Texas Instruments 960B

MANAGEMENT SUMMARY

The Texas Instruments 960B is a mature system that has undergone very few major changes during the past few years. Most of the changes have occurred in the peripheral offerings, with users reaping the most benefits from the expanded number of mass storage units available. All of the mass storage devices currently in the product line are of the cartridge disc or magnetic tape variety.

The 960B, introduced in May 1974, is an enhanced version of its predecessor, the TI 960A. The improvements that set it apart from the 960A are memories with error-correction logic and 4K RAM chips in pluggable sockets, and improved power supplies.

The 960B memory not only corrects one-bit data errors on-the-fly, but also detects double-bit errors and interrupts the system. Light-emitting diodes (LED's), located along the sides of the memory controller board, give failure information so that single-bit errors can be identified at an individual RAM device level. Further, the chips are mounted in sockets, allowing easy removal and replacement by on-site personnel. Early 960 users view this maintenance feature as a welcome relief—especially

The 16-bit Texas Instruments 960B features extensive bit manipulation capabilities and is designed to support real-time monitoring and process control applications. In-house, the 960B is the heart of the Texas Instruments Data Exchange Systems, marketed as terminal-oriented processing systems, and the ATS family of automatic printed circuit board testers.

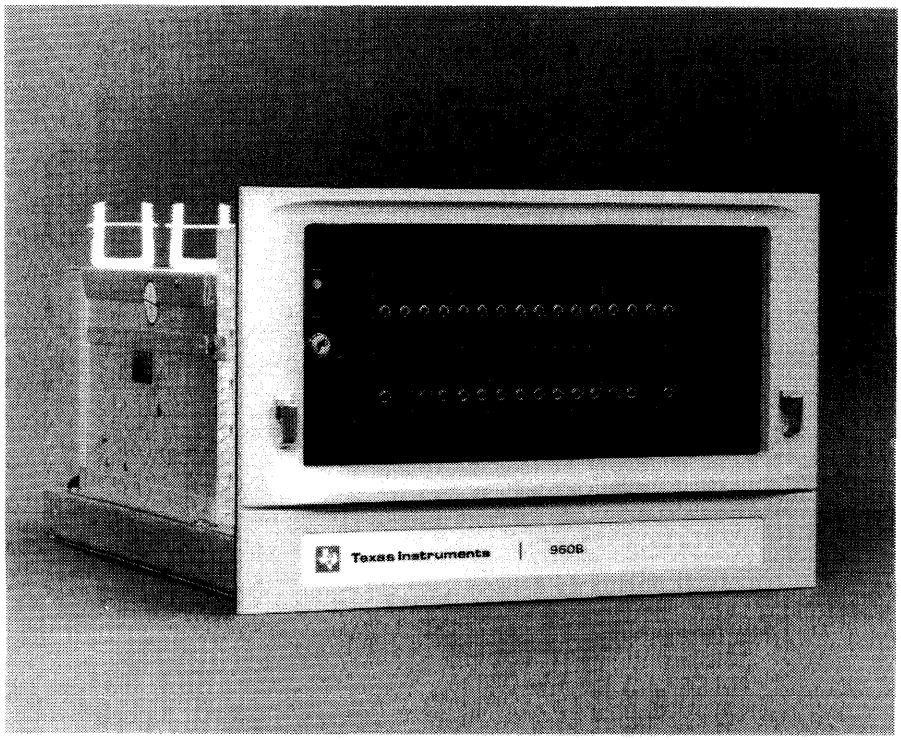
CHARACTERISTICS

MANUFACTURER: Texas Instruments Incorporated, Digital Systems Division, P.O. Box 1444, Mail Stop 784, Houston, Texas 77001. Telephone (713) 494-5115.

Texas Instruments is a leading supplier of semiconductor products to all branches of the electronics industry. In addition, the company is active in the fields of process control, instrumentation, and computer peripheral equipment.

MODEL: 960B.

DATE ANNOUNCED: First quarter 1974.



The Texas Instruments 960B, in a rack-mountable chassis configured with 8K words of error-correcting MOS memory, carries a purchase price of $4,500. With the addition of a battery pack and internal communications register unit (CRU) expansion, the purchase price is increased by $400. Standard features of the 960B include memory write protect, power-up interrupt, removable control panel, keylock, power fail warning interrupt, bit manipulation capability, and a register unit that permits breakdown of the input and output data ports into 4,096 input and 4,096 output individual 1-bit data lines, each separately controlled or sensed.

REFERENCE EDITION. This is a mature product line, and no significant further developments are anticipated. Because of its importance, coverage is being continued, but no future update is planned.

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OEM's who normally did not purchase contract maintenance from TI. These users are now able to repair memory problems directly without having to use the TI factory service plan under which bad modules can be swapped for a fee.

Another important feature of the 960B memory is the use of 4K RAM chips, enabling TI to offer memory modules of 8K, 16K, or 24K words. Using these modules, users can assemble a full 64K memory in a single chassis without additional cabling or other hardware.

The 960B is the heart of TI's Data Exchange Systems, which are terminal-oriented processing systems used as directly linked concentrators for data bases supported by larger host computers. Two models are available, the DXS/20 and DXS/40. The major difference between the models is the type of disc storage implemented on each. The DXS/20 system uses cartridge disc drives, while the DXS/40 uses TI's IBM 3330-equivalent DS330 disc drives.

The DXS systems are intended for use as workstations in large data processing networks, but can also be used as stand-alone processing systems. Software for the DXS systems includes the DXS Operating System (DXS/OS), the DXS Statement Translator (DXS/ST), the PTM/OS system for handling mixtures of communications terminals, and emulation packages for various host computer systems.

The architecture of the 960B is also suited for use in TI's ATS-960 and ATS-961 automatic printed circuit board testers.

The TI 960A was introduced in November 1971 as a reduced-price, semiconductor version of the earlier core-memory Model 960 that had originally been announced in May 1970. The basic 960A CPU plus 4K words of 16-bit 750-nanosecond MOS memory sold for $2,850 and was available with a full complement of peripherals, terminals, sensor I/O interfaces, and software.

The 960B is an extension of the 960A, and uses all of the 960A peripherals and interfaces. The basic 960B CPU with an 8K memory sells for $4,500.

One noteworthy peripheral device available with the 960B is the Twin Cassette "Silent 700" ASR Data Terminal. This TI-built device offers manual data entry on a limited ASCII keyboard, a 30-cps silent thermal printer, cassette write/read/copy, and full-duplex communications at 1200 bps. However, this unit is not commonly used in control environments, and would more likely be used in a multi-purpose minicomputer environment or to support program development.

Among the aspects of the 960B that are especially well suited to process control are: 1) specially written real-time monitors, 2) special instructions that perform frequently encountered control functions with a minimum of processor cycles, 3) the use of dual-state operation with full

DATE OF FIRST DELIVERY: May 1974.

NUMBER INSTALLED TO DATE: 2,900 in U.S.A.; 1,200 elsewhere.

DATA FORMATS

BASIC UNIT: 16-bit word plus 6 bits for error correction code.

FIXED-POINT OPERANDS: 16 bits; the 960B also has bit manipulation instructions.

FLOATING-POINT OPERANDS: There is no floating-point hardware for the 960B, but single-precision (2-word) floating-point operations are supported through subroutines. These operands consist of an 8-bit exponent and 24-bit fraction.

INSTRUCTIONS: Basic machine instructions are two words long. The first six bits are used for the operation code for all instruction types. For bit and field manipulation instructions, the next 10 bits are used as an address, 4 bits are used to define field width, 1 bit is used to define a 0/2 value (if employed), 1 bit is used to specify mode register, and the last 10 bits are used to specify an operand address. For move, compare, add, and branch relative with link instructions, the operation code is followed by a 10-bit operand address. For add and compare immediate operations, a 13-bit immediate operand is used instead of the 10-bit address plus 3-bit register. Other instruction formats follow the operation code with 3 bits to specify indexing, indirect addressing, and/or specifying an immediate operation, 3 bits for index register addressing, 4 bits for modifiers, and 16 bits for the operand address.

INTERNAL CODE: Binary.

MAIN STORAGE

STORAGE TYPE: Dynamic MOS. Memory employs 4K RAM chips in pluggable sockets. Light-emitting diodes (LED's), located along the side of the memory controller, give failure information so that single-bit errors can be identified at an individual RAM-device level.

CYCLE TIME: 750 nanoseconds. Refresh time is one memory cycle every 32 microseconds.

CAPACITY: The 960B minimum memory capacity is 16,384 bytes (8,192 words), expandable to a maximum of 131,072 bytes (65,536 words) in 16,384, 32,768, or 49,152-byte increments. A full 131,072-byte memory can be accommodated in one 960B chassis.

CHECKING: An error checking and correcting system is employed on the 960B. The system employs a six-bit, modified Hamming code to identify erroneous bits. The memory controller generates a six-bit code during a memory write operation, and stores it, along with the 16-bit data word, in a 22-bit memory word. During a read operation, the controller retrieves the stored data, generates a new code, and compares that code with the stored code to determine whether an error has occurred. Single-bit errors in the word are detected and corrected on the fly. If a double-bit error occurs, the controller detects it and interrupts the CPU.

STORAGE PROTECTION: The first 128 memory locations contain bootstrap loaders and are protected/unprotected under control of a front-panel switch. Standard hardware also permits protection of a fixed-length memory block, selectable through jumpers on the memory controller board. The protected block always extends from memory location 0, and the block length can be 256,512, 1,024, 2,048, 4,096, 8,192, 16,384, or 32,768 words. Memory locations 128

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PERIPHERALS/TERMINALS

DEVICE	DESCRIPTION & SPEED	MANUFACTURER
MAGNETIC TAPE EQUIPMENT		
948206-0001	Transport Master Kit; controller for up to three transports and master transport; 9-track, 800 bpi, NRZI, 10.5-inch reels, 37.5 ips, vacuum columns; add-on transport is 948206-0004; 30 KBS	Texas Instruments 979A
PRINTERS		
966767-0001	Printer kit; controller and serial impact printer; 132 positions, 64-character set, 9 x 7 dot matrix, 4 to 14.8-inch paper, 6 lines per inch, 10 characters per inch, 2-channel VFU, one-line buffer; 165 cps	Centronics 101A
966767-0011	Same as 966767-0001 but 330 cps	Centronics 102A
PUNCHED CARD EQUIPMENT		
943760-0001	Card Reader Kit; controller and 80-column reader; 1000-card input hopper, 500-card output stacker, fiber-optic read station; 400 cps	True Data 804
PUNCHED TAPE EQUIPMENT		
965935-0003	Reader; sprocket-driven, bidirectional, asynchronous, 5 to 8-level codes; 300 cps	Remex 6300
973523-0003	Reader/Punch; sprocket-driven, bidirectional, asynchronous, 5 to 8-level codes; 300/75 cps	Remex 6375
TERMINALS		
966647-0001	733 ASR Terminal Kit; controller and Silent 700 terminal; 80-position thermal printer with 96 ASCII character set, 10 characters per inch, friction feed and 5 x 7 dot matrix; twin magnetic tape cassette drives; write/read/copy capability with off-line edit, buffered transmit/receive, 55-key keyboard, 64 ASCII character set, EIA interface, full duplex; 30 cps print rate, 1200 bps data rate	Texas Instruments 733
943805-0011	743 KSR Terminal Kit; controller and Silent 700 terminal; 80-position thermal printer with 64 ASCII character set, 10 characters per inch, 6 lines per inch, friction feed and 5 x 7 dot matrix; limited ASCII keyboard, EIA interface, full duplex; 30 cps	Texas Instruments 743
973305-0013	Video Display Terminal; 12-inch, 5 x 7 dot matrix, 64 ASCII characters, 24 lines by 80 characters per line, MOS refresh memory, 61-key keyboard including 5 function keys and 4 direction cursor controls, EIA interface; switch-selectable data rates to 9600 bps	Texas Instruments 912

duplicate sets of general-purpose registers for efficient, high-speed context or job switching, and, most importantly, 4) the Communications Register Unit (CRU).

The CRU replaces the traditional I/O bus on general-purpose computers with an 8,192-bit register (4,096 input and 4,096 output bits). Slow-speed I/O devices can be attached directly to this large register and accessed under program control in varying data widths, down to the individual bit. This ability allows the 960B to conveniently handle analog-to-digital input or digital-to-analog output as well as peripherals with slow-to-medium-speed data transfer rates (card equipment, printers, etc.).

In addition to the CRU, the 960B has a standard direct memory access (DMA) channel that is identical with that on the 980B general-purpose computer system (Report M11-840-201). Also, the 960B's basic 8K words of main memory can be expanded to 64K words of MOS memory, all in the same chassis. The 960B uses the same sheet metal, power supply, memory modules, and peripherals as the 980B, but the software for the 960B has been written to take full advantage of the 960B's process control

through 167 are excluded from the protection scheme and are never protected. TI software does not support protected areas beyond the initial 128 words.

RESERVED STORAGE: 24 words of memory are reserved for interrupt traps and I/O status, 128 words are reserved for bootstrap programs, and 16 words are reserved for the general-purpose register file.

CENTRAL PROCESSOR

GENERAL: The basic 960B CPU includes a standard power fail detection/auto restart feature, plus a removable control panel with key lock. Options for the 960B include a ROM bootstrap loader, interval timer modules with 1, 2, 4, or 8-microsecond intervals; and an extended arithmetic option for multiply and divide, as well as 10 double-precision instructions for load, store, add, subtract, shift, etc. Of particular interest is the communications register unit (CRU), which is used instead of an I/O bus to facilitate direct programming of digital interfaces. The 960B chassis also provides space for CRU expansion.

Dual Mode operation is also provided for fast context switching between two separate sets of registers under either interrupt or programmed instruction control. The two modes, "supervisor" and "worker," each contain a

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features. This software provides data management and overall system support on a level similar to that of most DOS-type supervisors.

Software for the 960B reflects its primary application area. The operating systems, programming languages, and utility routines are all designed primarily for process control.

The 960B is offered on a purchase or lease basis with separately priced maintenance. Besides standard maintenance service with various options for extended coverage, Texas Instruments offers on-call service, shop service, and fixed-priced repair service. Shop service is available during normal working hours at TI service centers for customer-delivered parts. Fixed-price repair service is offered on standard electronic interface assemblies only, and offers repair and/or exchange of parts. This service is normally for customers who perform their own equipment maintenance.

TI provides two one-week hardware or software training courses free with the purchase of each 960B system (up to three systems for discounted purchases). Additional courses are available for fixed fees. All courses are conducted at TI's DSD Education and Development Center in Austin, Texas.

USER REACTION

Detailed below are the results of Datapro's interviews with five TI 960 users selected at random from a list supplied by Texas Instruments and the responses to Datapro's 1977 computer survey from two other TI customers. The five OEM customers and two end users had collectively installed more than 500 systems. Each of the two end users had two systems installed.

Applicational uses for the 960 included process control in the chemical industry, in the petroleum industry, for machine tools, and for pneumatic tube equipment. Among the seven users, TI hardware and software experience ranged from a minimum of two years to a maximum of five years.

A typical OEM configuration purchased from TI by the users in the survey included a 960B processor with 8K to 32K bytes of memory and a CRI board. Typical end user configurations were similar but added one or more 911 VDT terminals.

All five of the OEM accounts utilized TI's fixed-price repair service (rated expensive but excellent), designed to repair and replace boards for customers who normally do their own maintenance. With one exception, the OEM accounts did not employ software from TI, but rather had developed their own.

The table below shows how these users rated the TI 960 Series.

program counter (called an event counter in worker mode) and are entered under control of a status register.

A plug-in battery pack, optionally available for the volatile semiconductor memory, can sustain an 8K-word memory module's contents for 20 hours at room temperature.

CONTROL MEMORY: A read-only memory (ROM) with 256 16-bit words is available to provide bootstrap loading for up to five devices under switch control. Devices supported include teletypewriter, paper tape reader, moving-head cartridge disc, card reader, and Silent 733 ASR Data Terminal.

REGISTERS: Two separate files of eight 16-bit general-purpose registers are provided for the two processor states. These registers serve, respectively, as general registers (4), base or machine data (1), base or machine procedures (1), base or software flag areas (1), and base or CRU address (1). One 16-bit status register is used to control context switching between the two register files. All 16 general-purpose registers are available to programs in either mode through alternate-mode addressing techniques. The register file is located in memory locations 128 through 143.

ADDRESSING MODES: The 960B has 15 addressing modes. These include 8-, 16-, and 32-bit immediate; direct (16-bit); indexed; program relative (+128 displacement); double indexed (program counter plus index register); indexed program relative; program relative indirect; program relative indirect with pre-indexing; program relative indirect with post-indexing; base displaced; base displaced indirect; and base displaced indexed. In addition, every bit of each memory location can be individually set, reset, or tested. Indirect addressing is to one level only.

INSTRUCTION REPERTOIRE: 78 instructions are standard: 36 register-to-storage instructions, 9 bit and field manipulation instructions, 5 storage-to-storage instructions, and 28 program control instructions. An additional 14 instructions are available with the extended arithmetic option for multiply, divide, double-precision arithmetic, etc.

INSTRUCTION TIMINGS: All times are in microseconds for full-word, fixed-point operands:

Load/Store:	3.3/3.6
Add/Subtract:	3.6/3.6
Multiply/Divide:	8.6/10.9
Compare and Branch:	6.8

Indirect addressing adds 0.75 microsecond and indexing adds 0.6 microsecond to the instruction execution times.

INTERRUPTS: Three levels are standard, with first priority for internal interrupts, second priority for CRU interrupts, and third priority for DMA interrupts. CRU modules containing 8 interrupts are available as options for expanding the CRU interrupt system.

A total of 4096 interrupt lines can be implemented, and each line can be individually addressed, sensed, and enabled/disabled.

Two dedicated memory locations are reserved for each of the three interrupts, which permits one instruction to be stored for each. Interrupts do not automatically change the program counter. If a change is to be made, it must be accomplished through the instruction stored in the dedicated memory locations. If the instruction executed as a result of the interrupt does not modify the program counter, the next instruction in the normal program sequence is executed.

PHYSICAL SPECIFICATIONS: The 960B is 12¼ inches high, 19 inches wide, 24 inches deep, and weighs 75 pounds

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	Excellent	Good	Fair	Poor	WA*
Ease of operation	3	4	0	0	3.4
Reliability of mainframe	5	2	0	0	3.7
Reliability of peripherals	1	0	1	0	3.0
Maintenance service:					
Responsiveness	0	0	1	1	1.5
Effectiveness	0	0	1	1	1.5
Technical support	1	4	0	0	3.2
Manufacturer's software:					
Operating system	0	2	1	0	2.7
Compilers and assemblers	0	1	1	2	1.8
Ease of programming	0	2	1	0	2.7
Ease of conversion	0	1	0	0	3.0
Overall satisfaction	1	6	0	0	3.1

*Weighted Average on a scale of 4.0 for Excellent.

This is a mature product line that was designed primarily for OEM sales and was well liked by the OEM users in this survey. From the ratings given to TI's maintenance by the two end users, it is obvious that the product was geared toward OEM sales, where TI was better prepared for servicing.

The only areas that drew criticism from the OEM customers were poor communications with corporate marketing and slowness to process paper work by TI.

These signs are indicative of a company feeling its way into a new area of marketing. (TI's initial impetus was to produce minicomputers for its own internal use.) A lot of the early trial-and-error procedures are still on the minds of the 960 users. Datapro feels sure that TI is aware of these problems and has instituted corrective actions for its newer product lines.□

with 8K words of memory. Power requirements for the CPU are 115/230 VAC (+10V, —15V), 47 to 63 Hz, 600 watts. The CRU expansion chassis is 8¾ inches high, 19 inches wide, and 23½ inches deep and requires 115 VAC ±10 percent, 47 to 63 Hz, 500 watts.

Operating environment for all 960B units is 32 to 122 degrees F., 0 to 95 percent relative humidity (non-condensing).

INPUT/OUTPUT CONTROL

I/O CHANNELS: I/O operations can take place via the Direct Memory Access (DMA) Channel or Communications Register Unit (CRU). The standard DMA channel permits the attachment of up to eight high-speed device controllers with a maximum aggregate data transfer rate of 1.3 million words/second.

COMMUNICATIONS REGISTER UNIT: The CRU provides an 8,192-bit (256 16-bit words for both input and output) that can interface directly to low-speed peripherals or sensors in place of a traditional I/O bus. This can be programmed directly, using the register addresses as storage locations. Addressing in the CRU can be done to the individual bit level, with register-to-register-type instructions capable of manipulating operands of 1 to 16 bits in length beginning at any position in the CRU. This makes the CRU especially useful for A/D or D/A operations and also provides an effective means of handling multiple low-speed devices such as card readers, terminals, modems, paper tape readers and punches, etc. An extensive line of modular interfaces to the CRU is also provided for EIA interfacing, interrupts, contacts, and blanks for custom-designed modules.

The basic 960B chassis provides 4 CRU slots, plus an expansion position to interface 12 more CRU modules (4 slots on 0.5-inch centers and 8 slots on 1-inch centers). External CRU expansion racks are available with 16 positions each to expand the total CRU device interface to the 4,096 input bits and 4,096 output bits. Maximum (burst mode) CRU data transfer rate is 4 million bits per second (256K words/second).

CONFIGURATION RULES: The basic 960 chassis has three memory slots, providing a total internal main memory capability of 64K words. For memory expansion beyond two modules, the sum of the memory on the first two modules should be 32K or greater.

The 960B will support up to eight controllers for discs and/or magnetic tape units through the standard DMA bus. A single DMAC controller, either for cartridge disc or for magnetic tape, can be mounted in the CRU expansion space of the CPU or in a small external chassis. If multiple DMAC controllers are configured in the system, then external expansion via a large (PU-size) rack-mounted chassis is required for te DMAC peripheral subsystems. Internal expansion of the CRU is possible only if the DMAC expansion is mounted externally to the basic 960B chassis. A combination of internal and external expansion of the CRU can provide ports that will handle a total of 256 CRU modules. Each CRU port can handle 16 bits in and 16 bits out for attachment of individual sensors or slow-speed peripherals to each port.

Port requirements of various devices include the following: each interrupt module (eight TTL or 16 OCT external interrupt lines), one CRU port; each 16-bit input/output module (TTL or EIA), one CRU port; each A/D or D/A module, one CRU port; each 32-bit input or 32-bit output module, one CRU port; each full duplex EIA communications interface, one CRU port; each interval timer module, one CRU port; each synchronous communications module, one CRU port (one-inch spacing); each 733 or 743 Terminal, one CRU port; and each 912 Video Display terminal, one CRU port. Also, each punched tape reader requires one CRU port; each punched tape reader/punch, two CRU ports; each card reader, one CRU port; and each printer, one CRU port.

MASS STORAGE

DS31/DS32 MAGNETIC DISC SUBSYSTEM: Consists of one drive and a controller capable of interfacing up to four removable or nonremovable cartridge disc drives. Each drive has a capacity of 1.14 million 16-bit words, for a total system capacity of 4.56 million 16-bit words. The 955157-0001 DS31 Magnetic Disc Master Kit consists of a rack-mountable DS31 Removable-Cartridge Disc Drive and controller. The first and third add-on DS31 Drive is the 955157-0002; the second add-on (with power supply) is the 955157-0003. The DS32 is a nonremovable version of DS31. The first and third add-on DS32 Drive is the 966669-0002; the second add-on (with power supply) is the 966669-0003.

The drives rotate at 1500 rpm. Data transfer rate is 97.6K words per second, average rotational delay is 20 milliseconds, and average head positioning time is 70 milliseconds. Track-to-track and across-all-tracks head positioning times are 15 and 135 milliseconds, respectively.

Data is stored on a two-surface disc cartridge organized into 203 data tracks with 88 32-word sectors per track. There are 2816 words per track, 571,648 words per surface, and 1,143,296 words per drive. Recording density is 2200 bpi. The drives use IBM 2315-type discs. The D31 Cartridge Disc Drive is a Diablo Model 31, while the D32 is a Diablo Model 33F.

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DS44 MAGNETIC DISC SUBSYSTEM: Consists of one drive and a controller capable of interfacing up to four fixed and removable-cartridge disc drives. Each drive has a capacity of 4.56 million 16-bit words, for a total system capacity of 18.24 million 16-bit words. The 973674-0001 DS44 Magnetic Disc Master Kit consists of a rack-mountable DS44 Cartridge Disc Drive and controller. The add-on drive is the 973674-0004.

Data is stored on 4 surfaces, each organized into 405 data tracks plus 3 spares per surface. There are 88 32-word sectors per track. Total track capacity is 2816 words. Recording track density is 2200 bpi (inner track). There are four tracks per cylinder and 408 cylinders per drive. Total drive capacity is 4,561,920 words.

The drive rotates at 2400 rpm with an average rotational delay of 12.5 milliseconds. The data transfer rate is 156,250 words per second. Track-to-track, average, and across-all-tracks head positioning times are 10, 38, and 70 milliseconds, respectively. The drive employs IBM 5440-type disc cartridges. The DS44 Cartridge Disc Drive is a Diablo Model 44.

I/O UNITS

See Peripherals/Terminals table.

In addition to the conventional devices listed in the Peripherals/Terminals table, TI offers a broad line of interface devices particularly useful in measurement and control applications. These interfaces include 9 types of "4TI" industrial interface modules, 16 models of A/D and D/A converters, and 13 general-purpose interfaces.

COMMUNICATIONS CONTROL

961642 FULL DUPLEX EIA COMMUNICATIONS INTERFACES: These modules can be used to interface the CRU to a Bell 103A, 103F, 202C, 202D or equivalent modem; to any peripheral utilizing the standard RS-232C interface; or to any device utilizing a 20-milliampere current loop interface.

The 961642-0005 has a data rate of 110 bps; the 961642-0001, 300 bps; the 961642-0003 and -0007, 1200 bps; the 961642-0004, 2400 bps; the 961642-0010, 4800 bps; and the 961542-0011, 9600 bps. The 961642-0007 is specifically designed for any terminal with an RS-232C interface.

966752 SYNCHRONOUS COMMUNICATIONS MODULE: This module features programmable sync character, selectable parity (odd, even, none), new sync character generation, transparent mode operation, and a 500-millisecond timer. The unit provides interfacing for a Bell 201, 208, or equivalent modem, which furnishes clocking. Speeds up to 9600 bps are supported.

360/370 ADAPTER: Texas Instruments also manufactures an adapter which permits the 960B to transfer data to and from an IBM 360/370 host computer using either asynchronous or Binary Synchronous techniques at data rates up to 9600 bits per second. When used with one of TI's several emulation software packages, the adapter can look like any of IBM's terminal controllers. This unit is usually supplied with TI's Data Exchange Systems and is not quoted as a standard interface with the 960B. Contact a local TI sales office for pricing and available configurations.

SOFTWARE

OPERATING SYSTEMS: There are three operating systems available for the 960B: Programming Support Monitor (PSM), Process Automation Monitor (PAM), and the disc-based Process Automation Monitor (PAM/D). PSM executes one user program at a time using the worker/supervisor processor operating modes for sequential processing. PAM and PAM/D provide a multiprogramming environment for concurrent on-line execution of real-time jobs. These three operating systems are upward-compatible, and all major TI software programs can run under all three.

Program Support Monitor (PSM) is the lowest-level monitor. It is a single program executive system using a supervisor/worker (2-mode) operation to load one user program (worker) at a time on a minimum 8K-word processor. Functions performed by PSM in addition to program loading include logical I/O device assignment, I/O control for standard peripherals, optional arithmetic and code conversion operations, interrupt processing, and error detection and recovery. A 960B with a minimum of 16K words of memory running under PSM provides all the facilities required to support the assembler (SAL), the Linking Relocating Loader (LRL), the Terminal Source Editor (TSE), TI's Language Translator (TILT), the FORTRAN compiler with Process Control extensions (PCLA), and utility programs.

Process Automation Monitor (PAM) is a multiprogramming operating system that uses an executive/worker method of program execution. In general, PAM provides all the functions performed by PSM plus additional functions which support on-line, real-time process automation programming and other applications requiring a number of interacting worker programs. These enhancements include time delay processing, time and date support, time-sharing between I/O and other processing, worker task restarting via interrupts, management of re-entrant subroutines, and initiation of tasks by other tasks.

Peripheral I/O operations are performed through the use of a physical record block. Programmers write to a logical device, allowing peripheral assignment at task execution time. This permits alternate assignments in the event of device unavailability.

Task priority under PAM is determined at the time each task is installed, and can be changed by deleting the task and reinstalling it at a different priority level.

A minimum PAM system includes 16K words of memory, an interval timer, and a teletypewriter, but addition of either a high-speed paper tape reader or card reader is recommended. PAM supports the same programs as the Program Support Monitor.

Process Automation Monitor Disc (PAM/D) is similar to PAM except that multi-level priority support is provided for disc-resident application programs and data files where bulk storage and file management are required. Additional features of PAM/D include: loading of worker tasks and procedures on disc in relocatable form, memory space management, relocation and loading of disc-resident tasks into memory when requested by other tasks or by the operator, creation and management of sequential access files and indexed direct access files on disc, and background task roll in/roll out. The disc-based monitor also provides an expanded job control language to permit easy "compile and go" functions, improved diagnostics, and on-line debug facilities.

PAM/D requires at least 16K words of memory and a minimum disc subsystem storage area of 114K words to support the SAL/D assembler, Link Editor (LNK) and Librarian (LIB), Source Editor (SED), Sequential File Copy utility (COPY), Sequential/Indexed File Copy utility (COPYSX), and other utility programs. If the FORTRAN compiler with Process Control extensions is to be run, the minimum memory requirements increase to 24K words. PAM/D is recommended for systems that include a large number of programs of which only a few are active at any one time.

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STORAGE REQUIREMENTS OF 960B SOFTWARE

	Main Memory (words)		Disk Storage (words)	
	Minimum	Typical	Minimum	Typical
PSM Monitor	32K	—	—	—
PAM Monitor	32K	—	—	—
PAM/D Monitor	32K	—	114K	1024K
PCLA Compiler for use with PSM Run-time package	32K	—	—	—
PCLA Compiler for use with PAM Run-time package	32K	—	—	—
PCLA Compiler for use with PAM/D Run-time package	48K	—	—	—
DEB960 for use with PSM	32K	—	—	—
DEB960 for use with PAM, PAM/D	32K	—	—	—
CPU PAT Package	16K	—	—	—
PDT Package	16K	—	—	—
Linking Relocating Loader (LRL)	32K	—	—	—
Overlay Link Editor (LNK 960)	32K	—	—	—
Library Support Program (LIB 960)	32K	—	—	—
Terminal Source Editor (TSE)	32K	—	—	—
Source Editor/Disc (SED)	32K	—	—	—

PROGRAMMING LANGUAGES: Texas Instruments offers two programming languages for the 960B: the Symbolic Assembly Language (SAL960) and the Process Control Language (PCLA). Both are supported by the PSM, PAM, and PAM/D operating systems.

Symbolic Assembly Language (SAL960) is a two-pass assembler, with capabilities (in certain versions) of storing the source code on an intermediate device to eliminate reloading. SAL produces both absolute and relocatable outputs. The SAL assemblers generate relocatable code and allow external references, address arithmetic, and op-code definition. Up to 4,096 output communications lines or sequential groups of lines can be addressed symbolically or explicitly.

There are two versions of SAL. One runs on a 960B with a minimum of 16K words of memory and a teletypewriter or 733 ASR. The second runs on IBM System/360 or 370 computers and requires 108K bytes of memory.

Process Control Language (PCLA) is a variation of FORTRAN II (ANSI Standard X3.10-1966) with extensions to permit manipulation of one-bit logical variables and constants. It also supports direct communications with external devices. Four standard FORTRAN functions have been deleted, and 19 enhancements have been added to the compiler. The four deleted items are the EQUIVALENCE and PAUSE statements, nested parentheses in the FORMAT statement, and statement functions. The enhancements include treatment of single I/O lines as logical variables and groups of I/O lines as integer variables; a logical IF statement, a logical Assignment statement, an UNLOAD statement for magnetic tape systems, and a DATA statement which permits initialization of scalar variables; inclusion of assembly-language statements in the FORTRAN stream; and improved real-time control functions to permit more control by the system monitor.

PCLA includes basic support functions for absolute value, float, fix and transfer sign; external functions for natural logarithm, trigonometric sine, trigonometric cosine, square root, arc tangent, and exponentiation; and further run-time library routines. PCL/A runs in a 16K-word minimum system under PSM and PAM, and in a 24K-word minimum system under PAM/D.

APPLICATIONS PROGRAMS: Users must develop their own application programs using PCL/A or the SAL system.

UTILITIES: TI offers six utilities for the 960B: a Linking Relocating Loader (LRL), an overlay Link Edit (LNK960), Library Support (LIB960), a Debug Package (DEB960), and two source editors, Terminal Source Editor (TSE) and Source Editor (SED).

LRL runs under PAM or PSM and accepts input modules in relocatable format from paper tape, cards, or cassette tape to produce an output file in either relocatable or absolute form. Absolute object outputs are in ready-to-run form.

The *Overlay Link Editor (LNK960)* is available for disc systems only and exists in two versions, one for the 960 and one which runs on an IBM 360 or 370 computer. LNK960 accepts relocatable object modules and control statements which have been previously and separately assembled and combines them into an output object file. Assembly of externally referenced symbols is then completed. LNK960 has five options available to the user, including three load map variations, output of binary text records with condensed text and automatic sequencing, input object module selection from a disc object library, and production of overlapping output text modules (overlays). Input is normally from cards. The work file is normally on magnetic tape. The load maps and error reports are normally sent to a line printer.

The *Library Support Program (LIB960)* prepares and maintains indexed files on disc and is, therefore, available to disc systems only. Two versions are available, one for the 960 and one which runs on an IBM 360 or 370 computer. LIB960 accepts relocatable object modules, ASCII source programs, and control statements as input and stores these in designated library files as directed by control statements. Some of the functions performed by LIB960 are: produce an index listing, create a library map of either modules or files, output relocatable binary object for either a module or an entire file, insert modules in a library using the first segment's identification record name as the module name, delete modules from files, rename modules, or output on ASCII source for a module. Input is normally performed through a card reader. Index and content reporting is

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normally via a line printer. Binary output modules are normally prepared on a card punch.

The *Terminal Source Editor (TSE)* is an interactive, single-terminal-oriented program which runs under PSM or PAM. Line or string editing of source files from any sequential input device can be performed, including insertion of new source code or deletion of existing code. TSE is generally used in non-disc systems.

The *Source Editor/Disc (SED)* is a multiple-terminal programming system for building and editing source files on disc systems. It is designed to run under PAM/D, and therefore is used only in disc systems. Normally, up to two terminals are supported, but additional terminals can be added by generating and installing additional tasks in SED.

The Debug Package (DEB960) is a batch and interactive software tool that permits the user to modify or display the contents of memory and registers. It controls the execution of the program being debugged and the setting of breakpoints to specify traces. DEB960 checks for the validity of supervisor calls when feasible, checks for validity of instructions, and checks for memory references or branch addresses outside of the area assigned to the program being debugged. The latter is to prevent accesses outside the range of DEB960.

PRICING

POLICY: Texas Instruments offers the 960B Series computers on a purchase or lease basis with separately priced maintenance. Monthly leasing charges are based on 9.1 to 2.46 percent of the purchase price for lease terms ranging from one to five years, respectively. OEM discounts up to 20 percent are allowed on quantities of 25 units or more.

Basic-coverage maintenance prices, as detailed in the Equipment Prices section of this report, apply for eight hours during the period from 8 a.m. to 5 p.m., Monday through Friday, excluding holidays. Extended-coverage service on equipment for 16 consecutive hours during the period from 8 a.m. to midnight each day, Monday through Friday, and during the period from 8 a.m. to 5 p.m. on Saturday, excluding holidays, is priced at 1.5 times the basic-coverage prices. For full 24-hour, 7-days-a-week coverage, including holidays, maintenance is priced at two times the basic monthly maintenance charges. In addition, a per-zone monthly surcharge of five percent of the basic monthly maintenance charged is assessed for travel beyond zone 0 (a 25-mile radius of the field service office).

Service on an on-call basis is provided for customers without a basic-coverage maintenance contract and for service performed outside the hours of agreement. On-call service is charged at $40 per hour between 8 a.m. and 5 p.m., Monday through Friday, excluding holidays, and at $50 per hour (4-hour emergency call-out minimum) for calls exceeding 8 hours during standard working hours, for calls made before 8 a.m. and after 5 p.m. Monday through Friday, and for calls made any time on Saturday. Double-time charges of $60 per hour (4-hour emergency call-out minimum) are made for Sundays and holidays. The transportation charge for on-call service is 15 cents per mile plus commercial travel costs, if any.

Shop service is available at $25 per man-hour or part thereof during normal working hours if the customer delivers the equipment in need of repair to a Texas Instruments service center.

A fixed-price repair service is offered on standard electronic interface assemblies for those customers who stock their own spares of standard 960 computer family products and service their own equipment. The service offers a 14-day repair or exchange of most assemblies for the cost of labor and material. For an additional per-part charge of $25, Texas Instruments will either repair and return to the user the same customer-modified serial-numbered assembly or replace a single standard part within 48 hours (subject to availability).

Two one-week software or hardware training courses are provided free with each system 960 purchased. Courses are conducted at the Digital Systems Division Education and Development center in Austin, Texas. The courses include both classroom lectures and laboratory projects. Course prices average about $400 each. Prices for special courses conducted at customer locations will be quoted upon request.

Certain developmental software is supplied free of charge, dependent on hardware configuration and purchase agreement. Included in this category are the CPU performance assurance tests (PAT's) and performance demonstration tests (PDT's).

A one-year software subscription service is available for the 960, providing software updates on media supplied by Texas Instruments. The option for annual renewal of the subscription service is available for a 60-day period after the initial one-year term lapses. An "update subscription service" provides an updated version of the software and a one-year subscription service. The update subscription service is aimed at those who have never had the subscription service or have allowed it to lapse.

Support for noncurrent software releases is limited to correcting any deficiencies deemed necessary by Texas Instruments, and will be available for only six months from the date of the most current release.

EQUIPMENT: The following typical purchase prices include controllers and adapters.

STAND-ALONE PROGRAM DEVELOPMENT SYSTEM: Consists of 960B CPU with 8K words of memory, twin-cassette "Silent 700" ASR, and cassette software package. Purchase price is $8,320.

LARGE-SCALE PAM/D MULTIPROGRAMMING SYSTEM: Consists of 960B stand-alone CPU with 32K words of memory, twin-cassette "Silent 700" ASR, and a 1.14-million-word disc drive. Purchase price is $12,620.

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EQUIPMENT PRICES

		Purchase Price	Monthly Maintenance
PROCESSORS			
960B processors are configured with standard features including memory error detection/correction, memory write protect, power fail warning interrupt, power-up interrupt, removable control panel, keylock, three ports for semiconductor memory modules, one port for DMAC interface, four ports on 0.5-inch centers for CRU cards, one port for extended arithmetic option, space for internal CRU expansion option, power supply, rack-mount chassis, slides, and selected software.			
943709-0100	With 8K words of MOS memory	$ 4,500	$ 75
943709-0101	With 8K words of MOS memory and battery pack	4,600	80
943709-0102	With 8K words of MOS memory, battery pack, and internal CRU expansion	4,900	80
PROCESSOR OPTIONS			
214087-0001	Interrupt module; provides 8 interrupts and 8 mask bits	200	7
214114-000X	Interval Timer module; 1, 2, 4, or 8-msec interval; X=1, 2, 4, or 8	250	5
226819-0001	Extended Arithmetic (M/D) Option	900	11
226882-0001	ROM Bootstrap Loader	250	6
943659-0001	Battery Pack	100	5
226853-001	Plug-In Power Supply Extender Board	150	—
MEMORY			
975155-0002	8K MOS Memory Add-on Module; requires 943740-0002	1,400	7
975155-0004	16K MOS Add-on Module; requires 943740-0002	2,800	14
975155-0006	24K MOS Memory Add-on Module; requires 943740-0002	4,200	21
975155-0104	8K to 16K Memory Expansion Kit	1,400	7
975155-0106	8K to 24K Memory Expansion Kit	2,800	14
943740-0002	Memory expansion internal connector	100	—
MASS STORAGE			
955157-0001	Magnetic Disc Master Kit for moving-head, removable-cartridge disc drives; requires DMAC; includes controller and one drive	8,000	90
955157-0007	DMAC Interface Kit for 955157 series; requires DMAC	2,800	25
955157-0002	Third add-on moving-head disc drive; requires 955157-0001	5,000	60
955157-0003	Second add-on moving-head removable disc drive with power supply; requires 955157-0001	5,400	65
966669-0002	First or third add-on moving-head disc drive with non-removable disc; requires 955157-0001	3,000	60
966669-0003	Second add-on moving-head, non-removable disc drive with power; requires 955157-0001	3,400	65
961687-0001	Disc Cartridge for 955157 Disc Drives	175	—
973674-0001	Magnetic Disc Master kit for moving-head, fixed and removable-cartridge disc drives; includes controller and one drive	12,000	115
973674-0002	DMAC Interface kit for 973674 series; requires DMAC and EIA interface	2,800	25
973674-0004	Second, third, or fourth add-on moving-head, fixed and removable-cartridge disc drive	9,200	90
973681-0001	Disc Cartridge for 973674 Disc Drives	175	—
MAGNETIC TAPE EQUIPMENT			
948206-0001	Magnetic Tape Transport, Master kit; includes controller and 9-track, 800-bpi, 37.5-ips transport; requires DMAC	11,000	120
948206-0004	First or second add-on 9-track, 800-bpi, 37.5-ips transport	8,000	95
PRINTERS			
966767-0001	Line Printer, 132-column, medium duty, 165 cps; includes interface	6,250	95
966767-0011	Line Printer, 132-column, medium duty, 330 cps; includes interface	6,850	100
966767-0002	Line Printer Interface; for user-supplied 966767 line printer	800	7
966765-0003	Line Printer Stand	350	—
PUNCHED CARD EQUIPMENT			
943760-0001	Card Reader Kit; includes 400-cpm card reader and CRU interface	4,300	55
943760-0002	Card Reader Interface; for user-supplied 943760 reader	550	7
PAPER TAPE EQUIPMENT			
965935-0003	High-Speed Reader; 300 cps	1,400	25
973523-0003	High-Speed Reader/Punch; 300/75 cps	5,950	50
965935-0002	High-Speed Reader Interface	550	7
973523-0002	High-Speed Reader/Punch Interface	750	7
TERMINALS			
966647-0001	733 ASR Twin-Cassette Silent 700 Data Terminal kit; includes terminal and interface	3,820	44
966647-0002	Interface for user-supplied 733 ASR Twin-Cassette Silent 700 Data Terminal	450	7
943805-0001	743 KSR Printer Keyboard Data Terminal Kit; includes terminal	1,800	25
943805-0002	Interface for user-supplied 743 KSR Printer Keyboard Data Terminal	450	7
981336-0001	Stand for any Silent 700	150	—
961755-0002	Interface for user-supplied ASR33-5JE Teletypewriter	450	7
973305-0013	Video Display Terminal	2,300	30
973305-002	Interface Kit for 973305-0013; requires $\pm 15\underline{V}$ Power	450	7

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COMMUNICATIONS INTERFACES

961642-0005	Full Duplex EIA interface; 110 bps	350	7
961642-0001	300 bps	350	7
861642-0003	1200 bps	350	7
961642-0004	2400 bps	350	7
961642-0010	4800 bps	350	7
961642-0011	9600 bps	350	7
961642-0007	1200 bps; any terminal with RS-232C interface; 103 and 202 modems	350	7
966304-0001	Full Duplex EIA Interface Test Kit	60	—
966752-0001	Synchronous Communications Module	700	7
942055-0001	Test Kit	360	—

I/O INTERFACES

214082-0001	Universal Solder 960 CRU Board; single-ended card	95	—
214084-0001	Double-ended card	100	—
217867-0001	Universal Wire-Wrap 960 CRU PC Board; single-ended card	200	—
217863-0001	Double-ended card	250	—
226851-0001	Plug-In CRU and DMA Extender Board	150	—
966556-0001	CRU expansion chassis, +5V power only; uses 8.75 inches of rack space	1,320	12
966556-0002	CRU expansion chassis, with +5V and ±15V power; uses 8.75 inches of rack space	1,650	17
214095-0001	CRU expansion card, for 4 additional CRU expansion chassis	100	—
226855-0001	±15V Regulator; for 966556-0001	200	6
966390-0002	DMAC Interface card; one required	200	3

HARDWARE

945080-0001	Standard 19-inch Rack-Mounting Cabinet with removable doors, vertical AC power strip, system circuit breaker, removable air filters and blowers; 63-inch vertical mounting space	1,000	—
945130-0001	Vertical Blank Front Panel; 1.75 inches high	12	—
945130-0002	3.5 inches high	14	—
945130-0003	7 inches high	16	—
945130-0005	10.5 inches high	18	—
966601-0004	Style I mounting space, 54.25-inch high cabinet	1,500	—
973730-0001	Style II mounting space, 64-inch high cabinet	1,200	—
957482-0001	Single DMAC Controller Mounting Kit for moving-head cartridge disc interface; mounts CRU expansion space of CPU	600	7
957483-0003	For magnetic tape transport interface	600	7
966340-0001	Single DMAC Controller Mounting for moving-head cartridge disc interface; rack-mount in 8.75 inches of vertical space	1,100	12
966340-0003	For magnetic tape transport interface	1,100	12
966423-0001	DMAC expansion chassis, for up to 56 DMAC controller cards; requires 966555-0001	1,400	14
966777-0001	External DMAC expansion kit	1,300	20

SOFTWARE PRICES*

		Purchase Price	Update Price	New Subscription, Including Update	Renewal Subscription
942870	Monitor Starter Package	$200	$100	$ **	$ **
943871	PSM Monitor Builder Kit; requires 943873	150	75	425	100
942872	PAM Monitor Builder Kit; requires 943873	150	75	425	100
942873	PAM/PSM Utility Package; requires 943870	300	150	**	**
944243	PAM/D Monitor Builder Kit; requires 942870 and 942872	400	120	450	150
944244	PAM/D Utility Package; requires 944243	350	180	**	**
942876	PCLA Run-Time and Compiler for PSM; requires 942871	150	75	175	100
942877	PCLA Run-Time and Compiler for PAM; requires 942872	150	75	175	100
967582	PCLA Run-Time and Compiler for PAM/D; requires 944244	150	75	175	100
942896	DEB960 debug for PSM; requires 942871	75	35	110	75
942897	DEB960 debug for PAM or PAM/D; requires 942872 or 944244	75	35	110	75
955420	CPU PAT Package	80	40	200	75
942704	PDT Package	140	70	**	**
942881	PAT/PDT Cassette	140	70	**	**

* Software is available in object form on paper tape (option 0001), cards (option 0002), or magnetic tape cassette (option 0003).

**Subscription service is offered for this software only as part of another package.