothing \wedge X \cap M = \varnothing \right\}$	$(-Inf, Inf)$	{Inf, -Inf, NaN}

Subset of input domain	Worst-case error bounds for fltArg1 output [ulp]	Allowed specific values (regardless the error bounds) for fltArg1 output
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2, fltArg3) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ \{ir_1, ir_2, ir_3, ir_4, ir_5, ir_6\} \subset N \cup \{-0, +0\}, \end{array} \right\}$	$\langle -me_2, me_2 \rangle$	N/A
Normalized or zero input values which cause result overflow, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2, fltArg3) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ \exists n : ir_n \cap M \neq \varnothing \end{array} \right\}$	$(-Inf, Inf)$	{Inf, –Inf, NaN}
Normalized or zero input values which cause result underflow, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2, fltArg3) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ \exists n : ir_n \cap D \neq \varnothing \end{array} \right\}$	$(-Inf, Inf)$	{Inf, -Inf, NaN}

Table 141. GMCLIB_BetaProjection_FLT Worst-Case Error Bounds - fltArg2 Output

Subset of input domain	Worst-case error bounds for fltArg2 output [ulp]	Allowed specific values (regardless the error bounds) for fltArg2 output
Any of the inputs is NaN or infinity, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2, fltArg3) \in X \mid \\ X \cap M \neq \varnothing \end{array} \right\}$	$(-Inf, Inf)$	{Inf, -Inf, NaN}
Any of the inputs is denormalized, others are normalized or zero, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2, fltArg3) \in X \mid \\ X \cap D \neq \varnothing \wedge X \cap M = \varnothing \end{array} \right\}$	$(-Inf, Inf)$	{Inf, -Inf, NaN}
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2, fltArg3) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ \{ir_1, ir_2, ir_3, ir_4, ir_5, ir_6\} \subset N \cup \{-0, +0\}, \end{array} \right\}$	(-2.5, 2.5)	N/A

Subset of input domain	Worst-case error bounds for fltArg2 output [ulp]	Allowed specific values (regardless the error bounds) for fltArg2 output
Normalized or zero input values which cause result overflow, i.e. $\left\{\begin{matrix}(fltArg1, fltArg2, fltArg3) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ \exists n: ir_n \cap M \neq \varnothing\end{matrix}\right\}$	$(-Inf, Inf)$	{Inf, –Inf, NaN}
Normalized or zero input values which cause result underflow, i.e. $\left\{\begin{matrix}(fltArg1, fltArg2, fltArg3) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ \exists n: ir_n \cap D \neq \varnothing\end{matrix}\right\}$	$(-Inf, Inf)$	{Inf, -Inf, NaN}

2.41 Function GMCLIB_BetaProjection3Ph_FLT

Declaration

```
void GMCLIB_BetaProjection3Ph_FLT(SWLIBS_3Syst_FLT *const pOut,
const SWLIBS_3Syst_FLT *const pIn);
```

Arguments

Table 142. GMCLIB_BetaProjection3Ph_FLT arguments

Type	Name	Direction	Description
const SWLIBS_3Syst_FLT *const	pIn	**input**	Pointer to the structure containing data of the input three-phase stationary system (fltA-fltB-fltC). Arguments of the structure contain single precision floating point values.
SWLIBS_3Syst_FLT *const	pOut	**output**	Pointer to the structure containing data of the output three-phase stationary orthogonal system (fltAout-fltBout-fltCout). Arguments of the structure contain single precision floating point values.

Worst-Case Error Bounds

Let (*fltArg1*, *fltArg2*, *fltArg3*) ∈ *X* be a set of inputs to GMCLIB_BetaProjection3Ph_FLT,

$$ir_1 = fltArg2 + fltArg3,$$

$$ir_2 = 2 \cdot fltArg1,$$

$$ir_3 = ir_1 + ir_2,$$

$$ie_1 = \max(\mathrm{fe}(|ir_1| + 0.5 \cdot \mathrm{ULP}(ir_1)), \mathrm{fe}(|ir_2|)),$$

$$ie_2 = \mathrm{fe}(ir_3),$$

$$cb_1 = \begin{cases} 0, & ie_1 - ie_2 \le 0 \\ ie_1 - ie_2, & ie_1 - ie_2 > 0 \end{cases},$$

$$me_1 = 0.5 + 0.5 \cdot 2^{cb_1},$$

$ir_4 = \frac{ir_3}{3}$,

$me_2 = 1.5 + 2 \cdot me_1$,

$ir_5 = fltArg1 + fltArg3$,

$ir_6 = 2 \cdot fltArg2$,

$ir_7 = ir_5 + ir_6$,

$ie_3 = \max(\mathrm{fe}(|ir_5| + 0.5 \cdot \mathrm{ULP}(ir_5)), \mathrm{fe}(|ir_6|))$,

$ie_4 = \mathrm{fe}(ir_7)$,

$$cb_2 = \begin{cases} 0, & ie_3 - ie_4 \le 0 \\ ie_3 - ie_4, & ie_3 - ie_4 > 0 \end{cases},$$

$me_3 = 0.5 + 0.5 \cdot 2^{cb_2}$,

$ir_8 = \frac{ir_7}{3}$,

$me_4 = 1.5 + 2 \cdot me_3$,

$ir_9 = fltArg1 + fltArg2$,

$ir_{10} = 2 \cdot fltArg3$,

$ir_{11} = ir_9 + ir_{10}$,

$ie_5 = \max(\mathrm{fe}(|ir_9| + 0.5 \cdot \mathrm{ULP}(ir_9)), \mathrm{fe}(|ir_{10}|))$,

$ie_6 = \mathrm{fe}(ir_{11})$,

$$cb_3 = \begin{cases} 0, & ie_5 - ie_6 \le 0 \\ ie_5 - ie_6, & ie_5 - ie_6 > 0 \end{cases},$$

$me_5 = 0.5 + 0.5 \cdot 2^{cb_3}$,

$ir_{12} = \frac{ir_{11}}{3}$,

$me_6 = 1.5 + 2 \cdot me_5$,

then

Table 143. GMCLIB_BetaProjection3Ph_FLT Worst-Case Error Bounds - fltArg1 Output

Subset of input domain	Worst-case error bounds for fltArg1 output [ulp]	Allowed specific values (regardless the error bounds) for fltArg1 output
Any of the inputs is NaN or infinity, i.e. $\left\{ (fltArg1, fltArg2, fltArg3) \in X \;\middle|\; X \cap M \neq \varnothing \right\}$	$(-Inf, Inf)$	{Inf, -Inf, NaN}

Subset of input domain	Worst-case error bounds for fltArg1 output [ulp]	Allowed specific values (regardless the error bounds) for fltArg1 output
Any of the inputs is denormalized, others are normalized or zero, i.e. $\left\{ (fltArg1, fltArg2, fltArg3) \in X \;\middle\|\; X \cap D \neq \varnothing \wedge X \cap M = \varnothing \right\}$	$(-Inf, Inf)$	N/A
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{ (fltArg1, fltArg2, fltArg3) \in X \;\middle\|\; X \subset N \cup \{-0, +0\}, ir_n \subset N \cup \{-0, +0\} \;\; for \;\forall n \right\}$	$\langle -me_2, me_2 \rangle$	N/A
Normalized or zero input values which cause result overflow, i.e. $\left\{ (fltArg1, fltArg2, fltArg3) \in X \;\middle\|\; X \subset N \cup \{-0, +0\}, \exists n : ir_n \cap M \neq \varnothing \right\}$	$(-Inf, Inf)$	{Inf, –Inf, NaN}
Normalized or zero input values which cause result underflow, i.e. $\left\{ (fltArg1, fltArg2, fltArg3) \in X \;\middle\|\; X \subset N \cup \{-0, +0\}, \exists n : ir_n \cap D \neq \varnothing \right\}$	$(-Inf, Inf)$	N/A

Table 144. GMCLIB_BetaProjection3Ph_FLT Worst-Case Error Bounds - fltArg2 Output

Subset of input domain	Worst-case error bounds for fltArg2 output [ulp]	Allowed specific values (regardless the error bounds) for fltArg2 output
Any of the inputs is NaN or infinity, i.e. $\left\{ (fltArg1, fltArg2, fltArg3) \in X \;\middle\|\; X \cap M \neq \varnothing \right\}$	$(-Inf, Inf)$	{Inf, -Inf, NaN}
Any of the inputs is denormalized, others are normalized or zero, i.e. $\left\{ (fltArg1, fltArg2, fltArg3) \in X \;\middle\|\; X \cap D \neq \varnothing \wedge X \cap M = \varnothing \right\}$	$(-Inf, Inf)$	N/A

Subset of input domain	Worst-case error bounds for fltArg2 output [ulp]	Allowed specific values (regardless the error bounds) for fltArg2 output
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2, fltArg3) \in X \\ X \subset N \cup \{-0, +0\}, \\ ir_n \subset N \cup \{-0, +0\} \;\; for \;\; \forall n \end{matrix} \right\|\right\}$	$\langle -me_4, me_4 \rangle$	N/A
Normalized or zero input values which cause result overflow, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2, fltArg3) \in X \\ X \subset N \cup \{-0, +0\}, \\ \exists n : ir_n \cap M \neq \varnothing \end{matrix} \right\|\right\}$	$(-Inf, Inf)$	{Inf, –Inf, NaN}
Normalized or zero input values which cause result underflow, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2, fltArg3) \in X \\ X \subset N \cup \{-0, +0\}, \\ \exists n : ir_n \cap D \neq \varnothing \end{matrix} \right\|\right\}$	$(-Inf, Inf)$	N/A

Table 145. GMCLIB_BetaProjection3Ph_FLT Worst-Case Error Bounds - fltArg3 Output

Subset of input domain	Worst-case error bounds for fltArg3 output [ulp]	Allowed specific values (regardless the error bounds) for fltArg3 output
Any of the inputs is NaN or infinity, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2, fltArg3) \in X \\ X \cap M \neq \varnothing \end{matrix} \right\|\right\}$	$(-Inf, Inf)$	{Inf, -Inf, NaN}
Any of the inputs is denormalized, others are normalized or zero, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2, fltArg3) \in X \\ X \cap D \neq \varnothing \wedge X \cap M = \varnothing \end{matrix} \right\|\right\}$	$(-Inf, Inf)$	N/A
Normalized or zero input values which lead to normalized or zero results, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2, fltArg3) \in X \\ X \subset N \cup \{-0, +0\}, \\ ir_n \subset N \cup \{-0, +0\} \;\; for \;\; \forall n \end{matrix} \right\|\right\}$	$\langle -me_6, me_6 \rangle$	N/A

Subset of input domain	Worst-case error bounds for fltArg3 output [ulp]	Allowed specific values (regardless the error bounds) for fltArg3 output
Normalized or zero input values which cause result overflow, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2, fltArg3) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ \exists n: ir_n \cap M \neq \varnothing \end{array} \right\}$	$(-Inf, Inf)$	{Inf, –Inf, NaN}
Normalized or zero input values which cause result underflow, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2, fltArg3) \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ \exists n: ir_n \cap D \neq \varnothing \end{array} \right\}$	$(-Inf, Inf)$	N/A

2.42 Function GMCLIB_Clark_FLT

Declaration

```
void GMCLIB_Clark_FLT(SWLIBS_2Syst_FLT *const pOut, const
SWLIBS_3Syst_FLT *const pIn);
```

Arguments

Table 146. GMCLIB_Clark_FLT arguments

Type	Name	Direction	Description
const SWLIBS_3Syst_ FLT *const	pIn	**input**	Pointer to the structure containing data of the three-phase stationary system (fltA-fltB-fltC). Arguments of the structure contain single precision floating point values.
SWLIBS_2Syst_FLT *const	pOut	**output**	Pointer to the structure containing data of the two-phase stationary orthogonal system (α-β). Arguments of the structure contain single precision floating point values.

Worst-Case Error Bounds

Let (*fltArg1*, *fltArg2*, *fltArg3*) ∊ *X* be a set of inputs to GMCLIB_Clark_FLT,

reffltArg1, *reffltArg2* be the theoretical exact results for outputs *fltArg1* and *fltArg2*, respectively,

$ir = fltArg2 - fltArg3$,

then

Table 147. GMCLIB_Clark_FLT Worst-Case Error Bounds - fltArg1 Output

Subset of input domain	Worst-case error bounds for fltArg1 output [ulp]	Allowed specific values (regardless the error bounds) for fltArg1 output
Entire input domain	0	*fltArg1*

Table 148. GMCLIB_Clark_FLT Worst-Case Error Bounds - fltArg2 Output

Subset of input domain	Worst-case error bounds for fltArg2 output [ulp]	Allowed specific values (regardless the error bounds) for fltArg2 output
Inputs fltArg2 and fltArg3 infinity, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2, fltArg3) \in X \mid \\ fltArg2 \in \{Inf, -Inf\}, \\ fltArg3 \in \{Inf, -Inf\} \end{array} \right\}$	N/A	{Inf, -Inf, NaN, *pmax*, *nmax*}
fltArg2 arbitrary value, *fltArg3* NaN, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2, fltArg3) \in X \mid \\ fltArg3 = NaN \end{array} \right\}$	N/A	{NaN, *pmax*, *nmax*}
fltArg2 infinity, *fltArg3* normalized, denormalized, or zero, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2, fltArg3) \in X \mid \\ fltArg2 \in \{Inf, -Inf\}, \\ fltArg3 \in N \cup D \cup \{-0, +0\} \end{array} \right\}$	N/A	{sign(*fltArg2*)•Inf, sign(*fltArg2*)•pmax}
fltArg2 NaN, *fltArg3* arbitrary value, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2, fltArg3) \in X \mid \\ fltArg2 = NaN \end{array} \right\}$	N/A	{NaN, *pmax*, *nmax*}
fltArg2 normalized, denormalized, or zero, *fltArg3* infinity, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2, fltArg3) \in X \mid \\ fltArg2 \in N \cup D \cup \{-0, +0\}, \\ fltArg3 \in \{Inf, -Inf\} \end{array} \right\}$	N/A	{-sign(*fltArg3*)•Inf, -sign(*fltArg3*)•pmax}
Inputs fltArg2 and fltArg3 denormalized, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2, fltArg3) \in X \mid \\ X \subset D \end{array} \right\}$	$(-Inf, Inf)$	{-0, +0}
fltArg2 denormalized, *fltArg3* zero, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2, fltArg3) \in X \mid \\ fltArg2 \in D, fltIn_2 = 0 \end{array} \right\}$	$(-Inf, Inf)$	{-0, +0}
fltArg2 denormalized, *fltArg3* normalized, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2, fltArg3) \in X \mid \\ fltArg2 \in D, \\ fltArg3 \in N \end{array} \right\}$	$(-Inf, Inf)$	N/A

Subset of input domain	Worst-case error bounds for fltArg2 output [ulp]	Allowed specific values (regardless the error bounds) for fltArg2 output
fltArg2 zero, *fltArg3* denormalized, i.e. $$\left\{ \begin{matrix} (fltArg1, fltArg2, fltArg3) \in X \mid \\ fltArg2 = 0, fltArg3 \in D \end{matrix} \right\}$$	$(-Inf, Inf)$	{-0, +0}
Inputs fltArg2 and fltArg3 zero, i.e. $$\left\{ \begin{matrix} (fltArg1, fltArg2, fltArg3) \in X \mid \\ fltArg2 = 0, fltArg3 = 0 \end{matrix} \right\}$$	0	N/A
fltArg2 zero, *fltArg3* normalized, i.e. $$\left\{ \begin{matrix} (fltArg1, fltArg2, fltArg3) \in X \mid \\ fltArg2 = 0, \\ fltArg3 \in N \end{matrix} \right\}$$	$\langle -2.5, 2.5 \rangle$	N/A
fltArg2 normalized, *fltArg3* denormalized, i.e. $$\left\{ \begin{matrix} (fltArg1, fltArg2, fltArg3) \in X \mid \\ fltArg2 \in N, fltArg3 \in D \end{matrix} \right\}$$	$(-Inf, Inf)$	N/A
fltArg2 normalized, *fltArg3* zero, i.e. $$\left\{ \begin{matrix} (fltArg1, fltArg2, fltArg3) \in X \mid \\ fltArg2 \in N, fltArg3 = 0 \end{matrix} \right\}$$	$\langle -2.5, 2.5 \rangle$	N/A
Inputs fltArg2 and fltArg3 normalized, results normalized or zero, i.e. $$\left\{ \begin{matrix} (fltArg1, fltArg2, fltArg3) \in X \mid \\ X \subset N, \\ reffltArg2 = 0 \lor \\ \left(\begin{matrix} \lvert reffltArg2 \rvert - 0.5 \cdot \mathrm{ULP}(reffltArg2) \notin D \land \\ \lvert reffltArg2 \rvert + 0.5 \cdot \mathrm{ULP}(reffltArg2) \neq Inf \end{matrix} \right) \end{matrix} \right\}$$	$\langle -2.5, 2.5 \rangle$	N/A
Inputs fltArg2 and fltArg3 normalized, result overflow, i.e. $$\left\{ \begin{matrix} (fltArg1, fltArg2, fltArg3) \in X \mid \\ X \subset N, \\ \lvert reffltArg2 \rvert + 0.5 \cdot \mathrm{ULP}(reffltArg2) = Inf \end{matrix} \right\}$$	$(-Inf, Inf)$	{sign(reffltArg2)•Inf, sign(reffltArg2)•pmax, NaN}

Subset of input domain	Worst-case error bounds for fltArg2 output [ulp]	Allowed specific values (regardless the error bounds) for fltArg2 output
Inputs fltArg2 and fltArg3 normalized, intermediate result overflow, i.e. $\left\{\begin{matrix}(fltArg1, fltArg2, fltArg3) \in X \mid \\ X \subset N, \\ \lvert ir\rvert + 0.5 \cdot \mathrm{ULP}(ir) = Inf\end{matrix}\right\}$	$(-Inf, Inf)$	{sign(reffltArg2)•Inf, sign(reffltArg2)•pmax, NaN}
Inputs fltArg2 and fltArg3 normalized, intermediate result underflow, i.e. $\left\{\begin{matrix}(fltArg1, fltArg2, fltArg3) \in X \mid \\ X \subset N, \\ \lvert ir\rvert - 0.5 \cdot \mathrm{ULP}(ir) \in D \wedge \\ ir \neq 0\end{matrix}\right\}$	$\langle -2.5, 2.5\rangle$	{-0, +0}

2.43 Function GMCLIB_ClarkInv_FLT

Declaration

```
void GMCLIB_ClarkInv_FLT(SWLIBS_3Syst_FLT *const pOut, const
SWLIBS_2Syst_FLT *const pIn);
```

Arguments

Table 149. GMCLIB_ClarkInv_FLT arguments

Type	Name	Direction	Description
const SWLIBS_2Syst_ FLT *const	pIn	**input**	Pointer to the structure containing data of the two-phase stationary orthogonal system (α-β). Arguments of the structure contain single precision floating point values.
SWLIBS_3Syst_FLT *const	pOut	**output**	Pointer to the structure containing data of the three-phase stationary system (fltA-fltB-fltC). Arguments of the structure contain single precision floating point values.

Worst-Case Error Bounds

Let (*fltArg1*, *fltArg2*) ∊ *X* be a set of inputs to GMCLIB_ClarkInv_FLT,

reffltArg2, *reffltArg3* be the theoretical exact results for outputs *fltArg2* and *fltArg3*, respectively,

$ir_1 = 0.5 \cdot fltArg1$,

$ir_2 = \frac{\sqrt{3}}{2} \cdot fltArg2$,

$ie_1 = \max(\mathrm{fe}(\lvert ir_1\rvert), \mathrm{fe}(\lvert ir_2\rvert + 1.5 \cdot \mathrm{ULP}(ir_2)))$,

$refInteg = \ fltIntegPartK\_1 + ir_2$,

$ix = \mathrm{fe}(reffltArg2)$,

$iy = \mathrm{fe}(ref\,fltArg3)$,

$$cb_1 = \begin{cases} 0, & ie_1 - ix \le 0 \\ ie_1 - ix, & ie_1 - ix > 0 \end{cases},$$

$$cb_2 = \begin{cases} 0, & ie_1 - iy \le 0 \\ ie_1 - iy, & ie_1 - iy > 0 \end{cases},$$

$me_1 = 0.5 + 1.5 \cdot 2^{cb_1}$,

$me_2 = 0.5 + 1.5 \cdot 2^{cb_2}$,

then

Table 150. GMCLIB_ClarkInv_FLT Worst-Case Error Bounds - Output *fltArg1*

Subset of input domain	Worst-case error bounds for *fltArg1* output [ulp]	Allowed specific values (regardless the error bounds) for *fltArg1* output
Entire input domain	0	N/A

Table 151. GMCLIB_ClarkInv_FLT Worst-Case Error Bounds - Output *fltArg2*

Subset of input domain	Worst-case error bounds for *fltArg2* output [ulp]	Allowed specific values (regardless the error bounds) for *fltArg2* output
Both inputs infinity, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ X \subset \{Inf, -Inf\} \end{matrix} \right\}$	$(-Inf, Inf)$	{NaN, 0, -0} if sign(*fltArg1*)=sign(*fltArg2*), {sign(*fltArg2*)•Inf, sign(*fltArg2*)•pmax} otherwise
fltArg1 infinity, *fltArg2* NaN, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 = NaN \end{matrix} \right\}$	$(-Inf, Inf)$	{NaN, 0, -0, *pmax*, *nmax*}
fltArg1 infinity, *fltArg2* denormalized, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 \in D \end{matrix} \right\}$	$(-Inf, Inf)$	{-sign(*fltArg1*)•Inf, sign(*fltArg1*)•pmax}
fltArg1 infinity, *fltArg2* zero, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 = 0 \end{matrix} \right\}$	$(-Inf, Inf)$	{-sign(*fltArg1*)•Inf, sign(*fltArg1*)•pmax}

Subset of input domain	Worst-case error bounds for *fltArg2* output [ulp]	Allowed specific values (regardless the error bounds) for *fltArg2* output
fltArg1 infinity, *fltArg2* normalized, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 \in N \end{matrix} \right\}$	$(-Inf, Inf)$	{-sign(*fltArg1*)•Inf, sign(*fltArg1*)•pmax}
fltArg1 NaN, *fltArg2* infinity, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ fltIn_1 = NaN, \\ fltIn_2 \in \{Inf, -Inf\} \end{matrix} \right\}$	$(-Inf, Inf)$	{NaN, *pmax*, *nmax*}
Both inputs NaN, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ fltIn_1 = NaN, \\ fltIn_2 = NaN \end{matrix} \right\}$	$(-Inf, Inf)$	{NaN, *pmax*, *nmax*}
fltArg1 NaN, *fltArg2* denormalized, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ fltIn_1 = NaN, \\ fltIn_2 \in D \end{matrix} \right\}$	$(-Inf, Inf)$	{NaN, *pmax*, *nmax*}
fltArg1 NaN, *fltArg2* zero, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ fltIn_1 = NaN, \\ fltIn_2 \in D \end{matrix} \right\}$	$(-Inf, Inf)$	{NaN, *pmax*, *nmax*}
fltArg1 NaN, *fltArg2* normalized, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ fltIn_1 = NaN, \\ fltIn_2 \in N \end{matrix} \right\}$	$(-Inf, Inf)$	NaN
fltArg1 denormalized, *fltArg2* infinite, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ fltIn_1 \in D, \\ fltIn_2 \in \{Inf, -Inf\} \end{matrix} \right\}$	$(-Inf, Inf)$	{sign(*fltArg2*)•Inf, sign(*fltArg2*)•pmax}

Subset of input domain	Worst-case error bounds for *fltArg2* output [ulp]	Allowed specific values (regardless the error bounds) for *fltArg2* output
fltArg1 denormalized, *fltArg2* NaN, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ fltIn_1 \in D, \\ fltIn_2 = NaN \end{matrix} \right\}$	$(-Inf, Inf)$	{NaN, *pmax*, *nmax*}
Both inputs denormalized, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ fltIn_1 \in D, \\ fltIn_2 \in D \end{matrix} \right\}$	$\langle -2^{23}, 2^{23} \rangle$	{0, -0}
fltArg1 zero, *fltArg2* infinite, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ fltIn_1 = 0, \\ fltIn_2 \in \{Inf, -Inf\} \end{matrix} \right\}$	$(-Inf, Inf)$	{sign(*fltArg2*)•Inf, sign(*fltArg2*)•pmax}
fltArg1 zero, *fltArg2* NaN, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ fltIn_1 = 0, \\ fltIn_2 = NaN \end{matrix} \right\}$	$(-Inf, Inf)$	{NaN, *pmax*, *nmax*}
fltArg1 denormalized, *fltArg2* zero, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ fltIn_1 \in D, \\ fltIn_2 = 0 \end{matrix} \right\}$	$\langle -0.5, 0.5 \rangle$	{0, -0}
fltArg1 zero, *fltArg2* denormalized, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ fltIn_1 = 0, \\ fltIn_2 \in D \end{matrix} \right\}$	$\langle -1.5, 1.5 \rangle$	{0, -0}
fltArg1 normalized, *fltArg2* infinite, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ fltIn_1 \in N, \\ fltIn_2 \in \{Inf, -Inf\} \end{matrix} \right\}$	$(-Inf, Inf)$	sign(*fltArg2*)•Infsign(*fltArg2*)•Inf

Subset of input domain	Worst-case error bounds for *fltArg2* output [ulp]	Allowed specific values (regardless the error bounds) for *fltArg2* output
fltArg1 normalized, *fltArg2* NaN, i.e. $$\left\{\begin{matrix}(fltArg1, fltArg2) \in X \mid \\ fltIn_1 \in N, \\ fltIn_2 = NaN\end{matrix}\right\}$$	$(-Inf, Inf)$	NaN
fltArg1 denormalized, *fltArg2* normalized, i.e. $$\left\{\begin{matrix}(fltArg1, fltArg2) \in X \mid \\ fltIn_1 \in D, \\ fltIn_2 \in N\end{matrix}\right\}$$	$\langle -2^{23}, 2^{23}\rangle$	N/A
fltArg1 normalized, *fltArg2* denormalized, i.e. $$\left\{\begin{matrix}(fltArg1, fltArg2) \in X \mid \\ fltIn_1 \in D, \\ fltIn_2 \in N\end{matrix}\right\}$$	$\langle -2^{23}, 2^{23}\rangle$	N/A
Both inputs normalized or zero, i.e. $$\left\{\begin{matrix}(fltArg1, fltArg2) \in X \mid \\ X \in N \cup \{-0, +0\}\end{matrix}\right\}$$	$\langle -me_1, me_1\rangle$	N/A
Both inputs normalized or zero, *fltArg2* output underflow i.e. $$\left\{\begin{matrix}(fltArg1, fltArg2) \in X \mid \\ X \in N \cup \{-0, +0\}, \\ \left(\begin{matrix}\lvert reffltArg2\rvert - me_1 \cdot \mathrm{ULP}(reffltArg2) \in D \wedge \\ reffltArg2 \neq 0,\end{matrix}\right)\end{matrix}\right\}$$	$(-Inf, Inf)$	{-0, +0}
Both inputs normalized or zero, intermediate result underflow i.e. $$\left\{\begin{matrix}(fltArg1, fltArg2) \in X \mid \\ X \in N \cup \{-0, +0\}, \\ ir_1 \in D \vee \\ \left(\begin{matrix}\lvert ir_2\rvert - 1.5 \cdot \mathrm{ULP}(ir_2) \in D \wedge \\ ir_2 \neq 0,\end{matrix}\right)\end{matrix}\right\}$$	$(-Inf, Inf)$	{NaN, -Inf, Inf}
Both inputs normalized or zero, *fltArg2* output overflow i.e. $$\left\{\begin{matrix}(fltArg1, fltArg2) \in X \mid \\ X \in N \cup \{-0, +0\}, \\ \lvert reffltArg2\rvert + me_1 \cdot \mathrm{ULP}(reffltArg2) \in M\end{matrix}\right\}$$	$(-Inf, Inf)$	{NaN, -Inf, Inf}

Table 152. GMCLIB_ClarkInv_FLT Worst-Case Error Bounds - Output *fltArg3*

Subset of input domain	Worst-case error bounds for fltArg3 output [ulp]	Allowed specific values (regardless the error bounds) for fltArg3 output
Both inputs infinity, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2) \in X \mid \\ X \subset \{Inf, -Inf\} \end{array} \right\}$	$(-Inf, Inf)$	{-sign(*fltArg2*)•Inf, sign(*fltArg2*)•pmax} if sign(*fltArg1*)=sign(*fltArg2*), {NaN, 0, -0} otherwise
fltArg1 infinity, *fltArg2* NaN, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2) \in X \mid \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 = NaN \end{array} \right\}$	$(-Inf, Inf)$	{NaN, 0, -0, *pmax*, *nmax*}
fltArg1 infinity, *fltArg2* denormalized, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2) \in X \mid \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 \in D \end{array} \right\}$	$(-Inf, Inf)$	{-sign(*fltArg1*)•Inf, sign(*fltArg1*)•pmax}
fltArg1 infinity, *fltArg2* zero, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2) \in X \mid \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 = 0 \end{array} \right\}$	$(-Inf, Inf)$	{-sign(*fltArg1*)•Inf, sign(*fltArg1*)•pmax}
fltArg1 infinity, *fltArg2* normalized, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2) \in X \mid \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 \in N \end{array} \right\}$	$(-Inf, Inf)$	{-sign(*fltArg1*)•Inf, sign(*fltArg1*)•pmax}
fltArg1 NaN, *fltArg2* infinity, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2) \in X \mid \\ fltIn_1 = NaN, \\ fltIn_2 \in \{Inf, -Inf\} \end{array} \right\}$	$(-Inf, Inf)$	{NaN, *pmax*, *nmax*}
Both inputs NaN, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2) \in X \mid \\ fltIn_1 = NaN, \\ fltIn_2 = NaN \end{array} \right\}$	$(-Inf, Inf)$	{NaN, *pmax*, *nmax*}

Subset of input domain	Worst-case error bounds for fltArg3 output [ulp]	Allowed specific values (regardless the error bounds) for fltArg3 output
fltArg1 NaN, *fltArg2* denormalized, i.e. $\left\{ (fltArg1, fltArg2) \in X \;\middle|\; \begin{matrix} fltIn_1 = NaN, \\ fltIn_2 \in D \end{matrix} \right\}$	$(-Inf, Inf)$	{NaN, *pmax*, *nmax*}
fltArg1 NaN, *fltArg2* zero, i.e. $\left\{ (fltArg1, fltArg2) \in X \;\middle|\; \begin{matrix} fltIn_1 = NaN, \\ fltIn_2 \in D \end{matrix} \right\}$	$(-Inf, Inf)$	{NaN, *pmax*, *nmax*}
fltArg1 NaN, *fltArg2* normalized, i.e. $\left\{ (fltArg1, fltArg2) \in X \;\middle|\; \begin{matrix} fltIn_1 = NaN, \\ fltIn_2 \in N \end{matrix} \right\}$	$(-Inf, Inf)$	NaN
fltArg1 denormalized, *fltArg2* infinite, i.e. $\left\{ (fltArg1, fltArg2) \in X \;\middle|\; \begin{matrix} fltIn_1 \in D, \\ fltIn_2 \in \{Inf, -Inf\} \end{matrix} \right\}$	$(-Inf, Inf)$	{-sign(*fltArg2*)•Inf, sign(*fltArg2*)•pmax}
fltArg1 denormalized, *fltArg2* NaN, i.e. $\left\{ (fltArg1, fltArg2) \in X \;\middle|\; \begin{matrix} fltIn_1 \in D, \\ fltIn_2 = NaN \end{matrix} \right\}$	$(-Inf, Inf)$	{NaN, *pmax*, *nmax*}
Both inputs denormalized, i.e. $\left\{ (fltArg1, fltArg2) \in X \;\middle|\; \begin{matrix} fltIn_1 \in D, \\ fltIn_2 \in D \end{matrix} \right\}$	$\langle -2^{23}, 2^{23} \rangle$	{0, -0}
fltArg1 zero, *fltArg2* infinite, i.e. $\left\{ (fltArg1, fltArg2) \in X \;\middle|\; \begin{matrix} fltIn_1 = 0, \\ fltIn_2 \in \{Inf, -Inf\} \end{matrix} \right\}$	$(-Inf, Inf)$	{-sign(*fltArg2*)•Inf, sign(*fltArg2*)•pmax}

Subset of input domain	Worst-case error bounds for fltArg3 output [ulp]	Allowed specific values (regardless the error bounds) for fltArg3 output
fltArg1 zero, *fltArg2* NaN, i.e. $\left\{ (fltArg1, fltArg2) \in X \;\middle|\; \begin{array}{c} fltIn_1 = 0, \\ fltIn_2 = NaN \end{array} \right\}$	$(-Inf, Inf)$	{NaN, *pmax*, *nmax*}
fltArg1 denormalized, *fltArg2* zero, i.e. $\left\{ (fltArg1, fltArg2) \in X \;\middle|\; \begin{array}{c} fltIn_1 \in D, \\ fltIn_2 = 0 \end{array} \right\}$	$\langle -0.5, 0.5 \rangle$	{0, -0}
fltArg1 zero, *fltArg2* denormalized, i.e. $\left\{ (fltArg1, fltArg2) \in X \;\middle|\; \begin{array}{c} fltIn_1 = 0, \\ fltIn_2 \in D \end{array} \right\}$	$\langle -1.5, 1.5 \rangle$	{0, -0}
fltArg1 normalized, *fltArg2* infinite, i.e. $\left\{ (fltArg1, fltArg2) \in X \;\middle|\; \begin{array}{c} fltIn_1 \in N, \\ fltIn_2 \in \{Inf, -Inf\} \end{array} \right\}$	$(-Inf, Inf)$	{-sign(*fltArg2*)•Inf}
fltArg1 normalized, *fltArg2* NaN, i.e. $\left\{ (fltArg1, fltArg2) \in X \;\middle|\; \begin{array}{c} fltIn_1 \in N, \\ fltIn_2 = NaN \end{array} \right\}$	$(-Inf, Inf)$	NaN
fltArg1 denormalized, *fltArg2* normalized, i.e. $\left\{ (fltArg1, fltArg2) \in X \;\middle|\; \begin{array}{c} fltIn_1 \in D, \\ fltIn_2 \in N \end{array} \right\}$	$\langle -2^{23}, 2^{23} \rangle$	N/A
fltArg1 normalized, *fltArg2* denormalized, i.e. $\left\{ (fltArg1, fltArg2) \in X \;\middle|\; \begin{array}{c} fltIn_1 \in D, \\ fltIn_2 \in N \end{array} \right\}$	$\langle -2^{23}, 2^{23} \rangle$	N/A

Subset of input domain	Worst-case error bounds for fltArg3 output [ulp]	Allowed specific values (regardless the error bounds) for fltArg3 output
Both inputs normalized or zero, i.e. $$\left\{ \begin{array}{c} (fltArg1, fltArg2) \in X \mid \\ X \in N \cup \{-0, +0\} \end{array} \right\}$$	$\langle -me_1, me_1 \rangle$	N/A
Both inputs normalized or zero, *fltArg3* output underflow i.e. $$\left\{ \begin{array}{c} (fltArg1, fltArg2) \in X \mid \\ X \in N \cup \{-0, +0\}, \\ \left(\begin{array}{c} \lvert reffltArg2 \rvert - me_1 \cdot \mathrm{ULP}(reffltArg2) \in D \wedge \\ reffltArg2 \neq 0, \end{array} \right) \end{array} \right\}$$	$(-Inf, Inf)$	{-0, +0}
Both inputs normalized or zero, intermediate result underflow i.e. $$\left\{ \begin{array}{c} (fltArg1, fltArg2) \in X \mid \\ X \in N \cup \{-0, +0\}, \\ ir_1 \in D \vee \\ \left(\begin{array}{c} \lvert ir_2 \rvert - 1.5 \cdot \mathrm{ULP}(ir_2) \in D \wedge \\ ir_2 \neq 0, \end{array} \right) \end{array} \right\}$$	$(-Inf, Inf)$	{NaN, -Inf, Inf}
Both inputs normalized or zero, *fltArg3* output overflow i.e. $$\left\{ \begin{array}{c} (fltArg1, fltArg2) \in X \mid \\ X \in N \cup \{-0, +0\}, \\ \lvert reffltArg2 \rvert + me_1 \cdot \mathrm{ULP}(reffltArg2) \in M \end{array} \right\}$$	$(-Inf, Inf)$	{NaN, -Inf, Inf}

2.44 Function GMCLIB_DecouplingPMSM_FLT

Declaration

```
void GMCLIB_DecouplingPMSM_FLT(SWLIBS_2Syst_FLT *const pUdqDec,
const SWLIBS_2Syst_FLT *const pUdq, const SWLIBS_2Syst_FLT *const
pIdq, tFloat fltAngularVel, const GMCLIB_DECOUPLINGPMSM_T_FLT
*const pParam);
```

Arguments

Table 153. GMCLIB_DecouplingPMSM_FLT arguments

Type	Name	Direction	Description
SWLIBS_2Syst_FLT *const	pUdqDec	**output**	Pointer to the structure containing direct (u_{df_dec}) and quadrature (u_{qf_dec}) components of the decoupled stator voltage vector to be applied on the motor terminals.
const SWLIBS_2Syst_FLT *const	pUdq	**input**	Pointer to the structure containing direct (u_{df}) and quadrature (u_{qf}) components of the stator voltage vector generated by the current controllers.

Type	Name	Direction	Description
const SWLIBS_2Syst_FLT *const	pIdq	**input**	Pointer to the structure containing direct (i_{df}) and quadrature (i_{qf}) components of the stator current vector measured on the motor terminals.
tFloat	fltAngularVel	**input**	Rotor angular velocity in rad/sec, referred to as ($omega_{ef}$) in the detailed section of the documentation.
const GMCLIB_DECOUPLINGPMSM_T_FLT *const	pParam	**input**	Pointer to the structure containing L_D and L_Q coefficients (see the detailed section of the documentation).

Worst-Case Error Bounds

Let (*UfltArg1*, *UfltArg2*, *IfltArg1*, *IfltArg2*, *fltAngularVel*, *fltLD*, *fltLQ*) ∊ *X* be a set of inputs to GMCLIB_DecouplingPMSM_FLT,

reffltArg1, *reffltArg2* be the theoretical exact results for outputs *fltArg1* and *fltArg2*, respectively,

$ira_1 = fltAngularVel \cdot IfltArg2$,

$ira_2 = ira_1 \cdot fltLQ$,

$irb_1 = fltAngularVel \cdot IfltArg1$,

$irb_2 = irb_1 \cdot fltLD$,

then

Table 154. GMCLIB_DecouplingPMSM_FLT Worst-Case Error Bounds - fltArg1 Output

Subset of input domain	Worst-case error bounds for fltArg1 output [ulp]	Allowed specific values (regardless the error bounds) for fltArg1 output
Any of {*UfltArg1*, *IfltArg2*, *fltLQ*, *fltAngularVel*} is NaN, i.e. $\left\{ \left(\begin{matrix} UfltArg1, UfltArg2, \\ IfltArg1, IfltArg2, \\ fltAngularVel, fltLD, fltLQ \end{matrix} \right) \in X \;\middle|\; \begin{Bmatrix} UfltArg1, IfltArg2, \\ fltLQ, \;\; fltAngularVel \end{Bmatrix} \cap NaN \neq \varnothing \right\}$	$(-Inf, Inf)$	{NaN, *pmax*, *nmax*}
Any of {*UfltArg1*, *IfltArg2*, *fltLQ*, *fltAngularVel*} is infinity, i.e. $\left\{ \left(\begin{matrix} UfltArg1, UfltArg2, \\ IfltArg1, IfltArg2, \\ fltAngularVel, fltLD, fltLQ \end{matrix} \right) \in X \;\middle|\; \begin{Bmatrix} UfltArg1, IfltArg2, \\ fltLQ, \;\; fltAngularVel \end{Bmatrix} \cap \{Inf, -Inf\} \neq \varnothing \right\}$	$(-Inf, Inf)$	{NaN, *pmax*, *nmax*, Inf, -Inf, 0, -0}

Subset of input domain	Worst-case error bounds for fltArg1 output [ulp]	Allowed specific values (regardless the error bounds) for fltArg1 output
At least one of {*UfltArg1*, *IfltArg2*, *fltLQ*, *fltAngularVel*} is denormalized, others are normalized, denormalized, or zero, i.e. $$\left\{ \left(\begin{matrix} UfltArg1, UfltArg2, \\ IfltArg1, IfltArg2, \\ fltAngularVel, fltLD, fltLQ \end{matrix} \right) \in X \;\middle|\; \begin{matrix} \left\{ \begin{matrix} UfltArg1, IfltArg2, \\ fltLQ, \quad fltAngularVel \end{matrix} \right\} \cap D \neq \varnothing, \\ \left\{ \begin{matrix} UfltArg1, IfltArg2, \\ fltLQ, \quad fltAngularVel \end{matrix} \right\} \cap M = \varnothing \end{matrix} \right\}$$	$(-Inf, Inf)$	{0, -0}
All of {*UfltArg1*, *IfltArg2*, *fltLQ*, *fltAngularVel*} are zero, i.e. $$\left\{ \left(\begin{matrix} UfltArg1, UfltArg2, \\ IfltArg1, IfltArg2, \\ fltAngularVel, fltLD, fltLQ \end{matrix} \right) \in X \;\middle|\; \begin{matrix} UfltArg1 = 0, \\ IfltArg2 = 0, \\ fltLQ = 0, \\ fltAngularVel = 0 \end{matrix} \right\}$$	0	N/A
All of {*UfltArg1*, *IfltArg2*, *fltLQ*, *fltAngularVel*} are normalized or zero, inputs lead to normalized or zero results, i.e. $$\left\{ \left(\begin{matrix} UfltArg1, UfltArg2, \\ IfltArg1, IfltArg2, \\ fltAngularVel, fltLD, fltLQ \end{matrix} \right) \in X \;\middle|\; \begin{matrix} \left\{ \begin{matrix} UfltArg1, IfltArg2, \\ fltLQ, \quad fltAngularVel \end{matrix} \right\} \subset N \cup \{-0, +0\}, \\ \{ira_1, ira_2\} \subset N \cup \{-0, +0\}, \\ reffltArg1 = 0 \vee \\ \left(\begin{matrix} 0.5 \cdot (\lvert reffltArg1 \rvert - \mathrm{ULP}(reffltArg1)) \notin D \wedge \\ \lvert reffltArg1 \rvert + \mathrm{ULP}(reffltArg1) \neq Inf \end{matrix} \right) \end{matrix} \right\}$$	$\langle -1, 1 \rangle$	N/A
All of {*UfltArg1*, *IfltArg2*, *fltLQ*, *fltAngularVel*} are normalized or zero, *fltArg1* output overflow, i.e. $$\left\{ \left(\begin{matrix} UfltArg1, UfltArg2, \\ IfltArg1, IfltArg2, \\ fltAngularVel, fltLD, fltLQ \end{matrix} \right) \in X \;\middle|\; \begin{matrix} \left\{ \begin{matrix} UfltArg1, IfltArg2, \\ fltLQ, \quad fltAngularVel \end{matrix} \right\} \subset N \cup \{-0, +0\}, \\ \lvert reffltArg1 \rvert + \mathrm{ULP}(reffltArg1) = Inf \end{matrix} \right\}$$	$(-Inf, Inf)$	{sign(*reffltArg1*)•Inf, sign(*reffltArg1*)•pmax, NaN}

Subset of input domain	Worst-case error bounds for fltArg1 output [ulp]	Allowed specific values (regardless the error bounds) for fltArg1 output
All of {*UfltArg1*, *IfltArg2*, *fltLQ*, *fltAngularVel*} are normalized or zero, *fltArg1* output underflow or uncompensated calculation, i.e. $\left\{ \left(\begin{matrix} UfltArg1, UfltArg2, \\ IfltArg1, IfltArg2, \\ fltAngularVel, fltLD, fltLQ \end{matrix} \right) \in X \;\middle\vert\; \begin{matrix} \left\{ \begin{matrix} UfltArg1, IfltArg2, \\ fltLQ, \;\; fltAngularVel \end{matrix} \right\} \subset N \cup \{-0, +0\}, \\ reffltArg1 \neq 0 \wedge \\ 0.5 \cdot (\lvert reffltArg1 \rvert - \mathrm{ULP}(reffltArg1)) \in D \end{matrix} \right\}$	$\langle -2^{24}, 2^{24} \rangle$	{0, -0}
All of {*UfltArg1*, *IfltArg2*, *fltLQ*, *fltAngularVel*} are normalized or zero, intermediate result overflow, i.e. $\left\{ \left(\begin{matrix} UfltArg1, UfltArg2, \\ IfltArg1, IfltArg2, \\ fltAngularVel, fltLD, fltLQ \end{matrix} \right) \in X \;\middle\vert\; \begin{matrix} \left\{ \begin{matrix} UfltArg1, IfltArg2, \\ fltLQ, \;\; fltAngularVel \end{matrix} \right\} \subset N \cup \{-0, +0\}, \\ \left(\begin{matrix} \lvert ira_1 \rvert + 0.5 \cdot \mathrm{ULP}(ira_1), \\ \lvert ira_2 \rvert + \mathrm{ULP}(ira_2) \end{matrix} \right) \cap \{Inf, -Inf\} \neq \varnothing \end{matrix} \right\}$	$(-Inf, Inf)$	{*pmax*, *nmax*, Inf, -Inf}
All of {*UfltArg1*, *IfltArg2*, *fltLQ*, *fltAngularVel*} are normalized or zero, intermediate result underflow, i.e. $\left\{ \left(\begin{matrix} UfltArg1, UfltArg2, \\ IfltArg1, IfltArg2, \\ fltAngularVel, fltLD, fltLQ \end{matrix} \right) \in X \;\middle\vert\; \begin{matrix} \left\{ \begin{matrix} UfltArg1, IfltArg2, \\ fltLQ, \;\; fltAngularVel \end{matrix} \right\} \subset N \cup \{-0, +0\}, \\ \left(\begin{matrix} 0.5 \cdot (\lvert ira_1 \rvert - 0.5 \cdot \mathrm{ULP}(ira_1)) \in D \wedge \\ ira_1 \neq 0, \end{matrix} \right) \vee \\ \left(\begin{matrix} 0.5 \cdot (\lvert ira_2 \rvert - \mathrm{ULP}(ira_2)) \in D \wedge \\ ira_2 \neq 0, \end{matrix} \right) \end{matrix} \right\}$	$\langle -2^{24}, 2^{24} \rangle$	{0, -0}

Table 155. GMCLIB_DecouplingPMSM_FLT Worst-Case Error Bounds - fltArg2 Output

Subset of input domain	Worst-case error bounds for fltArg2 output [ulp]	Allowed specific values (regardless the error bounds) for fltArg2 output
Any of {*UfltArg2*, *IfltArg1*, *fltLD*, *fltAngularVel*} is NaN, i.e. $\left\{ \begin{pmatrix} UfltArg1, UfltArg2, \\ IfltArg1, IfltArg2, \\ fltAngularVel, fltLD, fltLQ \end{pmatrix} \in X \;\middle|\; \left\{ \begin{matrix} UfltArg2, IfltArg1, \\ fltLD, \quad fltAngularVel \end{matrix} \right\} \cap NaN \neq \varnothing \right\}$	$(-Inf, Inf)$	{NaN, *pmax*, *nmax*}
Any of {*UfltArg2*, *IfltArg1*, *fltLD*, *fltAngularVel*} is infinity, i.e. $\left\{ \begin{pmatrix} UfltArg1, UfltArg2, \\ IfltArg1, IfltArg2, \\ fltAngularVel, fltLD, fltLQ \end{pmatrix} \in X \;\middle|\; \left\{ \begin{matrix} UfltArg2, IfltArg1, \\ fltLD, \quad fltAngularVel \end{matrix} \right\} \cap \{Inf, -Inf\} \neq \varnothing \right\}$	$(-Inf, Inf)$	{NaN, *pmax*, *nmax*, Inf, -Inf, 0, -0}
At least one of {*UfltArg2*, *IfltArg1*, *fltLD*, *fltAngularVel*} is denormalized, others are normalized, denormalized, or zero, i.e. $\left\{ \begin{pmatrix} UfltArg1, UfltArg2, \\ IfltArg1, IfltArg2, \\ fltAngularVel, fltLD, fltLQ \end{pmatrix} \in X \;\middle|\; \begin{matrix} \left\{ \begin{matrix} UfltArg2, IfltArg1, \\ fltLD, \quad fltAngularVel \end{matrix} \right\} \cap D \neq \varnothing, \\ \left\{ \begin{matrix} UfltArg2, IfltArg1, \\ fltLD, \quad fltAngularVel \end{matrix} \right\} \cap M = \varnothing \end{matrix} \right\}$	$(-Inf, Inf)$	{0, -0}
All of {*UfltArg2*, *IfltArg1*, *fltLD*, *fltAngularVel*} are zero, i.e. $\left\{ \begin{pmatrix} UfltArg1, UfltArg2, \\ IfltArg1, IfltArg2, \\ fltAngularVel, fltLD, fltLQ \end{pmatrix} \in X \;\middle|\; \begin{matrix} UfltArg2 = 0, \\ IfltArg1 = 0, \\ fltLD = 0, \\ fltAngularVel = 0 \end{matrix} \right\}$	0	N/A

Subset of input domain	Worst-case error bounds for fltArg2 output [ulp]	Allowed specific values (regardless the error bounds) for fltArg2 output
All of {*UfltArg2*, *IfltArg1*, *fltLD*, *fltAngularVel*} are normalized or zero, inputs lead to normalized or zero results, i.e. $\left\{ \begin{pmatrix} UfltArg1, UfltArg2, \\ IfltArg1, IfltArg2, \\ fltAngularVel, fltLD, fltLQ \end{pmatrix} \in X \;\middle\vert\; \begin{array}{c} \left\{ \begin{array}{c} UfltArg2, IfltArg1, \\ fltLD, \ fltAngularVel \end{array} \right\} \subset N \cup \{-0, +0\}, \\ \{irb_1, irb_2\} \subset N \cup \{-0, +0\}, \\ reffltArg2 = 0 \vee \\ \left(\begin{array}{c} 0.5 \cdot (\lvert reffltArg2 \rvert - \mathrm{ULP}(reffltArg2)) \notin D \wedge \\ \lvert reffltArg2 \rvert + \mathrm{ULP}(reffltArg2) \neq Inf \end{array} \right) \end{array} \right\}$	$\langle -1, 1 \rangle$	N/A
All of {*UfltArg2*, *IfltArg1*, *fltLD*, *fltAngularVel*} are normalized or zero, *fltArg2* output overflow, i.e. $\left\{ \begin{pmatrix} UfltArg1, UfltArg2, \\ IfltArg1, IfltArg2, \\ fltAngularVel, fltLD, fltLQ \end{pmatrix} \in X \;\middle\vert\; \begin{array}{c} \left\{ \begin{array}{c} UfltArg2, IfltArg1, \\ fltLD, \ fltAngularVel \end{array} \right\} \subset N \cup \{-0, +0\}, \\ \lvert reffltArg2 \rvert + \mathrm{ULP}(reffltArg2) = Inf \end{array} \right\}$	$(-Inf, Inf)$	{sign(*reffltArg2*)•Inf, sign(*reffltArg2*)•pmax, NaN}
All of {*UfltArg2*, *IfltArg1*, *fltLD*, *fltAngularVel*} are normalized or zero, *fltArg2* output underflow or uncompensated calculation, i.e. $\left\{ \begin{pmatrix} UfltArg1, UfltArg2, \\ IfltArg1, IfltArg2, \\ fltAngularVel, fltLD, fltLQ \end{pmatrix} \in X \;\middle\vert\; \begin{array}{c} \left\{ \begin{array}{c} UfltArg2, IfltArg1, \\ fltLD, \ fltAngularVel \end{array} \right\} \subset N \cup \{-0, +0\}, \\ reffltArg2 \neq 0 \wedge \\ 0.5 \cdot (\lvert reffltArg2 \rvert - \mathrm{ULP}(reffltArg2)) \in D \end{array} \right\}$	$\langle -2^{24}, 2^{24} \rangle$	{0, -0}
All of {*UfltArg2*, *IfltArg1*, *fltLD*, *fltAngularVel*} are normalized or zero, intermediate result overflow, i.e. $\left\{ \begin{pmatrix} UfltArg1, UfltArg2, \\ IfltArg1, IfltArg2, \\ fltAngularVel, fltLD, fltLQ \end{pmatrix} \in X \;\middle\vert\; \begin{array}{c} \left\{ \begin{array}{c} UfltArg2, IfltArg1, \\ fltLD, \ fltAngularVel \end{array} \right\} \subset N \cup \{-0, +0\}, \\ \left(\begin{array}{c} \lvert irb_1 \rvert + 0.5 \cdot \mathrm{ULP}(irb_1), \\ \lvert irb_2 \rvert + \mathrm{ULP}(irb_2) \end{array} \right) \cap \{Inf, -Inf\} \neq \varnothing \end{array} \right\}$	$(-Inf, Inf)$	{*pmax*, *nmax*, Inf, -Inf}

Subset of input domain	Worst-case error bounds for fltArg2 output [ulp]	Allowed specific values (regardless the error bounds) for fltArg2 output
All of {*UfltArg2*, *IfltArg1*, *fltLD*, *fltAngularVel*} are normalized or zero, intermediate result underflow, i.e. $\left\{ \left(\begin{array}{c} UfltArg1, UfltArg2, \\ IfltArg1, IfltArg2, \\ fltAngularVel, fltLD, fltLQ \end{array} \right) \in X \;\middle|\; \begin{array}{l} \left\{ \begin{array}{l} UfltArg2, IfltArg1, \\ fltLD, fltAngularVel \end{array} \right\} \subset N \cup \{-0, +0\}, \\ \left(\begin{array}{c} 0.5 \cdot (\lvert irb_1 \rvert - 0.5 \cdot \mathrm{ULP}(irb_1)) \in D \wedge \\ ira_1 \neq 0, \end{array} \right) \vee \\ \left(\begin{array}{c} 0.5 \cdot (\lvert irb_2 \rvert - \mathrm{ULP}(irb_2)) \in D \wedge \\ irb_2 \neq 0, \end{array} \right) \end{array} \right\}$	$\langle -2^{24}, 2^{24} \rangle$	{0, -0}

2.45 Function GMCLIB_ElimDcBusRip_FLT

Declaration

```
void GMCLIB_ElimDcBusRip_FLT(SWLIBS_2Syst_FLT *const pOut, const
SWLIBS_2Syst_FLT *const pIn, const GMCLIB_ELIMDCBUSRIP_T_FLT
*const pParam);
```

Arguments

Table 156. GMCLIB_ElimDcBusRip_FLT arguments

Type	Name	Direction	Description
SWLIBS_2Syst_FLT *const	pOut	**output**	Pointer to the structure with direct (α) and quadrature (β) components of the required stator voltage vector re-calculated so as to compensate for voltage ripples on the DC bus. Outputs are normalized to the range [-1; 1].
const SWLIBS_2Syst_FLT *const	pIn	**input**	Pointer to the structure with direct (α) and quadrature (β) components of the required stator voltage vector before compensation of voltage ripples on the DC bus.
const GMCLIB_ELIMDCBUSRIP_T_FLT *const	pParam	**input**	Pointer to the parameters structure.

Worst-Case Error Bounds

Let (*fltArg1*, *fltArg2*, *fltModIndex*, *fltArgDcBusMsr*) ∊ *X* be a set of inputs to GMCLIB_ElimDcBusRip_FLT,

reffltArg1, *reffltArg2* be the theoretical exact results for outputs *fltArg1* and *fltArg2*, respectively,

$ir_1 = fltArg1 \cdot fltModIndex$,

$ir_2 = fltArg2 \cdot fltModIndex$,

then

Table 157. GMCLIB_ElimDcBusRip_FLT Worst-Case Error Bounds - *fltArg1* Output

Subset of input domain	Worst-case error bounds for *fltArg1* output [ulp]	Allowed specific values (regardless the error bounds) for *fltArg1* output
Any of {*fltArg1*, *fltModIndex*, *fltArgDcBusMsr*} is NaN, i.e. $$\left\{ \begin{pmatrix} fltArg1, fltArg2, \\ fltModIndex, fltArgDcBusMsr \end{pmatrix} \in X \;\middle|\; \begin{Bmatrix} fltArg1, \\ fltModIndex, \\ fltArgDcBusMsr \end{Bmatrix} \cap NaN \neq \varnothing \right\}$$	$\langle -Inf, Inf \rangle$	{NaN, *pmax*, *nmax*}
Any of {*fltArg1*, *fltModIndex*, *fltArgDcBusMsr*} is infinity, i.e. $$\left\{ \begin{pmatrix} fltArg1, fltArg2, \\ fltModIndex, fltArgDcBusMsr \end{pmatrix} \in X \;\middle|\; \begin{Bmatrix} fltArg1, \\ fltModIndex, \\ fltArgDcBusMsr \end{Bmatrix} \cap \{Inf, -Inf\} \neq \varnothing \right\}$$	$\langle -Inf, Inf \rangle$	{NaN, *pmax*, *nmax*, Inf, -Inf}
At least one of {*fltArg1*, *fltModIndex*, *fltArgDcBusMsr*} is denormalized, others are normalized, denormalized, or zero, i.e. $$\left\{ \begin{pmatrix} fltArg1, fltArg2, \\ fltModIndex, fltArgDcBusMsr \end{pmatrix} \in X \;\middle|\; \begin{matrix} \begin{Bmatrix} fltArg1, \\ fltModIndex, \\ fltArgDcBusMsr \end{Bmatrix} \cap D \neq \varnothing, \\ \begin{Bmatrix} fltArg1, \\ fltModIndex, \\ fltArgDcBusMsr \end{Bmatrix} \cap M = \varnothing \end{matrix} \right\}$$	$\langle -Inf, Inf \rangle$	{*pmax*, *nmax*, Inf, -Inf, 0, -0}
All of {*fltArg1*, *fltModIndex*} are normalized or zero, *fltArgDcBusMsr* is normalized, inputs lead to normalized or zero results, i.e. $$\left\{ \begin{matrix} \begin{pmatrix} fltArg1, fltArg2, \\ fltModIndex, fltArgDcBusMsr \end{pmatrix} \in X \;\middle|\; \\ \begin{Bmatrix} fltArg1, \\ fltModIndex \end{Bmatrix} \subset N \cup \{-0, +0\}, \\ fltArgDcBusMsr \in N, \\ ir_1 \in N \cup \{-0, +0\}, \\ ref fltArg1 = 0 \vee \\ \begin{pmatrix} \lvert ref fltArg1 \rvert - 1.5 \cdot \mathrm{ULP}(ref fltArg1) \notin D \wedge \\ \lvert ref fltArg1 \rvert + 1.5 \cdot \mathrm{ULP}(ref fltArg1) \neq Inf \end{pmatrix} \end{matrix} \right\}$$	$\langle -1.5, 1.5 \rangle$	N/A

Subset of input domain	Worst-case error bounds for *fltArg1* output [ulp]	Allowed specific values (regardless the error bounds) for *fltArg1* output
All of {*fltArg1*, *fltModIndex*} are normalized or zero, *fltArgDcBusMsr* is zero, i.e. $$\left\{ \begin{pmatrix} fltArg1, fltArg2, \\ fltModIndex, fltArgDcBusMsr \end{pmatrix} \in X \;\middle|\; \begin{matrix} \begin{Bmatrix} fltArg1, \\ fltModIndex \end{Bmatrix} \subset N \cup \{-0, +0\}, \\ fltArgDcBusMsr = 0 \end{matrix} \right\}$$	0	{0, -0}
All of {*fltArg1*, *fltModIndex*} are normalized or zero, *fltArgDcBusMsr* is normalized, *fltArg1* output overflow, i.e. $$\left\{ \begin{pmatrix} fltArg1, fltArg2, \\ fltModIndex, fltArgDcBusMsr \end{pmatrix} \in X \;\middle|\; \begin{matrix} \begin{Bmatrix} fltArg1, \\ fltModIndex \end{Bmatrix} \subset N \cup \{-0, +0\}, \\ fltArgDcBusMsr \in N, \\ \lvert reffltArg1 \rvert + 1.5 \cdot \mathrm{ULP}(reffltArg1) = Inf \end{matrix} \right\}$$	$(-Inf, Inf)$	{sign(*reffltArg1*)•Inf, sign(*reffltArg1*)•pmax, NaN}
All of {*fltArg1*, *fltModIndex*} are normalized or zero, *fltArgDcBusMsr* is normalized, *fltArg1* output underflow, i.e. $$\left\{ \begin{pmatrix} fltArg1, fltArg2, \\ fltModIndex, fltArgDcBusMsr \end{pmatrix} \in X \;\middle|\; \begin{matrix} \begin{Bmatrix} fltArg1, \\ fltModIndex \end{Bmatrix} \subset N \cup \{-0, +0\}, \\ fltArgDcBusMsr \in N, \\ reffltArg1 \neq 0 \wedge \\ \lvert reffltArg1 \rvert - 1.5 \cdot \mathrm{ULP}(reffltArg1) \in D \end{matrix} \right\}$$	$\langle -1.5, 1.5 \rangle$	{0, -0}
All of {*fltArg1*, *fltModIndex*} are normalized or zero, *fltArgDcBusMsr* is normalized, intermediate result overflow, i.e. $$\left\{ \begin{pmatrix} fltArg1, fltArg2, \\ fltModIndex, fltArgDcBusMsr \end{pmatrix} \in X \;\middle|\; \begin{matrix} \begin{Bmatrix} fltArg1, \\ fltModIndex \end{Bmatrix} \subset N \cup \{-0, +0\}, \\ fltArgDcBusMsr \in N, \\ \lvert ir_1 \rvert + 0.5 \cdot \mathrm{ULP}(ir_1) \in \{Inf, -Inf\} \end{matrix} \right\}$$	$(-Inf, Inf)$	{NaN, *pmax*, *nmax*, Inf, -Inf, 0, -0}

Subset of input domain	Worst-case error bounds for *fltArg1* output [ulp]	Allowed specific values (regardless the error bounds) for *fltArg1* output
All of {*fltArg1*, *fltModIndex*} are normalized or zero, *fltArgDcBusMsr* is normalized, intermediate result underflow, i.e. $$\left\{\begin{pmatrix} fltArg1, fltArg2, \\ fltModIndex, fltArgDcBusMsr \end{pmatrix} \in X \;\middle|\; \begin{array}{c} \begin{Bmatrix} fltArg1, \\ fltModIndex \end{Bmatrix} \subset N \cup \{-0, +0\}, \\ fltArgDcBusMsr \in N, \\ \lvert ir_1 \rvert - 0.5 \cdot \mathrm{ULP}(ir_1) \in D \wedge \\ ir_1 \neq 0 \end{array} \right\}$$	$\langle -1.5, 1.5 \rangle$	{NaN, *pmax*, *nmax*, Inf, -Inf, 0, -0}

Table 158. GMCLIB_ElimDcBusRip_FLT Worst-Case Error Bounds - *fltArg2* Output

Subset of input domain	Worst-case error bounds for *fltArg2* output [ulp]	Allowed specific values (regardless the error bounds) for *fltArg2* output
Any of {*fltArg2*, *fltModIndex*, *fltArgDcBusMsr*} is NaN, i.e. $$\left\{\begin{pmatrix} fltArg1, fltArg2, \\ fltModIndex, fltArgDcBusMsr \end{pmatrix} \in X \;\middle|\; \begin{Bmatrix} fltArg2, \\ fltModIndex, \\ fltArgDcBusMsr \end{Bmatrix} \cap NaN \neq \varnothing \right\}$$	$(-Inf, Inf)$	{NaN, *pmax*, *nmax*}
Any of {*fltArg2*, *fltModIndex*, *fltArgDcBusMsr*} is infinity, i.e. $$\left\{\begin{pmatrix} fltArg1, fltArg2, \\ fltModIndex, fltArgDcBusMsr \end{pmatrix} \in X \;\middle|\; \begin{Bmatrix} fltArg2, \\ fltModIndex, \\ fltArgDcBusMsr \end{Bmatrix} \cap \{Inf, -Inf\} \neq \varnothing \right\}$$	$(-Inf, Inf)$	{NaN, *pmax*, *nmax*, Inf, -Inf}
At least one of {*fltArg2*, *fltModIndex*, *fltArgDcBusMsr*} is denormalized, others are normalized, denormalized, or zero, i.e. $$\left\{\begin{pmatrix} fltArg1, fltArg2, \\ fltModIndex, fltArgDcBusMsr \end{pmatrix} \in X \;\middle|\; \begin{array}{c} \begin{Bmatrix} fltArg2, \\ fltModIndex, \\ fltArgDcBusMsr \end{Bmatrix} \cap D \neq \varnothing, \\ \begin{Bmatrix} fltArg2, \\ fltModIndex, \\ fltArgDcBusMsr \end{Bmatrix} \cap M = \varnothing \end{array} \right\}$$	$(-Inf, Inf)$	{*pmax*, *nmax*, Inf, -Inf, 0, -0}

Subset of input domain	**Worst-case error bounds for *fltArg2* output [ulp]**	**Allowed specific values (regardless the error bounds) for *fltArg2* output**
All of {*fltArg2*, *fltModIndex*} are normalized or zero, *fltArgDcBusMsr* is normalized, inputs lead to normalized or zero results, i.e. $$\left\{\begin{array}{c} \left.\begin{pmatrix} fltArg1,\ fltArg2, \\ fltModIndex,\ fltArgDcBusMsr \end{pmatrix} \in X \right\vert \\ \begin{Bmatrix} fltArg2, \\ fltModIndex \end{Bmatrix} \subset N \cup \{-0,\ +0\}, \\ fltArgDcBusMsr \in N, \\ ir_2 \in N \cup \{-0,\ +0\}, \\ ref\,fltArg2 = 0 \vee \\ \begin{pmatrix} \lvert ref\,fltArg2\rvert - 1.5 \cdot \mathrm{ULP}(ref\,fltArg2) \notin D \wedge \\ \lvert ref\,fltArg2\rvert + 1.5 \cdot \mathrm{ULP}(ref\,fltArg2) \neq Inf \end{pmatrix} \end{array}\right\}$$	$\langle -1.5,\ 1.5\rangle$	N/A
All of {*fltArg1*, *fltModIndex*} are normalized or zero, *fltArgDcBusMsr* is zero, i.e. $$\left\{\begin{array}{c} \left.\begin{pmatrix} fltArg1,\ fltArg2, \\ fltModIndex,\ fltArgDcBusMsr \end{pmatrix} \in X \right\vert \\ \begin{Bmatrix} fltArg2, \\ fltModIndex \end{Bmatrix} \subset N \cup \{-0,\ +0\}, \\ fltArgDcBusMsr = 0 \end{array}\right\}$$	0	{0, -0}
All of {*fltArg2*, *fltModIndex*} are normalized or zero, *fltArgDcBusMsr* is normalized, *fltArg2* output overflow, i.e. $$\left\{\begin{array}{c} \left.\begin{pmatrix} fltArg1,\ fltArg2, \\ fltModIndex,\ fltArgDcBusMsr \end{pmatrix} \in X \right\vert \\ \begin{Bmatrix} fltArg2, \\ fltModIndex \end{Bmatrix} \subset N \cup \{-0,\ +0\}, \\ fltArgDcBusMsr \in N, \\ \lvert ref\,fltArg2\rvert + 1.5 \cdot \mathrm{ULP}(ref\,fltArg2) = Inf \end{array}\right\}$$	$(-Inf,\ Inf)$	{sign(*reffltArg2*)•Inf, sign(*reffltArg2*)•pmax, NaN}
All of {*fltArg2*, *fltModIndex*} are normalized or zero, *fltArgDcBusMsr* is normalized, *fltArg2* output underflow, i.e. $$\left\{\begin{array}{c} \left.\begin{pmatrix} fltArg1,\ fltArg2, \\ fltModIndex,\ fltArgDcBusMsr \end{pmatrix} \in X \right\vert \\ \begin{Bmatrix} fltArg2, \\ fltModIndex \end{Bmatrix} \subset N \cup \{-0,\ +0\}, \\ fltArgDcBusMsr \in N, \\ ref\,fltArg2 \neq 0 \wedge \\ \lvert ref\,fltArg2\rvert - 1.5 \cdot \mathrm{ULP}(ref\,fltArg2) \in D \end{array}\right\}$$	$\langle -1.5,\ 1.5\rangle$	{0, -0}

Subset of input domain	Worst-case error bounds for *fltArg2* output [ulp]	Allowed specific values (regardless the error bounds) for *fltArg2* output
All of {*fltArg2*, *fltModIndex*} are normalized or zero, *fltArgDcBusMsr* is normalized, intermediate result overflow, i.e. $$\left\{ \begin{matrix} \left(\begin{matrix} fltArg1, fltArg2, \\ fltModIndex, fltArgDcBusMsr \end{matrix} \right) \in X \end{matrix} \middle\vert \begin{matrix} \left\{ \begin{matrix} fltArg2, \\ fltModIndex \end{matrix} \right\} \subset N \cup \{-0, +0\}, \\ fltArgDcBusMsr \in N, \\ \lvert ir_2 \rvert + 0.5 \cdot \mathrm{ULP}(ir_2) \in \{Inf, -Inf\} \end{matrix} \right\}$$	$(-Inf, Inf)$	{NaN, *pmax*, *nmax*, Inf, -Inf, 0, -0}
All of {*fltArg2*, *fltModIndex*} are normalized or zero, *fltArgDcBusMsr* is normalized, intermediate result underflow, i.e. $$\left\{ \begin{matrix} \left(\begin{matrix} fltArg1, fltArg2, \\ fltModIndex, fltArgDcBusMsr \end{matrix} \right) \in X \end{matrix} \middle\vert \begin{matrix} \left\{ \begin{matrix} fltArg2, \\ fltModIndex \end{matrix} \right\} \subset N \cup \{-0, +0\}, \\ fltArgDcBusMsr \in N, \\ \lvert ir_2 \rvert - 0.5 \cdot \mathrm{ULP}(ir_2) \in D \wedge \\ ir_2 \neq 0 \end{matrix} \right\}$$	$\langle -1.5, 1.5 \rangle$	{NaN, *pmax*, *nmax*, Inf, -Inf, 0, -0}

2.46 Function GMCLIB_Park_FLT

Declaration

```
void GMCLIB_Park_FLT(SWLIBS_2Syst_FLT *pOut, const
SWLIBS_2Syst_FLT *const pInAngle, const SWLIBS_2Syst_FLT *const
pIn);
```

Arguments

Table 159. GMCLIB_Park_FLT arguments

Type	Name	Direction	Description
SWLIBS_2Syst_FLT *	pOut	**input, output**	Pointer to the structure containing data of the two-phase rotational orthogonal system (d-q).
const SWLIBS_2Syst_ FLT *const	pInAngle	**input**	Pointer to the structure where the values of the sine and cosine of the rotor position are stored.
const SWLIBS_2Syst_ FLT *const	pIn	**input**	Pointer to the structure containing data of the two-phase stationary orthogonal system (α-β).

Worst-Case Error Bounds

Let (*AnglefltArg1*, *AnglefltArg2*, *InfltArg1*, *InfltArg2*) $\in X$ be a set of inputs to GMCLIB_Park_FLT,

reffltArg1, *reffltArg2* be the theoretical exact results for outputs *fltArg1* and *fltArg2*, respectively,

$ir_1 = InfltArg1 \cdot AnglefltArg2$,

$ir_2 = InfltArg2 \cdot AnglefltArg1$,

$ir_3 = InfltArg2 \cdot AnglefltArg2$,

$ir_4 = -InfltArg1 \cdot AnglefltArg1$,

then

Table 160. GMCLIB_Park_FLT Worst-Case Error Bounds - fltArg1 Output

Subset of input domain	Worst-case error bounds for fltArg1 output [ulp]	Allowed specific values (regardless the error bounds) for fltArg1 output
Any of the inputs is NaN or infinity, i.e. $\left\{\left(\begin{matrix} AnglefltArg1, AnglefltArg2, \\ InfltArg1, InfltArg2 \end{matrix}\right) \in X \middle\vert \begin{matrix} \\ X \cap M \neq \varnothing \end{matrix}\right\}$	N/A	{Inf, -Inf, NaN, *pmax*, *nmax*, -0, +0}
Any of the inputs is denormalized, neither is NaN or infinity, i.e. $\left\{\left(\begin{matrix} AnglefltArg1, AnglefltArg2, \\ InfltArg1, InfltArg2 \end{matrix}\right) \in X \middle\vert \begin{matrix} \\ X \cap D \neq \varnothing, X \cap M = \varnothing \end{matrix}\right\}$	$(-Inf, Inf)$	N/A
All inputs normalized or zero, results normalized or zero, i.e. $\left\{\left(\begin{matrix} AnglefltArg1, AnglefltArg2, \\ InfltArg1, InfltArg2 \end{matrix}\right) \in X \middle\vert \begin{matrix} \\ X \subset N \cup \{-0, +0\}, \\ \{ir_1, ir_2\} \subset N \cup \{-0, +0\}, \\ reffltArg1 = 0 \vee \\ \left(\begin{matrix} \lvert reffltArg1\rvert - \mathrm{ULP}(reffltArg1) \notin D \wedge \\ \lvert reffltArg1\rvert + \mathrm{ULP}(reffltArg1) \neq Inf \end{matrix}\right) \end{matrix}\right\}$	$\langle -1, 1 \rangle$	N/A
All inputs zero, i.e. $\left\{\left(\begin{matrix} AnglefltArg1, AnglefltArg2, \\ InfltArg1, InfltArg2 \end{matrix}\right) \in X \middle\vert \begin{matrix} \\ X \subset \{-0, +0\} \end{matrix}\right\}$	0	N/A
All inputs normalized or zero, *fltArg1* output overflow, i.e. $\left\{\left(\begin{matrix} AnglefltArg1, AnglefltArg2, \\ InfltArg1, InfltArg2 \end{matrix}\right) \in X \middle\vert \begin{matrix} \\ X \subset N \cup \{-0, +0\}, \\ \lvert reffltArg1\rvert + \mathrm{ULP}(reffltArg1) = Inf \end{matrix}\right\}$	$\langle -1, 1 \rangle$	{sign(*reffltArg1*)•Inf, sign(*reffltArg1*)•pmax, NaN}

Subset of input domain	Worst-case error bounds for fltArg1 output [ulp]	Allowed specific values (regardless the error bounds) for fltArg1 output
All inputs normalized or zero, *fltArg1* output underflow or underflow in internal compensation calculation, i.e. $\left\{ \begin{pmatrix} AnglefltArg1, AnglefltArg2, \\ InfltArg1, InfltArg2 \end{pmatrix} \in X \middle\vert \begin{matrix} X \subset N \cup \{-0, +0\}, \\ 0.5 \cdot (\lvert reffltArg1 \rvert - \mathrm{ULP}(reffltArg1) \in D) \wedge \\ reffltArg1 \neq 0 \end{matrix} \right\}$	$\langle -2^{24}, 2^{24} \rangle$	{-0, +0}
All inputs normalized or zero, intermediate result overflow, i.e. $\left\{ \begin{pmatrix} AnglefltArg1, AnglefltArg2, \\ InfltArg1, InfltArg2 \end{pmatrix} \in X \middle\vert \begin{matrix} X \subset N \cup \{-0, +0\}, \\ \lvert ir_1 \rvert \in \{Inf, -Inf\} \vee \lvert ir_2 \rvert \in \{Inf, -Inf\} \end{matrix} \right\}$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)
All inputs normalized or zero, intermediate result underflow, i.e. $\left\{ \begin{pmatrix} AnglefltArg1, AnglefltArg2, \\ InfltArg1, InfltArg2 \end{pmatrix} \in X \middle\vert \begin{matrix} X \subset N \cup \{-0, +0\}, \\ ir_1 \in D \vee ir_2 \in D \end{matrix} \right\}$	$(-Inf, Inf)$	N/A

Table 161. GMCLIB_Park_FLT Worst-Case Error Bounds - fltArg2 Output

Subset of input domain	Worst-case error bounds for fltArg2 output [ulp]	Allowed specific values (regardless the error bounds) for fltArg2 output
Any of the inputs is NaN or infinity, i.e. $\left\{ \begin{pmatrix} AnglefltArg1, AnglefltArg2, \\ InfltArg1, InfltArg2 \end{pmatrix} \in X \middle\vert X \cap M \neq \varnothing \right\}$	N/A	{Inf, -Inf, NaN, *pmax*, *nmax*, -0, +0}
Any of the inputs is denormalized, neither is NaN or infinity, i.e. $\left\{ \begin{pmatrix} AnglefltArg1, AnglefltArg2, \\ InfltArg1, InfltArg2 \end{pmatrix} \in X \middle\vert X \cap D \neq \varnothing, X \cap M = \varnothing \right\}$	$(-Inf, Inf)$	N/A

Subset of input domain	Worst-case error bounds for fltArg2 output [ulp]	Allowed specific values (regardless the error bounds) for fltArg2 output
All inputs normalized or zero, results normalized or zero, i.e. $$\left\{\begin{matrix} \begin{pmatrix} AnglefltArg1, AnglefltArg2, \\ InfltArg1, InfltArg2 \end{pmatrix} \in X \;\middle\vert \\ X \subset N \cup \{-0, +0\}, \\ \{ir_3, ir_4\} \subset N \cup \{-0, +0\}, \\ reffltArg2 = 0 \vee \\ \begin{pmatrix} \lvert reffltArg2\rvert - \mathrm{ULP}(reffltArg2) \notin D \wedge \\ \lvert reffltArg2\rvert + \mathrm{ULP}(reffltArg2) \neq Inf \end{pmatrix} \end{matrix}\right\}$$	$\langle -1, 1\rangle$	N/A
All inputs zero, i.e. $$\left\{\begin{matrix} \begin{pmatrix} AnglefltArg1, AnglefltArg2, \\ InfltArg1, InfltArg2 \end{pmatrix} \in X \;\middle\vert \\ X \subset \{-0, +0\} \end{matrix}\right\}$$	0	N/A
All inputs normalized or zero, *fltArg2* output overflow, i.e. $$\left\{\begin{matrix} \begin{pmatrix} AnglefltArg1, AnglefltArg2, \\ InfltArg1, InfltArg2 \end{pmatrix} \in X \;\middle\vert \\ X \subset N \cup \{-0, +0\}, \\ \lvert reffltArg2\rvert + \mathrm{ULP}(reffltArg2) = Inf \end{matrix}\right\}$$	$\langle -1, 1\rangle$	{sign(*reffltArg2*)•Inf, sign(*reffltArg2*)•pmax, NaN}
All inputs normalized or zero, *fltArg2* output underflow or underflow in internal compensation calculation, i.e. $$\left\{\begin{matrix} \begin{pmatrix} AnglefltArg1, AnglefltArg2, \\ InfltArg1, InfltArg2 \end{pmatrix} \in X \;\middle\vert \\ X \subset N \cup \{-0, +0\}, \\ 0.5 \cdot (\lvert reffltArg2\rvert - \mathrm{ULP}(reffltArg2) \in D) \wedge \\ reffltArg2 \neq 0 \end{matrix}\right\}$$	$\langle -2^{24}, 2^{24}\rangle$	{-0, +0}
All inputs normalized or zero, intermediate result overflow, i.e. $$\left\{\begin{matrix} \begin{pmatrix} AnglefltArg1, AnglefltArg2, \\ InfltArg1, InfltArg2 \end{pmatrix} \in X \;\middle\vert \\ X \subset N \cup \{-0, +0\}, \\ \lvert ir_3\rvert \in \{Inf, -Inf\} \vee \lvert ir_4\rvert \in \{Inf, -Inf\} \end{matrix}\right\}$$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)
All inputs normalized or zero, intermediate result underflow, i.e. $$\left\{\begin{matrix} \begin{pmatrix} AnglefltArg1, AnglefltArg2, \\ InfltArg1, InfltArg2 \end{pmatrix} \in X \;\middle\vert \\ X \subset N \cup \{-0, +0\}, \\ ir_3 \in D \vee ir_4 \in D \end{matrix}\right\}$$	$(-Inf, Inf)$	N/A

2.47 Function GMCLIB_ParkInv_FLT

Declaration

```
void GMCLIB_ParkInv_FLT(SWLIBS_2Syst_FLT *const pOut, const
SWLIBS_2Syst_FLT *const pInAngle, const SWLIBS_2Syst_FLT *const
pIn);
```

Arguments

Table 162. GMCLIB_ParkInv_FLT arguments

Type	Name	Direction	Description
SWLIBS_2Syst_FLT *const	pOut	**input, output**	Pointer to the structure containing data of the two-phase stationary orthogonal system (α-β).
const SWLIBS_2Syst_FLT *const	pInAngle	**input**	Pointer to the structure where the values of the sine and cosine of the rotor position are stored.
const SWLIBS_2Syst_FLT *const	pIn	**input**	Pointer to the structure containing data of the two-phase rotational orthogonal system (d-q).

Worst-Case Error Bounds

Let (*AnglefltArg1*, *AnglefltArg2*, *InfltArg1*, *InfltArg2*) ∊ *X* be a set of inputs to GMCLIB_ParkInv_FLT,

reffltArg1, *reffltArg2* be the theoretical exact results for outputs *fltArg1* and *fltArg2*, respectively,

$ir_1 = InfltArg1 \cdot AnglefltArg2$,

$ir_2 = -InfltArg2 \cdot AnglefltArg1$,

$ir_3 = InfltArg1 \cdot AnglefltArg1$,

$ir_4 = InfltArg2 \cdot AnglefltArg2$,

then

Table 163. GMCLIB_ParkInv_FLT Worst-Case Error Bounds - fltArg1 Output

Subset of input domain	Worst-case error bounds for fltArg1 output [ulp]	Allowed specific values (regardless the error bounds) for fltArg1 output
Any of the inputs is NaN or infinity, i.e. $\left\{ \begin{pmatrix} AnglefltArg1, AnglefltArg2, \\ InfltArg1, InfltArg2 \end{pmatrix} \in X \middle\| \begin{matrix} \\ X \cap M \neq \varnothing \end{matrix} \right\}$	N/A	{Inf, -Inf, NaN, *pmax*, *nmax*, -0, +0}
Any of the inputs is denormalized, neither is NaN or infinity, i.e. $\left\{ \begin{pmatrix} AnglefltArg1, AnglefltArg2, \\ InfltArg1, InfltArg2 \end{pmatrix} \in X \middle\| \begin{matrix} \\ X \cap D \neq \varnothing, X \cap M = \varnothing \end{matrix} \right\}$	$(-Inf, Inf)$	N/A

Subset of input domain	**Worst-case error bounds for fltArg1 output [ulp]**	**Allowed specific values (regardless the error bounds) for fltArg1 output**
All inputs normalized or zero, results normalized or zero, i.e. $$\left\{\begin{matrix}\begin{pmatrix} AnglefltArg1, AnglefltArg2, \\ InfltArg1, InfltArg2 \end{pmatrix} \in X \\ X \subset N \cup \{-0, +0\}, \\ \{ir_1, ir_2\} \subset N \cup \{-0, +0\}, \\ reffltArg1 = 0 \vee \\ \begin{pmatrix} \lvert reffltArg1\rvert - \mathrm{ULP}(reffltArg1) \notin D \wedge \\ \lvert reffltArg1\rvert + \mathrm{ULP}(reffltArg1) \neq Inf \end{pmatrix}\end{matrix}\right\}$$	$\langle -1, 1\rangle$	N/A
All inputs zero, i.e. $$\left\{\begin{matrix}\begin{pmatrix} AnglefltArg1, AnglefltArg2, \\ InfltArg1, InfltArg2 \end{pmatrix} \in X \\ X \subset \{-0, +0\}\end{matrix}\right\}$$	0	N/A
All inputs normalized or zero, *fltArg1* output overflow, i.e. $$\left\{\begin{matrix}\begin{pmatrix} AnglefltArg1, AnglefltArg2, \\ InfltArg1, InfltArg2 \end{pmatrix} \in X \\ X \subset N \cup \{-0, +0\}, \\ \lvert reffltArg1\rvert + \mathrm{ULP}(reffltArg1) = Inf\end{matrix}\right\}$$	$\langle -1, 1\rangle$	{sign(*reffltArg1*)•Inf, sign(*reffltArg1*)•pmax, NaN}
All inputs normalized or zero, *fltArg1* output underflow or underflow in internal compensation calculation, i.e. $$\left\{\begin{matrix}\begin{pmatrix} AnglefltArg1, AnglefltArg2, \\ InfltArg1, InfltArg2 \end{pmatrix} \in X \\ X \subset N \cup \{-0, +0\}, \\ 0.5 \cdot (\lvert reffltArg1\rvert - \mathrm{ULP}(reffltArg1) \in D) \wedge \\ reffltArg1 \neq 0\end{matrix}\right\}$$	$\langle -2^{24}, 2^{24}\rangle$	{-0, +0}
All inputs normalized or zero, intermediate result overflow, i.e. $$\left\{\begin{matrix}\begin{pmatrix} AnglefltArg1, AnglefltArg2, \\ InfltArg1, InfltArg2 \end{pmatrix} \in X \\ X \subset N \cup \{-0, +0\}, \\ \lvert ir_1\rvert \in \{Inf, -Inf\} \vee \lvert ir_2\rvert \in \{Inf, -Inf\}\end{matrix}\right\}$$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)
All inputs normalized or zero, intermediate result underflow, i.e. $$\left\{\begin{matrix}\begin{pmatrix} AnglefltArg1, AnglefltArg2, \\ InfltArg1, InfltArg2 \end{pmatrix} \in X \\ X \subset N \cup \{-0, +0\}, \\ ir_1 \in D \vee ir_2 \in D\end{matrix}\right\}$$	$(-Inf, Inf)$	N/A

Table 164. GMCLIB_ParkInv_FLT Worst-Case Error Bounds - fltArg2 Output

Subset of input domain	Worst-case error bounds for fltArg2 output [ulp]	Allowed specific values (regardless the error bounds) for fltArg2 output
Any of the inputs is NaN or infinity, i.e. $\left\{ \left(\begin{array}{c} AnglefltArg1, AnglefltArg2, \\ InfltArg1, InfltArg2 \end{array} \right) \in X \middle\| \begin{array}{c} \\ \\ X \cap M \neq \varnothing \end{array} \right\}$	N/A	{Inf, -Inf, NaN, *pmax*, *nmax*, -0, +0}
Any of the inputs is denormalized, neither is NaN or infinity, i.e. $\left\{ \left(\begin{array}{c} AnglefltArg1, AnglefltArg2, \\ InfltArg1, InfltArg2 \end{array} \right) \in X \middle\| \begin{array}{c} \\ \\ X \cap D \neq \varnothing, X \cap M = \varnothing \end{array} \right\}$	$(-Inf, Inf)$	N/A
All inputs normalized or zero, results normalized or zero, i.e. $\left\{ \left(\begin{array}{c} AnglefltArg1, AnglefltArg2, \\ InfltArg1, InfltArg2 \end{array} \right) \in X \middle\| \begin{array}{c} X \subset N \cup \{-0, +0\}, \\ \{ir_3, ir_4\} \subset N \cup \{-0, +0\}, \\ reffltArg2 = 0 \vee \\ \left(\begin{array}{c} \|reffltArg2\| - \mathrm{ULP}(reffltArg2) \notin D \wedge \\ \|reffltArg2\| + \mathrm{ULP}(reffltArg2) \neq Inf \end{array} \right) \end{array} \right\}$	$\langle -1, 1 \rangle$	N/A
All inputs zero, i.e. $\left\{ \left(\begin{array}{c} AnglefltArg1, AnglefltArg2, \\ InfltArg1, InfltArg2 \end{array} \right) \in X \middle\| \begin{array}{c} \\ \\ X \subset \{-0, +0\} \end{array} \right\}$	0	N/A
All inputs normalized or zero, *fltArg2* output overflow, i.e. $\left\{ \left(\begin{array}{c} AnglefltArg1, AnglefltArg2, \\ InfltArg1, InfltArg2 \end{array} \right) \in X \middle\| \begin{array}{c} X \subset N \cup \{-0, +0\}, \\ \|reffltArg2\| + \mathrm{ULP}(reffltArg2) = Inf \end{array} \right\}$	$\langle -1, 1 \rangle$	{sign(*reffltArg2*)•Inf, sign(*reffltArg2*)•pmax, NaN}
All inputs normalized or zero, *fltArg2* output underflow or underflow in internal compensation calculation, i.e. $\left\{ \left(\begin{array}{c} AnglefltArg1, AnglefltArg2, \\ InfltArg1, InfltArg2 \end{array} \right) \in X \middle\| \begin{array}{c} X \subset N \cup \{-0, +0\}, \\ 0.5 \cdot (\|reffltArg2\| - \mathrm{ULP}(reffltArg2) \in D) \wedge \\ reffltArg2 \neq 0 \end{array} \right\}$	$\langle -2^{24}, 2^{24} \rangle$	{-0, +0}

Subset of input domain	Worst-case error bounds for fltArg2 output [ulp]	Allowed specific values (regardless the error bounds) for fltArg2 output
All inputs normalized or zero, intermediate result overflow, i.e. $\left\{ \begin{pmatrix} AnglefltArg1, AnglefltArg2, \\ InfltArg1, InfltArg2 \end{pmatrix} \in X \middle\vert \begin{matrix} X \subset N \cup \{-0, +0\}, \\ \lvert ir_3 \rvert \in \{Inf, -Inf\} \vee \lvert ir_4 \rvert \in \{Inf, -Inf\} \end{matrix} \right\}$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)
All inputs normalized or zero, intermediate result underflow, i.e. $\left\{ \begin{pmatrix} AnglefltArg1, AnglefltArg2, \\ InfltArg1, InfltArg2 \end{pmatrix} \in X \middle\vert \begin{matrix} X \subset N \cup \{-0, +0\}, \\ ir_3 \in D \vee ir_4 \in D \end{matrix} \right\}$	$(-Inf, Inf)$	N/A

2.48 Function GMCLIB_PwmIct_FLT

Declaration

```
tU32 GMCLIB_PwmIct_FLT(SWLIBS_3Syst_FLT *pOut, const
SWLIBS_2Syst_FLT *const pIn);
```

Arguments

Table 165. GMCLIB_PwmIct_FLT arguments

Type	Name	Direction	Description
SWLIBS_3Syst_FLT *	pOut	**input, output**	Pointer to the structure containing calculated duty-cycle ratios of the 3-Phase system.
const SWLIBS_2Syst_FLT *const	pIn	**input**	Pointer to the structure containing direct U_α and quadrature U_β components of the stator voltage vector.

Worst-Case Error Bounds

Note: The allowed error bounds for the floating-point outputs of this function are expressed in terms of allowed absolute error.

Let (*fltArg1*, *fltArg2*) $\in X$ be a set of inputs to GMCLIB_PwmIct_FLT,

then

Table 166. GMCLIB_PwmIct_FLT Return Value

Subset of input domain	Meaningful Return Value
Any of the inputs is NaN, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ fltArg1 = NaN \lor \\ fltArg2 = NaN \end{matrix} \right\}$	No
Normalized, denormalized, or zero inputs, at least one input is outside the [-1, 1] interval, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ X \subset N \cup D \cup \{-0, +0\}, \\ \lvert fltArg1 \rvert > 1 \lor \lvert fltArg2 \rvert > 1 \end{matrix} \right\}$	No
All inputs within the [-1, 1] interval, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ X \subset N \cup D \cup \{-0, +0\}, \\ \lvert fltArg1 \rvert \leq 1, \lvert fltArg2 \rvert \leq 1 \end{matrix} \right\}$	Yes

Table 167. GMCLIB_PwmIct_FLT Worst-Case Error Bounds - Output fltArg1

Subset of input domain	Worst-case absolute error for fltArg1 output	Allowed specific values (regardless the error bounds) for fltArg1 output
Any of the inputs is NaN, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ fltArg1 = NaN \lor \\ fltArg2 = NaN \end{matrix} \right\}$	Inf	NaN
Normalized, denormalized, or zero inputs, at least one input is outside the [-1, 1] interval, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ X \subset N \cup D \cup \{-0, +0\}, \\ \lvert fltArg1 \rvert > 1 \lor \lvert fltArg2 \rvert > 1 \end{matrix} \right\}$	Inf	{NaN, Inf, -Inf}
All inputs within the [-1, 1] interval, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ X \subset N \cup D \cup \{-0, +0\}, \\ \lvert fltArg1 \rvert \leq 1, \lvert fltArg2 \rvert \leq 1 \end{matrix} \right\}$	2^{-19}	N/A

Table 168. GMCLIB_PwmIct_FLT Worst-Case Error Bounds - Output fltArg2

Subset of input domain	Worst-case absolute error for fltArg2 output	Allowed specific values (regardless the error bounds) for fltArg2 output
Any of the inputs is NaN, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2) \in X \mid \\ fltArg1 = NaN \vee \\ fltArg2 = NaN \end{array} \right\}$	Inf	NaN
Normalized, denormalized, or zero inputs, at least one input is outside the [-1, 1] interval, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2) \in X \mid \\ X \subset N \cup D \cup \{-0, +0\}, \\ \lvert fltArg1 \rvert > 1 \vee \lvert fltArg2 \rvert > 1 \end{array} \right\}$	Inf	{NaN, Inf, -Inf}
All inputs within the [-1, 1] interval, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2) \in X \mid \\ X \subset N \cup D \cup \{-0, +0\}, \\ \lvert fltArg1 \rvert \le 1, \lvert fltArg2 \rvert \le 1 \end{array} \right\}$	2^{-19}	N/A

Table 169. GMCLIB_PwmIct_FLT Worst-Case Error Bounds - Output fltArg3

Subset of input domain	Worst-case absolute error for fltArg3 output	Allowed specific values (regardless the error bounds) for fltArg3 output
Any of the inputs is NaN, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2) \in X \mid \\ fltArg1 = NaN \vee \\ fltArg2 = NaN \end{array} \right\}$	Inf	NaN
Normalized, denormalized, or zero inputs, at least one input is outside the [-1, 1] interval, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2) \in X \mid \\ X \subset N \cup D \cup \{-0, +0\}, \\ \lvert fltArg1 \rvert > 1 \vee \lvert fltArg2 \rvert > 1 \end{array} \right\}$	Inf	{NaN, Inf, -Inf}
All inputs within the [-1, 1] interval, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2) \in X \mid \\ X \subset N \cup D \cup \{-0, +0\}, \\ \lvert fltArg1 \rvert \le 1, \lvert fltArg2 \rvert \le 1 \end{array} \right\}$	2^{-19}	N/A

2.49 Function GMCLIB_SvmSci_FLT

Declaration

```
tU32 GMCLIB_SvmSci_FLT(SWLIBS_3Syst_FLT *pOut, const
SWLIBS_2Syst_FLT *const pIn);
```

Arguments

Table 170. GMCLIB_SvmSci_FLT arguments

Type	Name	Direction	Description
SWLIBS_3Syst_FLT *	pOut	**input, output**	Pointer to the structure containing calculated duty-cycle ratios of the 3-Phase system.
const SWLIBS_2Syst_FLT *const	pIn	**input**	Pointer to the structure containing direct U_{α} and quadrature U_{β} components of the stator voltage vector.

Worst-Case Error Bounds

Let (*fltArg1*, *fltArg2*) ∈ *X* be a set of inputs to GMCLIB_SvmSci_FLT,

$$ir_1 = \frac{fltArg2}{\sqrt{3}},$$

$$me_1 = 1.5,$$

$$ir_2 = -\frac{fltArg1}{2\sqrt{3}},$$

$$me_2 = 1.0,$$

$$ie_1 = \max(fe(|fltArg2 \cdot 0.5|), fe(|ir_2| + me_2 \cdot ULP(ir_2))),$$

$$ir_3 = fltArg2 \cdot 0.5 + ir_2,$$

$$ie_2 = fe(ir_3),$$

$$cb_1 = \begin{cases} 0, & ie_1 - ie_2 \le 0 \\ ie_1 - ie_2, & ie_1 - ie_2 > 0' \end{cases}$$

$$me_3 = 0.5 + 1.0 \cdot 2^{cb_1},$$

$$ir_4 = -fltArg2 \cdot 0.5 + ir_2,$$

$$ie_3 = fe(ir_4),$$

$$cb_2 = \begin{cases} 0, & ie_1 - ie_3 \le 0 \\ ie_1 - ie_3, & ie_1 - ie_3 > 0' \end{cases}$$

$$me_4 = 0.5 + 1.0 \cdot 2^{cb_2},$$

$$ir_5 = 1 - ir_1,$$

$$ie_4 = fe(ir_5),$$

$$cb_3 = \begin{cases} 0, & 1 - ie_4 \le 0 \\ 1 - ie_4, & 1 - ie_4 > 0' \end{cases}$$

$$me_5 = 0.5 + me_1 \cdot 2^{cb_3},$$

$$ir_6 = 1 - ir_3,$$

$$ie_5 = fe(ir_6),$$

$$cb_4 = \begin{cases} 0, & 1 - ie_5 \le 0 \\ 1 - ie_5, & 1 - ie_5 > 0 \end{cases},$$

$$me_6 = 0.5 + me_3 \cdot 2^{cb_4},$$

$$ir_7 = 1 - ir_4,$$

$$ie_6 = fe(ir_7),$$

$$cb_5 = \begin{cases} 0, & 1 - ie_6 \le 0 \\ 1 - ie_6, & 1 - ie_6 > 0 \end{cases},$$

$$me_7 = 0.5 + me_4 \cdot 2^{cb_5},$$

$$ir_8 = \begin{cases} ir_5, & if\ (ir_1 > 0.5) \vee (ir_1 < -0.5) \\ ir_6, & if\ (ir_3 > 0.5) \vee (ir_3 < -0.5) \\ ir_7, & if\ (ir_4 > 0.5) \vee (ir_4 < -0.5) \\ 0.5, & otherwise \end{cases},$$

$$me_8 = \begin{cases} me_5, & if\ (ir_1 > 0.5) \vee (ir_1 < -0.5) \\ me_6, & if\ (ir_3 > 0.5) \vee (ir_3 < -0.5) \\ me_7, & if\ (ir_4 > 0.5) \vee (ir_4 < -0.5) \\ 0, & otherwise \end{cases},$$

$$ie_7 = \max(fe(|ir_8| + me_8 \cdot ULP(ir_8)), fe(|ir_1| + me_1 \cdot ULP(ir_1))),$$

$$ir_9 = ir_1 + ir_8,$$

$$ie_8 = fe(ir_9),$$

$$cb_6 = \begin{cases} 0, & ie_7 - ie_8 \le 0 \\ ie_7 - ie_8, & ie_7 - ie_8 > 0 \end{cases},$$

$$me_9 = 0.5 + (me_1 + me_8) \cdot 2^{cb_6},$$

$$ie_9 = \max(fe(|ir_8| + me_8 \cdot ULP(ir_8)), fe(|ir_3| + me_3 \cdot ULP(ir_3))),$$

$$ir_{10} = ir_3 + ir_8,$$

$$ie_{10} = fe(ir_{10}),$$

$$cb_7 = \begin{cases} 0, & ie_9 - ie_{10} \le 0 \\ ie_9 - ie_{10}, & ie_9 - ie_{10} > 0 \end{cases},$$

$$me_{10} = 0.5 + (me_3 + me_8) \cdot 2^{cb_7},$$

$$ie_{11} = \max(fe(|ir_8| + me_8 \cdot ULP(ir_8)), fe(|ir_4| + me_4 \cdot ULP(ir_4))),$$

$$ir_{11} = ir_4 + ir_8,$$

$$ie_{12} = fe(ir_{11}),$$

$$cb_8 = \begin{cases} 0, & ie_{11} - ie_{12} \le 0 \\ ie_{11} - ie_{12}, & ie_{11} - ie_{12} > 0 \end{cases},$$

$$me_{11} = 0.5 + \left(me_4 + me_8\right) \cdot 2^{cb_8},$$

then

Table 171. GMCLIB_SvmSci_FLT Return Value

Subset of input domain	Meaningful Return Value
Any of the inputs is NaN, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ fltArg1 = NaN \vee \\ fltArg2 = NaN \end{matrix} \right\}$	No
Normalized, denormalized, or zero inputs, at least one input is outside the [-1, 1] interval, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ X \subset N \cup D \cup \{-0, +0\}, \\ \lvert fltArg1 \rvert > 1 \vee \lvert fltArg2 \rvert > 1 \end{matrix} \right\}$	No
All inputs within the [-1, 1] interval, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ X \subset N \cup D \cup \{-0, +0\}, \\ \lvert fltArg1 \rvert \le 1, \lvert fltArg2 \rvert \le 1 \end{matrix} \right\}$	Yes

Table 172. GMCLIB_SvmSci_FLT Worst-Case Error Bounds - Output fltArg1

Subset of input domain	Worst-case absolute error for fltArg1 output	Allowed specific values (regardless the error bounds) for fltArg1 output
Any of the inputs is NaN, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ fltArg1 = NaN \vee \\ fltArg2 = NaN \end{matrix} \right\}$	$(-Inf, Inf)$	NaN

Subset of input domain	Worst-case absolute error for fltArg1 output	Allowed specific values (regardless the error bounds) for fltArg1 output
Normalized, denormalized, or zero inputs, at least one input is outside the [-1, 1] interval, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2) \in X \mid \\ X \subset N \cup D \cup \{-0, +0\}, \\ \lvert fltArg1 \rvert > 1 \vee \lvert fltArg2 \rvert > 1 \end{array} \right\}$	$(-Inf, Inf)$	{NaN, Inf, -Inf}
All inputs within the [-1, 1] interval, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2) \in X \mid \\ X \subset N \cup D \cup \{-0, +0\}, \\ \lvert fltArg1 \rvert \le 1, \lvert fltArg2 \rvert \le 1 \end{array} \right\}$	$\langle -me_9, me_9 \rangle$	N/A

Table 173. GMCLIB_SvmSci_FLT Worst-Case Error Bounds - Output fltArg2

Subset of input domain	Worst-case absolute error for fltArg2 output	Allowed specific values (regardless the error bounds) for fltArg2 output
Any of the inputs is NaN, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2) \in X \mid \\ fltArg1 = NaN \vee \\ fltArg2 = NaN \end{array} \right\}$	$(-Inf, Inf)$	NaN
Normalized, denormalized, or zero inputs, at least one input is outside the [-1, 1] interval, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2) \in X \mid \\ X \subset N \cup D \cup \{-0, +0\}, \\ \lvert fltArg1 \rvert > 1 \vee \lvert fltArg2 \rvert > 1 \end{array} \right\}$	$(-Inf, Inf)$	{NaN, Inf, -Inf}
All inputs within the [-1, 1] interval, i.e.	$\langle -me_{10}, me_{10} \rangle$	N/A

Table 174. GMCLIB_SvmSci_FLT Worst-Case Error Bounds - Output fltArg3

Subset of input domain	Worst-case absolute error for fltArg3 output	Allowed specific values (regardless the error bounds) for fltArg3 output
Any of the inputs is NaN, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2) \in X \mid \\ fltArg1 = NaN \vee \\ fltArg2 = NaN \end{array} \right\}$	$(-Inf, Inf)$	NaN
Normalized, denormalized, or zero inputs, at least one input is outside the [-1, 1] interval, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2) \in X \mid \\ X \subset N \cup D \cup \{-0, +0\}, \\ \lvert fltArg1 \rvert > 1 \vee \lvert fltArg2 \rvert > 1 \end{array} \right\}$	$(-Inf, Inf)$	{NaN, Inf, -Inf}
All inputs within the [-1, 1] interval, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2) \in X \mid \\ X \subset N \cup D \cup \{-0, +0\}, \\ \lvert fltArg1 \rvert \le 1, \lvert fltArg2 \rvert \le 1 \end{array} \right\}$	$\langle -me_{11}, me_{11} \rangle$	N/A

2.50 Function GMCLIB_SvmStd_FLT

Declaration

```
tU32 GMCLIB_SvmStd_FLT(SWLIBS_3Syst_FLT *pOut, const
SWLIBS_2Syst_FLT *const pIn);
```

Arguments

Table 175. GMCLIB_SvmStd_FLT arguments

Type	Name	Direction	Description
SWLIBS_3Syst_FLT *	pOut	**input, output**	Pointer to the structure containing calculated duty-cycle ratios of the 3-Phase system.
const SWLIBS_2Syst_FLT *const	pIn	**input**	Pointer to the structure containing direct U_α and quadrature U_β components of the stator voltage vector.

Worst-Case Error Bounds

Note: The allowed error bounds for the floating-point outputs of this function are expressed in terms of allowed absolute error.

Let $(fltArg1, fltArg2) \in X$ be a set of inputs to GMCLIB_SvmStd_FLT,

then

Table 176. GMCLIB_SvmStd_FLT Return Value

Subset of input domain	Meaningful Return Value
Any of the inputs is NaN, i.e. $\left\{\begin{matrix} (fltArg1, fltArg2) \in X \mid \\ fltArg1 = NaN \lor \\ fltArg2 = NaN \end{matrix}\right\}$	No
Normalized, denormalized, or zero inputs, at least one input is outside the [-1, 1] interval, i.e. $\left\{\begin{matrix} (fltArg1, fltArg2) \in X \mid \\ X \subset N \cup D \cup \{-0, +0\}, \\ \lvert fltArg1 \rvert > 1 \lor \lvert fltArg2 \rvert > 1 \end{matrix}\right\}$	No
All inputs within the [-1, 1] interval, i.e. $\left\{\begin{matrix} (fltArg1, fltArg2) \in X \mid \\ X \subset N \cup D \cup \{-0, +0\}, \\ \lvert fltArg1 \rvert \le 1, \lvert fltArg2 \rvert \le 1 \end{matrix}\right\}$	Yes

Table 177. GMCLIB_SvmStd_FLT Worst-Case Error Bounds - Output fltArg1

Subset of input domain	Worst-case absolute error for fltArg1 output	Allowed specific values (regardless the error bounds) for fltArg1 output
Any of the inputs is NaN, i.e. $\left\{\begin{matrix} (fltArg1, fltArg2) \in X \mid \\ fltArg1 = NaN \lor \\ fltArg2 = NaN \end{matrix}\right\}$	Inf	NaN
Normalized, denormalized, or zero inputs, at least one input is outside the [-1, 1] interval, i.e. $\left\{\begin{matrix} (fltArg1, fltArg2) \in X \mid \\ X \subset N \cup D \cup \{-0, +0\}, \\ \lvert fltArg1 \rvert > 1 \lor \lvert fltArg2 \rvert > 1 \end{matrix}\right\}$	Inf	{NaN, Inf, -Inf}
All inputs within the [-1, 1] interval, i.e. $\left\{\begin{matrix} (fltArg1, fltArg2) \in X \mid \\ X \subset N \cup D \cup \{-0, +0\}, \\ \lvert fltArg1 \rvert \le 1, \lvert fltArg2 \rvert \le 1 \end{matrix}\right\}$	2^{-19}	N/A

Table 178. GMCLIB_SvmStd_FLT Worst-Case Error Bounds - Output fltArg2

Subset of input domain	Worst-case absolute error for fltArg2 output	Allowed specific values (regardless the error bounds) for fltArg2 output
Any of the inputs is NaN, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ fltArg1 = NaN \vee \\ fltArg2 = NaN \end{matrix} \right\}$	Inf	NaN
Normalized, denormalized, or zero inputs, at least one input is outside the [-1, 1] interval, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ X \subset N \cup D \cup \{-0, +0\}, \\ \lvert fltArg1 \rvert > 1 \vee \lvert fltArg2 \rvert > 1 \end{matrix} \right\}$	Inf	{NaN, Inf, -Inf}
All inputs within the [-1, 1] interval, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ X \subset N \cup D \cup \{-0, +0\}, \\ \lvert fltArg1 \rvert \leq 1, \lvert fltArg2 \rvert \leq 1 \end{matrix} \right\}$	2^{-19}	N/A

Table 179. GMCLIB_SvmStd_FLT Worst-Case Error Bounds - Output fltArg3

Subset of input domain	Worst-case absolute error for fltArg3 output	Allowed specific values (regardless the error bounds) for fltArg3 output
Any of the inputs is NaN, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ fltArg1 = NaN \vee \\ fltArg2 = NaN \end{matrix} \right\}$	Inf	NaN
Normalized, denormalized, or zero inputs, at least one input is outside the [-1, 1] interval, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ X \subset N \cup D \cup \{-0, +0\}, \\ \lvert fltArg1 \rvert > 1 \vee \lvert fltArg2 \rvert > 1 \end{matrix} \right\}$	Inf	{NaN, Inf, -Inf}
All inputs within the [-1, 1] interval, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ X \subset N \cup D \cup \{-0, +0\}, \\ \lvert fltArg1 \rvert \leq 1, \lvert fltArg2 \rvert \leq 1 \end{matrix} \right\}$	2^{-19}	N/A

2.51 Function GMCLIB_SvmU0n_FLT

Declaration

```
tU32 GMCLIB_SvmU0n_FLT(SWLIBS_3Syst_FLT *pOut, const
SWLIBS_2Syst_FLT *const pIn);
```

Arguments

Table 180. GMCLIB_SvmU0n_FLT arguments

Type	Name	Direction	Description
SWLIBS_3Syst_FLT *	pOut	**input, output**	Pointer to the structure containing calculated duty-cycle ratios of the 3-Phase system.
const SWLIBS_2Syst_FLT *const	pIn	**input**	Pointer to the structure containing direct U_{α} and quadrature U_{β} components of the stator voltage vector.

Worst-Case Error Bounds

Note: The allowed error bounds for the floating-point outputs of this function are expressed in terms of allowed absolute error.

Let (*fltArg1*, *fltArg2*) ∊ *X* be a set of inputs to GMCLIB_SvmU0n_FLT,

then

Table 181. GMCLIB_SvmU0n_FLT Return Value

Subset of input domain	Meaningful Return Value
Any of the inputs is NaN, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2) \in X \mid \\ fltArg1 = NaN \vee \\ fltArg2 = NaN \end{array} \right\}$	No
Normalized, denormalized, or zero inputs, at least one input is outside the [-1, 1] interval, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2) \in X \mid \\ X \subset N \cup D \cup \{-0, +0\}, \\ \lvert fltArg1 \rvert > 1 \vee \lvert fltArg2 \rvert > 1 \end{array} \right\}$	No
All inputs within the [-1, 1] interval, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2) \in X \mid \\ X \subset N \cup D \cup \{-0, +0\}, \\ \lvert fltArg1 \rvert \le 1, \lvert fltArg2 \rvert \le 1 \end{array} \right\}$	Yes

Table 182. GMCLIB_SvmU0n_FLT Worst-Case Error Bounds - Output fltArg1

Subset of input domain	Worst-case absolute error for fltArg1 output	Allowed specific values (regardless the error bounds) for fltArg1 output
Any of the inputs is NaN, i.e. $\left\{\begin{array}{c}(fltArg1, fltArg2) \in X \mid \\ fltArg1 = NaN \vee \\ fltArg2 = NaN\end{array}\right\}$	Inf	NaN
Normalized, denormalized, or zero inputs, at least one input is outside the [-1, 1] interval, i.e. $\left\{\begin{array}{c}(fltArg1, fltArg2) \in X \mid \\ X \subset N \cup D \cup \{-0, +0\}, \\ \lvert fltArg1\rvert > 1 \vee \lvert fltArg2\rvert > 1\end{array}\right\}$	Inf	{NaN, Inf, -Inf}
All inputs within the [-1, 1] interval, i.e. $\left\{\begin{array}{c}(fltArg1, fltArg2) \in X \mid \\ X \subset N \cup D \cup \{-0, +0\}, \\ \lvert fltArg1\rvert \le 1, \lvert fltArg2\rvert \le 1\end{array}\right\}$	2^{-19}	N/A

Table 183. GMCLIB_SvmU0n_FLT Worst-Case Error Bounds - Output fltArg2

Subset of input domain	Worst-case absolute error for fltArg2 output	Allowed specific values (regardless the error bounds) for fltArg2 output
Any of the inputs is NaN, i.e. $\left\{\begin{array}{c}(fltArg1, fltArg2) \in X \mid \\ fltArg1 = NaN \vee \\ fltArg2 = NaN\end{array}\right\}$	Inf	NaN
Normalized, denormalized, or zero inputs, at least one input is outside the [-1, 1] interval, i.e. $\left\{\begin{array}{c}(fltArg1, fltArg2) \in X \mid \\ X \subset N \cup D \cup \{-0, +0\}, \\ \lvert fltArg1\rvert > 1 \vee \lvert fltArg2\rvert > 1\end{array}\right\}$	Inf	{NaN, Inf, -Inf}
All inputs within the [-1, 1] interval, i.e. $\left\{\begin{array}{c}(fltArg1, fltArg2) \in X \mid \\ X \subset N \cup D \cup \{-0, +0\}, \\ \lvert fltArg1\rvert \le 1, \lvert fltArg2\rvert \le 1\end{array}\right\}$	2^{-19}	N/A

Table 184. GMCLIB_SvmU0n_FLT Worst-Case Error Bounds - Output fltArg3

Subset of input domain	Worst-case absolute error for fltArg3 output	Allowed specific values (regardless the error bounds) for fltArg3 output
Any of the inputs is NaN, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2) \in X \mid \\ fltArg1 = NaN \vee \\ fltArg2 = NaN \end{array} \right\}$	Inf	NaN
Normalized, denormalized, or zero inputs, at least one input is outside the [-1, 1] interval, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2) \in X \mid \\ X \subset N \cup D \cup \{-0, +0\}, \\ \lvert fltArg1 \rvert > 1 \vee \lvert fltArg2 \rvert > 1 \end{array} \right\}$	Inf	{NaN, Inf, -Inf}
All inputs within the [-1, 1] interval, i.e. $\left\{ \begin{array}{c} (fltArg1, fltArg2) \in X \mid \\ X \subset N \cup D \cup \{-0, +0\}, \\ \lvert fltArg1 \rvert \le 1, \lvert fltArg2 \rvert \le 1 \end{array} \right\}$	2^{-19}	N/A

2.52 Function GMCLIB_SvmU7n_FLT

Declaration

```
tU32 GMCLIB_SvmU7n_FLT(SWLIBS_3Syst_FLT *pOut, const
SWLIBS_2Syst_FLT *const pIn);
```

Arguments

Table 185. GMCLIB_SvmU7n_FLT arguments

Type	Name	Direction	Description
SWLIBS_3Syst_FLT *	pOut	**input, output**	Pointer to the structure containing calculated duty-cycle ratios of the 3-Phase system.
const SWLIBS_2Syst_FLT *const	pIn	**input**	Pointer to the structure containing direct U_α and quadrature U_β components of the stator voltage vector.

Worst-Case Error Bounds

Note: The allowed error bounds for the floating-point outputs of this function are expressed in terms of allowed absolute error.

Let (*fltArg1*, *fltArg2*) $\in X$ be a set of inputs to GMCLIB_SvmU7n_FLT,

then

Table 186. GMCLIB_SvmU7n_FLT Return Value

Subset of input domain	Meaningful Return Value
Any of the inputs is NaN, i.e. $\left\{\begin{array}{c} (fltArg1, fltArg2) \in X \mid \\ fltArg1 = NaN \vee \\ fltArg2 = NaN \end{array}\right\}$	No
Normalized, denormalized, or zero inputs, at least one input is outside the [-1, 1] interval, i.e. $\left\{\begin{array}{c} (fltArg1, fltArg2) \in X \mid \\ X \subset N \cup D \cup \{-0, +0\}, \\ \lvert fltArg1 \rvert > 1 \vee \lvert fltArg2 \rvert > 1 \end{array}\right\}$	No
All inputs within the [-1, 1] interval, i.e. $\left\{\begin{array}{c} (fltArg1, fltArg2) \in X \mid \\ X \subset N \cup D \cup \{-0, +0\}, \\ \lvert fltArg1 \rvert \le 1, \lvert fltArg2 \rvert \le 1 \end{array}\right\}$	Yes

Table 187. GMCLIB_SvmU7n_FLT Worst-Case Error Bounds - Output fltArg1

Subset of input domain	Worst-case absolute error for fltArg1 output	Allowed specific values (regardless the error bounds) for fltArg1 output
Any of the inputs is NaN, i.e. $\left\{\begin{array}{c} (fltArg1, fltArg2) \in X \mid \\ fltArg1 = NaN \vee \\ fltArg2 = NaN \end{array}\right\}$	Inf	NaN
Normalized, denormalized, or zero inputs, at least one input is outside the [-1, 1] interval, i.e. $\left\{\begin{array}{c} (fltArg1, fltArg2) \in X \mid \\ X \subset N \cup D \cup \{-0, +0\}, \\ \lvert fltArg1 \rvert > 1 \vee \lvert fltArg2 \rvert > 1 \end{array}\right\}$	Inf	{NaN, Inf, -Inf}
All inputs within the [-1, 1] interval, i.e. $\left\{\begin{array}{c} (fltArg1, fltArg2) \in X \mid \\ X \subset N \cup D \cup \{-0, +0\}, \\ \lvert fltArg1 \rvert \le 1, \lvert fltArg2 \rvert \le 1 \end{array}\right\}$	2^{-19}	N/A

Table 188. GMCLIB_SvmU7n_FLT Worst-Case Error Bounds - Output fltArg2

Subset of input domain	Worst-case absolute error for fltArg2 output	Allowed specific values (regardless the error bounds) for fltArg2 output
Any of the inputs is NaN, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ fltArg1 = NaN \vee \\ fltArg2 = NaN \end{matrix} \right\}$	Inf	NaN
Normalized, denormalized, or zero inputs, at least one input is outside the [-1, 1] interval, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ X \subset N \cup D \cup \{-0, +0\}, \\ \lvert fltArg1 \rvert > 1 \vee \lvert fltArg2 \rvert > 1 \end{matrix} \right\}$	Inf	{NaN, Inf, -Inf}
All inputs within the [-1, 1] interval, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ X \subset N \cup D \cup \{-0, +0\}, \\ \lvert fltArg1 \rvert \le 1, \lvert fltArg2 \rvert \le 1 \end{matrix} \right\}$	2^{-19}	N/A

Table 189. GMCLIB_SvmU7n_FLT Worst-Case Error Bounds - Output fltArg3

Subset of input domain	Worst-case absolute error for fltArg3 output	Allowed specific values (regardless the error bounds) for fltArg3 output
Any of the inputs is NaN, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ fltArg1 = NaN \vee \\ fltArg2 = NaN \end{matrix} \right\}$	Inf	NaN
Normalized, denormalized, or zero inputs, at least one input is outside the [-1, 1] interval, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ X \subset N \cup D \cup \{-0, +0\}, \\ \lvert fltArg1 \rvert > 1 \vee \lvert fltArg2 \rvert > 1 \end{matrix} \right\}$	Inf	{NaN, Inf, -Inf}
All inputs within the [-1, 1] interval, i.e. $\left\{ \begin{matrix} (fltArg1, fltArg2) \in X \mid \\ X \subset N \cup D \cup \{-0, +0\}, \\ \lvert fltArg1 \rvert \le 1, \lvert fltArg2 \rvert \le 1 \end{matrix} \right\}$	2^{-19}	N/A

2.53 Function GMCLIB_VRot_FLT

Declaration

```
void GMCLIB_VRot_FLT(SWLIBS_2Syst_FLT *const fltOutVec, const
SWLIBS_2Syst_FLT *const fltInVec, tFloat fltAngle);
```

Arguments

Table 190. GMCLIB_VRot_FLT arguments

Type	Name	Direction	Description
SWLIBS_2Syst_FLT *const	fltOutVec	**output**	Rotated vector.
const SWLIBS_2Syst_FLT *const	fltInVec	**input**	Input vector to be rotated.
tFloat	fltAngle	**input**	Angle the input vector shall be rotated by.

Worst-Case Error Bounds

Let {*fltInVec = (fltInVec1, flotInVec2)*, *fltAngle*} ∈ *X* be a set of inputs to GMCLIB_VRot_FLT,

refResult = (refResult1, refResult2) be the theoretical exact result,

$ir_1 = fltInVec_1 \cdot \cos(fltAngle)$,

$me_1 = 84$,

$ir_2 = fltInVec_2 \cdot \sin(fltAngle)$,

$me_2 = 84$,

$ie_1 = \max(\mathrm{fe}(|ir_1| + me_1 \cdot \mathrm{ULP}(ir_1)), \mathrm{fe}(|ir_2| + me_2 \cdot \mathrm{ULP}(ir_2)))$,

$ir_3 = ir_1 - ir_2$,

$ie_2 = \mathrm{fe}(ir_3)$,

$$cb_1 = \begin{cases} 0, & ie_1 - ie_2 \leq 0 \\ ie_1 - ie_2, & ie_1 - ie_2 > 0 \end{cases},$$

$me_3 = 1 + 168 \cdot 2^{cb_1}$,

$ir_4 = fltInVec_1 \cdot \sin(fltAngle)$,

$me_4 = 84$,

$ir_5 = fltInVec_2 \cdot \cos(fltAngle)$,

$me_5 = 84$,

$ie_3 = \max(\mathrm{fe}(|ir_4| + me_4 \cdot \mathrm{ULP}(ir_4)), \mathrm{fe}(|ir_5| + me_5 \cdot \mathrm{ULP}(ir_5)))$,

$ir_6 = ir_4 + ir_5$,

$ie_4 = \mathrm{fe}(ir_6)$,

$$cb_2 = \begin{cases} 0, & ie_3 - ie_4 \le 0 \\ ie_3 - ie_4, & ie_3 - ie_4 > 0 \end{cases},$$

$$me_6 = 1 + 168 \cdot 2^{cb_2},$$

then

Table 191. GMCLIB_VRot_FLT Worst-Case Error Bounds - refResult1 output

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Any of the inputs is denormalized, NaN, or infinity, i.e. $\{X \mid X \cap D \neq \varnothing \vee X \cap M \neq \varnothing\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
All inputs normalized, i.e. $\begin{Bmatrix} fltInVec_1 \in N \\ fltInVec_2 \in N \\ fltAngle \in N \end{Bmatrix}$	$\langle -me_3, me_3 \rangle$	N/A
Normalized or zero input values which cause an underflow, i.e. $\left\{ \begin{matrix} X \mid X \subset N \cup \{-0, +0\}, \\ \exists n \subset \{1,2,3\} : ir_n \neq \varnothing \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \end{matrix} \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which cause an overflow, i.e. $\left\{ \begin{matrix} X \mid X \subset N \cup \{-0, +0\}, \\ \exists n \subset \{1,2,3\} : ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \end{matrix} \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Table 192. GMCLIB_VRot_FLT Worst-Case Error Bounds - refResult2 output

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Any of the inputs is denormalized, NaN, or infinity, i.e. $\{X \mid X \cap D \neq \varnothing \vee X \cap M \neq \varnothing\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
All inputs normalized, i.e. $\begin{Bmatrix} fltInVec_1 \in N \\ fltInVec_2 \in N \\ fltAngle \in N \end{Bmatrix}$	$\langle -me_6, me_6 \rangle$	N/A

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Normalized or zero input values which cause an underflow, i.e. $\left\{\begin{array}{c} X \mid X \subset N \cup \{-0, +0\}, \\ \exists n \subset \{4,5,6\}: ir_n \neq \varnothing \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \end{array}\right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which cause an overflow, i.e. $\left\{\begin{array}{c} X \mid X \subset N \cup \{-0, +0\}, \\ \exists n \subset \{4,5,6\}: ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \end{array}\right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

2.54 Function GMCLIB_VUnit_FLT

Declaration

```
void GMCLIB_VUnit_FLT(SWLIBS_2Syst_FLT *const fltOutVec, const
SWLIBS_2Syst_FLT *const fltInVec);
```

Arguments

Table 193. GMCLIB_VUnit_FLT arguments

Type	Name	Direction	Description
SWLIBS_2Syst_FLT *const	fltOutVec	**output**	Output unit vector.
const SWLIBS_2Syst_FLT *const	fltInVec	**input**	Input vector to be scaled to unit vector.

Worst-Case Error Bounds

Let *fltInVec = (fltInVec1, flotInVec2)* ∊ *X* be a set of inputs to GMCLIB_VUnit_FLT,

refResult = (refResult1, refResult2) be the theoretical exact result,

$ir_1 = \tan^{-1}\left(\frac{fltInVec_2}{fltInVec_1}\right)$,

$me_1 = 3.5$,

$ir_2 = \cos(ir_1)$,

$me_2 = 42 + 8 \cdot me_1$,

$ir_3 = \sin(ir_1)$,

$me_3 = 42 + 8 \cdot me_1$,

then

Table 194. GMCLIB_VUnit_FLT Worst-Case Error Bounds - refResult1 output

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Any of the inputs is denormalized, NaN, or infinity, i.e. $\{X \mid X \cap D \neq \varnothing \vee X \cap M \neq \varnothing\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values, intermediate results beyond the allowed range, i.e. $\left\{\begin{matrix} X \mid X \subset N \cup \{-0, +0\}, \\ ir_1 \notin \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle \end{matrix}\right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values, intermediate results in the allowed range, i.e. $\left\{\begin{matrix} X \mid X \subset N \cup \{-0, +0\}, \\ ir_1 \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle \end{matrix}\right\}$	$\langle -me_2, me_2 \rangle$	N/A
Normalized or zero input values which cause an underflow, i.e. $\left\{\begin{matrix} X \mid X \subset N \cup \{-0, +0\}, \\ \exists n \subset \{1,2\} : ir_n \neq \varnothing \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \end{matrix}\right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which cause an overflow, i.e. $\left\{\begin{matrix} X \mid X \subset N \cup \{-0, +0\}, \\ \exists n \subset \{1,2\} : ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \end{matrix}\right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Table 195. GMCLIB_VUnit_FLT Worst-Case Error Bounds - refResult2 output

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Any of the inputs is denormalized, NaN, or infinity, i.e. $\{X \mid X \cap D \neq \varnothing \vee X \cap M \neq \varnothing\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values, intermediate results beyond the allowed range, i.e. $\left\{\begin{matrix} X \mid X \subset N \cup \{-0, +0\}, \\ ir_1 \notin \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle \end{matrix}\right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Normalized or zero input values, intermediate results in the allowed range, i.e. $\left\{ \begin{array}{l} X \mid X \subset N \cup \{-0, +0\}, \\ ir_1 \in \langle \frac{\pi}{2} \cdot 1.1, \pi \cdot 0.9 \rangle \end{array} \right\}$	$\langle -me_3, me_3 \rangle$	N/A
Normalized or zero input values which cause an underflow, i.e. $\left\{ \begin{array}{c} X \mid X \subset N \cup \{-0, +0\}, \\ \exists n \subset \{1,3\} : ir_n \neq \varnothing \wedge \lvert ir_n \rvert - me_n \cdot \mathrm{ULP}(ir_n) \in D \end{array} \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)
Normalized or zero input values which cause an overflow, i.e. $\left\{ \begin{array}{c} X \mid X \subset N \cup \{-0, +0\}, \\ \exists n \subset \{1,3\} : ir_n \in M \vee \lvert ir_n \rvert + me_n \cdot \mathrm{ULP}(ir_n) = Inf \end{array} \right\}$	$(-Inf, Inf)$	Arbitrary floating-point value (including Inf, -Inf, NaN)

2.55 Function MLIB_Abs_FLT

Declaration

```
INLINEtFloat MLIB_Abs_FLT(register tFloat fltIn);
```

Arguments

Table 196. MLIB_Abs_FLT arguments

Type	Name	Direction	Description
register tFloat	fltIn	**input**	Input value.

Worst-Case Error Bounds

Let *fltIn* $\in X$ be an input to MLIB_Abs_FLT,

then

Table 197. MLIB_Abs_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Input infinity, i.e. $\{ fltIn \in X \mid fltIn \in \{Inf, -Inf\} \}$	N/A	{Inf, *pmax*}
Input NaN, i.e. $\{ fltIn \in X \mid fltIn = NaN \}$	N/A	{NaN, *pmax*}

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Denormalized input, i.e. $\{fltIn \in X \mid X \subset D\}$	0	0
Normalized input, i.e. $\{fltIn \in X \mid X \subset N\}$	0	N/A
Zero input, i.e. $\{fltIn \in X \mid fltIn = 0\}$	0	{-0, +0}

2.56 Function MLIB_Add_FLT

Declaration

```
INLINEtFloat MLIB_Add_FLT(register tFloat fltIn1, register tFloat
fltIn2);
```

Arguments

Table 198. MLIB_Add_FLT arguments

Type	Name	Direction	Description
register tFloat	fltIn1	**input**	First value to be add.
register tFloat	fltIn2	**input**	Second value to be add.

Worst-Case Error Bounds

Let (*fltIn1*, *fltIn2*) ∊ *X* be a set of inputs to MLIB_Add_FLT,

refResult be the theoretical exact result,

then

Table 199. MLIB_Add_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Both inputs infinity, i.e. $\left\{ \begin{array}{c} fltIn_1, fltIn_2 \in X \mid fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 \in \{Inf, -Inf\} \end{array} \right\}$	N/A	{Inf, -Inf, NaN, *pmax*, *nmax*}
fltIn1 arbitrary value, *fltIn2* NaN, i.e. $\{fltIn_1, fltIn_2 \in X \mid fltIn_2 = NaN\}$	N/A	{NaN, *pmax*, *nmax*}

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
fltIn1 infinity, *fltIn2* normalized, denormalized, or zero, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 \in N \cup D \cup \{-0, +0\} \end{matrix}\right\}$	N/A	{sign(*fltIn1*)•Inf, sign(*fltIn1*)•*pmax*}
fltIn1 NaN, *fltIn2* arbitrary value, i.e. $\{fltIn_1, fltIn_2 \in X \mid fltIn_1 = NaN\}$	N/A	{NaN, *pmax*, *nmax*}
fltIn1 normalized, denormalized, or zero, *fltIn2* infinity, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid \\ fltIn_1 \in N \cup D \cup \{-0, +0\}, \\ fltIn_2 \in \{Inf, -Inf\} \end{matrix}\right\}$	N/A	{sign(*fltIn2*)•Inf, sign(*fltIn2*)•*pmax*}
Both inputs denormalized, i.e. $\{fltIn_1, fltIn_2 \in X \mid X \subset D\}$	$\langle -0.5, 0.5 \rangle$	{-0, +0}
fltIn1 denormalized, *fltIn2* zero, i.e. $\{fltIn_1, fltIn_2 \in X \mid fltIn_1 \in D, fltIn_2 = 0\}$	$\langle -0.5, 0.5 \rangle$	{-0, +0}
fltIn1 denormalized, *fltIn2* normalized, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid fltIn_1 \in D, \\ fltIn_2 \in N \end{matrix}\right\}$	$\langle -(2^{24}-1), 2^{24}-1 \rangle$	N/A
fltIn1 zero, *fltIn2* denormalized, i.e. $\{fltIn_1, fltIn_2 \in X \mid fltIn_1 = 0, fltIn_2 \in D\}$	$\langle -0.5, 0.5 \rangle$	{-0, +0}
Both inputs zero, i.e. $\{fltIn_1, fltIn_2 \in X \mid fltIn_1 = 0, fltIn_2 = 0\}$	0	N/A
fltIn1 zero, *fltIn2* normalized, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid fltIn_1 = 0, \\ fltIn_2 \in N \end{matrix}\right\}$	0	N/A

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
fltIn1 normalized, *fltIn2* denormalized, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid \\ fltIn_1 \in N, fltIn_2 \in D \end{matrix}\right\}$	$\langle -(2^{24}-1), 2^{24}-1 \rangle$	N/A
fltIn1 normalized, *fltIn2* zero, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid \\ fltIn_1 \in N, fltIn_2 = 0 \end{matrix}\right\}$	0	N/A
Both inputs normalized, result normalized or zero, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid X \subset N, \\ refResult = 0 \vee \\ \left(\begin{matrix} \lvert refResult \rvert - 0.5 \cdot \mathrm{ULP}(refResult) \notin D \wedge \\ \lvert refResult \rvert + 0.5 \cdot \mathrm{ULP}(refResult) \neq Inf \end{matrix}\right) \end{matrix}\right\}$	$\langle -0.5, 0.5 \rangle$	N/A
Both inputs normalized, result overflow, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid X \subset N, \\ \lvert refResult \rvert + 0.5 \cdot \mathrm{ULP}(refResult) = Inf \end{matrix}\right\}$	$\langle -0.5, 0.5 \rangle$	{sign(*refResult*)•Inf, sign(*refResult*)•*pmax*}
Both inputs normalized, result underflow, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid X \subset N, \\ \lvert refResult \rvert - 0.5 \cdot \mathrm{ULP}(refResult) \in D \wedge \\ refResult \neq 0 \end{matrix}\right\}$	$\langle -0.5, 0.5 \rangle$	{-0, +0}

2.57 Function MLIB_Convert_F32FLT

Declaration

```
INLINEtFrac32 MLIB_Convert_F32FLT(register tFloat fltIn1,
register tFloat fltIn2);
```

Arguments

Table 200. MLIB_Convert_F32FLT arguments

Type	Name	Direction	Description
register tFloat	fltIn1	**input**	Input value in single precision floating point format to be converted.
register tFloat	fltIn2	**input**	Scale factor in single precision floating point format.

Worst-Case Error Bounds

This function returns a fixed-point result as specified in the Automotive Math and Motor Control Library Set for NXP S32K14x devices User's Guide. If any of the inputs is a NaN or infinity, then the function returns an arbitrary value.

2.58 Function MLIB_Convert_F16FLT

Declaration

```
INLINEtFrac16 MLIB_Convert_F16FLT(register tFloat fltIn1,
register tFloat fltIn2);
```

Arguments

Table 201. MLIB_Convert_F16FLT arguments

Type	Name	Direction	Description
register tFloat	fltIn1	**input**	Input value in single precision floating point format to be converted.
register tFloat	fltIn2	**input**	Scale factor in single precision floating point format.

Worst-Case Error Bounds

This function returns a fixed-point result as specified in the Automotive Math and Motor Control Library Set for NXP S32K14x devices User's Guide. If any of the inputs is a NaN or infinity, then the function returns an arbitrary value.

2.59 Function MLIB_Convert_FLTF16

Declaration

```
INLINEtFloat MLIB_Convert_FLTF16(register tFrac16 f16In1,
register tFrac16 f16In2);
```

Arguments

Table 202. MLIB_Convert_FLTF16 arguments

Type	Name	Direction	Description
register tFrac16	f16In1	**input**	Input value in 16-bit fractional format to be converted.
register tFrac16	f16In2	**input**	Scale factor in 16-bit fractional format.

Worst-Case Error Bounds

This function returns a result with worst-case error bounds of $\langle -1536, 1536 \rangle$ ulp. The result is always a normalized value or zero.

2.60 Function MLIB_Convert_FLTF32

Declaration

```
INLINEtFloat MLIB_Convert_FLTF32(register tFrac32 f32In1,
register tFrac32 f32In2);
```

Arguments

Table 203. MLIB_Convert_FLTF32 arguments

Type	Name	Direction	Description
register tFrac32	f32In1	**input**	Input value in 32-bit fractional format to be converted.
register tFrac32	f32In2	**input**	Scale factor in 32-bit fractional format.

Worst-Case Error Bounds

This function returns a result with worst-case error bounds of $\langle -1536, 1536 \rangle$ ulp. The result is always a normalized value or zero.

2.61 Function MLIB_ConvertPU_F32FLT

Declaration

```
INLINEtFrac32 MLIB_ConvertPU_F32FLT(register tFloat fltIn);
```

Arguments

Table 204. MLIB_ConvertPU_F32FLT arguments

Type	Name	Direction	Description
register tFloat	fltIn	**input**	Input value in single precision floating point format to be converted.

Worst-Case Error Bounds

This function returns a fixed-point result as specified in the Automotive Math and Motor Control Library Set for NXP S32K14x devices User's Guide. If any of the inputs is a NaN or infinity, then the function returns an arbitrary value.

2.62 Function MLIB_ConvertPU_F16FLT

Declaration

```
INLINEtFrac16 MLIB_ConvertPU_F16FLT(register tFloat fltIn);
```

Arguments

Table 205. MLIB_ConvertPU_F16FLT arguments

Type	Name	Direction	Description
register tFloat	fltIn	**input**	Input value in single precision floating point format to be converted.

Worst-Case Error Bounds

This function returns a fixed-point result as specified in the Automotive Math and Motor Control Library Set for NXP S32K14x devices User's Guide. If any of the inputs is a NaN or infinity, then the function returns an arbitrary value.

2.63 Function MLIB_ConvertPU_FLTF16

Declaration

```
INLINEtFloat MLIB_ConvertPU_FLTF16(register tFrac16 f16In);
```

Arguments

Table 206. MLIB_ConvertPU_FLTF16 arguments

Type	Name	Direction	Description
register tFrac16	f16In	**input**	Input value in 16-bit fractional format to be converted.

Worst-Case Error Bounds

This function returns a result with worst-case error bounds of $\langle -1536, 1536 \rangle$ ulp. The result is always a normalized value or zero.

2.64 Function MLIB_ConvertPU_FLTF32

Declaration

```
INLINEtFloat MLIB_ConvertPU_FLTF32(register tFrac32 f32In);
```

Arguments

Table 207. MLIB_ConvertPU_FLTF32 arguments

Type	Name	Direction	Description
register tFrac32	f32In	**input**	Input value in 32-bit fractional format to be converted.

Worst-Case Error Bounds

This function returns a result with worst-case error bounds of $\langle -1536, 1536 \rangle$ ulp. The result is always a normalized value or zero.

2.65 Function MLIB_Div_FLT

Declaration

```
INLINEtFloat MLIB_Div_FLT(register tFloat fltIn1, register tFloat
fltIn2);
```

Arguments

Table 208. MLIB_Div_FLT arguments

Type	Name	Direction	Description
register tFloat	fltIn1	**input**	Numerator of division.
register tFloat	fltIn2	**input**	Denominator of division.

Worst-Case Error Bounds

Let (*fltIn1*, *fltIn2*) $\in X$ be a set of inputs to MLIB_Div_FLT, *refResult* be the theoretical exact result,

then

Table 209. MLIB_Div_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Both inputs infinity, i.e. $\left\{ fltIn_1, fltIn_2 \in X \mid fltIn_1 \in \{Inf, -Inf\}, fltIn_2 \in \{Inf, -Inf\} \right\}$	N/A	{NaN, 0, -0}
fltIn1 infinity, *fltIn2* NaN, i.e. $\left\{ fltIn_1, fltIn_2 \in X \mid fltIn_1 \in \{Inf, -Inf\}, fltIn_2 = NaN \right\}$	N/A	{NaN, 0, -0}
fltIn1 infinity, *fltIn2* NaN, i.e. $\left\{ fltIn_1, fltIn_2 \in X \mid fltIn_1 \in \{Inf, -Inf\}, fltIn_2 \in D \right\}$	N/A	{Inf, *pmax*} if sign(*fltIn1*) = sign(*fltIn2*), {-Inf, *nmax*} if sign(*fltIn1*) ≠ sign(*fltIn2*)
fltIn1 infinity, *fltIn2* zero, i.e. $\left\{ fltIn_1, fltIn_2 \in X \mid fltIn_1 \in \{Inf, -Inf\}, fltIn_2 = 0 \right\}$	N/A	{Inf, *pmax*} if sign(*fltIn1*) = sign(*fltIn2*), {-Inf, *nmax*} if sign(*fltIn1*) ≠ sign(*fltIn2*)
fltIn1 infinity, *fltIn2* normalized, i.e. $\left\{ fltIn_1, fltIn_2 \in X \mid fltIn_1 \in \{Inf, -Inf\}, fltIn_2 \in N \right\}$	N/A	{Inf, *pmax*} if sign(*fltIn1*) = sign(*fltIn2*), {-Inf, *nmax*} if sign(*fltIn1*) ≠ sign(*fltIn2*)
fltIn1 NaN, *fltIn2* infinity, i.e. $\left\{ fltIn_1, fltIn_2 \in X \mid fltIn_1 = NaN, fltIn_2 \in \{Inf, -Inf\} \right\}$	N/A	{NaN, 0, -0}
Both inputs NaN, i.e. $\left\{ fltIn_1, fltIn_2 \in X \mid fltIn_1 = NaN, fltIn_2 = NaN \right\}$	N/A	{NaN, 0, -0}
fltIn1 NaN, *fltIn2* denormalized, i.e. $\left\{ fltIn_1, fltIn_2 \in X \mid fltIn_1 = NaN, fltIn_2 \in D \right\}$	N/A	{NaN, *pmax*, *nmax*}

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
fltIn1 NaN, *fltIn2* zero, i.e. $\{fltIn_1, fltIn_2 \in X \mid fltIn_1 = NaN, fltIn_2 = 0\}$	N/A	{NaN, *pmax*, *nmax*}
fltIn1 NaN, *fltIn2* normalized, i.e. $\{fltIn_1, fltIn_2 \in X \mid fltIn_1 = NaN, fltIn_2 \in N\}$	N/A	{NaN, *pmax*, *nmax*}
fltIn1 denormalized, *fltIn2* infinity, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid fltIn_1 \in D, \\ fltIn_2 \in \{Inf, -Inf\} \end{matrix}\right\}$	0	N/A
fltIn1 denormalized, *fltIn2* NaN, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid fltIn_1 \in D, \\ fltIn_2 = NaN \end{matrix}\right\}$	N/A	{NaN, 0, -0}
Both inputs denormalized, i.e. $\{fltIn_1, fltIn_2 \in X \mid X \subset D\}$	$\langle -0.5, 0.5 \rangle$	NaN or (*pmax* if sign(*fltIn1*) = sign(*fltIn2*), *nmax* if sign(*fltIn1*) ≠ sign(*fltIn2*))
fltIn1 denormalized, *fltIn2* zero, i.e. $\{fltIn_1, fltIn_2 \in X \mid fltIn_1 \in D, fltIn_2 = 0\}$	N/A	{Inf, *pmax*} if sign(*fltIn1*) = sign(*fltIn2*), {-Inf, *nmax*} if sign(*fltIn1*) ≠ sign(*fltIn2*)
fltIn1 denormalized, *fltIn2* normalized, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid fltIn_1 \in D, \\ fltIn_2 \in N \end{matrix}\right\}$	$\langle -0.5, 0.5 \rangle$	+0 if sign(*fltIn1*) = sign(*fltIn2*), -0 if sign(*fltIn1*) ≠ sign(*fltIn2*)
fltIn1 zero, *fltIn2* infinity, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid fltIn_1 = 0, \\ fltIn_2 \in \{Inf, -Inf\} \end{matrix}\right\}$	0	N/A
fltIn1 zero, *fltIn2* NaN, i.e. $\{fltIn_1, fltIn_2 \in X \mid fltIn_1 = 0, fltIn_2 = NaN\}$	N/A	{NaN, 0, -0}

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
fltIn1 zero, *fltIn2* denormalized, i.e. $\{fltIn_1, fltIn_2 \in X \mid fltIn_1 = 0, fltIn_2 \in D\}$	0	*pmax* if sign(*fltIn1*) = sign(*fltIn2*), *nmax* if sign(*fltIn1*) ≠ sign(*fltIn2*)
Both inputs zero, i.e. $\{fltIn_1, fltIn_2 \in X \mid fltIn_1 = 0, fltIn_2 = 0\}$	N/A	{NaN, *pmax*, *nmax*}
fltIn1 zero, *fltIn2* normalized, i.e. $\{fltIn_1, fltIn_2 \in X \mid fltIn_1 = 0, fltIn_2 \in N\}$	0	N/A
fltIn1 normalized, *fltIn2* infinity, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid fltIn_1 \in N, \\ fltIn_2 \in \{Inf, -Inf\} \end{matrix}\right\}$	0	N/A
fltIn1 normalized, *fltIn2* NaN, i.e. $\{fltIn_1, fltIn_2 \in X \mid fltIn_1 \in N, fltIn_2 = NaN\}$	N/A	{NaN, 0, -0}
fltIn1 normalized, *fltIn2* denormalized, i.e. $\{fltIn_1, fltIn_2 \in X \mid fltIn_1 \in N, fltIn_2 \in D\}$	$\langle -0.5, 0.5 \rangle$	{Inf, *pmax*} if sign(*fltIn1*) = sign(*fltIn2*), {-Inf, *nmax*} if sign(*fltIn1*) ≠ sign(*fltIn2*)
fltIn1 normalized, *fltIn2* zero, i.e. $\{fltIn_1, fltIn_2 \in X \mid fltIn_1 \in N, fltIn_2 = 0\}$	N/A	{Inf, *pmax*} if sign(*fltIn1*) = sign(*fltIn2*), {-Inf, *nmax*} if sign(*fltIn1*) ≠ sign(*fltIn2*)
Both inputs normalized, normalized result, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid X \subset N, \\ \left(\begin{matrix} \lvert refResult \rvert - 0.5 \cdot \mathrm{ULP}(refResult) \notin D \wedge \\ \lvert refResult \rvert + 0.5 \cdot \mathrm{ULP}(refResult) \neq Inf \end{matrix}\right) \end{matrix}\right\}$	$\langle -0.5, 0.5 \rangle$	N/A
Both inputs normalized, result overflow, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid X \subset N, \\ \lvert refResult \rvert + 0.5 \cdot \mathrm{ULP}(refResult) = Inf \end{matrix}\right\}$	$\langle -0.5, 0.5 \rangle$	{Inf, *pmax*} if sign(*fltIn1*) = sign(*fltIn2*), {-Inf, *nmax*} if sign(*fltIn1*) ≠ sign(*fltIn2*)

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Both inputs normalized, result underflow, i.e. $\left\{ \begin{array}{c} fltIn_1, fltIn_2 \in X \mid X \subset N, \\ \lvert refResult \rvert - 0.5 \cdot \mathrm{ULP}(refResult) \in D \wedge \\ refResult \neq 0 \end{array} \right\}$	$\langle -0.5, 0.5 \rangle$	+0 if sign(*fltIn1*) = sign(*fltIn2*), -0 if sign(*fltIn1*) ≠ sign(*fltIn2*)

2.66 Function MLIB_Mac_FLT

Declaration

```
INLINEtFloat MLIB_Mac_FLT(register tFloat fltIn1, register tFloat
fltIn2, register tFloat fltIn3);
```

Arguments

Table 210. MLIB_Mac_FLT arguments

Type	Name	Direction	Description
register tFloat	fltIn1	**input**	Input value to be add.
register tFloat	fltIn2	**input**	First value to be multiplied.
register tFloat	fltIn3	**input**	Second value to be multiplied.

Worst-Case Error Bounds

Let (*fltIn1*, *fltIn2*, *fltIn3*) ∊ *X* be a set of inputs to MLIB_Mac_FLT,

$mr = fltIn_2 \cdot fltIn_3$,

refResult be the theoretical exact result,

then

Table 211. MLIB_Mac_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
All inputs infinity, i.e. $\{ fltIn_1, fltIn_2, fltIn_3 \in X \mid X \subset \{Inf, -Inf\} \}$	N/A	{Inf, *pmax*} if (sign(*fltIn2*)=sign(*fltIn3*) and *fltIn1* > 0) or (sign(*fltIn2*)≠sign(*fltIn3*) and *fltIn1* < 0), {-Inf, *nmax*} otherwise
fltIn1 zero or denormalized, *fltIn2* and *fltIn3* infinity, i.e. $\left\{ \begin{array}{c} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in D \vee fltIn_1 = 0, \\ fltIn_2 \in \{Inf, -Inf\}, fltIn_3 \in \{Inf, -Inf\} \end{array} \right\}$	N/A	{Inf, *pmax*} if sign(*fltIn2*)=sign(*fltIn3*), {-Inf, *nmax*} otherwise

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
fltIn1 normalized, *fltIn2* and *fltIn3* infinity, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in N, \\ fltIn_2 \in \{Inf, -Inf\}, fltIn_3 \in \{Inf, -Inf\} \end{matrix}\right\}$	$(-Inf, Inf)$	Inf if sign(*fltIn2*)=sign(*fltIn3*), -Inf otherwise
fltIn1 NaN, i.e. $\{fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 = NaN\}$	$(-Inf, Inf)$	NaN
fltIn2 NaN, i.e. $\{fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_2 = NaN\}$	$(-Inf, Inf)$	NaN
fltIn3 NaN, i.e. $\{fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_3 = NaN\}$	$(-Inf, Inf)$	NaN
fltIn2 zero, *fltIn3* infinity, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_2 = 0, fltIn_3 \in \{Inf, -Inf\} \end{matrix}\right\}$	$(-Inf, Inf)$	{NaN, 0, -0}
fltIn2 infinity, *fltIn3* zero, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_2 \in \{Inf, -Inf\}, fltIn_3 = 0 \end{matrix}\right\}$	$(-Inf, Inf)$	{NaN, 0, -0}
fltIn1 infinity, *fltIn2* denormalized, *fltIn3* infinity, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 \in D, fltIn_3 \in \{Inf, -Inf\} \end{matrix}\right\}$	N/A	{NaN, Inf, -Inf, 0, -0, *pmax*, *nmax*}
fltIn1 zero, *fltIn2* denormalized, *fltIn3* infinity, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 = 0, fltIn_2 \in D, \\ fltIn_3 \in \{Inf, -Inf\} \end{matrix}\right\}$	N/A	{NaN, Inf, -Inf, 0, -0}

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
fltIn1 denormalized, *fltIn2* denormalized, *fltIn3* infinity, i.e. $\left\{\begin{array}{c} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in D, fltIn_2 \in D, \\ fltIn_3 \in \{Inf, -Inf\} \end{array}\right\}$	N/A	{NaN, Inf, -Inf, 0, -0}
fltIn1 normalized, *fltIn2* denormalized, *fltIn3* infinity, i.e. $\left\{\begin{array}{c} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in N, \\ fltIn_2 \in D, fltIn_3 \in \{Inf, -Inf\} \end{array}\right\}$	$(-Inf, Inf)$	{NaN, Inf, -Inf}
fltIn1 infinity, *fltIn2* normalized, *fltIn3* infinity, i.e. $\left\{\begin{array}{c} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 \in N, \\ fltIn_3 \in \{Inf, -Inf\} \end{array}\right\}$	$(-Inf, Inf)$	{NaN, Inf, -Inf}
fltIn1 zero, *fltIn2* normalized, *fltIn3* infinity, i.e. $\left\{\begin{array}{c} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 = 0, \\ fltIn_2 \in N, \\ fltIn_3 \in \{Inf, -Inf\} \end{array}\right\}$	N/A	{Inf, *pmax*} if sign(*fltIn2*)=sign(*fltIn3*), {-Inf, *nmax*} otherwise
fltIn1 denormalized, *fltIn2* normalized, *fltIn3* infinity, i.e. $\left\{\begin{array}{c} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in D, \\ fltIn_2 \in N, \\ fltIn_3 \in \{Inf, -Inf\} \end{array}\right\}$	N/A	{Inf, *pmax*} if sign(*fltIn2*)=sign(*fltIn3*), {-Inf, *nmax*} otherwise
fltIn1 normalized, *fltIn2* normalized, *fltIn3* infinity, i.e. $\left\{\begin{array}{c} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in N, fltIn_2 \in N, \\ fltIn_3 \in \{Inf, -Inf\} \end{array}\right\}$	$(-Inf, Inf)$	Inf if sign(*fltIn2*)=sign(*fltIn 3*), -Inf otherwise

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
fltIn1 infinity, *fltIn2* zero, *fltIn3* zero, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 = 0, fltIn_3 = 0 \end{matrix}\right\}$	N/A	{sign(*fltIn1*)•Inf, sign(*fltIn1*)•*pmax*}
All inputs zero, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 = 0, fltIn_2 = 0, fltIn_3 = 0 \end{matrix}\right\}$	0	{-0, +0}
fltIn1 denormalized, *fltIn2* zero, *fltIn3* zero, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in D, \\ fltIn_2 = 0, fltIn_3 = 0 \end{matrix}\right\}$	0	{-0, +0}
fltIn1 normalized, *fltIn2* zero, *fltIn3* zero, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in N, \\ fltIn_2 = 0, fltIn_3 = 0 \end{matrix}\right\}$	0	N/A
fltIn1 infinity, *fltIn2* denormalized, *fltIn3* zero, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 \in D, fltIn_3 = 0 \end{matrix}\right\}$	N/A	{sign(*fltIn1*)•Inf, sign(*fltIn1*)•*pmax*}
fltIn1 zero, *fltIn2* denormalized, *fltIn3* zero, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 = 0, \\ fltIn_2 \in D, fltIn_3 = 0 \end{matrix}\right\}$	0	{-0, +0}
fltIn1 denormalized, *fltIn2* denormalized, *fltIn3* zero, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in D, \\ fltIn_2 \in D, fltIn_3 = 0 \end{matrix}\right\}$	0	{-0, +0}

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
fltIn1 normalized, *fltIn2* denormalized, *fltIn3* zero, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \; \vert \\ fltIn_1 \in N, \\ fltIn_2 \in D, fltIn_3 = 0 \end{matrix} \right\}$$	0	N/A
fltIn1 infinity, *fltIn2* normalized, *fltIn3* zero, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \; \vert \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 \in N, \\ fltIn_3 = 0 \end{matrix} \right\}$$	0	{sign(*fltIn1*)•Inf, sign(*fltIn1*)•*pmax*}
fltIn1 zero, *fltIn2* normalized, *fltIn3* zero, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \; \vert \\ fltIn_1 = 0, \\ fltIn_2 \in N, \\ fltIn_3 = 0 \end{matrix} \right\}$$	0	N/A
fltIn1 denormalized, *fltIn2* normalized, *fltIn3* zero, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \; \vert \\ fltIn_1 \in D, \\ fltIn_2 \in N, \\ fltIn_3 = 0 \end{matrix} \right\}$$	0	{-0, +0}
fltIn1 normalized, *fltIn2* normalized, *fltIn3* zero, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \; \vert \\ fltIn_1 \in N, \\ fltIn_2 \in N, \\ fltIn_3 = 0 \end{matrix} \right\}$$	0	N/A
fltIn1 infinity, *fltIn2* infinity, *fltIn3* denormalized, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \; \vert \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 \in \{Inf, -Inf\}, \\ fltIn_3 \in D \end{matrix} \right\}$$	N/A	{NaN, Inf, -Inf, *pmax*, *nm ax*}

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
fltIn1 zero, *fltIn2* infinity, *fltIn3* denormalized, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 = 0, \\ fltIn_2 \in \{Inf, -Inf\}, \\ fltIn_3 \in D \end{matrix} \right\}$$	N/A	{NaN, Inf, -Inf, 0, -0}
fltIn1 denormalized, *fltIn2* infinity, *fltIn3* denormalized, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in D, \\ fltIn_2 \in \{Inf, -Inf\}, \\ fltIn_3 \in D \end{matrix} \right\}$$	N/A	{NaN, Inf, -Inf, 0, -0}
fltIn1 normalized, *fltIn2* infinity, *fltIn3* denormalized, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in N, \\ fltIn_2 \in \{Inf, -Inf\}, \\ fltIn_3 \in D \end{matrix} \right\}$$	$(-Inf, Inf)$	{NaN, Inf, -Inf, 0, -0}
fltIn1 infinity, *fltIn2* zero, *fltIn3* denormalized, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 = 0, fltIn_3 \in D \end{matrix} \right\}$$	N/A	{sign(*fltIn1*)•Inf, sign(*fltIn1*)•*pmax*}
fltIn1 zero, *fltIn2* zero, *fltIn3* denormalized, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 = 0, \\ fltIn_2 = 0, fltIn_3 \in D \end{matrix} \right\}$$	0	N/A
fltIn1 denormalized, *fltIn2* zero, *fltIn3* denormalized, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in D, \\ fltIn_2 = 0, fltIn_3 \in D \end{matrix} \right\}$$	0	{-0, +0}

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
fltIn1 normalized, *fltIn2* zero, *fltIn3* denormalized, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in N, \\ fltIn_2 = 0, fltIn_3 \in D \end{matrix} \right\}$$	0	N/A
fltIn1 infinity, *fltIn2* denormalized, *fltIn3* denormalized, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 = \in D, fltIn_3 \in D \end{matrix} \right\}$$	N/A	{sign(*fltIn1*)•Inf, sign(*fltIn1*)•*pmax*}
fltIn1 zero, *fltIn2* denormalized, *fltIn3* denormalized, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 = 0, \\ fltIn_2 \in D, fltIn_3 \in D \end{matrix} \right\}$$	0	N/A
All inputs denormalized, i.e. $$\{ fltIn_1, fltIn_2, fltIn_3 \in X \mid X \subset D, \}$$	0	{-0, +0}
fltIn1 normalized, *fltIn2* and *fltIn3* denormalized, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in N, \\ fltIn_2 \in D, fltIn_3 \in D \end{matrix} \right\}$$	0	N/A
fltIn1 infinity, *fltIn2* normalized, *fltIn3* denormalized, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 \in N, fltIn_3 \in D \end{matrix} \right\}$$	N/A	{sign(*fltIn1*)•Inf, sign(*fltIn1*)•*pmax*}
fltIn1 zero, *fltIn2* normalized, *fltIn3* denormalized, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 = 0, \\ fltIn_2 \in N, fltIn_3 \in D \end{matrix} \right\}$$	$\langle -0.5, 0.5 \rangle$	{-0, +0}
fltIn1 denormalized, *fltIn2* normalized, *fltIn3* denormalized, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in D, \\ fltIn_2 \in N, fltIn_3 \in D \end{matrix} \right\}$$	$\langle -0.5, 0.5 \rangle$	{-0, +0}

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
fltIn1 normalized, *fltIn2* normalized, *fltIn3* denormalized, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in N, \\ fltIn_2 \in N, fltIn_3 \in D \end{matrix}\right\}$	$(-Inf, Inf)$	N/A
fltIn1 infinity, *fltIn2* infinity, *fltIn3* normalized, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 \in \{Inf, -Inf\}, fltIn_3 \in N \end{matrix}\right\}$	N/A	{NaN, Inf, -Inf, 0, -0, *pmax*, *nmax*}
fltIn1 zero, *fltIn2* infinity, *fltIn3* normalized, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 = 0, \\ fltIn_2 \in \{Inf, -Inf\}, fltIn_3 \in N \end{matrix}\right\}$	N/A	{Inf, -Inf, *pmax*, *nmax*}
fltIn1 denormalized, *fltIn2* infinity, *fltIn3* normalized, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in D, \\ fltIn_2 \in \{Inf, -Inf\}, fltIn_3 \in N \end{matrix}\right\}$	N/A	{Inf, -Inf, *pmax*, *nmax*}
fltIn1 normalized, *fltIn2* infinity, *fltIn3* normalized, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in N, \\ fltIn_2 \in \{Inf, -Inf\}, fltIn_3 \in N \end{matrix}\right\}$	$(-Inf, Inf)$	{Inf, -Inf}
fltIn1 infinity, *fltIn2* zero, *fltIn3* normalized, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 = 0, fltIn_3 \in N \end{matrix}\right\}$	N/A	{sign(*fltIn1*)•Inf, sign(*fltIn1*)•*pmax*}
fltIn1 zero, *fltIn2* zero, *fltIn3* normalized, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 = 0, \\ fltIn_2 = 0, fltIn_3 \in N \end{matrix}\right\}$	0	N/A

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
fltIn1 denormalized, *fltIn2* zero, *fltIn3* normalized, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in D, \\ fltIn_2 = 0, fltIn_3 \in N \end{matrix}\right\}$	0	{-0, +0}
fltIn1 normalized, *fltIn2* zero, *fltIn3* normalized, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in N, \\ fltIn_2 = 0, fltIn_3 \in N \end{matrix}\right\}$	0	N/A
fltIn1 infinity, *fltIn2* denormalized, *fltIn3* normalized, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in N, \\ fltIn_2 \in D, fltIn_3 \in N \end{matrix}\right\}$	$(-Inf, Inf)$	{sign(*fltIn1*)•Inf, sign(*fltIn1*)•*pmax*}
fltIn1 zero, *fltIn2* denormalized, *fltIn3* normalized, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 = 0, \\ fltIn_2 \in D, fltIn_3 \in N \end{matrix}\right\}$	$\langle -0.5, 0.5 \rangle$	{-0, +0}
fltIn1 denormalized, *fltIn2* denormalized, *fltIn3* normalized, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in D, \\ fltIn_2 \in D, fltIn_3 \in N \end{matrix}\right\}$	$\langle -0.5, 0.5 \rangle$	{-0, +0}
fltIn1 normalized, *fltIn2* denormalized, *fltIn3* normalized, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in N, \\ fltIn_2 \in D, fltIn_3 \in N \end{matrix}\right\}$	$(-Inf, Inf)$	N/A
fltIn1 infinity, *fltIn2* normalized, *fltIn3* normalized, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 \in N, fltIn_3 \in N \end{matrix}\right\}$	N/A	{sign(*fltIn1*)•Inf, sign(*fltIn1*)•*pmax*}
fltIn1 zero, *fltIn2* normalized, *fltIn3* normalized, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 = 0, \\ fltIn_2 \in N, fltIn_3 \in N \end{matrix}\right\}$	$\langle -0.5, 0.5 \rangle$	N/A

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
fltIn1 denormalized, *fltIn2* normalized, *fltIn3* normalized, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in D, \\ fltIn_2 \in N, fltIn_3 \in N \end{matrix}\right\}$	$\langle -(2^{24}-1), 2^{24}-1 \rangle$	N/A
fltIn1 finite, *fltIn2* and *fltIn3* normalized or denormalized, normalized or zero result and intermediate result i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \notin M, \\ fltIn_2 \in N \cup D, fltIn_3 \in N \cup D \\ refResult = 0 \vee \\ \left(\begin{matrix} \lvert refResult \rvert - 0.5 \cdot \mathrm{ULP}(refResult) \notin D \wedge \\ \lvert refResult \rvert + 0.5 \cdot \mathrm{ULP}(refResult) \neq Inf \end{matrix}\right), \\ mr \subset N \cup \{-0, +0\} \end{matrix}\right\}$	$\langle -0.5, 0.5 \rangle$	N/A
fltIn1 finite, *fltIn2* and *fltIn3* normalized or denormalized, result underflow i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \notin M \\ fltIn_2 \in N \cup D, fltIn_3 \in N \cup D, \\ \lvert refResult \rvert - 0.5 \cdot \mathrm{ULP}(refResult) \in D \wedge \\ refResult \neq 0, \end{matrix}\right\}$	$\langle -0.5, 0.5 \rangle$	{-0, +0}
fltIn1 finite, *fltIn2* and *fltIn3* normalized or denormalized, result overflow i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \notin M \\ fltIn_2 \in N \cup D, fltIn_3 \in N \cup D, \\ \lvert refResult \rvert + 0.5 \cdot \mathrm{ULP}(refResult) \in M \end{matrix}\right\}$	$\langle -0.5, 0.5 \rangle$	{sign(refResult)•Inf, sign(refResult)•*pmax*}
fltIn1 finite, *fltIn2* and *fltIn3* normalized or denormalized, intermediate result underflow i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \notin M \\ fltIn_2 \in N \cup D, fltIn_3 \in N \cup D, \\ mr \in D \end{matrix}\right\}$	$(-Inf, Inf)$	N/A

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
fltIn1 finite, *fltIn2* and *fltIn3* normalized or denormalized, intermediate result overflow i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \notin M \\ fltIn_2 \in N \cup D, fltIn_3 \in N \cup D, \\ mr \in M \end{matrix}\right\}$	$(-Inf, Inf)$	{Inf, -Inf}

2.67 Function MLIB_Mnac_FLT

Declaration

```
INLINEtFloat MLIB_Mnac_FLT(register tFloat fltIn1, register
tFloat fltIn2, register tFloat fltIn3);
```

Arguments

Table 212. MLIB_Mnac_FLT arguments

Type	Name	Direction	Description
register tFloat	fltIn1	**input**	Input value to be subtracted.
register tFloat	fltIn2	**input**	First value to be multiplied.
register tFloat	fltIn3	**input**	Second value to be multiplied.

Worst-Case Error Bounds

Let (*fltIn1*, *fltIn2*, *fltIn3*) ∊ *X* be a set of inputs to MLIB_Mnac_FLT,

$mr = fltIn_2 \cdot fltIn_3,$

refResult be the theoretical exact result,

then

Table 213. MLIB_Mnac_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
All inputs infinity, i.e. $\{fltIn_1, fltIn_2, fltIn_3 \in X \mid X \subset \{Inf, -Inf\}\}$	N/A	{Inf, *pmax*, -Inf, *nmax* }
fltIn1 zero or denormalized, *fltIn2* and *fltIn3* infinity, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in D \bigvee fltIn_1 = 0, \\ fltIn_2 \in \{Inf, -Inf\}, fltIn_3 \in \{Inf, -Inf\} \end{matrix}\right\}$	N/A	{Inf, *pmax*} if sign(*fltIn2*)=sign(*fltIn3*), {-Inf, *nmax*} otherwise

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
fltIn1 normalized, *fltIn2* and *fltIn3* infinity, i.e. $$\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in N, \\ fltIn_2 \in \{Inf, -Inf\}, fltIn_3 \in \{Inf, -Inf\} \end{matrix}\right\}$$	$(-Inf, Inf)$	Inf if sign(*fltIn2*)=sign(*fltIn3*), -Inf otherwise
fltIn1 NaN, i.e. $$\{fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 = NaN\}$$	$(-Inf, Inf)$	NaN
fltIn2 NaN, i.e. $$\{fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_2 = NaN\}$$	$(-Inf, Inf)$	NaN
fltIn3 NaN, i.e. $$\{fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_3 = NaN\}$$	$(-Inf, Inf)$	NaN
fltIn2 zero, *fltIn3* infinity, i.e. $$\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_2 = 0, fltIn_3 \in \{Inf, -Inf\} \end{matrix}\right\}$$	$(-Inf, Inf)$	{NaN, 0, -0}
fltIn2 infinity, *fltIn3* zero, i.e. $$\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_2 \in \{Inf, -Inf\}, fltIn_3 = 0 \end{matrix}\right\}$$	$(-Inf, Inf)$	{NaN, 0, -0}
fltIn1 infinity, *fltIn2* denormalized, *fltIn3* infinity, i.e. $$\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 \in D, fltIn_3 \in \{Inf, -Inf\} \end{matrix}\right\}$$	N/A	{NaN, Inf, -Inf, 0, -0, *pmax*, *nmax*}
fltIn1 zero, *fltIn2* denormalized, *fltIn3* infinity, i.e. $$\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 = 0, fltIn_2 \in D, \\ fltIn_3 \in \{Inf, -Inf\} \end{matrix}\right\}$$	N/A	{NaN, Inf, -Inf, 0, -0}

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
fltIn1 denormalized, *fltIn2* denormalized, *fltIn3* infinity, i.e. $\left\{ \begin{array}{c} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in D, fltIn_2 \in D, \\ fltIn_3 \in \{Inf, -Inf\} \end{array} \right\}$	N/A	{NaN, Inf, -Inf, 0, -0}
fltIn1 normalized, *fltIn2* denormalized, *fltIn3* infinity, i.e. $\left\{ \begin{array}{c} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in N, \\ fltIn_2 \in D, fltIn_3 \in \{Inf, -Inf\} \end{array} \right\}$	$(-Inf, Inf)$	{NaN, Inf, -Inf}
fltIn1 infinity, *fltIn2* normalized, *fltIn3* infinity, i.e. $\left\{ \begin{array}{c} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 \in N, \\ fltIn_3 \in \{Inf, -Inf\} \end{array} \right\}$	$(-Inf, Inf)$	{NaN, Inf, -Inf}
fltIn1 zero, *fltIn2* normalized, *fltIn3* infinity, i.e. $\left\{ \begin{array}{c} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 = 0, \\ fltIn_2 \in N, \\ fltIn_3 \in \{Inf, -Inf\} \end{array} \right\}$	N/A	{Inf, *pmax*} if sign(*fltIn2*)=sign(*fltIn3*), {-Inf, *nmax*} otherwise
fltIn1 denormalized, *fltIn2* normalized, *fltIn3* infinity, i.e. $\left\{ \begin{array}{c} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in D, \\ fltIn_2 \in N, \\ fltIn_3 \in \{Inf, -Inf\} \end{array} \right\}$	N/A	{Inf, *pmax*} if sign(*fltIn2*)=sign(*fltIn3*), {-Inf, *nmax*} otherwise
fltIn1 normalized, *fltIn2* normalized, *fltIn3* infinity, i.e. $\left\{ \begin{array}{c} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in N, fltIn_2 \in N, \\ fltIn_3 \in \{Inf, -Inf\} \end{array} \right\}$	$(-Inf, Inf)$	Inf if sign(*fltIn2*)=sign(*fltIn 3*), -Inf otherwise

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
fltIn1 infinity, *fltIn2* zero, *fltIn3* zero, i.e. $$\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 = 0, fltIn_3 = 0 \end{matrix}\right\}$$	N/A	{-sign(*fltIn1*)•Inf, -sign(*fltIn1*)•*pmax*}
All inputs zero, i.e. $$\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 = 0, fltIn_2 = 0, fltIn_3 = 0 \end{matrix}\right\}$$	0	{-0, +0}
fltIn1 denormalized, *fltIn2* zero, *fltIn3* zero, i.e. $$\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in D, \\ fltIn_2 = 0, fltIn_3 = 0 \end{matrix}\right\}$$	0	{-0, +0}
fltIn1 normalized, *fltIn2* zero, *fltIn3* zero, i.e. $$\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in N, \\ fltIn_2 = 0, fltIn_3 = 0 \end{matrix}\right\}$$	0	N/A
fltIn1 infinity, *fltIn2* denormalized, *fltIn3* zero, i.e. $$\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 \in D, fltIn_3 = 0 \end{matrix}\right\}$$	N/A	{-sign(*fltIn1*)•Inf, -sign(*fltIn1*)•*pmax*}
fltIn1 zero, *fltIn2* denormalized, *fltIn3* zero, i.e. $$\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 = 0, \\ fltIn_2 \in D, fltIn_3 = 0 \end{matrix}\right\}$$	0	{-0, +0}
fltIn1 denormalized, *fltIn2* denormalized, *fltIn3* zero, i.e. $$\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in D, \\ fltIn_2 \in D, fltIn_3 = 0 \end{matrix}\right\}$$	0	{-0, +0}

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
fltIn1 normalized, *fltIn2* denormalized, *fltIn3* zero, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \\ fltIn_1 \in N, \\ fltIn_2 \in D, fltIn_3 = 0 \end{matrix} \right\|$$	0	N/A
fltIn1 infinity, *fltIn2* normalized, *fltIn3* zero, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 \in N, \\ fltIn_3 = 0 \end{matrix} \right\|$$	0	{-sign(*fltIn1*)•Inf, -sign(*fltIn1*)•*pmax*}
fltIn1 zero, *fltIn2* normalized, *fltIn3* zero, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \\ fltIn_1 = 0, \\ fltIn_2 \in N, \\ fltIn_3 = 0 \end{matrix} \right\|$$	0	N/A
fltIn1 denormalized, *fltIn2* normalized, *fltIn3* zero, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \\ fltIn_1 \in D, \\ fltIn_2 \in N, \\ fltIn_3 = 0 \end{matrix} \right\|$$	0	{-0, +0}
fltIn1 normalized, *fltIn2* normalized, *fltIn3* zero, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \\ fltIn_1 \in N, \\ fltIn_2 \in N, \\ fltIn_3 = 0 \end{matrix} \right\|$$	0	N/A
fltIn1 infinity, *fltIn2* infinity, *fltIn3* denormalized, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 \in \{Inf, -Inf\}, \\ fltIn_3 \in D \end{matrix} \right\|$$	N/A	{NaN, Inf, -Inf, *pmax*, *nmax*}

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
fltIn1 zero, *fltIn2* infinity, *fltIn3* denormalized, i.e. $\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 = 0, \\ fltIn_2 \in \{Inf, -Inf\}, \\ fltIn_3 \in D \end{matrix} \right\}$	N/A	{NaN, Inf, -Inf, 0, -0}
fltIn1 denormalized, *fltIn2* infinity, *fltIn3* denormalized, i.e. $\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in D, \\ fltIn_2 \in \{Inf, -Inf\}, \\ fltIn_3 \in D \end{matrix} \right\}$	N/A	{NaN, Inf, -Inf, 0, -0}
fltIn1 normalized, *fltIn2* infinity, *fltIn3* denormalized, i.e. $\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in N, \\ fltIn_2 \in \{Inf, -Inf\}, \\ fltIn_3 \in D \end{matrix} \right\}$	$(-Inf, Inf)$	{NaN, Inf, -Inf, 0, -0}
fltIn1 infinity, *fltIn2* zero, *fltIn3* denormalized, i.e. $\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 = 0, fltIn_3 \in D \end{matrix} \right\}$	N/A	{-sign(*fltIn1*)•Inf, -sign(*fltIn 1*)•*pmax*}
fltIn1 zero, *fltIn2* zero, *fltIn3* denormalized, i.e. $\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 = 0, \\ fltIn_2 = 0, fltIn_3 \in D \end{matrix} \right\}$	0	N/A
fltIn1 denormalized, *fltIn2* zero, *fltIn3* denormalized, i.e. $\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in D, \\ fltIn_2 = 0, fltIn_3 \in D \end{matrix} \right\}$	0	{-0, +0}

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
fltIn1 normalized, *fltIn2* zero, *fltIn3* denormalized, i.e. $\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in N, \\ fltIn_2 = 0, fltIn_3 \in D \end{matrix} \right\}$	0	N/A
fltIn1 infinity, *fltIn2* denormalized, *fltIn3* denormalized, i.e. $\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 = \in D, fltIn_3 \in D \end{matrix} \right\}$	N/A	{-sign(*fltIn1*)•Inf, -sign(*fltIn1*)•*pmax*}
fltIn1 zero, *fltIn2* denormalized, *fltIn3* denormalized, i.e. $\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 = 0, \\ fltIn_2 \in D, fltIn_3 \in D \end{matrix} \right\}$	0	N/A
All inputs denormalized, i.e. $\{ fltIn_1, fltIn_2, fltIn_3 \in X \mid X \subset D, \}$	0	{-0, +0}
fltIn1 normalized, *fltIn2* and *fltIn3* denormalized, i.e. $\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in N, \\ fltIn_2 \in D, fltIn_3 \in D \end{matrix} \right\}$	0	N/A
fltIn1 infinity, *fltIn2* normalized, *fltIn3* denormalized, i.e. $\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 \in N, fltIn_3 \in D \end{matrix} \right\}$	N/A	{-sign(*fltIn1*)•Inf, -sign(*fltIn1*)•*pmax*}
fltIn1 zero, *fltIn2* normalized, *fltIn3* denormalized, i.e. $\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 = 0, \\ fltIn_2 \in N, fltIn_3 \in D \end{matrix} \right\}$	$\langle -0.5, 0.5 \rangle$	{-0, +0}
fltIn1 denormalized, *fltIn2* normalized, *fltIn3* denormalized, i.e. $\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in D, \\ fltIn_2 \in N, fltIn_3 \in D \end{matrix} \right\}$	$\langle -0.5, 0.5 \rangle$	{-0, +0}

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
fltIn1 normalized, *fltIn2* normalized, *fltIn3* denormalized, i.e. $\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in N, \\ fltIn_2 \in N, fltIn_3 \in D \end{matrix} \right\}$	$(-Inf, Inf)$	N/A
fltIn1 infinity, *fltIn2* infinity, *fltIn3* normalized, i.e. $\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 \in \{Inf, -Inf\}, fltIn_3 \in N \end{matrix} \right\}$	N/A	{NaN, Inf, -Inf, 0, -0, *pmax*, *nmax*}
fltIn1 zero, *fltIn2* infinity, *fltIn3* normalized, i.e. $\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 = 0, \\ fltIn_2 \in \{Inf, -Inf\}, fltIn_3 \in N \end{matrix} \right\}$	N/A	{Inf, -Inf, *pmax*, *nmax*}
fltIn1 denormalized, *fltIn2* infinity, *fltIn3* normalized, i.e. $\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in D, \\ fltIn_2 \in \{Inf, -Inf\}, fltIn_3 \in N \end{matrix} \right\}$	N/A	{Inf, -Inf, *pmax*, *nmax*}
fltIn1 normalized, *fltIn2* infinity, *fltIn3* normalized, i.e. $\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in N, \\ fltIn_2 \in \{Inf, -Inf\}, fltIn_3 \in N \end{matrix} \right\}$	$(-Inf, Inf)$	{Inf, -Inf}
fltIn1 infinity, *fltIn2* zero, *fltIn3* normalized, i.e. $\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 = 0, fltIn_3 \in N \end{matrix} \right\}$	N/A	{-sign(*fltIn1*)•Inf, -sign(*fltIn1*)•*pmax*}
fltIn1 zero, *fltIn2* zero, *fltIn3* normalized, i.e. $\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 = 0, \\ fltIn_2 = 0, fltIn_3 \in N \end{matrix} \right\}$	0	N/A

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
fltIn1 denormalized, *fltIn2* zero, *fltIn3* normalized, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in D, \\ fltIn_2 = 0, fltIn_3 \in N \end{matrix}\right\}$	0	{-0, +0}
fltIn1 normalized, *fltIn2* zero, *fltIn3* normalized, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in N, \\ fltIn_2 = 0, fltIn_3 \in N \end{matrix}\right\}$	0	N/A
fltIn1 infinity, *fltIn2* denormalized, *fltIn3* normalized, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in N, \\ fltIn_2 \in D, fltIn_3 \in N \end{matrix}\right\}$	$(-Inf, Inf)$	{-sign(*fltIn1*)•Inf, -sign(*fltIn1*)•*pmax*}
fltIn1 zero, *fltIn2* denormalized, *fltIn3* normalized, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 = 0, \\ fltIn_2 \in D, fltIn_3 \in N \end{matrix}\right\}$	$\langle -0.5, 0.5 \rangle$	{-0, +0}
fltIn1 denormalized, *fltIn2* denormalized, *fltIn3* normalized, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in D, \\ fltIn_2 \in D, fltIn_3 \in N \end{matrix}\right\}$	$\langle -0.5, 0.5 \rangle$	{-0, +0}
fltIn1 normalized, *fltIn2* denormalized, *fltIn3* normalized, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in N, \\ fltIn_2 \in D, fltIn_3 \in N \end{matrix}\right\}$	$(-Inf, Inf)$	N/A
fltIn1 infinity, *fltIn2* normalized, *fltIn3* normalized, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 \in N, fltIn_3 \in N \end{matrix}\right\}$	N/A	{-sign(*fltIn1*)•Inf, -sign(*fltIn1*)•*pmax*}
fltIn1 zero, *fltIn2* normalized, *fltIn3* normalized, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 = 0, \\ fltIn_2 \in N, fltIn_3 \in N \end{matrix}\right\}$	$\langle -0.5, 0.5 \rangle$	N/A

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
fltIn1 denormalized, *fltIn2* normalized, *fltIn3* normalized, i.e. $\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in D, \\ fltIn_2 \in N, fltIn_3 \in N \end{matrix} \right\}$	$\langle -(2^{24}-1), 2^{24}-1 \rangle$	N/A
fltIn1 finite, *fltIn2* and *fltIn3* normalized or denormalized, normalized or zero result and intermediate result i.e. $\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \notin M, \\ fltIn_2 \in N \cup D, fltIn_3 \in N \cup D \\ refResult = 0 \vee \\ \left(\begin{matrix} \lvert refResult \rvert - 0.5 \cdot \mathrm{ULP}(refResult) \notin D \wedge \\ \lvert refResult \rvert + 0.5 \cdot \mathrm{ULP}(refResult) \neq Inf \end{matrix} \right), \\ mr \subset N \cup \{-0, +0\} \end{matrix} \right\}$	$\langle -0.5, 0.5 \rangle$	N/A
fltIn1 finite, *fltIn2* and *fltIn3* normalized or denormalized, result underflow i.e. $\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \notin M \\ fltIn_2 \in N \cup D, fltIn_3 \in N \cup D, \\ \lvert refResult \rvert - 0.5 \cdot \mathrm{ULP}(refResult) \in D \wedge \\ refResult \neq 0, \end{matrix} \right\}$	$\langle -0.5, 0.5 \rangle$	{-0, +0}
fltIn1 finite, *fltIn2* and *fltIn3* normalized or denormalized, result overflow i.e. $\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \notin M \\ fltIn_2 \in N \cup D, fltIn_3 \in N \cup D, \\ \lvert refResult \rvert + 0.5 \cdot \mathrm{ULP}(refResult) \in M \end{matrix} \right\}$	$\langle -0.5, 0.5 \rangle$	{sign(refResult)•Inf, sign(refResult)•*pmax*}
fltIn1 finite, *fltIn2* and *fltIn3* normalized or denormalized, intermediate result underflow i.e. $\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \notin M \\ fltIn_2 \in N \cup D, fltIn_3 \in N \cup D, \\ mr \in D \end{matrix} \right\}$	$(-Inf, Inf)$	N/A

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
fltIn1 finite, *fltIn2* and *fltIn3* normalized or denormalized, intermediate result overflow i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \notin M \\ fltIn_2 \in N \cup D, fltIn_3 \in N \cup D, \\ mr \in M \end{matrix}\right\}$	$(-Inf, Inf)$	{Inf, -Inf}

2.68 Function MLIB_Msu_FLT

Declaration

```
INLINEtFloat MLIB_Msu_FLT(register tFloat fltIn1, register tFloat
fltIn2, register tFloat fltIn3);
```

Arguments

Table 214. MLIB_Msu_FLT arguments

Type	Name	Direction	Description
register tFloat	fltIn1	**input**	Input value from which to subtract.
register tFloat	fltIn2	**input**	First value to be multiplied.
register tFloat	fltIn3	**input**	Second value to be multiplied.

Worst-Case Error Bounds

Let (*fltIn1*, *fltIn2*, *fltIn3*) ∊ *X* be a set of inputs to MLIB_Msu_FLT,

$mr = fltIn_2 \cdot fltIn_3,$

refResult be the theoretical exact result,

then

Table 215. MLIB_Msu_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
All inputs infinity, i.e. $\{fltIn_1, fltIn_2, fltIn_3 \in X \mid X \subset \{Inf, -Inf\}\}$	N/A	{Inf, *pmax*, -Inf, *nmax*, NaN}
fltIn1 zero or denormalized, *fltIn2* and *fltIn3* infinity, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in D \bigvee fltIn_1 = 0, \\ fltIn_2 \in \{Inf, -Inf\}, fltIn_3 \in \{Inf, -Inf\} \end{matrix}\right\}$	N/A	{-Inf, *nmax*} if sign(*fltIn2*)=sign(*fltIn3*), {Inf, *pmax*} otherwise

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
fltIn1 normalized, *fltIn2* and *fltIn3* infinity, i.e. $$\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in N, \\ fltIn_2 \in \{Inf, -Inf\}, fltIn_3 \in \{Inf, -Inf\} \end{matrix}\right\}$$	$(-Inf, Inf)$	-Inf if sign(*fltIn2*)=sign(*fltIn3*), Inf otherwise
fltIn1 NaN, i.e. $$\{fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 = NaN\}$$	$(-Inf, Inf)$	NaN
fltIn2 NaN, i.e. $$\{fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_2 = NaN\}$$	$(-Inf, Inf)$	NaN
fltIn3 NaN, i.e. $$\{fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_3 = NaN\}$$	$(-Inf, Inf)$	NaN
fltIn2 zero, *fltIn3* infinity, i.e. $$\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_2 = 0, fltIn_3 \in \{Inf, -Inf\} \end{matrix}\right\}$$	$(-Inf, Inf)$	{NaN, 0, -0}
fltIn2 infinity, *fltIn3* zero, i.e. $$\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_2 \in \{Inf, -Inf\}, fltIn_3 = 0 \end{matrix}\right\}$$	$(-Inf, Inf)$	{NaN, 0, -0}
fltIn1 infinity, *fltIn2* denormalized, *fltIn3* infinity, i.e. $$\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 \in D, fltIn_3 \in \{Inf, -Inf\} \end{matrix}\right\}$$	N/A	{NaN, Inf, -Inf, 0, -0, *pmax*, *nmax*}
fltIn1 zero, *fltIn2* denormalized, *fltIn3* infinity, i.e. $$\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 = 0, fltIn_2 \in D, \\ fltIn_3 \in \{Inf, -Inf\} \end{matrix}\right\}$$	N/A	{NaN, Inf, -Inf, 0, -0}

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
fltIn1 denormalized, *fltIn2* denormalized, *fltIn3* infinity, i.e. $\left\{ \begin{array}{c} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in D, fltIn_2 \in D, \\ fltIn_3 \in \{Inf, -Inf\} \end{array} \right\}$	N/A	{NaN, Inf, -Inf, 0, -0}
fltIn1 normalized, *fltIn2* denormalized, *fltIn3* infinity, i.e. $\left\{ \begin{array}{c} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in N, \\ fltIn_2 \in D, fltIn_3 \in \{Inf, -Inf\} \end{array} \right\}$	$(-Inf, Inf)$	{NaN, Inf, -Inf}
fltIn1 infinity, *fltIn2* normalized, *fltIn3* infinity, i.e. $\left\{ \begin{array}{c} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 \in N, \\ fltIn_3 \in \{Inf, -Inf\} \end{array} \right\}$	$(-Inf, Inf)$	{NaN, Inf, -Inf}
fltIn1 zero, *fltIn2* normalized, *fltIn3* infinity, i.e. $\left\{ \begin{array}{c} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 = 0, \\ fltIn_2 \in N, \\ fltIn_3 \in \{Inf, -Inf\} \end{array} \right\}$	N/A	{-Inf, *nmax*} if sign(*fltIn2*)=sign(*fltIn3*), {Inf, *pmax*} otherwise
fltIn1 denormalized, *fltIn2* normalized, *fltIn3* infinity, i.e. $\left\{ \begin{array}{c} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in D, \\ fltIn_2 \in N, \\ fltIn_3 \in \{Inf, -Inf\} \end{array} \right\}$	N/A	{-Inf, *nmax*} if sign(*fltIn2*)=sign(*fltIn3*), {Inf, *pmax*} otherwise
fltIn1 normalized, *fltIn2* normalized, *fltIn3* infinity, i.e. $\left\{ \begin{array}{c} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in N, fltIn_2 \in N, \\ fltIn_3 \in \{Inf, -Inf\} \end{array} \right\}$	$(-Inf, Inf)$	-Inf if sign(*fltIn2*)=sign(*fltIn 3*), Inf otherwise

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
fltIn1 infinity, *fltIn2* zero, *fltIn3* zero, i.e. $$\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 = 0, fltIn_3 = 0 \end{matrix}\right\}$$	N/A	{sign(*fltIn1*)•Inf, sign(*fltIn1*)•*pmax*}
All inputs zero, i.e. $$\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 = 0, fltIn_2 = 0, fltIn_3 = 0 \end{matrix}\right\}$$	0	{-0, +0}
fltIn1 denormalized, *fltIn2* zero, *fltIn3* zero, i.e. $$\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in D, \\ fltIn_2 = 0, fltIn_3 = 0 \end{matrix}\right\}$$	0	{-0, +0}
fltIn1 normalized, *fltIn2* zero, *fltIn3* zero, i.e. $$\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in N, \\ fltIn_2 = 0, fltIn_3 = 0 \end{matrix}\right\}$$	0	N/A
fltIn1 infinity, *fltIn2* denormalized, *fltIn3* zero, i.e. $$\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 \in D, fltIn_3 = 0 \end{matrix}\right\}$$	N/A	{sign(*fltIn1*)•Inf, sign(*fltIn1*)•*pmax*}
fltIn1 zero, *fltIn2* denormalized, *fltIn3* zero, i.e. $$\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 = 0, \\ fltIn_2 \in D, fltIn_3 = 0 \end{matrix}\right\}$$	0	{-0, +0}
fltIn1 denormalized, *fltIn2* denormalized, *fltIn3* zero, i.e. $$\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in D, \\ fltIn_2 \in D, fltIn_3 = 0 \end{matrix}\right\}$$	0	{-0, +0}

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
fltIn1 normalized, *fltIn2* denormalized, *fltIn3* zero, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in N, \\ fltIn_2 \in D, fltIn_3 = 0 \end{matrix} \right\}$$	0	N/A
fltIn1 infinity, *fltIn2* normalized, *fltIn3* zero, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 \in N, \\ fltIn_3 = 0 \end{matrix} \right\}$$	0	{sign(*fltIn1*)•Inf, sign(*fltIn1*)•*pmax*}
fltIn1 zero, *fltIn2* normalized, *fltIn3* zero, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 = 0, \\ fltIn_2 \in N, \\ fltIn_3 = 0 \end{matrix} \right\}$$	0	N/A
fltIn1 denormalized, *fltIn2* normalized, *fltIn3* zero, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in D, \\ fltIn_2 \in N, \\ fltIn_3 = 0 \end{matrix} \right\}$$	0	{-0, +0}
fltIn1 normalized, *fltIn2* normalized, *fltIn3* zero, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in N, \\ fltIn_2 \in N, \\ fltIn_3 = 0 \end{matrix} \right\}$$	0	N/A
fltIn1 infinity, *fltIn2* infinity, *fltIn3* denormalized, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 \in \{Inf, -Inf\}, \\ fltIn_3 \in D \end{matrix} \right\}$$	N/A	{NaN, Inf, -Inf, *pmax*, *nmax*}

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
fltIn1 zero, *fltIn2* infinity, *fltIn3* denormalized, i.e. $\left\{ \begin{array}{c} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 = 0, \\ fltIn_2 \in \{Inf, -Inf\}, \\ fltIn_3 \in D \end{array} \right\}$	N/A	{NaN, Inf, -Inf, 0, -0}
fltIn1 denormalized, *fltIn2* infinity, *fltIn3* denormalized, i.e. $\left\{ \begin{array}{c} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in D, \\ fltIn_2 \in \{Inf, -Inf\}, \\ fltIn_3 \in D \end{array} \right\}$	N/A	{NaN, Inf, -Inf, 0, -0}
fltIn1 normalized, *fltIn2* infinity, *fltIn3* denormalized, i.e. $\left\{ \begin{array}{c} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in N, \\ fltIn_2 \in \{Inf, -Inf\}, \\ fltIn_3 \in D \end{array} \right\}$	$(-Inf, Inf)$	{NaN, Inf, -Inf, 0, -0}
fltIn1 infinity, *fltIn2* zero, *fltIn3* denormalized, i.e. $\left\{ \begin{array}{c} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 = 0, fltIn_3 \in D \end{array} \right\}$	N/A	{sign(*fltIn1*)•Inf, sign(*fltIn1*)•*pmax*}
fltIn1 zero, *fltIn2* zero, *fltIn3* denormalized, i.e. $\left\{ \begin{array}{c} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 = 0, \\ fltIn_2 = 0, fltIn_3 \in D \end{array} \right\}$	0	N/A
fltIn1 denormalized, *fltIn2* zero, *fltIn3* denormalized, i.e. $\left\{ \begin{array}{c} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in D, \\ fltIn_2 = 0, fltIn_3 \in D \end{array} \right\}$	0	{-0, +0}

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
fltIn1 normalized, *fltIn2* zero, *fltIn3* denormalized, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in N, \\ fltIn_2 = 0, fltIn_3 \in D \end{matrix} \right\}$$	0	N/A
fltIn1 infinity, *fltIn2* denormalized, *fltIn3* denormalized, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 = \in D, fltIn_3 \in D \end{matrix} \right\}$$	N/A	{sign(*fltIn1*)•Inf, sign(*fltIn1*)•*pmax*}
fltIn1 zero, *fltIn2* denormalized, *fltIn3* denormalized, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 = 0, \\ fltIn_2 \in D, fltIn_3 \in D \end{matrix} \right\}$$	0	N/A
All inputs denormalized, i.e. $$\{ fltIn_1, fltIn_2, fltIn_3 \in X \mid X \subset D, \}$$	0	{-0, +0}
fltIn1 normalized, *fltIn2* and *fltIn3* denormalized, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in N, \\ fltIn_2 \in D, fltIn_3 \in D \end{matrix} \right\}$$	0	N/A
fltIn1 infinity, *fltIn2* normalized, *fltIn3* denormalized, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 \in N, fltIn_3 \in D \end{matrix} \right\}$$	N/A	{sign(*fltIn1*)•Inf, sign(*fltIn1*)•*pmax*}
fltIn1 zero, *fltIn2* normalized, *fltIn3* denormalized, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 = 0, \\ fltIn_2 \in N, fltIn_3 \in D \end{matrix} \right\}$$	$\langle -0.5, 0.5 \rangle$	{-0, +0}
fltIn1 denormalized, *fltIn2* normalized, *fltIn3* denormalized, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in D, \\ fltIn_2 \in N, fltIn_3 \in D \end{matrix} \right\}$$	$\langle -0.5, 0.5 \rangle$	{-0, +0}

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
fltIn1 normalized, *fltIn2* normalized, *fltIn3* denormalized, i.e. $\left\{ fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in N, fltIn_2 \in N, fltIn_3 \in D \right\}$	$(-Inf, Inf)$	N/A
fltIn1 infinity, *fltIn2* infinity, *fltIn3* normalized, i.e. $\left\{ fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in \{Inf, -Inf\}, fltIn_2 \in \{Inf, -Inf\}, fltIn_3 \in N \right\}$	N/A	{NaN, Inf, -Inf, 0, -0, *pmax*, *nmax*}
fltIn1 zero, *fltIn2* infinity, *fltIn3* normalized, i.e. $\left\{ fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 = 0, fltIn_2 \in \{Inf, -Inf\}, fltIn_3 \in N \right\}$	N/A	{Inf, -Inf, *pmax*, *nmax*}
fltIn1 denormalized, *fltIn2* infinity, *fltIn3* normalized, i.e. $\left\{ fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in D, fltIn_2 \in \{Inf, -Inf\}, fltIn_3 \in N \right\}$	N/A	{Inf, -Inf, *pmax*, *nmax*}
fltIn1 normalized, *fltIn2* infinity, *fltIn3* normalized, i.e. $\left\{ fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in N, fltIn_2 \in \{Inf, -Inf\}, fltIn_3 \in N \right\}$	$(-Inf, Inf)$	{Inf, -Inf}
fltIn1 infinity, *fltIn2* zero, *fltIn3* normalized, i.e. $\left\{ fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in \{Inf, -Inf\}, fltIn_2 = 0, fltIn_3 \in N \right\}$	N/A	{sign(*fltIn1*)•Inf, sign(*fltIn1*)•*pmax*}
fltIn1 zero, *fltIn2* zero, *fltIn3* normalized, i.e. $\left\{ fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 = 0, fltIn_2 = 0, fltIn_3 \in N \right\}$	0	N/A

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
fltIn1 denormalized, *fltIn2* zero, *fltIn3* normalized, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in D, \\ fltIn_2 = 0, fltIn_3 \in N \end{matrix} \right\}$$	0	{-0, +0}
fltIn1 normalized, *fltIn2* zero, *fltIn3* normalized, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in N, \\ fltIn_2 = 0, fltIn_3 \in N \end{matrix} \right\}$$	0	N/A
fltIn1 infinity, *fltIn2* denormalized, *fltIn3* normalized, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in N, \\ fltIn_2 \in D, fltIn_3 \in N \end{matrix} \right\}$$	$(-Inf, Inf)$	{sign(*fltIn1*)•Inf, sign(*fltIn1*)•*pmax*}
fltIn1 zero, *fltIn2* denormalized, *fltIn3* normalized, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 = 0, \\ fltIn_2 \in D, fltIn_3 \in N \end{matrix} \right\}$$	$\langle -0.5, 0.5 \rangle$	{-0, +0}
fltIn1 denormalized, *fltIn2* denormalized, *fltIn3* normalized, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in D, \\ fltIn_2 \in D, fltIn_3 \in N \end{matrix} \right\}$$	$\langle -0.5, 0.5 \rangle$	{-0, +0}
fltIn1 normalized, *fltIn2* denormalized, *fltIn3* normalized, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \in N, \\ fltIn_2 \in D, fltIn_3 \in N \end{matrix} \right\}$$	$(-Inf, Inf)$	N/A
fltIn1 infinity, *fltIn2* normalized, *fltIn3* normalized, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 \in N, fltIn_3 \in N \end{matrix} \right\}$$	N/A	{sign(*fltIn1*)•Inf, sign(*fltIn1*)•*pmax*}
fltIn1 zero, *fltIn2* normalized, *fltIn3* normalized, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 = 0, \\ fltIn_2 \in N, fltIn_3 \in N \end{matrix} \right\}$$	$\langle -0.5, 0.5 \rangle$	N/A

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
fltIn1 denormalized, *fltIn2* normalized, *fltIn3* normalized, i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid \\ fltIn_1 \in D, \\ fltIn_2 \in N, fltIn_3 \in N \end{matrix} \right\}$$	$\langle -(2^{24}-1), 2^{24}-1 \rangle$	N/A
fltIn1 finite, *fltIn2* and *fltIn3* normalized or denormalized, normalized or zero result and intermediate result i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \notin M, \\ fltIn_2 \in N \cup D, fltIn_3 \in N \cup D \\ refResult = 0 \vee \\ \left(\begin{matrix} \lvert refResult \rvert - 0.5 \cdot \mathrm{ULP}(refResult) \notin D \wedge \\ \lvert refResult \rvert + 0.5 \cdot \mathrm{ULP}(refResult) \neq Inf \end{matrix} \right), \\ mr \subset N \cup \{-0, +0\} \end{matrix} \right\}$$	$\langle -0.5, 0.5 \rangle$	N/A
fltIn1 finite, *fltIn2* and *fltIn3* normalized or denormalized, result underflow i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \notin M \\ fltIn_2 \in N \cup D, fltIn_3 \in N \cup D, \\ \lvert refResult \rvert - 0.5 \cdot \mathrm{ULP}(refResult) \in D \wedge \\ refResult \neq 0, \end{matrix} \right\}$$	$\langle -0.5, 0.5 \rangle$	{-0, +0}
fltIn1 finite, *fltIn2* and *fltIn3* normalized or denormalized, result overflow i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \notin M \\ fltIn_2 \in N \cup D, fltIn_3 \in N \cup D, \\ \lvert refResult \rvert + 0.5 \cdot \mathrm{ULP}(refResult) \in M \end{matrix} \right\}$$	$\langle -0.5, 0.5 \rangle$	{sign(refResult)•Inf, sign(refResult)•*pmax*}
fltIn1 finite, *fltIn2* and *fltIn3* normalized or denormalized, intermediate result underflow i.e. $$\left\{ \begin{matrix} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \notin M \\ fltIn_2 \in N \cup D, fltIn_3 \in N \cup D, \\ mr \in D \end{matrix} \right\}$$	$(-Inf, Inf)$	N/A

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
fltIn1 finite, *fltIn2* and *fltIn3* normalized or denormalized, intermediate result overflow i.e. $\left\{ \begin{array}{c} fltIn_1, fltIn_2, fltIn_3 \in X \mid fltIn_1 \notin M \\ fltIn_2 \in N \cup D, fltIn_3 \in N \cup D, \\ mr \in M \end{array} \right\}$	$(-Inf, Inf)$	{Inf, -Inf}

2.69 Function MLIB_Mul_FLT

Declaration

```
INLINEtFloat MLIB_Mul_FLT(register tFloat fltIn1, register tFloat
fltIn2);
```

Arguments

Table 216. MLIB_Mul_FLT arguments

Type	Name	Direction	Description
register tFloat	fltIn1	**input**	Operand is a single precision floating point number.
register tFloat	fltIn2	**input**	Operand is a single precision floating point number.

Worst-Case Error Bounds

Let (*fltIn1*, *fltIn2*) ∊ *X* be a set of inputs to MLIB_Mul_FLT,

refResult be the theoretical exact result,

then

Table 217. MLIB_Mul_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Both inputs infinity, i.e. $\left\{ \begin{array}{c} fltIn_1, fltIn_2 \in X \mid fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 \in \{Inf, -Inf\} \end{array} \right\}$	N/A	{Inf, -Inf, *pmax*, *nmax*}
fltIn1 normalized number, NaN, or infinity, *fltIn2* NaN, i.e. $\left\{ \begin{array}{c} fltIn_1, fltIn_2 \in X \mid \\ fltIn_1 \in N \cup NaN \cup \{Inf, -Inf\}, \\ fltIn_2 = NaN \end{array} \right\}$	N/A	{NaN, *pmax*, *nmax*}

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
fltIn1 denormalized or zero, *fltIn2* NaN, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid fltIn_1 \in D \cup \{-0, +0\}, \\ fltIn_2 = NaN \end{matrix}\right\}$	N/A	{NaN, -0, +0}
fltIn1 infinity, *fltIn2* denormalized or zero, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid fltIn_1 \in \{Inf, -Inf\} \\ fltIn_1 \in D \cup \{-0, +0\} \end{matrix}\right\}$	N/A	{NaN, Inf, -Inf, -0, +0}
fltIn1 infinity, *fltIn2* normalized, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid fltIn_1 \in \{Inf, -Inf\} \\ fltIn_1 \in N \end{matrix}\right\}$	N/A	{Inf, -Inf, *pmax*, *nmax*}
fltIn1 NaN, *fltIn2* infinity or normalized, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid fltIn_1 = NaN, \\ fltIn_2 \in N \cup \{Inf, -Inf\} \end{matrix}\right\}$	N/A	{NaN, *pmax*, *nmax*}
fltIn1 NaN, *fltIn2* denormalized or zero, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid fltIn_1 = NaN, \\ fltIn_2 \in D \cup \{-0, +0\} \end{matrix}\right\}$	N/A	{NaN, -0, +0}
fltIn1 denormalized or zero, *fltIn2* infinity, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid \\ fltIn_1 \in D \cup \{-0, +0\}, \\ fltIn_2 \in \{Inf, -Inf\} \end{matrix}\right\}$	N/A	{NaN, Inf, -Inf, -0, +0}
fltIn1 normalized, *fltIn2* infinity, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid fltIn_1 \in N, \\ fltIn_2 \in \{Inf, -Inf\} \end{matrix}\right\}$	N/A	{Inf, -Inf, *pmax*, *nmax*}
Both inputs denormalized, i.e. $\{fltIn_1, fltIn_2 \in X \mid X \subset D\}$	$\langle -0.5, 0.5 \rangle$	{-0, +0}

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
fltIn1 denormalized, *fltIn2* zero, i.e. $\left\{ fltIn_1, fltIn_2 \in X \mid fltIn_1 \in D, fltIn_2 = 0 \right\}$	0	N/A
fltIn1 denormalized, *fltIn2* normalized, i.e. $\left\{ \begin{matrix} fltIn_1, fltIn_2 \in X \mid fltIn_1 \in D, \\ fltIn_2 \in N \end{matrix} \right\}$	$\langle -0.5, 0.5 \rangle$	{-0, +0}
fltIn1 zero, *fltIn2* denormalized, i.e. $\left\{ fltIn_1, fltIn_2 \in X \mid fltIn_1 = 0, fltIn_2 \in D \right\}$	0	N/A
Both inputs zero, i.e. $\left\{ fltIn_1, fltIn_2 \in X \mid fltIn_1 = 0, fltIn_2 = 0 \right\}$	0	N/A
fltIn1 zero, *fltIn2* normalized, i.e. $\left\{ \begin{matrix} fltIn_1, fltIn_2 \in X \mid fltIn_1 = 0, \\ fltIn_2 \in N \end{matrix} \right\}$	0	N/A
fltIn1 normalized, *fltIn2* denormalized, i.e. $\left\{ \begin{matrix} fltIn_1, fltIn_2 \in X \mid \\ fltIn_1 \in N, fltIn_2 \in D \end{matrix} \right\}$	$\langle -0.5, 0.5 \rangle$	{-0, +0}
fltIn1 normalized, *fltIn2* zero, i.e. $\left\{ \begin{matrix} fltIn_1, fltIn_2 \in X \mid \\ fltIn_1 \in N, fltIn_2 = 0 \end{matrix} \right\}$	0	N/A
Both inputs normalized, result normalized, i.e. $\left\{ \begin{matrix} fltIn_1, fltIn_2 \in X \mid X \subset N, \\ \lvert refResult \rvert - 0.5 \cdot \mathrm{ULP}(refResult) \notin D \wedge \\ \lvert refResult \rvert + 0.5 \cdot \mathrm{ULP}(refResult) \neq Inf \end{matrix} \right\}$	$\langle -0.5, 0.5 \rangle$	N/A
Both inputs normalized, result overflow, i.e. $\left\{ \begin{matrix} fltIn_1, fltIn_2 \in X \mid X \subset N, \\ \lvert refResult \rvert + 0.5 \cdot \mathrm{ULP}(refResult) = Inf \end{matrix} \right\}$	$\langle -0.5, 0.5 \rangle$	{Inf, -Inf, *pmax*, *nmax*}

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Both inputs normalized, result underflow, i.e. $\left\{ \begin{array}{c} fltIn_1, fltIn_2 \in X \mid X \subset N, \\ \lvert refResult \rvert - 0.5 \cdot \mathrm{ULP}(refResult) \in D \wedge \\ refResult \neq 0 \end{array} \right\}$	$\langle -0.5, 0.5 \rangle$	{-0, +0}

2.70 Function MLIB_Neg_FLT

Declaration

```
INLINEtFloat MLIB_Neg_FLT(register tFloat fltIn);
```

Arguments

Table 218. MLIB_Neg_FLT arguments

Type	Name	Direction	Description
register tFloat	fltIn	**input**	Input value which negative value should be returned.

Worst-Case Error Bounds

Let (*fltIn*) $\in X$ be an input to MLIB_Neg_FLT,

then

Table 219. MLIB_Neg_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Input infinity, i.e. $\{ fltIn \in X \mid fltIn \in \{ Inf, -Inf \} \}$	N/A	{-sign(*fltIn*)•Inf, -sign(*fltIn*)•*pmax*}
Input NaN, i.e. $\{ fltIn \in X \mid fltIn = NaN \}$	N/A	{NaN, *pmax*, *nmax*}
Denormalized input, i.e. $\{ fltIn \in X \mid X \subset D \}$	0	{-0, +0}
Normalized input, i.e. $\{ fltIn \in X \mid X \subset N \}$	0	N/A

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Zero input, i.e. $\{ fltIn \in X \mid fltIn = 0 \}$	0	N/A

2.71 Function MLIB_Sub_FLT

Declaration

```
INLINEtFloat MLIB_Sub_FLT(register tFloat fltIn1, register tFloat
fltIn2);
```

Arguments

Table 220. MLIB_Sub_FLT arguments

Type	Name	Direction	Description
register tFloat	fltIn1	**input**	Operand is a single precision floating point number.
register tFloat	fltIn2	**input**	Operand is a single precision floating point number.

Worst-Case Error Bounds

Let (*fltIn1*, *fltIn2*) $\in X$ be a set of inputs to MLIB_Sub_FLT,

then

Table 221. MLIB_Sub_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Both inputs infinity, i.e. $\left\{ \begin{array}{l} fltIn_1, fltIn_2 \in X \mid fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 \in \{Inf, -Inf\} \end{array} \right\}$	N/A	{Inf, -Inf, NaN, *pmax*, *nmax*}
fltIn1 arbitrary value, *fltIn2* NaN, i.e. $\{ fltIn_1, fltIn_2 \in X \mid fltIn_2 = NaN \}$	N/A	{NaN, *pmax*, *nmax*}
fltIn1 infinity, *fltIn2* normalized, denormalized, or zero, i.e. $\left\{ \begin{array}{l} fltIn_1, fltIn_2 \in X \mid fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 \in N \cup D \cup \{-0, +0\} \end{array} \right\}$	N/A	{sign(*fltIn1*)•Inf, sign(*fltIn1*)•*pmax*}
fltIn1 NaN, *fltIn2* arbitrary value, i.e. $\{ fltIn_1, fltIn_2 \in X \mid fltIn_1 = NaN \}$	N/A	{NaN, *pmax*, *nmax*}

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
fltIn1 normalized, denormalized, or zero, *fltIn2* infinity, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid \\ fltIn_1 \in N \cup D \cup \{-0, +0\}, \\ fltIn_2 \in \{Inf, -Inf\} \end{matrix}\right\}$	N/A	{-sign(*fltIn2*)•Inf, -sign(*fltIn 2*)•*pmax*}
Both inputs denormalized, i.e. $\{fltIn_1, fltIn_2 \in X \mid X \subset D\}$	$\langle -0.5, 0.5 \rangle$	{-0, +0}
fltIn1 denormalized, *fltIn2* zero, i.e. $\{fltIn_1, fltIn_2 \in X \mid fltIn_1 \in D, fltIn_2 = 0\}$	$\langle -0.5, 0.5 \rangle$	{-0, +0}
fltIn1 denormalized, *fltIn2* normalized, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid fltIn_1 \in D, \\ fltIn_2 \in N \end{matrix}\right\}$	$\langle -(2^{24}-1), 2^{24}-1 \rangle$	N/A
fltIn1 zero, *fltIn2* denormalized, i.e. $\{fltIn_1, fltIn_2 \in X \mid fltIn_1 = 0, fltIn_2 \in D\}$	$\langle -0.5, 0.5 \rangle$	{-0, +0}
Both inputs zero, i.e. $\{fltIn_1, fltIn_2 \in X \mid fltIn_1 = 0, fltIn_2 = 0\}$	0	N/A
fltIn1 zero, *fltIn2* normalized, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid fltIn_1 = 0, \\ fltIn_2 \in N \end{matrix}\right\}$	0	N/A
fltIn1 normalized, *fltIn2* denormalized, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid \\ fltIn_1 \in N, fltIn_2 \in D \end{matrix}\right\}$	$\langle -(2^{24}-1), 2^{24}-1 \rangle$	N/A
fltIn1 normalized, *fltIn2* zero, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid \\ fltIn_1 \in N, fltIn_2 = 0 \end{matrix}\right\}$	0	N/A

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Both inputs normalized, result normalized or zero, i.e. $$\left\{\begin{array}{c} fltIn_1, fltIn_2 \in X \mid X \subset N, \\ refResult = 0 \vee \\ \left(\begin{array}{l} \lvert refResult \rvert - 0.5 \cdot \mathrm{ULP}(refResult) \notin D \wedge \\ \lvert refResult \rvert + 0.5 \cdot \mathrm{ULP}(refResult) \neq Inf \end{array}\right) \end{array}\right\}$$	$\langle -0.5, 0.5 \rangle$	N/A
Both inputs normalized, result overflow, i.e. $$\left\{\begin{array}{c} fltIn_1, fltIn_2 \in X \mid X \subset N, \\ \lvert refResult \rvert + 0.5 \cdot \mathrm{ULP}(refResult) = Inf \end{array}\right\}$$	$\langle -0.5, 0.5 \rangle$	{sign(refResult)•Inf, sign(refResult)•*pmax*}
Both inputs normalized, result underflow, i.e. $$\left\{\begin{array}{c} fltIn_1, fltIn_2 \in X \mid X \subset N, \\ \lvert refResult \rvert - 0.5 \cdot \mathrm{ULP}(refResult) \in D \wedge \\ refResult \neq 0 \end{array}\right\}$$	$\langle -0.5, 0.5 \rangle$	{-0, +0}

2.72 Function MLIB_VAdd_FLT

Declaration

```
INLINE void MLIB_VAdd_FLT(SWLIBS_2Syst_FLT *const fltOut, const
SWLIBS_2Syst_FLT *const fltIn1, const SWLIBS_2Syst_FLT *const
fltIn2);
```

Arguments

Table 222. MLIB_VAdd_FLT arguments

Type	Name	Direction	Description
SWLIBS_2Syst_FLT *const	fltOut	**output**	Sum of two input vector.
const SWLIBS_2Syst_FLT *const	fltIn1	**input**	First vector to be add.
const SWLIBS_2Syst_FLT *const	fltIn2	**input**	Second vector to be add.

Worst-Case Error Bounds

Let (*fltIn1*, *fltIn2*) ∊ *X* be a set of inputs to MLIB_VAdd_FLT,

refResult be the theoretical exact result,

then

Table 223. MLIB_VAdd_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Both inputs infinity, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 \in \{Inf, -Inf\} \end{matrix}\right\}$	N/A	{Inf, -Inf, NaN, *pmax*, *nmax*}
fltIn1 arbitrary value, *fltIn2* NaN, i.e. $\{fltIn_1, fltIn_2 \in X \mid fltIn_2 = NaN\}$	N/A	{NaN, *pmax*, *nmax*}
fltIn1 infinity, *fltIn2* normalized, denormalized, or zero, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 \in N \cup D \cup \{-0, +0\} \end{matrix}\right\}$	N/A	{sign(*fltIn1*)•Inf, sign(*fltIn1*)•*pmax*}
fltIn1 NaN, *fltIn2* arbitrary value, i.e. $\{fltIn_1, fltIn_2 \in X \mid fltIn_1 = NaN\}$	N/A	{NaN, *pmax*, *nmax*}
fltIn1 normalized, denormalized, or zero, *fltIn2* infinity, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid \\ fltIn_1 \in N \cup D \cup \{-0, +0\}, \\ fltIn_2 \in \{Inf, -Inf\} \end{matrix}\right\}$	N/A	{sign(*fltIn2*)•Inf, sign(*fltIn2*)•*pmax*}
Both inputs denormalized, i.e. $\{fltIn_1, fltIn_2 \in X \mid X \subset D\}$	$\langle -0.5, 0.5 \rangle$	{-0, +0}
fltIn1 denormalized, *fltIn2* zero, i.e. $\{fltIn_1, fltIn_2 \in X \mid fltIn_1 \in D, fltIn_2 = 0\}$	$\langle -0.5, 0.5 \rangle$	{-0, +0}
fltIn1 denormalized, *fltIn2* normalized, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid fltIn_1 \in D, \\ fltIn_2 \in N \end{matrix}\right\}$	$\langle -(2^{24} - 1), 2^{24} - 1 \rangle$	N/A
fltIn1 zero, *fltIn2* denormalized, i.e. $\{fltIn_1, fltIn_2 \in X \mid fltIn_1 = 0, fltIn_2 \in D\}$	$\langle -0.5, 0.5 \rangle$	{-0, +0}

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Both inputs zero, i.e. $\{fltIn_1, fltIn_2 \in X \mid fltIn_1 = 0, fltIn_2 = 0\}$	0	N/A
fltIn1 zero, *fltIn2* normalized, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid fltIn_1 = 0, \\ fltIn_2 \in N \end{matrix}\right\}$	0	N/A
fltIn1 normalized, *fltIn2* denormalized, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid \\ fltIn_1 \in N, fltIn_2 \in D \end{matrix}\right\}$	$\langle -(2^{24} - 1), 2^{24} - 1 \rangle$	N/A
fltIn1 normalized, *fltIn2* zero, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid \\ fltIn_1 \in N, fltIn_2 = 0 \end{matrix}\right\}$	0	N/A
Both inputs normalized, result normalized or zero, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid X \subset N, \\ refResult = 0 \vee \\ \left(\begin{matrix} \lvert refResult \rvert - 0.5 \cdot \mathrm{ULP}(refResult) \notin D \wedge \\ \lvert refResult \rvert + 0.5 \cdot \mathrm{ULP}(refResult) \neq Inf \end{matrix}\right) \end{matrix}\right\}$	$\langle -0.5, 0.5 \rangle$	N/A
Both inputs normalized, result overflow, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid X \subset N, \\ \lvert refResult \rvert + 0.5 \cdot \mathrm{ULP}(refResult) = Inf \end{matrix}\right\}$	$\langle -0.5, 0.5 \rangle$	{sign(*refResult*)•Inf, sign(*refResult*)•*pmax*}
Both inputs normalized, result underflow, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid X \subset N, \\ \lvert refResult \rvert - 0.5 \cdot \mathrm{ULP}(refResult) \in D \wedge \\ refResult \neq 0 \end{matrix}\right\}$	$\langle -0.5, 0.5 \rangle$	{-0, +0}

2.73 Function MLIB_VMac_FLT

Declaration

```
INLINEtFloat MLIB_VMac_FLT(register tFloat fltIn1, register
tFloat fltIn2, register tFloat fltIn3, register tFloat fltIn4);
```

Arguments

Table 224. MLIB_VMac_FLT arguments

Type	Name	Direction	Description
register tFloat	fltIn1	**input**	First input value to first multiplication.
register tFloat	fltIn2	**input**	Second input value to first multiplication.
register tFloat	fltIn3	**input**	First input value to second multiplication.
register tFloat	fltIn4	**input**	Second input value to second multiplication.

Worst-Case Error Bounds

Let (*fltIn1*, *fltIn2*, *fltIn3*, *fltIn4*) ∈ *X* be a set of inputs to MLIB_VMac_FLT,

$ir_1 = fltIn_1 \cdot fltIn_2,$

$ir_2 = fltIn_3 \cdot fltIn_4,$

refResult be the theoretical exact result,

then

Table 225. MLIB_VMac_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Any of the inputs is NaN or infinity, i.e. $\{fltIn_1, fltIn_2, fltIn_3, fltIn_4 \in X \mid X \cap M \neq \varnothing\}$	N/A	{Inf, -Inf, NaN, *pmax*, *nmax*, -0, +0}
Any of the inputs is denormalized, neither is NaN or infinity, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3, fltIn_4 \in X \mid \\ X \cap D \neq \varnothing, X \cap M = \varnothing \end{matrix}\right\}$	$(-Inf, Inf)$	N/A
All inputs normalized or zero, results normalized or zero, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3, fltIn_4 \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ ir_1 \in N \cup \{-0, +0\}, ir_2 \in N \cup \{-0, +0\}, \\ refResult = 0 \vee \\ \left(\begin{matrix} \lvert refResult \rvert - \mathrm{ULP}(refResult) \notin D \wedge \\ \lvert refResult \rvert + \mathrm{ULP}(refResult) \neq Inf \end{matrix}\right) \end{matrix}\right\}$	$\langle -1, 1 \rangle$	N/A
All inputs zero, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3, fltIn_4 \in X \mid \\ X \subset \{-0, +0\} \end{matrix}\right\}$	0	N/A

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
All inputs normalized or zero, result overflow, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3, fltIn_4 \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ \lvert refResult \rvert + \mathrm{ULP}(refResult) = Inf \end{matrix}\right\}$	$\langle -1, 1 \rangle$	{sign(refResult)•Inf, sign(refResult)•*pmax*, NaN}
All inputs normalized or zero, result underflow or underflow in internal compensation calculation, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3, fltIn_4 \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ 0.5 \cdot (\lvert refResult \rvert - \mathrm{ULP}(refResult) \in D) \wedge \\ refResult \neq 0 \end{matrix}\right\}$	$\langle -2^{24}, 2^{24} \rangle$	{-0, +0}
All inputs normalized or zero, intermediate result overflow, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3, fltIn_4 \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ \lvert ir_1 \rvert \in \{Inf, -Inf\} \vee \lvert ir_2 \rvert \in \{Inf, -Inf\} \end{matrix}\right\}$	N/A	Arbitrary floating-point value (including Inf, –Inf, NaN)
All inputs normalized or zero, intermediate result underflow, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2, fltIn_3, fltIn_4 \in X \mid \\ X \subset N \cup \{-0, +0\}, \\ ir_1 \in D \vee ir_2 \in D \end{matrix}\right\}$	$(-Inf, Inf)$	N/A

2.74 Function MLIB_VScale_FLT

Declaration

```
INLINE void MLIB_VScale_FLT(SWLIBS_2Syst_FLT *const fltOutVec,
const SWLIBS_2Syst_FLT *const fltInVec, tFloat fltInScale);
```

Arguments

Table 226. MLIB_VScale_FLT arguments

Type	Name	Direction	Description
SWLIBS_2Syst_FLT *const	fltOutVec	**output**	Scaled vector.
const SWLIBS_2Syst_FLT *const	fltInVec	**input**	Input vector to be scaled.
tFloat	fltInScale	**input**	Scaling coefficient.

Worst-Case Error Bounds

Let (*fltIn1*, *fltInScale*) ∈ *X* be a set of inputs to MLIB_VScale_FLT,

refResult be the theoretical exact result,

then

Table 227. MLIB_VScale_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Both inputs infinity, i.e. $\left\{ fltIn_1, fltIn_2 \in X \mid fltIn_1 \in \{Inf, -Inf\}, fltIn_2 \in \{Inf, -Inf\} \right\}$	N/A	{Inf, -Inf, *pmax*, *nmax*}
fltIn1 normalized number, NaN, or infinity, *fltIn2* NaN, i.e. $\left\{ fltIn_1, fltIn_2 \in X \mid fltIn_1 \in N \cup NaN \cup \{Inf, -Inf\}, fltIn_2 = NaN \right\}$	N/A	{NaN, *pmax*, *nmax*}
fltIn1 denormalized or zero, *fltIn2* NaN, i.e. $\left\{ fltIn_1, fltIn_2 \in X \mid fltIn_1 \in D \cup \{-0, +0\}, fltIn_2 = NaN \right\}$	N/A	{NaN, -0, +0}
fltIn1 infinity, *fltIn2* denormalized or zero, i.e. $\left\{ fltIn_1, fltIn_2 \in X \mid fltIn_1 \in \{Inf, -Inf\} fltIn_1 \in D \cup \{-0, +0\} \right\}$	N/A	{NaN, Inf, -Inf, -0, +0}
fltIn1 infinity, *fltIn2* normalized, i.e. $\left\{ fltIn_1, fltIn_2 \in X \mid fltIn_1 \in \{Inf, -Inf\} fltIn_1 \in N \right\}$	N/A	{Inf, -Inf, *pmax*, *nmax*}
fltIn1 NaN, *fltIn2* infinity or normalized, i.e. $\left\{ fltIn_1, fltIn_2 \in X \mid fltIn_1 = NaN, fltIn_2 \in N \cup \{Inf, -Inf\} \right\}$	N/A	{NaN, *pmax*, *nmax*}
fltIn1 NaN, *fltIn2* denormalized or zero, i.e. $\left\{ fltIn_1, fltIn_2 \in X \mid fltIn_1 = NaN, fltIn_2 \in D \cup \{-0, +0\} \right\}$	N/A	{NaN, -0, +0}

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
fltIn1 denormalized or zero, *fltIn2* infinity, i.e. $$\left\{\begin{array}{c} fltIn_1, fltIn_2 \in X \mid \\ fltIn_1 \in D \cup \{-0, +0\}, \\ fltIn_2 \in \{Inf, -Inf\} \end{array}\right\}$$	N/A	{NaN, Inf, -Inf, -0, +0}
fltIn1 normalized, *fltIn2* infinity, i.e. $$\left\{\begin{array}{c} fltIn_1, fltIn_2 \in X \mid fltIn_1 \in N, \\ fltIn_2 \in \{Inf, -Inf\} \end{array}\right\}$$	N/A	{Inf, -Inf, *pmax*, *nmax*}
Both inputs denormalized, i.e. $$\{fltIn_1, fltIn_2 \in X \mid X \subset D\}$$	$\langle -0.5, 0.5 \rangle$	{-0, +0}
fltIn1 denormalized, *fltIn2* zero, i.e. $$\{fltIn_1, fltIn_2 \in X \mid fltIn_1 \in D, fltIn_2 = 0\}$$	0	N/A
fltIn1 denormalized, *fltIn2* normalized, i.e. $$\left\{\begin{array}{c} fltIn_1, fltIn_2 \in X \mid fltIn_1 \in D, \\ fltIn_2 \in N \end{array}\right\}$$	$\langle -0.5, 0.5 \rangle$	{-0, +0}
fltIn1 zero, *fltIn2* denormalized, i.e. $$\{fltIn_1, fltIn_2 \in X \mid fltIn_1 = 0, fltIn_2 \in D\}$$	0	N/A
Both inputs zero, i.e. $$\{fltIn_1, fltIn_2 \in X \mid fltIn_1 = 0, fltIn_2 = 0\}$$	0	N/A
fltIn1 zero, *fltIn2* normalized, i.e. $$\left\{\begin{array}{c} fltIn_1, fltIn_2 \in X \mid fltIn_1 = 0, \\ fltIn_2 \in N \end{array}\right\}$$	0	N/A
fltIn1 normalized, *fltIn2* denormalized, i.e. $$\left\{\begin{array}{c} fltIn_1, fltIn_2 \in X \mid \\ fltIn_1 \in N, fltIn_2 \in D \end{array}\right\}$$	$\langle -0.5, 0.5 \rangle$	{-0, +0}

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
fltIn1 normalized, *fltIn2* zero, i.e. $\left\{ \begin{matrix} fltIn_1, fltIn_2 \in X \mid \\ fltIn_1 \in N, fltIn_2 = 0 \end{matrix} \right\}$	0	N/A
Both inputs normalized, result normalized, i.e. $\left\{ \begin{matrix} fltIn_1, fltIn_2 \in X \mid X \subset N, \\ \lvert refResult \rvert - 0.5 \cdot \mathrm{ULP}(refResult) \notin D \wedge \\ \lvert refResult \rvert + 0.5 \cdot \mathrm{ULP}(refResult) \neq Inf \end{matrix} \right\}$	$\langle -0.5, 0.5 \rangle$	N/A
Both inputs normalized, result overflow, i.e. $\left\{ \begin{matrix} fltIn_1, fltIn_2 \in X \mid X \subset N, \\ \lvert refResult \rvert + 0.5 \cdot \mathrm{ULP}(refResult) = Inf \end{matrix} \right\}$	$\langle -0.5, 0.5 \rangle$	{Inf, -Inf, *pmax*, *nmax*}
Both inputs normalized, result underflow, i.e. $\left\{ \begin{matrix} fltIn_1, fltIn_2 \in X \mid X \subset N, \\ \lvert refResult \rvert - 0.5 \cdot \mathrm{ULP}(refResult) \in D \wedge \\ refResult \neq 0 \end{matrix} \right\}$	$\langle -0.5, 0.5 \rangle$	{-0, +0}

2.75 Function MLIB_VSub_FLT

Declaration

```
INLINE void MLIB_VSub_FLT(SWLIBS_2Syst_FLT *const fltOut, const
SWLIBS_2Syst_FLT *const fltIn1, const SWLIBS_2Syst_FLT *const
fltIn2);
```

Arguments

Table 228. MLIB_VSub_FLT arguments

Type	Name	Direction	Description
SWLIBS_2Syst_FLT *const	fltOut	**output**	Subtraction of two input vectors.
const SWLIBS_2Syst_FLT *const	fltIn1	**input**	Vector representing first operand.
const SWLIBS_2Syst_FLT *const	fltIn2	**input**	Vector representing second operand.

Worst-Case Error Bounds

Let (*fltIn1*, *fltIn2*) $\in X$ be a set of inputs to MLIB_VSub_FLT,

then

Table 229. MLIB_VSub_FLT Worst-Case Error Bounds - Return Value

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Both inputs infinity, i.e. $\left\{ \begin{matrix} fltIn_1, fltIn_2 \in X \mid fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 \in \{Inf, -Inf\} \end{matrix} \right\}$	N/A	{Inf, -Inf, NaN, *pmax*, *nmax*}
fltIn1 arbitrary value, *fltIn2* NaN, i.e. $\{fltIn_1, fltIn_2 \in X \mid fltIn_2 = NaN\}$	N/A	{NaN, *pmax*, *nmax*}
fltIn1 infinity, *fltIn2* normalized, denormalized, or zero, i.e. $\left\{ \begin{matrix} fltIn_1, fltIn_2 \in X \mid fltIn_1 \in \{Inf, -Inf\}, \\ fltIn_2 \in N \cup D \cup \{-0, +0\} \end{matrix} \right\}$	N/A	{sign(*fltIn1*)•Inf, sign(*fltIn1*)•*pmax*}
fltIn1 NaN, *fltIn2* arbitrary value, i.e. $\{fltIn_1, fltIn_2 \in X \mid fltIn_1 = NaN\}$	N/A	{NaN, *pmax*, *nmax*}
fltIn1 normalized, denormalized, or zero, *fltIn2* infinity, i.e. $\left\{ \begin{matrix} fltIn_1, fltIn_2 \in X \mid \\ fltIn_1 \in N \cup D \cup \{-0, +0\}, \\ fltIn_2 \in \{Inf, -Inf\} \end{matrix} \right\}$	N/A	{-sign(*fltIn2*)•Inf, -sign(*fltIn2*)•*pmax*}
Both inputs denormalized, i.e. $\{fltIn_1, fltIn_2 \in X \mid X \subset D\}$	$\langle -0.5, 0.5 \rangle$	{-0, +0}
fltIn1 denormalized, *fltIn2* zero, i.e. $\{fltIn_1, fltIn_2 \in X \mid fltIn_1 \in D, fltIn_2 = 0\}$	$\langle -0.5, 0.5 \rangle$	{-0, +0}
fltIn1 denormalized, *fltIn2* normalized, i.e. $\left\{ \begin{matrix} fltIn_1, fltIn_2 \in X \mid fltIn_1 \in D, \\ fltIn_2 \in N \end{matrix} \right\}$	$\langle -(2^{24} - 1), 2^{24} - 1 \rangle$	N/A
fltIn1 zero, *fltIn2* denormalized, i.e. $\{fltIn_1, fltIn_2 \in X \mid fltIn_1 = 0, fltIn_2 \in D\}$	$\langle -0.5, 0.5 \rangle$	{-0, +0}

Subset of input domain	Worst-case return value error bounds [ulp]	Allowed specific return values (regardless the error bounds)
Both inputs zero, i.e. $\{fltIn_1, fltIn_2 \in X \mid fltIn_1 = 0, fltIn_2 = 0\}$	0	N/A
fltIn1 zero, *fltIn2* normalized, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid fltIn_1 = 0, \\ fltIn_2 \in N \end{matrix}\right\}$	0	N/A
fltIn1 normalized, *fltIn2* denormalized, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid \\ fltIn_1 \in N, fltIn_2 \in D \end{matrix}\right\}$	$\langle -(2^{24}-1), 2^{24}-1 \rangle$	N/A
fltIn1 normalized, *fltIn2* zero, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid \\ fltIn_1 \in N, fltIn_2 = 0 \end{matrix}\right\}$	0	N/A
Both inputs normalized, result normalized or zero, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid X \subset N, \\ refResult = 0 \vee \\ \left(\begin{matrix} \lvert refResult \rvert - 0.5 \cdot \mathrm{ULP}(refResult) \notin D \wedge \\ \lvert refResult \rvert + 0.5 \cdot \mathrm{ULP}(refResult) \neq Inf \end{matrix}\right) \end{matrix}\right\}$	$\langle -0.5, 0.5 \rangle$	N/A
Both inputs normalized, result overflow, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid X \subset N, \\ \lvert refResult \rvert + 0.5 \cdot \mathrm{ULP}(refResult) = Inf \end{matrix}\right\}$	$\langle -0.5, 0.5 \rangle$	{sign(refResult)•Inf, sign(refResult)•*pmax*}
Both inputs normalized, result underflow, i.e. $\left\{\begin{matrix} fltIn_1, fltIn_2 \in X \mid X \subset N, \\ \lvert refResult \rvert - 0.5 \cdot \mathrm{ULP}(refResult) \in D \wedge \\ refResult \neq 0 \end{matrix}\right\}$	$\langle -0.5, 0.5 \rangle$	{-0, +0}

Contents

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