The Macrotech
MI-286

by Charles Strom

For several months, we have been working with several MI-286 CPU boards from Macrotech International. Always looking to improve throughput in leading-edge, multi-user, multi-tasking systems, Macrotech engineers have designed a board from the ground up to be plug-compatible with the CompuPro 8085/88 dual-processor board. This meant hardware and software compatibility, and therein lies a tale to be explored later in this article. The CompuPro 8085/88 board is a popular CPU board, due in large part to the reliability of hardware as well as the advanced technical features built into the CompuPro line allowing DMA transfers, interrupt-driven operation, etc.

A strong point in the design is the 8080-compatible processor on board. It is a simple matter for the user to insert a CP/M 2.2 disk, if desired, or change to a sixteen bit operating system such as CP/M-86, MP/M, MP/M 8-16, or Concurrent-CPM merely by inserting the appropriate boot disk. The beauty of MP/M 8-16 and other 8/16-bit operating systems, is that the user can transparently run virtually any CP/M-80 program. This is performed by automatic invocation of a utility which transfers control of the actual program to the eight-bit processor while funneling all operating system calls through to the sixteen bit chip. Macrotech recognized the value of this scheme and decided to bring the concept of the 8085/88 board up to date.

THE EIGHT-BIT PROCESSOR

The eight-bit chip is the Z80H running at 8MHz, as opposed to the *standard* Z80 4Mhz clock speed so common in the many eight bit machines produced today. There are extant a few proprietary programs that depend on the Z80 for operation, and many more public domain programs that use relative jumps, for example, and therefore crash on an 8085. Now we can run these utilities without incident; Gifford has even upgraded their SW.CMD (the "switch" program which is used to enable an eight-bit program to run under Gifford's MC-DOS) to support the extra registers of the Z80. What's more, the Z80H at

A State of-the-art 80286/Z80 S-100 CPU Card

8MHz operates significantly faster than the 8085 at 5MHz on the older CompuPro board. There is 100% compatibility between the CompuPro and Macrotech boards in eight-bit operation as far as we can determine, except, of course, for the additional functionality we have gained through acquisition of a Z80 rather than an 8085. However, a program using the 8085 RIM and SIM (Read Interrupt Mask and Set Interrupt Mask) instructions, would not operate correctly (but we have never run across such a program).

There are several options available that configure Z80 operation. They include a choice of the default 8MHz operation or optional 2MHz operation for time-critical applications, Z80 reset on processor swap (when Z80 regains control after 80286 relinquishes control), and several wait-state generator options. We will discuss the latter along with the 80286 wait-state options below. Let it suffice to say that the Z80 side of the MI-286 operates as a perfectly domesticated eight-bit CPU board in all applications we have tested. Several representative benchmarks comparing the Z80H operation to equivalent 8085 tasks appear below.

THE SIXTEEN-BIT PROCESSOR

I will devote considerably more space to a description of the 16-bit personality of the MI-286 processor board. The basic computational power is supplied by an Intel 80286 chip running at 6MHz. The 80286 is a state-of-the-art 16-bit processor. The basic set of registers, instructions and addressing modes are upward compatible with the 8086, 8088 and 80186 CPU's. Programs written for these CPU's will run unchanged on the 80286. Intel specifies clock rates of 4, 6

and 8MHz available for the 80286 in the preliminary datasheet, but 8MHz parts are not yet generally available and Macrotech is offering their board only with the 6MHz part.

The 80286 two basic operating modes, real address and protected virtual address. The chip's default mode is real, permitting direct addressing of one megabyte (a 20-bit address field). The details of the real addressing mode are nearly identical to that of the earlier Intel 16-bit chips so that all operating systems running on the 8086 or 8088 will operate without modification with the 80286. An exciting future growth path involves the protected virtual address mode. The protected mode offers one full one gigabyte of virtual address space mapped into 16 megabyte physical address blocks through a full 24 bit physical address field. In addition, the protected mode prevents critical instructions from affecting the CPU's execution, restricts writing to certain memory segments, and has a heirarchical system of task priorities.

Digital Research is reportedly designing a piece of software, called *Concurrent DOS-286*, which will operate with the 80286 and make full use of the protected mode of operation thus supporting a much-improved multiuser operating system. Unfortunately DRI seems to have a penchant for changing the name of their product on a monthly basis so this operating system will most likely be known by another monicker by the time it is released! The above-mentioned modes will allow a multiuser system to operate without crashing in the midst of a renegade application program. But not knowing anything concrete about this DRI project I cannot really make any significant pronouncements, though I do know our MI-286 is all ready to use it.

Some other 80286 features include 64K 8-bit (or 32K 16-bit) I/O ports, a six byte instruction prefetch queue, and pipelined addressing. The latter supports overlapping instruction fetches, instruction decoding and improved execution to increase processing throughput. Not being a microprocessor engineer, I do not feel competent to make a comparative analysis of the 80286 with respect to
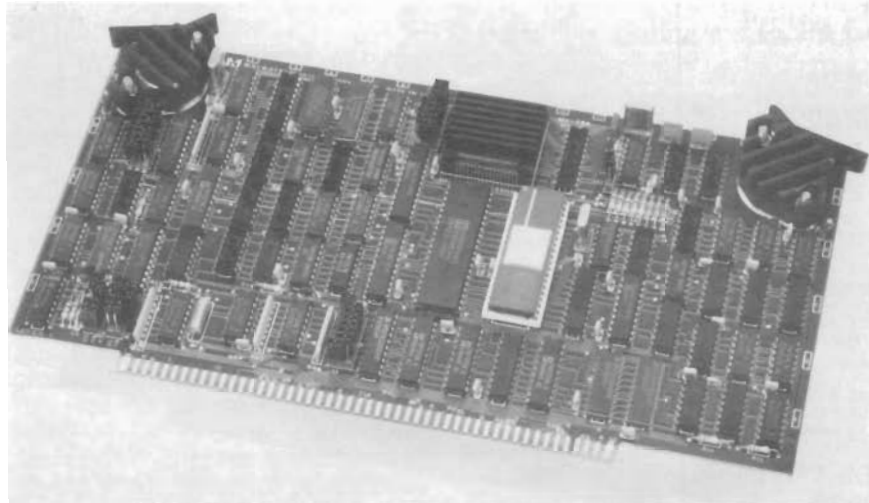
other state of the art chips such as the National Semiconductor 16032 or Motorola 68000 families. However, it appears to me that the 80286 is an excellent choice of a processor that offers 100% upward compatibility with previous Intel chips, allowing me to run my current operating systems software without modification. In addition, I am looking forward to using the protected mode feature when the software becomes available.

MI-286 BOARD OPTIONS

There are a host of options on the board. Memory management control can be set as shown in table 1:

TABLE 1

Mode	Processor	A23-A20	A19-A16	A15-A0
0 (default)	Z80	latch	latch	direct
	286	latch	direct	direct
1 (virtual)	Z80	latch	latch	direct
	286	direct	direct	direct
2 (286 primary)	Z80	zero	latch	direct
	286	latch	direct	direct
3 (Z80 primary)	Z80	latch	latch	direct
	286	zero	direct	direct

Direct control of the upper address line refers to the existence of real address lines, while latched control involves writing data to the memory management port. The memory management port can be optionally cleared on reset. Mode zero sets up the process to be equivalent to the CompuPro 8085/88 addressing scheme, while mode one will presumably be used for Concurrent-286.

WAIT STATE SELECTION

Little did I realize when I received the first beta-test MI-286 board that the subject of wait state selection would consume so much of my attention. The Z80 wait state jumpers are flexible, permitting optional choice of one I/O, memory, and/or M1 wait. Our system

operates properly with the factory default setting of no memory waits, having one I/O and one M1 wait state inserted for the Z80H. The 286 is a far more complicated proposition. Jumpers allow for zero through three wait states to be inserted for I/O and memory operations. Obviously, a primary design goal was to permit high speed operation (without 80286 waits) using CompuPro memory boards. Unfortunately, Macrotech developed their CPU board using their own 512K static memory board and had few problems in this area. They also tried some CompuPro boards from a nearby client's system, and true to Murphy's law, experienced no problems there either. But upon receipt of the original board, we were unable to operate our CompuPro RAM 16's or RAM 21's without inserting two memory waits. This slowed down the system to a speed which was unacceptable to Macrotech. After several weeks of of constant labor, Macrotech engineers discovered a bug in the current version of the 80286! To paraphrase Intel's 80286 (B-2/B-3) errata sheet of 22 May, 1984, if the 80286 executes a POPF (pop F) instruction, a pending maskable interrupt may be improperly recognized even if maskable interrupts were disabled before the POPF instruction and the value popped had IF=0. In an interrupt-driven operating system such as MP/M 8-16, this would be disastrous as indicated by randomly produced "Panic! Interrupt" messages. On the other hand, no such problem was encountered on non-interrupt-driven systems.

Intel's suggested fixes included recoding to eliminate POPF instructions. This is impossible since the MI-286 was designed to drop into an existing system with existing hardware and software. Another suggestion was insertion of two wait

states. The latter fix, which we observed to operate effectively on our system, was also unacceptable because of the cost in speed. After considerable research, Macrotech determined that insertion of two wait states for every memory **data read** operation **only** would be the best compromise at this time. Thus, there is a special jumper for this operation on the current revision of the circuit board. The cost of this speed was determined by a **compute-bound** benchmark which decreased from 2.5 to 2.3 with use of the jumpers. Therefore, we are paying a worst-case price of 12% by inserting these waits.

MORE JUMPERS

There are a host of other jumpering options including reset options for both processors, 16/24 bit DMA addressing, MWRT enable, power-on-jump address selection, I/O base address selection, etc. There are four I/O ports defined for processor swap, memory manager address specification, and memory management mode control. Lastly, there are two jumpers (or "sense switches") available on the board which may be read as two bits when a specific port is read. These jumpers are not used by Macrotech (or CompuPro for that matter) and are available for custom programming purposes.

THE NUMERIC PROCESSOR

Macrotech offers an optional 80287 numeric processor. The 80287 is similar in instruction set to the 8087, but differs in that it may run asynchronously with the main processor. Thus, while the 80286 runs at 6MHz, the 80287 was initially set up to run at 4MHz. Macrotech engineers concluded that the numeric processor will run reliably at 5.33MHz. Thus, they supply a simple patch to change the clock frequency. There have been no problems whatsoever in several months of operation.

The 80287 chip is an optional extra with a list price of $375. It is also possible to purchase the chip from another source at a lower cost, but Macrotech points out that selection of this option with the initial board purchase will include complete testing of that 80287 chip in place as well as a one year warranty. Rumor has it that some competitors have designed their CPU boards in such a manner that it is impossible for a user to field-install his own numeric processor, but Macrotech advises that their design allows the owner to simply plug and go. Consequently, those of us with the "hacker" spirit can roll their own 80287 installation at any time.

INSTALLING THE BOARD

The MI-286 board was designed from the bottom-up specifically as a plug-and-go replacement for the CompuPro 8085/8088 CPU board. As such, great pains were taken to make the transition to the new board as simple as possible. Since the MI-286 is considerably faster than the older board, timing of the bus signals is a serious concern. Over months of beta testing by a small group followed by actual field experience with the real product, Macrotech engineers have compiled a detailed dossier of suitable solutions for problems encountered during the upgrade process. The manual provides detailed guidelines on the proper setting of wait states and other critical CompuPro board switch settings. There is also considerable information on hard disk controller boards of other manufacture, especially those offered by Gifford Engineering, as that firm has also taken part in beta testing of the MI-286, having adopted the CPU board as the primary offering in their S-100 systems. Hard disk controllers which are known to work satisfactorily, include the CompuPro Disk 2 and Disk 3 and the Konan DGC-100. There are definite problems with Morrow hard disk controllers. I would suggest that Macrotech be consulted before attempting to upgrade a system with a Morrow controller.

Both Macrotech's and CompuPro's static memories operate properly with the MI-286. All existing CompuPro I/O boards have been shown to operate correctly. If one intends to upgrade a non-standard system with the MI-286, I strongly recommend that the prospective purchaser contact Macrotech directly. It is my experience that the company is willing to work with system integrators to insure the best chance of success. In a worst case situation, the board might have to be returned (for full credit), but considering the substantial experience the troubleshooting engineers have gained over the past months, this is unlikely.

BENCHMARKS

In evaluating the CompuPro 8085/8088 and the Macrotech MI-286 processor boards, the bottom-line is found by comparing the execution of specific operations. Paul Homchick of Chimitt, Gilman, Homchick, Radnor, PA has done an exhaustive benchmarking and has graciously granted permission to present relevant details from his article. The full report is available directly from Macrotech or from Section DL9 of CP-MIG, the CP/M special interest group on Compuserve.

SIXTEEN BIT BENCHMARKS - First, a few simple machine instructions were executed 12,582,912 times. The running times(in seconds) are:

	8MHz	6 Mhz	
	8088	80286	ratio
add ax,1	18.9	7.4	2.55
mov ax, [30]	31.6	11.6	2.72
short JMP	28.3	21.1	1.34

The two arithmetic instructions were executed 4,194,304 times:

| mul Word [30] | 75.0 | 14.2 | 5.28 |
| mul Byte [30] | 45.6 | 8.6 | 5.30 |

The Sieve of Eratosthenes is a very widely known and oft-used benchmark. Homchick coded it in Digital Research CB-86. Using either 8-or 16-bit wide RAM, the 8088 ran the program in 8.1 sec. The Macrotech 80286, using 16-bit wide memory and one wait state for memory reads only (a typical setup for a system using CompuPro memory) executed the same program in 3.6 sec. Thus the Macrotech MI-286 represents a 2.25-fold improvement in speed over the 8088.

EIGHT-BIT BENCHMARKS

I compiled a C language version of the sieve program with the Software Toolworks' C80 compiler. CompuPro 8085 clocked in at 13 sec., while the Macrotech Z80H (using one M1 wait state, a typical requirement for CompuPro memory) ran the benchmark at 10.8 sec. Note that an additional advantage over the CompuPro board would be realized with a compiler that produced optimized Z80, rather than 8085 (8080), code.

BENCHMARK SUMMARY

Homchick went into further detail in comparing the 80287 processor to a variety of other systems, as well as timing several "real-life" operations such as file copying, spreadsheet operation, etc. To summarize, the MI-286 out-performed the 8085/8088 yielding 2.3 and 1.2-fold decreases in the speed of 16- and 8-bit operations, respectively, during compute-bound applications. Application programs will vary widely of course, but it is reasonable to expect a minimum improvement in speed of 1.2 to 1.7-fold. Needless to say, the addition of the 80287 coupled with software designed to use it, will improve the speed of math-intensive applications up to two orders of magnitude.

CONCLUSION

As a devoted S-100 bus enthusiast, I have felt privileged to work with the MI-286, a truly state-of-the art CPU board. Clearly, the S-100 bus has a promising future notwithstanding the tales of its demise so frequently reported in the trade press. Firms, such as Macrotech and CompuPro, are certainly in excellent technical health and I look forward to more advanced products from them in the months ahead.