MI-AN-064
Math Benchmarks on the QED Board

(by Paul Clifford, last updated 2000-09-22)

The computational speed attainable in an application is influenced by which compiler is used, FORTH or C, and also by the use of the multitasker, so we'll discuss each of these influences separately. See also MI-AN-062 Multitasking Benchmarks on the QED Board.

Benchmarks using the FORTH compiler

The on-board FORTH operating system and compiler contains an integrated mathematical development environment that relies on its own 16-bit mantissa floating point package. On a QED Board clocked at 16 MHz, floating point arithmetical operations are performed at a rate of about 6000 operations per second for realistic mixes of operations and memory accesses, and up to 11,000 operations per second for uncommon but attainable mixes (e.g. multiply-accumulate onto the stack rather than into variables). Integer multiplies and summations into variables are done at a rate in excess of 15,000 operations per second.

The FORTH compiler's full featured mathematical programming environment includes the following:

- arithmetic operations;
- transcendental functions including all of the trigonometric and exponential functions;
- floating point binary/ASCII string conversion;
- on-the-fly matrix allocation and de-allocation;
- matrix inversion;
- LU decomposition;
- various row & column editing and arithmetic operations;
- simultaneous equation solution;
- general least squares curve fitting for calibrations; and,
- and Fast Fourier Transforms.

Our goal in designing this mathematical programming environment was to make all the signal processing tools usually available only in the top-of-the-line analysis programs for the PC available in a small real-time computer that can be embedded in your product. Here are pertinent benchmarks for isolated operations:

Operation	**Time (milliseconds)**
Floating point arithmetic operations (+, -, * or /)	0.09
Floating point arithmetic including variable access	0.16
Floating point transcendental functions	0.8 - 1.7
10 x 10 floating point matrix multiply	325.
128 point floating point FFT of a real-valued waveform	420.
128 point integer FFT of a real-valued waveform	60.

Benchmarks using the C compiler

If using the C language, floating point arithmetical operations are performed at a rate of 1500 operations per second for realistic mixes of operations and memory accesses. In this case the floating point format used is a 24-bit mantissa IEEE standard. The ANSI standard C compiler does not include the linear algebra package of the FORTH language, but allows programming of mathematical algorithms using standard C syntax. The C compiler also uses ANSI C's standard math library which includes trigonometric functions.

An advantage of using FORTH rather than C is that a wealth of matrix algebra routines are then available. These include pre-coded routines for curve fitting, matrix algebra, and calibration.

How fast is fast enough?

While multitasking can be used to assure that critical functions are addressed by the software in a timely manner, the total computational load must be within the processor's capability. Determining the computational load in any application can be tricky business. It usually depends on two overarching factors: the data throughput, and the operations count per datum.

Data throughput relates to the rate of data entering and leaving the application. For example, analysis of a waveform may require that the waveform be sampled one hundred times every second, some features (averages, extrema) of the waveform extracted, and summary results displayed. This application naturally parses into three tasks, one for data acquisition, one for analysis, and one for display and operator interface. If this system is to operate continuously then the computational load in terms of arithmetical operations per second is the product of the number of operations required for each data point times the data sample rate. Hence finding the computational load requires a detailed look at the algorithms used for signal processing and the data rates necessary.