Abstract

The IEEE 754 floating point standard, important in science and engineering, is due to expire in 2018 unless it is reviewed, and the P-754 working group has again become active. We review the IEEE 754-2008 floating point standard, explain some issues, and invite input and participation.
Early computers used “fixed point” arithmetic, but those computations suffered extreme limitations on size.
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Origins and Early History
(prehistory)

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- Univac and Honeywell systems had base 2, with a 36-bit word length.
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However, different accuracies on different machines could sometimes be exploited to identify ill-conditioning.
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* Bill (Velvel) Kahan, the “Father of Floating Point,” has been a highly outspoken advocate of reliable floating point arithmetic, did early work in interval arithmetic, and has supervised prominent graduate students at U.C. Berkeley.
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2008: A revision is published, and IEEE 754-2008 becomes the official standard.
Main Features in both 1985 and 2008

Classic binary

- Single Precision is based on a 32-bit word (viewed as 4 8-bit bytes), with a 23-bit fraction:

![Diagram showing single precision format](image)

(roughly 7 decimal digits and decimal exponent range ±38)

(figures from Wikipedia: “IEEE 754 Single Floating Point Format” by Codekaizen)
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  ![Single Precision Diagram]

  (roughly 7 decimal digits and decimal exponent range $\pm 38$)

- Double Precision is based on a 64-bit word (viewed as 8 8-bit bytes), with a 52-bit fraction:

  ![Double Precision Diagram]

  (roughly 16 decimal digits and decimal exponent range $\pm 308$)

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- Requires $+, -, \times, \div, \sqrt{}$ be correctly rounded, as well as binary to decimal, decimal to binary, binary to integer, and integer to binary conversions.
- When used astutely, with or without interval arithmetic, the rounding modes* can provide mathematically rigorous lower and upper bounds on exact solutions.
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For example, the Intel line of chips (80x87, “Pentium”, “Core...”) have 80-bit registers, with 3 extra bits.

In contrast, the Motorola chips that were used in Sun workstations did not have an extended format, but achieved correct rounding in other ways.
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- Requires logical and comparison operators ($<, >, \leq, \not=, \text{etc.}$)
- Specifies operations involving $\infty$ and NaN.
Invalid operation: Operations on a NaN, 0 × ∞, etc.
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The default is to set the flag and continue execution; once set, a flag remains set.
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*The two formats are the result of competing requirements between two different manufacturers.
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- A larger set of *recommended* functions is specified.
Issues

Inhibition of parallelization, an example:

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- Such a scheme may aid reproducibility.
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Multiple operating system functions beyond user control are performed concurrently.

These system functions may force the user’s computation out of registers or cache at some times but not others. (A string of computations done in registers will be more accurate.)
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Pros and cons

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- Do we want exactly the same results on all systems, even if they are incorrect on all systems?
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Note: The Java programming language, meant for web applications, attempts to achieve complete reproducibility, at the expense of maximum performance.
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- Although chip hardware implements the basic operations, the programming language standard does not require correct rounding upon conversion, and often does not supply it.
- The values users see are sometimes significantly less accurate than the actual internal binary representations.
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If these are present, a system is standard-conforming if the values of these functions are correctly rounded within specified ranges.
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Programming language implementations of IEEE 754-2008 standard functions may not conform to the standard.
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Lack of User Access to Features

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Matlab generally uses IEEE 754 double precision for computations, but has not provided documentation to routines to set the rounding mode.
Abandonment of the Standard

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The fastest supercomputers, consisting of many tiny units such as graphics processors, are presently constrained by power consumption, and have opted to forego standard compliance.
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- This can be a good thing. (It allows innovation in design.)
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Current Status

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There will be a combination of in-person, teleconference, and email conduct of business.
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Nonetheless, wide participation and discussion is important.
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- The working group is responsible for formulating the revision.
How to Participate

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- When the Sponsor Ballot Group reaches consensus, the document is submitted for procedural review.
- When the document passes procedural review it becomes a revised standard.
The Microprocessor Standardization Committee website is at
http://grouper.ieee.org/groups/msc/

As chair of the Microprocessor Standardization Committee (the oversight committee for the P-754 working group), you may ask me (at rbk@louisiana.edu or in person) about the organization, parliamentary procedures, whom to contact, etc.