PART 2:

MASS STORAGE

EDN's All-Star PC incorporates several mass-storage devices that provide flexible information storage and easy data interchange among PCs. We frequently crossed the thin line between the leading and the bleeding edges of data-storage technology as we tested various storage devices, host adapters, and peripheral controllers. What we learned applies to all types of computer systems, not just PCs.

STEVEN H LEIBSON,
Senior Regional Editor

IBM's original Model 5151 PC provided data storage on single-sided, 160k-byte floppy disks and on audio cassette tapes. The floppy-disk-drive capacity was mediocre, even by early 1980s standards, and the 200 bytes/sec audio-cassette interface was a joke. Fortunately, mass-storage capacity on PCs has come a long way since those humble beginnings. Floppy disks now hold megabytes of data, PC-compatible hard disks store hundreds and even thousands of megabytes, and tape drives store gigabytes.

EDN's All-Star PC incorporates eight mass-storage peripheral devices managed by three controller or host-adapter cards (**Fig 1**). Each of these three mass-storage subsystems—floppy disk, SCSI, and WORM (write-once, read-many) optical drive—has unique capabilities. The floppy-disk subsystem supports four floppy-disk drives, which furnish convenient, removable data storage and permit standardized

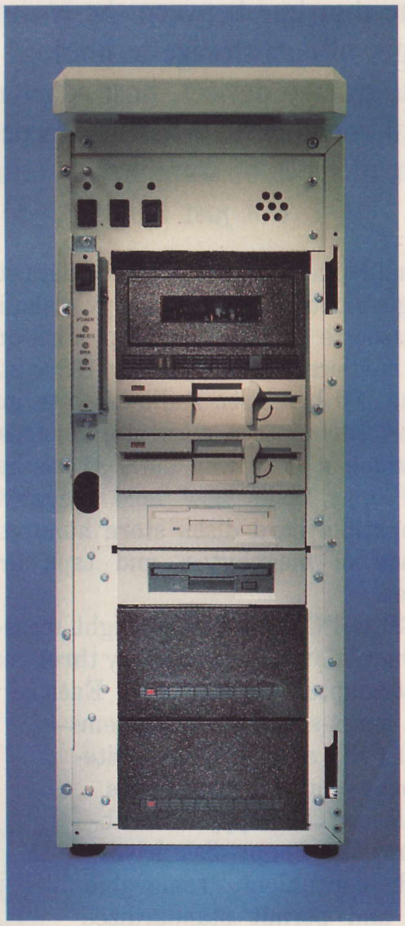
data interchange with other PCs. The SCSI subsystem controls two 330M-byte hard disks for the computer's primary data-storage needs and a 2.5G-byte tape unit for archival and backup storage (**Fig 2**). Finally, the PC's optical WORM drive provides indelible file storage on 1G-byte cartridges.

Floppy-disk drives are the one common element in every PC's mass-storage repertoire. IBM's floppy formats swept away the microcomputer industry's hundreds of 5¼-in. floppy-disk formats developed for the CP/M operating system. However, even IBM's 160k-byte disk format didn't last long. Microsoft's DOS 1.1 introduced a 320k-byte, double-sided format. DOS 2.0 added hierarchical file structures to the disk, bumped the single-sided floppy-disk capacity to 180k bytes, and increased the double-sided format's capacity to 360k bytes. The 360k-byte format's rapid proliferation consigned the earlier PC floppy formats to oblivion.

The next major change in PC floppy-disk formats occurred when IBM introduced its PC/AT with 1.2M-byte, "high-density," 5¼-in. floppy-disk drives. Then came 3½-in. floppy-disk drives that stored 720k bytes, followed by the introduction of IBM's PS/2 computers and 1.44M-byte, 3½-in. drives. Over a 9-year span, the PC, which had unified the industry's floppy-disk formats, evolved its own collection of incompatible formats.

The All-Star PC needed to accommodate these various floppy formats for maximum compatibility with other PCs. It needed at least two floppy-disk drives: a 5¼-in., 1.2M-byte drive and a 3½-in., 1.44M-byte drive. However, with only one 5¼-in. and one 3½-in. floppy-disk drive, the All-Star PC would not be able to duplicate floppy disks directly; it would have to temporarily store the information being copied on a hard disk while the source and destination disks were swapped in the floppy-disk drive. Because of an idiosyncratic aversion to 2-step floppy duplication, I decided early on that the All-Star PC would incorporate four floppy-disk drives: two 5¼-in. and two 3½-in. drives.

Meeting that 4-drive requirement was tough because most PC floppy-disk controllers manage only two floppy-disk drives. The All-Star PC would require a floppy-disk controller card that could manage four floppy-disk drives and support the PC's floppy-disk formats. The Compaticard IV from MicroSolutions Computer Products met these requirements.



Seven mass-storage peripherals cram the All-Star PC's 10 half-height drive bays. From top to bottom, the peripherals include a 2.5G-byte tape drive, two 5.25-in. and two 3.5-in. floppy-disk drives, and two 330M-byte hard-disk drives.

Table 1 lists the PC floppy-disk formats that the Compaticard IV supports. The Compaticard IV, along with one 5¼-in. high-capacity drive and one 3½-in. high-capacity drive, can read any standard PC floppy-disk format. The Compaticard IV also supports other types of floppy-disk drives, such as the now archaic 8-in. units, and can store 2.8M bytes on certain 3½-in. drives that accept a new type of floppy disk based on barium-ferrite media. The All-Star PC incorporates a 2.8M-byte floppy drive—an FD-235J from Teac America Inc. This drive can read and write standard 720k- and 1.44M-byte PC disks and can also use barium-ferrite disks. The All-Star PC incorporates three other floppy-disk drives from Teac—two FD-55GFR 5¼-in., high-density drives and one FD-235HF 3½-in. drive. Thus, the All-Star PC's full complement of drives includes two 5¼-in. and two 3½-in. units.

Twisted cables make it tough

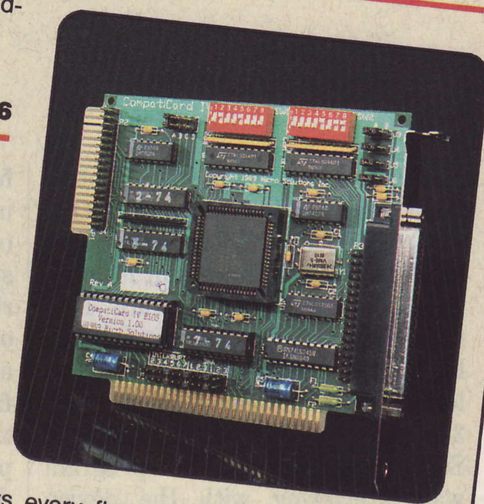
Two factors in IBM's floppy-disk-subsystem design complicated efforts to put four floppy-disk drives in the All-Star PC. The first is a very peculiar floppy-disk-drive cable for the PC. The cable includes a twist that interchanges the drive-select and motor-enable signal lines between the cable's two drive connectors. This cute scheme simplifies

EDN's PC All-Stars

Compaticard IV

MicroSolutions Computer Products, 132 W Lincoln Hwy, DeKalb, IL 60115. (815) 756-3411. FAX (815) 756-2928.

Circle No. 666



STATS:
BUS: PC or PC/AT
DRIVES SUPPORTED: 4
DRIVE SIZES SUPPORTED: 3½, 5¼, 8 in.
TRANSFER RATES: 1M, 500k, 300k, 250k bps
SPECIAL FEATURES: Boot from any drive, background formatting

BIO: The Compaticard IV supports every floppy-disk format ever created for the PC, and a few more. It can replace or work in tandem with a PC's existing floppy controller.

system configuration by allowing you to set all of the floppy-disk-drive select jumpers to address 1, but it negates the original floppy-disk-drive cable's ability to address four drives. **Fig 3** illustrates how the Compaticard IV circumvents IBM's eccentric floppy-disk-drive cable limitations by splitting the four drives under its control into two pairs. Each pair of floppy-disk drives connects to the controller with a separate floppy-disk-drive cable.

However, solving the hardware limitations of IBM's floppy-disk-subsystem design doesn't fix the second problem—BIOS (basic I/O system) limitations. Most PC mother-board BIOS ROMs control only two floppy-disk drives. Although the Compaticard IV manages as many as four floppy-disk drives, IBM's original PC/AT computer did not. Consequently, computers and BIOS ROMs patterned after the PC/AT support only two floppy-disk drives. MicroSolutions skirted this problem by incorporating a floppy BIOS ROM on the Compaticard IV and supplying a loadable device driver for the extra two drives. The device driver adds the extra floppy-disk drives onto the end of the existing drive-designator chain. Thus, if your system has four floppy-disk drives and two hard drives, the first two floppy designators are A and B, the hard-drive designators are C and D, and the third and fourth floppy designators are E and F. This scheme works for most PCs, but can cause problems for systems that use enormous hard-disk drives and older versions of DOS.

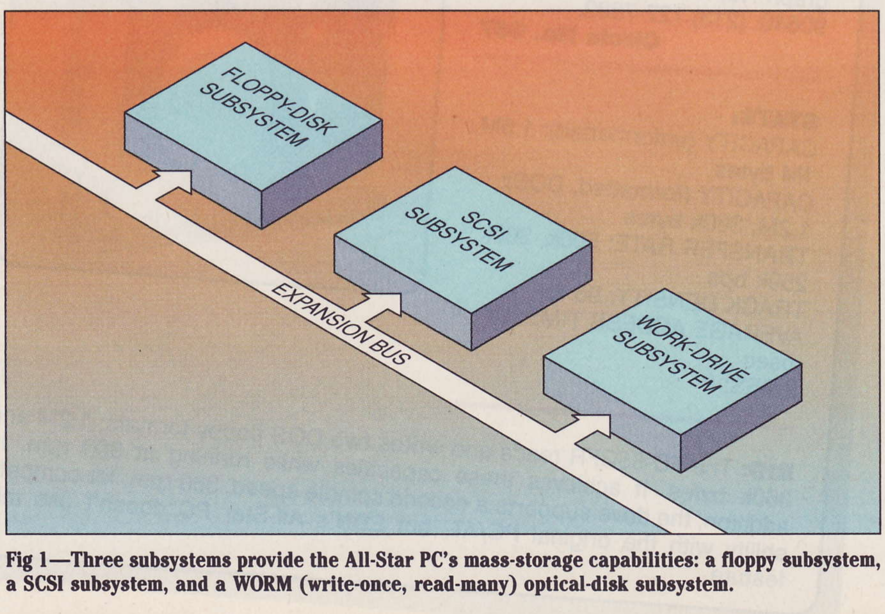


Fig 1—Three subsystems provide the All-Star PC's mass-storage capabilities: a floppy subsystem, a SCSI subsystem, and a WORM (write-once, read-many) optical-disk subsystem.

This is not merely a hypothetical problem. The All-Star PC includes a pair of enormous hard-disk drives and initially used Microsoft's DOS 3.3, which accommodates disk drives with capacities to 32M bytes. The All-Star PC's hard-disk drives have a formatted capacity of 330M bytes each. DOS 3.3's solution to this mismatch was to create 10 logical drives out of each physical drive. As a result, the first hard-disk drive transmuted into logical drives C through L; the second hard-disk drive became drives M through V. The Compaticard IV therefore assigned designators W and X to the second pair of floppies. DOS only handles 26 logical drives (A through Z), leaving only two drive designators for use with other storage devices. Because the All-Star PC was going to have an optical WORM disk drive, there was actually only one drive designator left to play with.

Designator-related problems arose with a disk-caching program called PC-Cache, part of the PC Tools De-

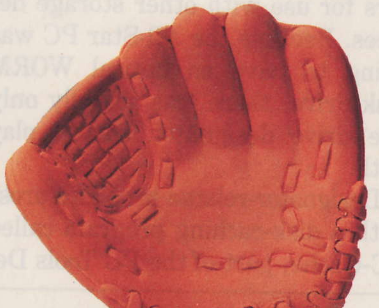
Sculpture by Kathy Jeffers/Sculpture Photography by Chris Vincent. Photography by The Photo Works and Steven Leibson unless otherwise noted.

luxe software package from Central Point Software Inc (Beaverton, OR, (503) 690-8090). PC-Cache improves hard-disk performance, but it interfered with the Compaticard IV's floppy-disk device driver. After loading the program, I could no longer read or write from the two 3½-in. floppy-disk drives, W and X. Suspecting that the cache program was interfering with the device driver, I instructed PC-Cache to ignore drives W and X. It couldn't, however, because it recognized only the first 16 drive designators, A through P. Clearly, PC-Cache and DOS 3.3 could not be used together on the All-Star PC. You'll find the solutions to this problem in Part 4.

As long as PC-Cache wasn't activated, the floppy-disk drives worked fine. Even without a caching program, the All-Star PC's hard-disk drives, a pair of Seagate Technology's SCSI-based Wren Runners, are very fast. The hard-disk drives have an average-seek-time rating of 12.8 msec and a maximum track-to-track seek-time rating of 4.8 msec. (Both ratings include controller overhead.) They also support SCSI transfers at burst rates to 4.7M bytes/sec for synchronous transfers and 2M bytes/sec for asynchronous transfers. The All-Star PC could have used drives with larger capacities (some 5¼-in. SCSI hard-disk drives such as Micropolis Corp's 1590 series now have capacities in excess of 1G byte), but we couldn't find any 5¼-in. hard drives that were faster than the Wren Runners. For this project, speed reigned over capacity, because a pair of 330M-byte drives seemed to provide all the capacity the All-Star PC required.

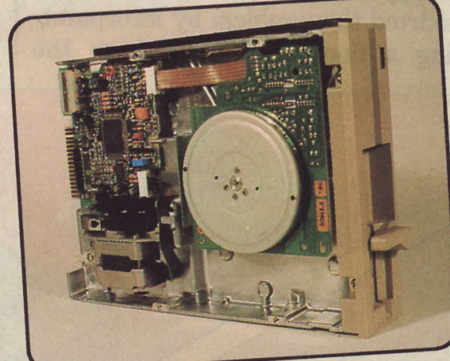
No sane system integrator would omit a way to back up 660M bytes of on-line data. Because the Wren Runners employ SCSI I/O, I planned to use a SCSI-based tape drive that could back up both hard-disk drives on just one tape cartridge. These constraints left only one choice: Exabyte's EXB-8200 cartridge-tape subsystem. I briefly considered using a DAT (digital audio tape) drive, but one wasn't available in time for this project. The EXB-8200 stores 2.5G bytes on one 8-mm videotape cartridge, yet the entire unit, including an integral formatter/controller, occupies the space of a full-height, 5¼-in. drive. It also employs helical-scan recording.

The Wren Runners and the EXB-8200 require a SCSI host adapter for operation, but because of expediency (or perhaps because of a lack of foresight), the PC's BIOS only works with a Western Digital WD1003 controller card and ST-506 hard-disk drives. Tape drives are somewhat less trouble because PC BIOS ROMs don't support them at all. Therefore, there are no compatibility problems to overcome. PC disk controllers that don't imi-



EDN's PC All-Stars FD-55GFR 5¼-in. Mini Floppy-Disk Drive

Teac America Inc, 7733 Telegraph Rd, Montebello, CA 90640. (213) 727-7682.
Circle No. 667



STATS:
CAPACITY (unformatted): 1.6M, 1M bytes
CAPACITY (formatted, DOS): 1.2M, 360k bytes
TRANSFER RATE: 500k, 300k, 250k bps
TRACK DENSITY: 96 tpi
AVERAGE ACCESS TIME: 94 msec
SIDES: 2

BIO: The FD-55GFR reads and writes two DOS floppy formats: 1.2M and 360k bytes. It achieves these capacities while running at 300 rpm. In addition, the drive supports a second spindle speed, 360 rpm, for compatiebility with the original PC/AT, but EDN's All-Star PC doesn't use this feature.

Table 1—Compaticard IV floppy-disk formats

Drive Type	Formatted capacity (bytes)	Sides	First supported in DOS version:
5¼ in.	360k	2	2.00
48 tpi	320k	2	1.10
2 sided	180k	1	2.00
	160k	1	1.00
5¼ in.	800k	2	Proprietary to Compaticard
96 tpi	360k	2	2.00
2 sided	320k	2	1.10
	180k	1	2.00
	160k	1	1.00
5¼ in.	1.2M	2	3.00
96 tpi	800k	2	Proprietary to Compaticard
2 sided	360k	2	2.00
High capacity	320k	2	1.10
	180k	1	2.00
	160k	1	1.00
8 in.	1.2M	2	Proprietary to Compaticard
2 sided	250k	1	1.00
3½ in. 2 sided	720k	2	3.20
3½ in.	1.4M	2	3.30
2 sided	720k	2	3.20
High capacity			
3½ in.	2.8M	2	Proprietary to Compaticard
2 sided	1.4M	2	3.30
Exended density	720k	2	3.20

tate the PC/AT's original disk controller card do have compatibility problems. However, the rewards of using the SCSI bus are worth the risks of incompatibility.

SCSI provides many benefits

SCSI compatibility gives you a wide choice of high-performance storage peripherals, including hard-disk drives with a range of capacities (from less than 100M bytes to more than 1G byte), high-capacity floppy-disk drives, and tape drives. One industry group, the CAM (Common Access Method) Committee, is developing specifications to solve the driver problems for SCSI-based products, but the All-Star PC needed a SCSI host adapter that would work with the software and the storage peripherals immediately, not when CAM-compatible products finally appear (see **box**, "CAM: A common access method for SCSI").

There were two criteria for selecting the SCSI host adapter: speed and compatibility. Because the Wren Runners are so fast, a slow host adapter would introduce a bottleneck in the SCSI subsystem. And the compatibility objec-

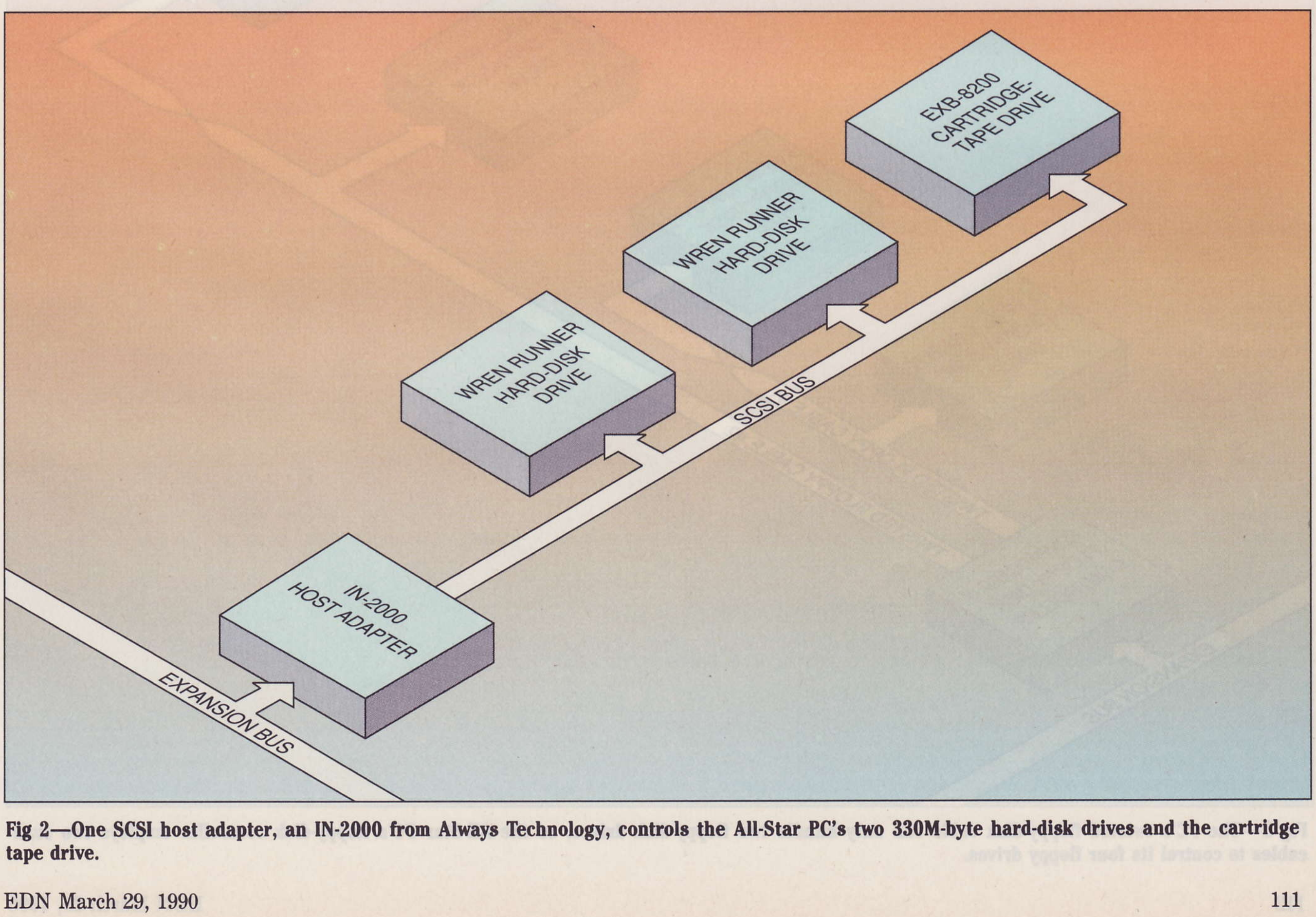


Fig 2—One SCSI host adapter, an IN-2000 from Always Technology, controls the All-Star PC's two 330M-byte hard-disk drives and the cartridge tape drive.

tive presented an even more complex problem. The SCSI firmware and software supplied with the host adapter had to be compatible with the variety of DOS extenders and operating systems that the All-Star PC would use. In addition, the host adapter had to support the Wren Runners and the Exabyte EXB-8200.

After testing host adapter cards from several manufacturers, I selected Adaptec's AHA-1540A. The AHA-1540A employs first-party DMA to achieve high transfer speeds. Even after confining the AHA-1540A to its slowest DMA transfer rate to prevent it from overrunning the All-Star PC's memory subsystem, it still achieved transfer rates of almost 1.3M bytes/sec, according to version 2.8 of a disk-performance test program from Core International (Boca Raton, FL, (407) 997-6055). However, after installing Quarterdeck Office Systems' (Santa Monica, CA, (213) 392-9701) QEMM memory manager, problems arose, which eventually forced me to choose an alternative SCSI host adapter (see **box,** "Lost in (memory) space").

Climbing out of the box

The lessons learned from working with the AHA-1540A led away from SCSI host adapters that employed first-party DMA. EDN Regional Editor Maury Wright helped find a product that offered format compatibility with the AHA-1540A (eliminating the need to reformat

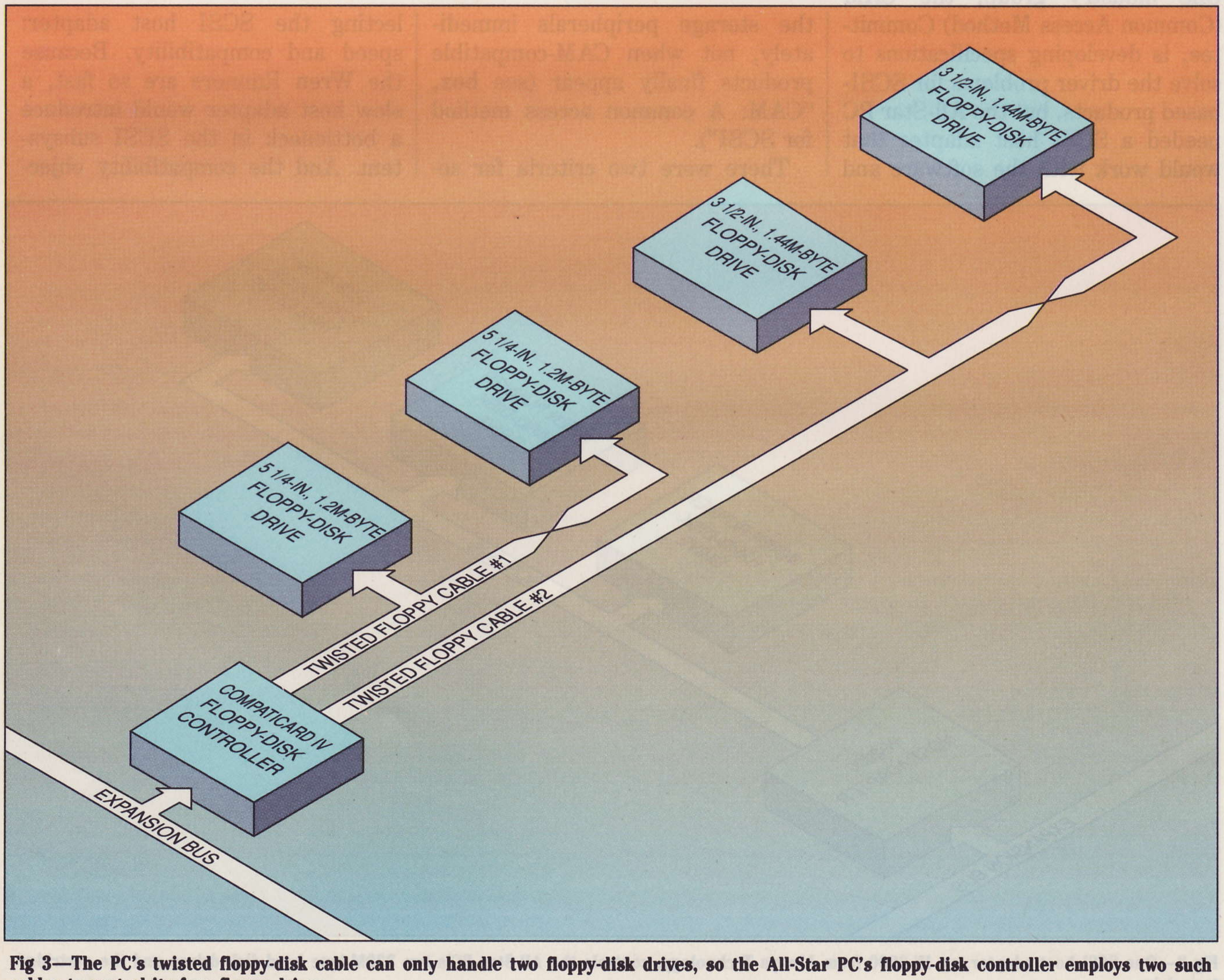
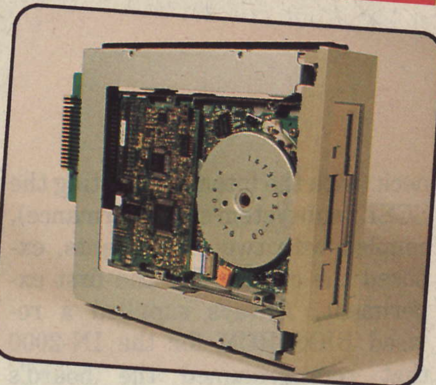


Fig 3—The PC's twisted floppy-disk cable can only handle two floppy-disk drives, so the All-Star PC's floppy-disk controller employs two such cables to control its four floppy drives.

EDN's PC All-Stars **FD-235HF 3½-in. Micro Floppy-Disk Drive**

Teac America Inc, 7733 Telegraph Rd, Montebello, CA 90640. (213) 727-7682.

Circle No. 668



STATS:
CAPACITY (unformatted): 2M, 1M bytes
CAPACITY (formatted, DOS): 1.44M, 720k bytes
TRANSFER RATE: 500k, 250k bps
TRACK DENSITY: 135 tpi
AVERAGE ACCESS TIME: 94 msec
SIDES: 2

BIO: The FD-235HR weighs little more than ½ lb and measures exactly 1 in. high, yet it can store more than 1M byte of data on a floppy disk.

the hard-disk drives), had the requisite operating-system and device drivers available, didn't use first-party DMA, and promised good performance. That product is Always Technology's IN-2000 AT SCSI Host Adapter.

Once installed in the All-Star PC, the IN-2000 worked as advertised. The machine booted without reformatting the hard-disk drives. In addition, the board proved compatible with QEMM's memory-mapping abilities, indicating that the first-party DMA problem was indeed solved. However, after a keyboard reset (invoked by pressing the control, alt, and delete keys simultaneously), the PC locked up shortly after initializing the SCSI drives. Always quickly determined that the problem was caused by the consecutive SCSI addresses I used for the hard-disk and tape drives. Moving the tape drive to SCSI address 4 solved the problem by separating the tape drive and the hard-disk drives at addresses 0 and 1. Without the address gap, the IN-2000 was attempting to initialize the tape drive as if it were a disk drive, and as a result, locked up.

The Core test claimed that the IN-2000 initially transferred 970k bytes/sec, roughly 25% less than the AHA-1540A. This is a respectable speed, but the Wren Runners can do better, as earlier experiments with the AHA-1540A proved. A search for the I/O bottle-

CAM: A common access method for SCSI

The PC's lack of adequate drivers for SCSI host adapters and peripherals caused many of the All-Star PC Project's mass-storage problems. Peripheral vendors rely on host-adapter vendors to write the peripheral drivers because those drivers are always specific to the host adapter. The host-adapter vendors can't possibly write software drivers for every conceivable SCSI peripheral; they're too busy writing drivers that couple their boards to the most popular PC operating systems. Consequently, every SCSI host adapter for the PC works with only a few PC operating systems and supports only a subset of the available peripherals. The CAM (Common Access Method) Committee is trying to eradicate this problem.

Formed in 1988, the committee is developing several specifications that will allow vendors to write one set of drivers for every operating system, host adapter, and peripheral device. It includes representatives from a wide cross section of peripheral, host-adapter, and computer vendors. Currently, the committee is focusing on the needs of PC systems, but the software-access methods it develops should be extensible to other computer systems as well.

For the PC, the committee is approaching the problem at the lowest level. Most PC operating-system software can control disk drives attached to a Western Digital WD1003 hard-disk controller because that is the controller IBM shipped with the PC/AT. The CAM Committee's ATA (AT Attachment) spec defines a standard method that allows SCSI host adapters to mimic the WD1003 by emulating its register set. This approach eliminates the need for special SCSI drivers. Perceptive Solutions Inc (DeSoto, TX, (214) 224-6774) offers a caching disk controller, the Hyperstore 1600, that has a WD1003 emulation mode along the lines of CAM's ATA spec. The committee is also developing an enhanced AT attachment (EATA) specification that allows a driver to take advantage of SCSI features not available through the ATA emulation mode. For more information about the CAM Committee, contact its chairman, I Dal Allen, 14426 Black Walnut Ct, Saratoga, CA 95070. Phone (408) 867-6630.

neck (with the intent of boosting the SCSI subsystem's performance), coupled with two experiments, exposed the culprit. For the first experiment, Always supplied a revised BIOS ROM for the IN-2000 that reprogrammed the board's SCSI protocol chip, a Western Digital WD33C93, to eliminate handshake delays that the chip was generating. Always put the delays in as a conservative measure, though they weren't needed. Eliminating those delays boosted the IN-2000's Core test results to almost 1.3M bytes/sec, tying the AHA-1540A.

Exonerating the expansion bus

The second experiment took place at Cheetah International, where, after plugging the original BIOS ROM back into the IN-2000, we changed a PLD on the Cheetah Gold 425 mother board to speed its expansion bus from 6 to 8 MHz. That experiment had no effect on the Core test, proving that the "slow" ISA bus was not interfering with the All-Star PC's disk-transfer-rate efficiency. Of course, absolute test numbers don't tell you very much about a computer system, but these two experiments demonstrate a valid use for benchmarks. The All-Star PC won't in all likelihood consistently transfer data over the SCSI bus at 1.3M bytes/sec for every application, no matter what Core's test results say. However, in carefully controlled experiments such as the two described above, the Core benchmark provided relative performance data that helped improve the All-Star PC's performance.

With the SCSI performance problem supposedly licked, I loaded a suite of tape-backup-software programs, supplied by Novastor Corp (Westlake Village, CA, (818) 707-9900), onto the system. When the All-Star PC tried to run the Novastor programs, every one locked up the computer. Frantic calls to Novastor and Always Technology resulted in the discovery that the Novastor files on the hard disk were corrupted; they simply didn't match their counterparts on the floppy disks. Further testing revealed that the IN-2000 SCSI host adapter with the new BIOS ROM was no longer writing data to the disk correctly.

Lost in (memory) space

DMA controllers have a tough time working with µPs that incorporate on-chip memory-management units, especially if the code running the DMA controller doesn't know that address translation is occurring. This scenario occurs when you use DOS extender programs, such as Quarterdeck's QEMM memory manager, in conjunction with expansion cards that employ first-party DMA. QEMM can map blocks of extended memory (located above 1M byte in the µP's address space) into unused address spaces below 1M byte, and it can also switch extended memory into the program area—between 0 and 640k bytes—for multitasking operations.

QEMM handles mother-board DMA transfers by providing a protected buffer area, but this technique won't work for first-party DMA controllers that are not aware of QEMM. DOS is ignorant of memory management and provides no way for QEMM to tell it that logical memory addresses no longer match physical addresses. Most DOS services don't need to know about remapped addresses. However, DOS manages first-party DMA controllers and supplies them with the destination addresses for transfers. If logical and physical addresses no longer correspond, the first-party DMA controller will write data into the wrong physical addresses, which is exactly what happened to the All-Star PC when it used Adaptec's AHA-1540A.

Quarterdeck and Phar Lap Software Inc (Cambridge, MA, (617) 661-1510) jointly developed, published, and support a specification that allows software such as a disk BIOS to find out how memory has been mapped by the DOS-extension program. This specification, called the VCPI (Virtual Control Program Interface), provides a function call that supplies the logical-to-physical address-mapping information.

VCPI has become a de facto standard that several major software vendors support. Adaptec's software doesn't support VCPI. Instead, it creates a buffer for DMA transfers when they are used with DOS extenders. Invoking this feature of Adaptec's driver carves 64k bytes from DOS's already overcrowded 640k program space. Although you can shrink the size of Adaptec's DMA buffer (resulting in a speed reduction), I judged this solution to be inadequate for the All-Star PC's needs and reluctantly benched the AHA-1540A.

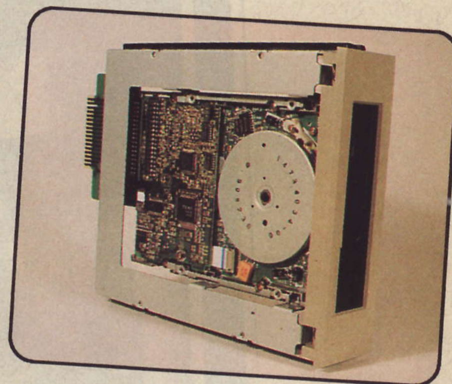
Johan Olstenius, the IN-2000's designer, discovered a logic path on the host adapter that was too slow to handle the faster SCSI transfers. Fortunately, the IN-2000 employs Xilinx field-programmable gate arrays (FPGAs) for most of the board's logic, so the correction required only a ROM change. A small EPROM on the IN-2000 holds the FPGA configuration information, which is loaded automatically by the Xilinx parts at power up. Olstenius rewired some of the circuitry in the Xilinx chip to speed up the slow logic path. This exercise underscores the advantages of the "soft hardware" design approach employed on the IN-2000. I plugged in the new configuration ROM, and after reinstalling the tape software, backed up the information on the hard disks.

EDN's All-Star PC incorporates a second type of storage peripheral that provides archival storage: an APX-5000 optical-disk subsystem from Maximum Storage Inc. The APX-5000's WORM optical-disk cartridge stores more than 500M bytes on each side for a total capacity of approximately 1003M bytes. You may wonder why the All-Star PC has a WORM drive when it already has the Exabyte tape drive. Both the Exabyte and Maximum

EDN's PC All-Stars **FD-235J 3½-in. Micro Floppy-Disk Drive**

Teac America Inc, 7733 Telegraph Rd, Montebello, CA 90640. (213) 727-7682.

Circle No. 669



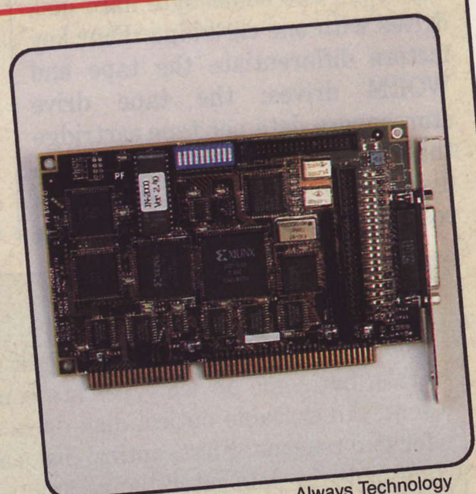
STATS:
CAPACITY (unformatted): 4M, 2M, 1M bytes
CAPACITY (formatted, DOS): 2.8M, 1.44M, 720k bytes
TRANSFER RATE: 1M, 500k, 250k bps
TRACK DENSITY: 135 tpi
AVERAGE ACCESS TIME: 94 msec
SIDES: 2

BIO: The FD-235J stores 2.8M bytes of formatted data on special barium-ferrite media while maintaining read and write compatibility with earlier 3½-in. floppy-disk drives.

EDN's PC All-Stars **IN-2000 AT SCSI Host Adapter**

Always Technology, 31336 Via Colinas, Suite 101, Westlake Village, CA 91362. (818) 597-1400. FAX (818) 597-1496

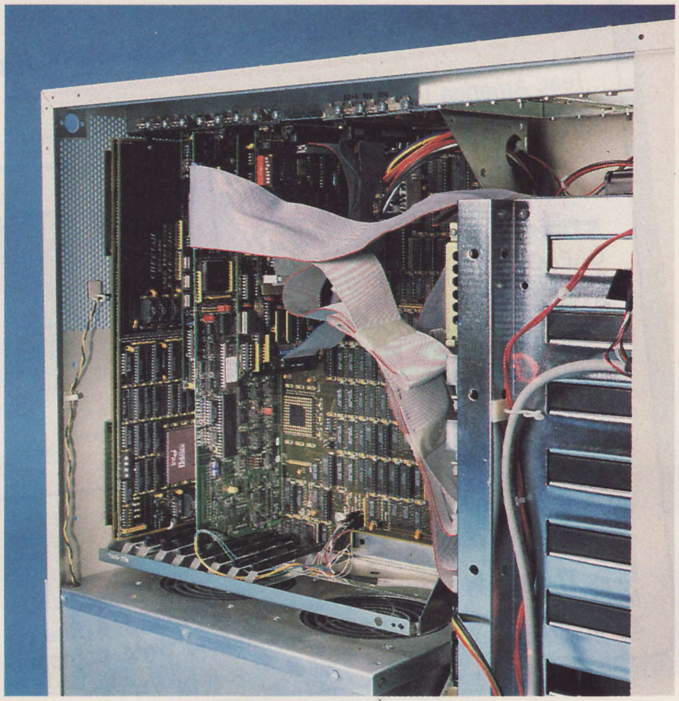
Circle No. 670



Always Technology

STATS:
BUS: ISA (PC/AT)
BUS-TRANSFER MODE: 16-bit programmed I/O
COMPATIBILITY: INT 13H BIOS calls
BIOS ADDRESS: Selectable
CONNECTORS: Internal and external SCSI
EXTRA FEATURE: AT-style floppy-disk controller

BIO: Each IN-2000 host adapter controls as many as seven SCSI peripherals. You can plug four IN-2000s in a system for a maximum system capacity of 28 SCSI devices.



Even with just the SCSI and floppy cabling in place, the interior of the All-Star PC is becoming a rat's nest of wiring.

Storage drives can back up the All-Star PC's two 330M-byte hard-disk drives with one cartridge. Four key factors differentiate the tape and WORM drives: the tape drive stores more data per tape cartridge than the WORM drive stores on a disk cartridge; the tape cartridges cost much less than the optical-disk cartridges; the WORM drive provides much faster access to data than the tape cartridge; and the WORM drive provides indelible storage.

Storage on the tape drive costs less per byte, making tape a better alternative for backup storage, which retains information as an insurance policy against a hard-disk crash. Although the Maximum Storage WORM drive could satisfy the need for backup storage, you would quickly fill up the relatively expensive and nonerasable WORM cartridge if you used it for daily or even weekly backups. However, the indelible storage and higher speed of the WORM drive provide many benefits to a PC-based (or any other) workstation that are not related to backup storage but to archival storage. Archival storage holds files that you wish to save but don't necessarily need to have immediately at hand.

For example, you could use the WORM disk cartridge to freeze a suite of design and development software in case you ever need to revert to that particular version. Sad stories abound of engineers who needed to revise a design, only to discover that the particular versions of the CAD and CAE software tools required for editing the old design files were long gone. A 1G-byte WORM cartridge allows you to save several down-level versions of your favorite software tools. You can be confident that those files cannot be erased to make room for newer software. The same advantage applies to different versions of your design

What's missing?

The All-Star PC incorporates eight storage peripherals, but some device types are conspicuously absent. An erasable optical disk drive wasn't included for two reasons. First, optical disks are not standard methods for data interchange among PCs; second, the Exabyte and Maximum Storage drives provide all the archival and backup storage the All-Star PC needs. Also omitted is a CD ROM drive, because the use of such drives is still very application specific. For example, Cahners's Technical Information Service (Newton, MA, (617) 558-4960) provides a comprehensive electronic device catalog called CAPS (Computer-Aided Product Selection) on CD ROMs and supplies you with the CD ROM drives when you subscribe to the CAPS service.

Also missing from the All-Star PC's mass-storage menagerie is a network connection—not because networks lack merit, rather, because of realistic constraints on the project. With only one machine, there is simply no way to test a network card.

specifications and your designs. Maximum Storage provides tools for version control as you update files. You can always retrieve an older version of a file from the WORM disk cartridge.

The APX-5000 is an external unit. The All-Star PC uses an external unit for two reasons. First, it has no more drive bays to accommodate a WORM disk drive. Second, in an environment where engineers may have an irregular need for the capabilities of the WORM disk drive, the external drive can be passed around. You can plug a Maximum Storage controller board into each engineer's workstation and share the drive. That configuration costs much less than equipping every engineering workstation with a WORM drive.

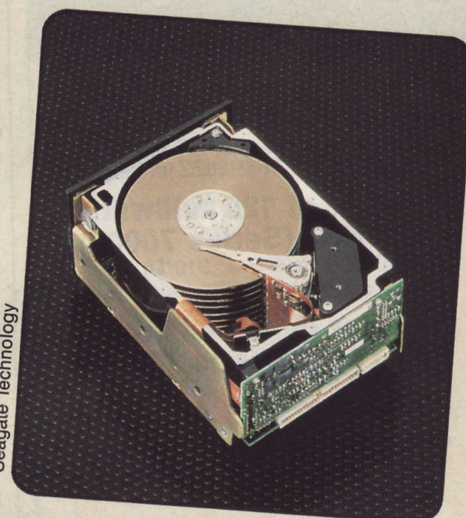
Maximum Storage developed its own file-storage system instead of using the DOS file structure, so its APX-5000 works on a variety of computer systems and workstations. The common file format across multiple computers makes the ability to move the drive from system to system even more attractive because the APX-5000's disk cartridge becomes a good medium for data interchange among otherwise incompatible systems.

The APX-5000 drive has an ESDI (Enhanced Small Device Interface) port, so it doesn't work on the SCSI bus. Maximum Storage supplies a proprietary disk-controller card for the drive. The APX-5000, when

EDN's PC All-Stars **Wren Runner 5¼-in. Rigid-Disk Drive**

Seagate Technology, 920 Disc Dr, Scotts Valley, CA 95066. (408) 438-6550. FAX (408) 438-4127. **Circle No. 671**

STATS:
CAPACITY (unformatted): 385M bytes
CAPACITY (formatted, 512-byte sectors): 338M bytes
AVERAGE DATA-TRANSFER RATE: 15.5M bps
AVERAGE SEEK TIME: 10.7 msec
INTERFACE: SCSI
STORAGE METHOD: Zone bit recording

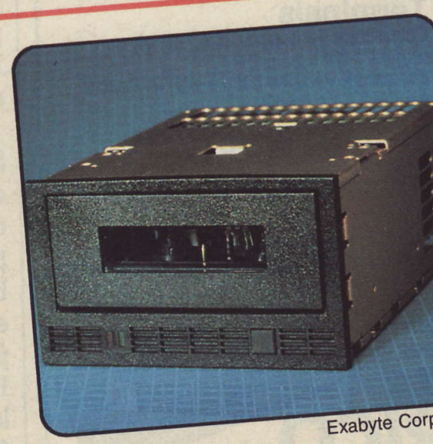

Seagate Technology

BIO: The Wren Runner achieves its fast average-seek time by limiting the area on the disk used for storage. Zone bit recording gives the drive high capacity even with the reduced storage area.

EDN's PC All-Stars **EXB-8200 8-mm Cartridge Tape Subsystem**

Exabyte Corp, 1745 38th St, Boulder, CO 80301. (303) 442-4333. FAX (303) 442-4269. TLX 361740. **Circle No. 672**

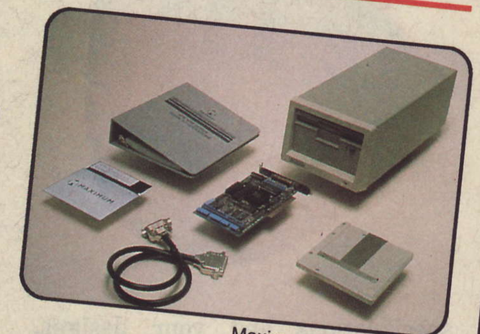
STATS:
CAPACITY: 2500M bytes
DATA TRANSFER RATE (peak): 1.5M bytes/sec
DATA TRANSFER RATE (average): 246k bytes/sec
TAPE SPEED: 0.429 ips
CARTRIDGE: Standard 8-mm videotape
INTERFACE: SCSI


Exabyte Corp

BIO: The EXB-8200 can store more than 2500M bytes on a standard 8-mm videocassette tape. It fits in a 5¼-in., full-height peripheral bay.

EDN's PC All-Stars — **APX-5000 Optical-Disk Subsystem**

Maximum Storage Inc, 5025 Centennial Blvd, Colorado Springs, CO 80919. (719) 531-6888. FAX (719) 531-0227.
Circle No. 673



Maximum Storage Inc

STATS:
CAPACITY: 1003M bytes
DATA TRANSFER RATE: 5M bps
EFFECTIVE AVERAGE ACCESS TIME: 28 msec
CARTRIDGE: 2-sided, removable
INTERFACE: Modified ESDI
DISK CONTROLLER: Proprietary

BIO: The APX-5000 stores more than 500M bytes on each side of its WORM (write-once, read-many) optical-disk cartridge. It is available in both internal-mount and external versions for PCs.

first plugged into the All-Star PC, didn't work. The controller had trouble communicating with the drive. However, turning off the 80486 µP's internal cache RAM cured the problem. That clue pointed an accusing finger at the APX-5000's device-driver software. In many high-speed PCs, the expansion-bus's speed may cause problems. However, the All-Star PC's expansion bus runs at 6 MHz specifically to avoid such problems.

Barry Bremsteller at Maximum Storage discovered the problem's cause. The driver routines that monitored the proper operation of the controller card were timing out before the hardware had time to execute its commands. The culprit proved to be the delay function in Borland International's (Scotts Valley, CA, (408) 439-1800) Turbo C function library. The delay routine is self- calibrating over a range of µP speeds, but the 80486 simply burst past the limits of the self-calibration algorithm. The company has fixed the delay function in its Turbo C and Turbo Pascal libraries and you can get that revised library code from Borland.

With the device driver fixed, the APX-5000 worked flawlessly and the All-Star PC's complement of mass-storage devices was complete. That still left the machine deaf, mute, and blind. **EDN**

References

1. Wright, Maury, "Recent 3M- to 20M-byte, 3½-in. floppy-disk drives suit mainstream uses," *EDN*, October 27, 1988, pg 103.
2. Wright, Maury, "Winchester disk drives," *EDN*, May 25, 1989, pg 122.
3. Wright, Maury, "Helical-scan drives store gigabytes on tiny tape cartridges," *EDN*, December 22, 1988, pg 129.
4. Leibson, Steven H, "Optical-disk drives target standard 5¼-in. sites," *EDN*, December 25, 1986, pg 42.
5. Terry, Chris, "Rewritable optical-disk drives, optical units provide mass storage," *EDN*, May 11, 1989, pg 59.

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