

EEMBC[®] FPMARK[™]

THE EMBEDDED INDUSTRY'S FIRST STANDARDIZED FLOATING-POINT BENCHMARK SUITE

Supporting Both Single- and Double-Precision
Floating-Point Performance



Quick Background:

Industry-Standard Benchmarks for the Embedded Industry

- EEMBC formed in 1997 as non-profit consortium
 - Defining and developing application-specific benchmarks
 - Targeting processors and systems
 - Expansive Industry Support
 - >47 members
 - >90 commercial licensees
 - >120 university licensees
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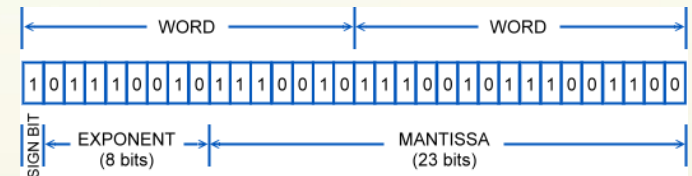


**BUILDING BETTER BENCHMARKS
SINCE 1997**



WHY FLOATING POINT MATH?

- Use exponents to shift the decimal point
 - Store more accurate fractional values than fixed point numbers

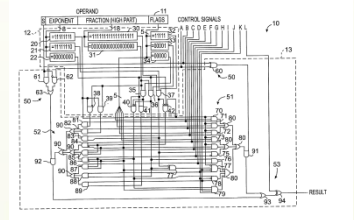


- Floating point representation makes numerical computation much easier
 - Integer representations are tedious and error-prone, especially when scaling.
- FP implementations of many algorithms take fewer cycles to execute than fixed point code (assuming the fixed-point code offers similar precision)

JUSTIFYING THE NEED FOR FP MARK

- Floating point arithmetic appearing in many embedded applications such as audio, DSP/math, graphics, automotive, motor control
- In the same way that CoreMark[®] was intended to be a “better Dhrystone”, FPMark provides something better than the “somewhat quirky” Whetstone and Linpack
- Several FP benchmarks are already in general use (i.e. Linpack, Nbench, Livermore loops)
 - Each with multiple versions
 - No standardized way of running them or reporting results
- The industry lacks a good floating-point benchmark

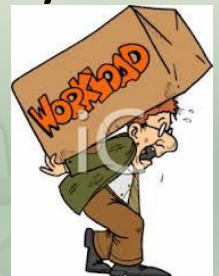
INCREASING NUMBER OF PROCESSORS WITH FP SUPPORT



- Processors with FPU backends with multi-issue / speculation / out-of-order execution (for example, high end Cortex-A cores)
- FPU capability in low cost microcontroller parts (e.g. Cortex-M4) much faster than doing it using a sw library
- Vector instruction sets and FMA (Intel)
- Ability to do single cycle FP MAC with dual memory access (ADI)
- MIPS with new FPU as part as the proAptiv core.

GENERAL FPMARK FEATURES

- Both single- and double-precision workloads
- Broad applicability - small, medium, and large data sets
 - Small useful for low-end microcontrollers and emulation/simulation platforms
 - Large useful for high-end processors
- Multicore support – ability to launch multiple contexts
- 53 workloads test FP performance in a balanced way
 - Very wide range of workloads
 - Not overly dependent on specific operations
 - Minimal requirement for FP library support
- Comprises pre-existing benchmarks and ‘home-grown’



RELIABILITY IS PRIMARY GOAL

- Pseudo-random data generation prevents compiler from pre-calculating values
- Computations are not loop invariant to eliminate compiler's ability to remove work



Rock of Gibraltar



ENSURING CORRECT FUNCTIONALITY

- All benchmarks implement self-verification
- Input generated using integer math, then converted to FP representation
 - Ensures same input regardless of platform's FP implementation
- Convert output to large integer representation, mantissa bits shifted to account for reference exponent if needed, then the absolute value of the difference from the expected value is computed, which is used to determine the number of bits that match.
 - The required minimum can be different depending on the workload (single vs. double precision, or the number of compute operations in the chain can impact the number of bits of the final output we require to match the reference).

THE FPMARK SUITE

- **Fast Fourier Transform** - Takes any function and converts it to an equivalent set of sine waves; applications such as audio, spectral analysis, and image compression
- **Horner's Method** - Used to approximate the roots of a polynomial.
- **Linear Algebra** - Derived from Linpack; useful for understanding balancing forces in structural engineering, converting between reference frames in relativity, solving differential equations, and understanding rotation and fluid flow, among other problems
- **ArcTan** - also known as inverse trigonometric functions; calculates angles of right triangle by using the ratio of two sides of the triangle to calculate the angle between them
- **Fourier Coefficients** - numerical analysis routine for calculating series or representing a periodic function by a discrete sum of complex exponentials
- **Neural Net** - small but functional back-propagation neural net simulator; computer programs that can identify complex relationships among data
- **Black Scholes** - mathematical model developed to calculate the value of financial derivatives, such as stock options
- **Enhanced Livermore Loops** - loops of computer code extracted from programs used at Lawrence Livermore Labs that test the computational capabilities of parallel hardware and compiled software
- **LU Decomposition** – apps like solving linear equations or matrix inversion
- **Ray tracer** - technique for image generation by tracing light path through pixels in an image plane and simulating the effects of its encounters with virtual objects

SIMPLIFYING THE FPMARK SCORING INTERPRETATION

- Workload performance is measured in iterations/second
- EEMBC has created several “marks” for the FPMark suite
 - A “mark” is an aggregate score for a given device, which is based on individual scores in a group of related workloads.
 - Hierarchy approach provides insight at different levels of granularity
- For individual "marks": ‘x [Precision][Datasize]-FPMarks’;
 - x = the score
 - Precision = Dp or Sp (double- or single-precision, respectively)
 - Datasize = S, M, or L (small, medium, or large data sizes, respectively)
 - Example: score of 8.25 for the double precision small dataset mark is 8.25 DpS-FPMarks

THE OFFICIAL FPMARK SCORES – ‘FPMARK’, MICROFPMARK, AND SUBMARKS

- ‘FPMark’ is the highest level of the hierarchy
 - Official EEMBC endorsed mark for the FPMark Suite
 - Calculation
 - Geomean of all the individual scores
 - Multiply the result by 100 for scaling
- Support for low-end microcontrollers with limited resources
 - Official MicroFPMark Score
 - Utilizes only the single-precision/small data (i.e. SpS mark)
 - Submarks
 - Geomean of SpS, SpM, SpL, DpS, DpM, DpL, plus the geomean of all Dp (S, M, and L) and all Sp (S, M, and L)

LICENSING, SCORING, AND CERTIFICATION

- All source code and documentation publicly available
- Certification program
 - Certified scores are not required (similar to CoreMark)
 - EEMBC will provide higher visibility and promotion for certified scores



FPMARK TO THE RESCUE

- FPMark has already helped members identify toolchain shortcomings, particularly regarding FP library implementations
- Comprehensive and reliable method for comparing devices and architectures
- Only FP benchmark with single/double precision and variable data set sizes
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