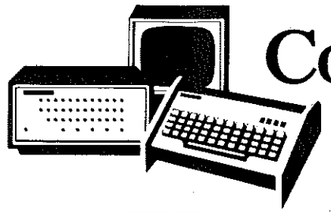

Computer Bits

By Hal Chamberlin

16-BIT MICROPROCESSORS

RECENTLY, there has been a great furor over the announcement of new 16-bit microprocessor ICs. The truth is that there are many 16-bit microprocessors already available so why should manufacturers, users, and the press take such a sudden interest in more of the same—if, in fact, they are the same? To find the answer to this question, let us briefly describe the 16-bit processors—past, present, and upcoming—known to this author. We will then see if such a summary, though it can't deal with each unit in depth, will show real differences among them.

IMP-16 and INS8900 (PACE). The IMP-16 was the first 16-bit microprocessor introduced (1974) and is still one of the most powerful in wide use. Its instruction set resembles that of the Data General NOVA minicomputer, but has many enhancements such as memory-to-register arithmetic. Its speed is 7 μs for a memory-to-register add instruction. Full 16-by-16-bit hardware multiply is available as an option and executes in about 150 μs. Memory up to 64K words (128K bytes) can be addressed.

Supplementing the IMP-16 in new designs is the INS-8900, which is a single IC rather than five or six devices. The instruction set is essentially the same as the IMP, but it has provisions for unlimited stack depth and five different interrupts. Hardware multiply/divide is not available. The standard version is slower than the IMP (10 μs add rather than 7 μs) though a twice-as-fast version has been rumored. In 1976, there was an abortive attempt to design a modular hobbyist oriented system around the PACE microprocessor.

MCP1600. This is a three (or more) IC set that may be *microprogrammed* by the manufacturer to mimic nearly any 16-bit processor desired. First available in 1975, this chip set is the basis of the LSI-11 microcomputer manufactured by Digital Equipment Corp., which is used by Heath in its H11 microcomputer. The instruction set is precisely that of the PDP-11/40, a very powerful minicomputer. The LSI-11 can perform a 16-bit add from memory in 5.6 μs. Hardware multiply (60 μs), divide, and *floating point* are available as an option. Maximum memory size is 56K bytes excluding those addresses assigned to I/O.

Western Digital, creators of the MCP1600, also has microprogrammed the set to emulate a NOVA minicomputer. Although instruction timing is not available, it should be in the 4 μs range for an add because of the much simpler NOVA architecture. Alpha Microsystems has also written a microprogram for its proprietary instruction set. Its AM-100 16-bit microcomputer has been on the market for more than a year and uses the S-100 bus. The AM-100 is claimed to be significantly faster and more powerful than the LSI-11.

CP-1600. A single-chip 16-bit microprocessor, the CP-1600 has been around nearly as long as those just described. Its architecture and instruction set resemble those of the PDP-11, but is substantially simplified to keep costs down. The standard version performs an add from memory in 4 μs, while a reduced cost version ($8 each in 100's makes it the least expensive 16-bitter so far) takes twice as long. One feature that has probably done the most to discourage popularity is its use of a 10-bit instruction word. This leads to inefficiencies in general-purpose systems where programs are stored in 16-bit read/write memory. Up to 64K words of memory can be addressed, however.

MICRO NOVA. This one-chip microprocessor, now in its third year, uses the NOVA-3 instruction set precisely. The manufacturer is Data General, developers of the NOVA minicomputer in the late 1960's and one of only three minicomputer manufacturers who also make microprocessor ICs. Since the NOVA instruction set does not include an add-from-memory instruction, its speed is difficult to compare. Load from memory, however, takes 2.9 μs while register-to-register add requires 2.4 μs. Hardware multiply is accomplished in 42 μs. The NOVA instruction set normally provides for addressing of 32K words of memory, although a special mode that inhibits multilevel indirect addressing allows 64K. Many designers have avoided the Micro Nova because of its odd non-TTL logic levels and the four supply voltages (+14, +10, +5, −4.25) required.

9900. The 9900 is probably the most popular of the currently available 16-bit microprocessors. Made by Texas Instruments, it is simultaneously innovative, powerful, and easy to use. The full 16-bit version boasts an instruction set similar to the PDP-11, but with an increase to 16 general-purpose registers and a unique memory-to-memory architecture. The registers are actually kept in memory, which allows very rapid response to interrupts by simply shifting the portion of memory devoted to registers. Since the number of on-chip registers is drastically reduced, a smaller, more economical IC chip is the result. Even though an "add from memory" requires no fewer than five memory cycles, it is executed in a respectable 6 μs. Hardware multiply/divide is standard and multiply time is a very speedy 18 μs. The input/output mechanism uses a unique semiserial technique that obviates the need for special I/O chips to accomplish simple I/O ports. Another striking feature is the 64-lead package that allows full 16-bit address and data buses without multiplexing. Because of its byte addressing feature, only 32K words of memory can be addressed.

The 9900 has been available to hobbyists for more than two years in the Technico System 16. The forthcoming TI personal computer is rumored to utilize the 9900 for its CPU.

9440 Microflame. This is another, though considerably newer, NOVA emulator microprocessor. Compared with the Micro Nova it is faster (2.4-μs load and 1.25-μs add) and much easier to interface and power. Hardware multiply/divide is not available in the 9940. It is unique in that bipolar integrated injection logic (I^2L) is used rather than p- or n-channel MOS logic. A model (9445)

that will be three times as fast is planned. The name "Microflame" has given rise to all sorts of whimsical names for associated products. Examples are the "Firebug" debugging system and "Spark 16" computer.

6809. At this point we start getting into microprocessors that have been announced but are not yet generally available. The Motorola 6809, for example, is an enhancement of the popular 6800 8-bit microprocessor. Its status as a 16-bit microprocessor is arguable, however, since the data bus is only 8 bits wide. This means that the efficiency advantage of 16-bit instructions is only partially realized, although it does make retrofitting to existing hardware easier. The 6809 retains all of the original 6800 instructions. Operation codes have been changed, however, which necessitates reassembly. Improvements include the addition of a second index register, another stack pointer, and a relocatable zero page. A 16-bit add from memory requires 5 μs with the standard 2-MHz clock frequency. Hardware multiply is included. It is only 8x8, although the 10-μs speed allows 16x16 multiply at a speed comparable to earlier 16-bit microprocessors. Memory up to 64K bytes can be addressed.

8086. This is Intel's entry into the current 16-bit microprocessor race. Although source code compatibility with its 8080 microprocessor is claimed, it is only through a rather complex translating assembler. Besides some carryovers from the 8080, the instruction set is unique and as powerful as those of current minicomputers. Compared to the 8080, the biggest improvement is the inclusion of numerous addressing modes, though relative and indirect through memory are not available. The average speed of the 8086 is impressive: 1.6 μs for a memory-to-register add and a mere 375 ns for a register-to-register add. Note the use of the term "average"; part of the speed improvement is owed to an instruction "lookahead" circuit which is rendered ineffective when a lot of conditional branch instructions are executed.

A definite departure from what we have seen so far is the ability to address 1-million bytes of memory! This extended addressing capability is through a memory bank switching scheme, however. Hence, only 128K (64K program storage and 64K data storage) can be reached by a program without the hassle of using a bank switch.

Z8000. The Z8000 is Zilog's 16-bit contender. The Z8000 instruction set gives nearly every possible combination of instruction type and data lengths of 4, 8, 16, and 32 bits! Yes, there are instructions that deal directly with 32-bit operands and registers. Naturally, with such instruction-set sophistication, hardware multiply and divide are available with up to 32-bit operands as well. Sales literature compares Z8000 speed with the PDP-11/45 minicomputer (a popular but expensive minicomputer that fills a rack) and declares the Z8000 winner with an add time of 1.75 μs. Multiply is less speedy in comparison (17.5 μs for 16x16 and 88 μs for 32x32) but is still quite respectable for a single-chip microcomputer. Up to 8-million words of memory can be *directly* addressed by the Z8000. This is made possible by the 32-bit registers, which is much more convenient than bank switching.

MC68000. This last processor is also the most powerful and farthest from being available. In reality it is a 32-bit machine with a 16-bit data bus. All 8 accumulators and 8 index registers are a full 32-bits in length. This puts it in the maxicomputer league along with the IBM 370. At this time, exact specifications are not available, but the add time is stated to be 1.5 μs. Multiply/divide is said to be faster than the Z8000, but no figures are available. Programs can directly address up to 16-million bytes of memory through use of the 32-bit index registers and a 24-bit program counter.

Conclusions. By now it should be obvious why there's a great interest in the recently announced 8086, Z8000, and MC68000 microprocessors. These machines are at least three times faster than existing 16-bit units. Their ability to address vast quantities of memory promises to once more fill up computer cabinets with memory, this time with 64K rather than 4K boards. The latter property makes programmers happy; the former makes everyone happy.

In short, the new microprocessors give more of what 16-bit (and 32-bit) architecture is good for. But don't expect to find a system using the new chips in computer stores right now. Of the top three, only the 8086 has actually been manufactured, so it might be well into 1980 before personal systems using these chips are available. Meantime, LSI-11 and 9900-based systems still greatly outperform 8-bit-based systems and are available now. ◇