# LibmCS Mathematical Library for Critical Systems

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## Why Your Project Needs the LibmCS

Mathematical libraries are used in nearly any flight software, in particular in the AOCS/GNC and scientific algorithms.

The Mathematical Library for Critical Systems (LibmCS) provides an open source, standard compliant (IEEE-754, ISO C18, and POSIX) mathematical library (libm), pre-qualified to ECSS E-ST-40 and Q-ST-80 Category B, so that project specific integration and delta-qualification efforts for this building block are minimized and its long term maintenance guaranteed.

#### LibmCS Main Attributes

- ► Standard compliance (IEEE-754-2019, ISO C18, POSIX, MISRA C:2012)
- ECSS Category B qualification evidence including ISVV
- ▶ Designed to support many processor architectures: x86-64, SPARC V8 (all LEON), ARM, RISC-V...
- ▶ Fully compatible with qualified RTEMS 6 SMP and EDISOFT RTEMS 4.8
- ▶ Provides step by step Qualification Guideline and qualification template
- ▶ Minimized project specific delta-qualification effort (below 2 days of test execution)
- Freely available (Qualification Kit also free for ESA Missions)
- ▶ Much extended functionality and improved test-suite over the precursor MLFS library
- ▶ Improved accuracy compared to the Newlib libm
- Clearly characterized accuracy and execution time behavior

#### Provided math.h Procedures in 32 bit and 64 bit Precision

- Classification macros: fpclassify, isfinite, isinf, isnan, isnormal, signbit
- ▶ Trigonometric functions: acos, asin, atan, atan2, cos, sin, tan
- ▶ Hyperbolic functions: acosh, asinh, atanh, cosh, sinh, tanh
- ▶ Exponential and logarithmic functions: exp, exp2, expm1, frexp, ilogb, ldexp, log, log10, log1p, log2, logb, modf, scalbn, scalbln
- ▶ Power and absolute-value functions: cbrt, fabs, hypot, pow, sqrt
- ▶ Error and gamma functions: erf, erfc, lgamma, tgamma
- ▶ Nearest integer functions: ceil, floor, nearbyint, rint, lrint, llrint, round, lround, llround, trunc
- ▶ Remainder functions: fmod, remainder, remquo
- ▶ Manipulation functions: copysign, nan, nextafter, nexttoward
- ▶ Maximum, minimum, and positive difference functions: fdim, fmax, fmin
- ► Fused multiply-add: fma
- ▶ Comparison macros: isgreater, isgreaterequal, isless, islessequal, islessgreater, isunordered
- Bessel functions (only in 64 bits): j0, j1, jn, y0, y1, yn In addition all required standard complex functions of complex.h are provided for integration purposes.

### The Test-Suite (MAXI)

The provided Test-Suite enables through its GUI:

- ▶ the assessment (numerical and timing behavior) of the mathematical procedures and
- their full automated qualification on target.



### The Test Specification

- ▶ Over 4.000 Unit-Tests achieving full statement, decision, and even 100% MC/DC coverage
- ▶ Over 1.000 single value Validation-Tests
- ► Over 250.000.000 floating-point accuracy tests

# **Provided Data Package**

The complete Qualification-Kit includes:

- ▶ Full ECSS engineering documentation in compliance with E-ST-40 and Q-ST-80
- ► Full qualification evidence on x86-64, LEON2 (AT697), and LEON4 (N2X) platforms
- Qualification Guideline and gualification template

## **Availability and Contact**

- ESA ESSR:
- https://essr.esa.int/project/libmcs-mathematical-library-for-critical-systems
- GitLab:
  - https://gitlab.com/gtd-gmbh/libmcs
- ► GTD GmbH: libmcs@gtd-gmbh.de



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