BTI 8000

MANAGEMENT SUMMARY

Even in the early days of marketing the 4000, BTI felt that to reach the general EDP marketplace, a totally new system with substantially greater processing power and I/O capacity was needed. Therefore, while continuing with the development of the BTI 5000 and 5000/ES (see M11-089-101), BTI embarked on a program which culminated in the announcement of the BTI 8000 at the 1980 National Computer Conference.

The BTI 8000 is based on a 32-bit, 67-nanosecond bus serving multiple processors, controllers for main memory modules, a System Services Unit, and peripheral processors which in turn control I/O device controllers, an approach which BTI calls "Variable Resource Architecture." Computational Processing Units (CPUs), Memory Control Units (MCUs), Peripheral Processing Units (PPUs), and System Services Units (SSUs) can be plugged into the bus in any mix to match the requirements of the application. A minimum configuration requires at least one of each. The system's computational power, memory, and I/O resources are automatically pooled for efficient processing of the overall workload. If an application subsequently requires more computational power, memory, or I/O capacity, additional modules can be plugged into the bus. Conventional manual regeneration of the operating system (Sysgen) is not required when changing the hardware configuration—the system does it automatically under control of one front-panel switch. The 8000's hardware configuration is totally isolated from the user software, preserving a user's software investment as the system grows.

Background

BTI Computer Systems started out in 1968 as Basic Timesharing, Inc., a time-sharing service company ▷

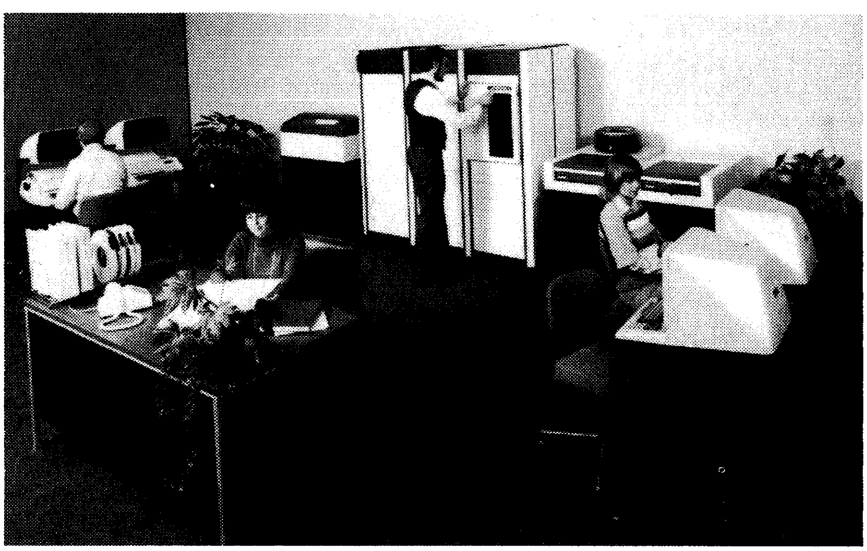
The BTI 8000 is a 32-bit, multiprocessor, multi-user, multilanguage, and multifunction system. Modular in configuration, the 8000 is designed around a central bus with a 32-bit-wide data path and 16 slots for plug-in attachment of system resource modules. The system is capable of supporting as many as 200 interactive users, and provides a high level of security for users in a time-sharing environment.

MAIN MEMORY: 512K to 16M bytes
DISK CAPACITY: Up to 8 billion bytes
WORKSTATIONS: Up to 200 (interactive)
PRINTERS: Up to 900 lpm
OTHER I/O: Magnetic tape cartridge drives, magnetic tape reel-to-reel drive

CHARACTERISTICS

MANUFACTURER: BTI Computer Systems, Inc., 870 West Maude Avenue, Sunnyvale, California 94806. Telephone (408) 733-1122.

BTI Computer Systems started in the San Francisco Bay area in 1968 as a time-sharing service company under the name Basic Timesharing, Inc., and took its present name in 1978. From this time-sharing experience, the company developed a series of interactive systems initially based on a modified Hewlett-Packard minicomputer. Today, the company manufactures three product lines: two 16-bit single-processor systems capable of supporting up to 32 users, and a 32-bit, modular, multiprocessor system which can support as many as 200 active users. BTI's manufacturing facility is in Sunnyvale, California, and U.S. sales offices are in Piscataway and Cherry Hill, New Jersey; Washington, D.C.; El Monte, Los Angeles and Sunnyvale, California; Boston; Seattle; Denver; Atlanta; Cincinnati; Dallas; Minneapolis; Chicago; and St. Louis. BTI also has ▶



The BTI 8000 supports a number of peripheral devices and terminals. The BTI 8000 configuration shown here includes four terminals, two disk-pack drives, a reel-to-reel magnetic tape unit, and a line printer. This 32-bit system can support up to 200 interactive users in a multilanguage, multifunction environment.

serving the San Francisco peninsula. The experience gained in the next two years led to the development of a packaged proprietary time-sharing system capable of accommodating up to 16 users.

BTI's first formal product line, the BTI 3000 Series, an outgrowth of the company's assembled systems, was introduced in November 1972. This new system was based on a Hewlett-Packard 2100 minicomputer, chosen primarily because its user-microprogrammability enabled implementation of an efficient time-sharing facility in a system of relatively modest cost. In addition to the 48K bytes of 980-nanosecond core memory and the on-line disk storage, the basic 3000 system included 8 user ports, expandable to 16 ports, and the ability to extend the disk storage capacity beyond 9.6 megabytes by adding more disk controllers as required.

The 4000 Series, introduced in January 1975, was a continuation of the total hardware and software system established by the 3000 Series. The 4000 Series was based on the newer, more cost-effective, Hewlett-Packard 21MX minicomputer and initially consisted of three models: the 4000/10, 4000/20, and 4000/30. The new CPUs incorporated many system functions implemented in microcode. All of the 4000 Series models had 64K-byte core memories and differed in the type and amount of mass storage offered with each system. The 4000/10 used the same 2.4-megabyte disk drives as the 3000/20 and 3000/30, while the 4000/20 used the same 49-megabyte disk pack drives as the 3000/40. The 4000/30 featured 73-megabyte disk drives. All models were supplied initally with ports for up to 16 users, with the 4000/20 and 4000/30 having expansion capabilities to 32 ports.

In March 1976, the 4000 Series was upgraded and redesignated as the Models 4000/15, 4000/25, and 4000/35. The most visible difference between the new 4000s and the old was the cabinetry. Using a special modular packaging technique, the equipment mounting chassis were stacked together. Decorative skins were then added to lock the stack together and form an integrated cabinet.

Less visible differences included 650-nanosecond MOS memory instead of the 980-nanosecond core, more internal functions implemented in microcode, and 7.5-megabyte disk drives substituted for the 2.4-megabyte drives on the low-end model. Sources within Hewlett-Packard regarded the BTI product line as one in which the microprogramming capabilities of the 21MX were most extensively exploited.

Initially, an essential component of all time-sharing systems, user terminals, was not supplied by BTI. The company recognized that many asynchronous terminals with a data rate between 100 and 9600 bits per second and a standard RS-232-C interface are available directly to users, and passed on to its customers the potential savings of direct procurement. Similarly, any modem with compatible transmission specifications and an a European subsidiary, BTI Computer Systems (UK), Ltd., with a sales office in Slough, England, and a service office in Birmingham.

MODEL: 8000.

DATE ANNOUNCED: May 1980.

DATE OF FIRST DELIVERY: Scheduled for mid-1981.

DATA FORMATS

BASIC UNITS: 32-bit word and 8-bit byte.

FIXED-POINT OPERANDS: Operands can be single or double words, a character, or a field of from 1 to 32 bits.

FLOATING-POINT OPERANDS: Sixteen floating-point instructions deal with 64-bit, double-word operands, which include 11-bit biased exponents (10^{-154} to 10^{154}) and 52-bit mantissas (over 15 decimal digits).

INSTRUCTIONS: Machine instructions are all one word in length and reside on memory word boundaries. There are 174 machine instructions available to the user. The lowest 22 bits of most instructions specify an operand, while the next three higher bits are sometimes used to specify a register. Different methods of referencing operands are provided by the "address mode" field and 54 addressing modes. Indirect addressing further involves special one-word structures called pointers, which themselves contain address mode fields and parameters for operand specification.

Instructions provided for subroutine linkage check entry points and provide parameter-type checking for the subroutine. The calling sequence and the entry sequence are executed part by part, passing one parameter at a time with the pass parameter instructions on the calling side and corresponding store parameter instructions on the subprogram side. The instructions specify the parameter type, whether the parameter is being passed by location or value, and whether this is the last parameter in the protocol.

INTERNAL CODE: ASCII.

MAIN STORAGE

TYPE: Semiconductor.

CYCLE TIME: 670 nanoseconds per 32-bit word, full cycle.

CAPACITY: Up to 16M bytes of main memory can be interfaced to the BTI 8000 via Memory Control Units (MCUs), with a single MCU controlling from 512K to 4M bytes of semiconductor memory. Additional memory is available in increments of 512K bytes. Memory is organized in pages of 4096 bytes. (Each MCU occupies 1 of the system's 16 basic module slots.)

CHECKING: ECC (Hamming code).

PROTECTION: Security mechanisms have been designed into the system, including its hardware, to enable the system to operate in a secure, multi-user, on-line environment. The account structure is closed and secure, in that all operations and data remain private within account boundaries, unless explicit action to grant foreign access is taken. All passwords required are stored in encrypted form only, and there is no way to decrypt stored passwords. Users can share files on a read-only basis, can limit writing privileges to "append-only," or can grant full access to a file. On-line disk packs are not encrypted. A special recording format is used to provide security.

PERIPHERALS/TERMINALS

DEVICE	DESCRIPTION & SPEED	MANUFACTURER
MAGNETIC TAPE UNITS		
8310	Cartridge, 3M-type, 10M bytes/cartridge, 6400 bpi	DEI
8330	9-track, 800/1600 bpi, switch-selectable density, IBM/ANSI-compatible, 45 ips	*
PRINTERS		
8420	Line printer, 64- or 96-character set, 136 columns, 300 lpm	*
8425	Line printer, 64- or 96-character set, 136 columns, 600 lpm	*
8430	Line printer, 64- or 96-character set, 136 columns, 900 lpm	*
TERMINALS		
1410	80x24 CRT screen format, 5x7 character matrix, 64 displayable characters, TTY-style keyboard with numeric keypad, transmission rate to 19.2K bps	Hazeltine
1420	80x24 CRT screen format, 5x8 character matrix, 94 displayable characters (including lower case), dual-density, typewriter-style keyboard with numeric keypad, transmission rate to 19.2K bps	Hazeltine
1500	80x24 CRT screen format, 7x10 character matrix, 94 displayable characters, dual-density and reverse video, ANSI standard keyboard with numeric keypad, serial printer output, transmission rate to 19.2K bps	Hazeltine
1510	80x24 CRT screen format, 7x10 character matrixc; 94 displayable characters, dual-density, reverse video, screen protect, and block transmission (254 characters per block), ANSI standard keyboard with numeric keypad, serial printer output, transmission rate to 19.2K bps	Hazeltine
1800	Printing terminal; includes 9x7 character matrix, 132 columns, 150-cps impact printer, full ACSII 128-character keyboard, transmission rates to 110 to 9600 bps	Texas Instruments
	**Available from a number of vendors.*	

RS-232-C interface could be used for remote terminals. However, BTI does now offer, as options, a line of CRT terminals and printer terminals.

BTI chose not to develop application software, but reached end-users requiring such software through an informal alignment of its computer systems with application software furnished by independent vendors. BTI was able to offer a unique advantage to the application software supplier; protection for his software comparable to that of BTI's proprietary operating system. With his software protected by an exclusive "proprietary" screen initially set up by BTI, the vendor was able to install his software on BTI systems of his choice where he could support his software over the telephone, much as BTI supported its own software. This exclusive proprietary software protection facility is also available with BTI's current products. The 4000's special protection for added-value software made it easier for the company to establish joint selling arrangements with independent software suppliers, including OEM purchasers. This feature was also an advantage in selling to service bureaus because it enabled the service bureau to become an OEM supplier to clients whose billings had grown to the point of justifying the acquisition of an in-house system.

In September 1978, BTI introduced the 5000, which superseded the 3000 and 4000 and became BTI's mainstay 16-bit product line. The 5000 uses an upgraded version of the operating system proven on the 4000, and the CPU enables BTI to perform automatic remote fault diagnosis. The 5000's design allows it to be called and tested by a computer at BTI's service center without on-site assistance by the customer. BTI's diagnostic computers are also used to monitor a customer's system after a repair has been made and to carry out periodic

RESERVED STORAGE: The lowest n+9 pages (4096 bytes per page) on the system, where "n" is the number of Computational Processing Units present, are reserved for resident operating system use.

COMPUTATIONAL PROCESSOR

The major resource modules and all peripheral controllers are special-purpose microprogrammed processors, which in turn use microcomputer-based submodules for many service functions. The foundation of the system is the Variable Resource Architecture (VRA) bus, a distributed-logic, passive, synchronous bus with a 32-bit-wide data path and 16 slots for the attachment of major modules. All data transfers between major modules take place through the VRA bus at 67 nanoseconds per 32-bit word (15 million words per second or 60 million bytes per second).

The four major modules are the System Services Unit (SSU), the Computational Processing Unit (CPU), the Memory Control Unit (MCU), and the Peripheral Processing Unit (PPU). A system must include at least one of each, but no more than one System Services Unit is required. Additional CPUs, MCUs, and PPUs can be configured to the system to increase throughput and to provide fail-soft operation.

All resource modules automatically carry out self-tests at system start-up. On completion of its self-test, the SSU completes system start-up. If all modules are operative, the operating system is automatically configured to match the resources present. Faulty resource modules are identified with the aid of a front panel display. In multi-module configurations, faulty modules can be removed and the system restarted (one-button bootstrap).

The System Services Unit is internally cabled to the operator's panel, which is mounted on the top of the left-most system cabinet. The panel contains a readout of 10 alphanumeric characters for reporting system status and exception conditions, an alarm light, and 8 rocker switches. The switches include the main power switch, a switch to disable BTI remote maintenance access, a switch to select between normal start-up and dedicated diagnostic start-up,

"health checks," looking, for example, at the incidence of soft (disk-read) errors which might later lead to a hard failure. Another advantage of computer-to-computer communication is the ease with which patches can be inserted into an operating system. If a bug is discovered, possibly on just one system, a patch can be made automatically and quickly by BTI's service computers (usually overnight) on *all* Model 5000 installations.

The BTI 5000/ES, introduced in August 1979, is the entry-level system of the BTI 5000 product line. Its base configuration includes a 64K-byte CPU, 10 megabytes of on-line disk storage, a magnetic tape cartridge subsystem for application software backup, and a four-port communications controller/interface. Up to 262 megabytes of disk storage is available for the BTI 5000/ES, along with an additional capacity of 40 megabytes provided by four magnetic tape cartridge drives. A 9-track, 800/1600-bpi, IBM/ANSI-compatible magnetic tape drive is also available for the entry-level system.

BTI 8000

The 8000's operating system creates private virtual machine environments for each process, independent of and isolated from the hardware configuration. Users may therefore develop application programs without reference to the specific system's hardware, and reprogramming is unnecessary as a system is expanded or otherwise changed in configuration.

BTI's Variable Resource Architecture also makes the 8000 fail-soft. In a multi-module configuration, the loss of a processor or memory bank merely reduces the resource pool. The operator removes or replaces the faulty module—identified by built-in diagnostics—and resumes system operation with a one-button restart.

The BTI 8000's bus provides a 32-bit-wide data path and uses distributed logic to achieve a data transfer rate between resource modules of 60 megabytes per second. Up to 16 resource modules can be plugged into the bus. In addition to the CPU, MCU, and PPU modules, the system requires one System Services Unit (SSU), a microprogrammed processor that provides system control.

The SSU includes the system's operator control panel, with pushbuttons for various system operations and a 10-character alphanumeric display. The display informs the operator of normal and exception status conditions and the results of self-test diagnostics. Each resource module automatically runs a self-test at system start-up (bootstrap). On completion of the self-tests, the SSU continues "bootstrap," which, if all modules are operative, configures the operating system. Any module not in working order is identified by the SSU display. The operating system also checks the resource modules present and, if the hardware configuration has been expanded or reduced by the operator since the previous start-up, automatically reconfigures the operating the run/halt switch, and four switches to select from 16 variations of start-up or diagnostic operation.

CONTROL STORAGE: Although the BTI 8000 CPU is microprogrammed, the user cannot modify control storage.

REGISTERS: Eight 32-bit general-purpose registers, a program counter, and a processor status register are available for machine-language programming.

ADDRESSING: Fifty-four addressing modes reference operands in registers, in memory, and instructions themselves. Addressing modes directly support compiler data structures, including stack, queue, and linked-list, with data elements of arbitrary size. Virtual to physical memory address conversion is performed in a one-bus cycle (67 nanoseconds) in parallel with instruction execution.

INSTRUCTION REPERTOIRE: 174 user-mode instructions, each one word long, include fixed-point, floating-point, double-precision floating-point, and Boolean arithmetic; subroutine linkage; character string manipulation, and address mode instructions.

INPUT/OUTPUT CONTROL

I/O CHANNELS: Peripheral Processing Units (PPUs) are special-purpose processors which relieve CPUs of channel management overhead. Each PPU manages up to four independent I/O channel activities initiated by the CPUs, handling data transfers between memory and the peripheral devices. PPUs also provide buffering, blocking and deblocking capabilities. The PPUs' channels can be connected to the controllers of the following peripherals: disk drives, 9-track magnetic tape drives, magnetic tape cartridge drives, line printers with speeds of 300 to 900 lpm, and user communications facilities.

SIMULTANEOUS OPERATIONS: Up to 8 PPUs can be configured to a BTI 8000 system providing an input/output capacity of 32 channels. All peripheral devices interfaced to the respective number of channels provided by the PPUs can be active simultaneously accommodating multi-tasking operations.

CONFIGURATION RULES

Maximum configuration parameters for the BTI 8000 are as follows:

- **Up to 16M bytes of main memory,**
- **Up to 8 billion bytes of on-line disk storage,**
- **Up to 32 channels for peripheral devices, and**
- **Up to 200 active ports for terminals and modems.**

The 8000 is completely modular in configuration and is designed around a Variable Resource Architecture bus with a 32-bit-wide data path and 16 slots for the attachment of major modules in priority order. At least one each of the four major modules (System Services Unit, Computational Processing Unit, Memory Control Unit, and Peripheral Processing Unit) must be included. Only one System Services Unit is necessary, but multiples of the other three may be attached as needed to increase memory size, to add peripherals, or to increase computational power.

WORKSTATIONS: Virtually any terminal with a standard RS-232-C interface can be used with the BTI 8000 system. Any modems with facilities for the RS-232-C interface can be used for remote applications. The BTI 8000 is capable of supporting up to 200 interactive users.

system to match the resources available. The SSU contains a program-accessible system ID, a permanently assigned number which identifies the system in which the SSU is installed, which permits vendors of proprietary software packages control of which systems can run their packages by checking the system ID before executing.

The Computational Processing Unit is a microprogrammed processor which uses 32-bit architecture throughout. Integer arithmetic is 32 or 64 bits; floating-point arithmetic is 64 bits. Fifty-four addressing modes directly support compiler data structures, including stack, queue, array, and linked-list structures, with arbitrary size data elements. System computation is performed by one or more Computational Processing Units, operating concurrently. To gain more computational power, additional CPUs are plugged into the bus. The operating system software assigns tasks equally among available CPUs to achieve true concurrent processing. As an indication of the CPUs' speed, a fully-configured, multiple-CPU system performs floating-point multiplication with 64-bit operands in an average time of approximately three microseconds. Hardware address mapping in the CPU converts virtual memory addresses to physical memory addresses in parallel with instruction execution.

The 8000 uses semiconductor memory with ECC and features a 670-nanosecond full cycle time (including Memory Control Unit operation). Read access time is under 400 nanoseconds. Memory is furnished in 512K-byte increments and is interfaced to the system via the MCUs. Minimum memory is 512K bytes, and the system will support up to 16M bytes of main memory. All memory present is treated by the system as an entity (even if interfaced through more than one MCU) organized in pages of 4096 bytes. In the event of a memory malfunction, the system eliminates the bad area on a page basis and reconfigures the available memory.

Mass storage for the BTI 8000 is provided by disk drives in formatted capacities of 67 and 254 megabytes. All drives use high-density, removable storage modules (packs). One disk controller can control up to four drives in any mix and can provide for overlapping seeks to minimize access times. A special error-correction technique substantially reduces the risk of data loss in the event of disk read problems. Mass storage data transfers take place one page at a time, and each page occupies one "block" of disk capacity. Blocks are stored on disk in a number of segments in such a way that an entire block can be reconstructed even if a segment becomes totally unreadable. The system "remembers" bad areas and dynamically reassigns block placements to work around them.

All system peripherals, including disk drives, are controlled by device controllers. Each Peripheral Processing Unit can support up to four controllers. Peripherals currently available for the 8000 include serial magnetic

MEMORY: Each Memory Control Unit supports up to 4M bytes of memory in units of 512K bytes. Memory connected to a given MCU must be of one type, but different MCUs can control different types of memory as BTI makes future memory offerings available.

DISK STORAGE: The Model 8205 disk controller used in the BTI 8000 supports up to four 67- or 254-megabyte disk drives.

MAGNETIC TAPE UNITS: A 9-track, 800/1600-bpi, 45-ips, reel-to-reel magnetic tape drive and a high-density cartridge tape unit can be configured to the BTI 8000 for loading and dumping data files and programs.

MASS STORAGE

67- AND 254-MEGABYTE DISK DRIVES: One 8205 disk controller supports up to four 8215 or 8225 disk drives in any mix, with overlapped seeks. Disk drives are storage module type. Access times are identical for all sizes. The average seek time is 30 milliseconds, and the average rotational delay is 8.3 milliseconds. The data transfer rate is 1.2 million bytes per second, and transfers to and from memory occur one full page (4096 bytes) at a time.

INPUT/OUTPUT UNITS

See the PERIPHERALS/TERMINALS table on M11-089-203.

COMMUNICATIONS CONTROL

The BTI 8000, in its largest configuration, can support a practical limit of 200 interactive users.

8510 ASYNCHRONOUS COMMUNICATIONS CONTROLLER (ACC): Supports up to eight 8515 8-port (RS-232-C) interfaces for a maximum configuration of 64 ports. One Peripheral Processing Unit can control four ACCs (a total of 256 ports per PPU). Data rates can be set individually to any standard rate from 110 to 19,200 bps. The ACC includes internal buffering to accommodate full-screen (1920 characters), interactive terminals.

SOFTWARE

OPERATING SYSTEM: The BTI 8000 operating system pools and coordinates physical machine resources, including processors, to provide a secure environment for each user of the system. The operating system shields all users from actual hardware configurations, creating a virtual machine for each user process, and is itself protected from violation by user processes. It is also responsible for automating as much of the system operation as possible.

When the system is started, either from the operator's panel or through the remote maintenance facility, the System Services Unit sends a start signal through the bus, causing all units to run self-contained diagnostics. Upon successful completion of this stage of system start, the first Computational Processing Unit to become ready temporarily takes over the system. It locks out other CPUs so that it can control system initialization, reads resident operating system code from a known location on the system disk volume into the low pages of physical memory, and then executes that code. This is the only circumstance in which one CPU assumes control of the system to the exclusion of other CPUs.

When the other CPUs are unlocked, the system immediately enters its normal run mode. At the start, there are no users on the system (assuming a cold start), and all CPUs run that portion of the operating system code (from a fixed physical memory location) which investigates a task assign-

tape cartridge drives, 9-track open-reel magnetic tape drives, and three line printers with print rates of from 300 to 900 lines per minute.

Terminals and modems are interfaced to the 8000 through an Asynchronous Communications Controller (ACC), which is in turn controlled through a PPU channel. One PPU can control up to four ACCs, and each ACC can control up to 64 ports in increments of 8 ports. BTI considers a practical maximum for the 8000 to be 200 ports. Any or all ports can be used at rates up to 19,200 bps. To allow users flexibility in the type of asynchronous terminal or other asynchronous device to be used with the system, user programs have full control over interface pins, selection of terminating characters, and input and output buffers. BTI now offers four models of CRT terminals and one printer terminal model as options.

The 8000's operating system provides private virtual machine environments in which the system manager, operator, and all other users operate. The virtual system shields all users from the actual hardware present in any given configuration. Any program will execute regardless of the number of CPUs, amount of physical memory, or even the specific peripherals connected to the system. The user can make I/O assignments externally to his program to suit his convenience. The operating system is protected to ensure inviolate system operation despite any possibly harmful activities attempted by any user process or the system operator. Each user program runs in a virtual work space of 512K bytes regardless of the actual amount of physical memory present or the number of other users sharing that memory. The operating system itself uses address space separate from the user's work space for all I/O services associated with the user's process.

Memory is organized in pages of 4096 bytes, all of which is available to the programmer. Real memory is dynamically allocated to users' processes on a demand-paged basis in a manner transparent to users. User processes can generate other concurrent processes to handle heavy work loads in parallel.

Software emphasis is on the commercial DP market stressing data protection and on-line terminal access. Software bundled with the system includes the operating system, Control Mode (the system's command language), and the following utilities: copy, sort/merge, help, loader, spooler, backup/recovery, operator/manager, interactive editor, debugger, plus one programming language. Sequential, relative and multi-keyed indexed sequential file access methods are supported. A file utility package (futil) is also provided as part of the bundled software. Languages offered by BTI include COBOL 74, FORTRAN 77, PASCAL/8000, and BASIC/8000.□

ment table elsewhere in memory; at this point there will be no tasks, so all CPUs will go idle. When a device (particularly a communications controller) signals the beginning of what might be a user log-on activity, the associated Peripheral Processing Unit places an interrupt signal on the bus. The first CPU to respond will handle the interrupt and post to the appropriate operating system tables.

In the steady state of system operation, when there are more processes than processors, each CPU requests an interrupt from the SSU (in varying intervals) after it "switches in" to any task to see if another task should be executed. Periodic interruption to run the operating system's task dispatching code does not require full context switching.

The memory tables used to direct and coordinate the activities of multiple CPUs are read and updated using software lockout. The lockout algorithms and the CPU instructions used to implement them are the same as those that the non-operating system software can use to coordinate any set of cooperating simultaneous processes. A given memory location is chosen by mutual agreement to contain a "lock" word. Before proceeding through a critical region of code to be entered and executed completely by only one process at a time, the process executes a non-interruptible instruction that sets a special locked value into the public lock word while simultaneously bringing the previous value of that word into private storage for examination. If the retrieved value is other than locked, the process continues through the critical region, unlocking it when done. If, on the other hand, the retrieved value is locked, then the process waits, since this indicates that some other process has entered the critical region.

Even though memory modules can be physically interfaced through separate Memory Control Units, the system treats all of memory as a single continuous resource. The low n+9 pages ("n" is the number of resident CPUs) are unavailable for paging, since they contain resident operating system code and tables. The rest of memory is used on a page basis for temporary location of code and data transferred in from mass storage, with no pre-assigned boundaries or regions.

When a routine executing in a CPU instructs a PPU to transfer a page into memory from mass storage, the PPU is given two memory addresses. One is the location of the page itself; the other is the address of an operating system table element for storage of the structural information included in every mass storage block. In this way, programs can make use of the full 1024 words in every page, since pointers, flags, and other maintenance information are kept externally to the page contents. A similar procedure is used to write to disk.

The operating system keeps track of the logical status of all pages in memory, including their "home" addresses on mass storage. If a user requests execution of a program, the operating system will search its lists before executing a disk-read request and will take advantage of memory residency of any of the program pages to avoid disk access; any number of users can share any number of pages. This list searching takes place with every page-read request, including those for file data blocks.

Access control flags associated with each page indicate whether the page is read-only or writable, and, if writable, whether it has been altered during its residency. This information allows pages of writable program data or file data to be shared among multiple users. They will share the same physical memory page initially, but the operating system will create a private copy of a shared writable page for any process that issues an instruction that would alter the page contents.

The access control and status flags, including a "page referenced" flag, are carried into the page files of the CPUs, so that the system need not make an extra memory

reference merely to update or examine them. The page referenced flag is used to identify the working set of a process as it executes, for scheduling purposes.

The system is disk-based in the sense that structural information and operating parameters are ultimately entrusted to mass storage. Main memory is treated as a temporary area for process operation, with any structured or parameter changes written to disk. System restart presumes no information in memory. Thus the main concern in mass storage management is maintaining the integrity of its structures.

Disk drives, disk modules, and disk volumes (the logical contents of packs) are all identified separately, so that, for example, volumes can be copied from module to module. Files and libraries of files reside on individual mass storage volumes, so that volumes may be dismounted either logically or physically without halting system operation or destroying the integrity of structures. The system volume, containing the operating system's operational tables and routines as well as other data, cannot be dismounted, but can be located on any physical disk drive in the system.

Internal system tables that are critical to operation or to the use of an entire volume are recorded redundantly in the interests of protecting operations and data. During a structural update, the more junior table is created first and removed last. Even relatively complex structures are handled in a crash-resistant manner by using the worst-case technique of creating an entirely new structure containing the new information and a copy of any previous information to be retained, updating the block that points to it, and finally freeing the old structure space.

Since the purpose of the BTI 8000 is to support many simultaneous processes, it is properly described as a multitasking system as well as a multiprocessor system. A "process" is the distinct invocation or separate execution of a program. Each process on the system is usually, but not always, associated one-for-one with an on-line interactive user. An interactive user process may generate other concurrent processes. Programs executed from batch queues are processes, and invocations of the operating system's routines are also processes.

The operating system creates a basically private, but identical, virtual machine for each process; one of its aspects is the process address space, or virtual memory. Any and every program on the BTI 8000 may be written to address a continuous virtual memory of 128 pages (512K bytes) as if it were the only program executing on a private computer with that much physical memory. The operating system creates and maintains the correspondence between each page of every process' virtual memory and some page in physical memory; this is what is loaded into a CPU's page file when a CPU runs a process.

Processes on the BTI 8000 may be running in some CPU, runnable, but waiting for a CPU to become available, or waiting for some other resource, including a page of virtual memory which is not yet resident in physical memory. Every process has all of its required virtual pages represented on blocks of a mass storage volume, but normally not all of them will be represented in physical main memory. When a running process references a virtual page that is not resident, as indicated by the page file, the process becomes suspended and the operating system assumes the responsibility of loading the page from mass storage into some page of physical main memory.

Three characteristics of this technique should be noted. First, the pages of a given process may be placed anywhere in paged memory. Second, a memory page that the operating system chooses to overlay with a new page will not first be written back to disk if it has not been altered since it was loaded in from disk. Third, frequently referenced pages, including pages referenced by more than one process, tend to remain resident, since the operating system's replacement algorithm tries to minimize disk access.

Demand-paging systems normally operate with a least-recently-used replacement algorithm; that is, the page chosen for overlaying is that which has "aged" the longest since being referenced by any process. This algorithm is entirely reasonable with a moderate load on a system, but invites "thrashing" when the load grows too large. The pages used by a given process during a specified period of time are its working set for that period. In a demand-paging system, the relationship between the total pages required to hold all active working sets and the total number of memory pages available determines the amount of disk activity on the system. As the page load grows, disk transfers become more frequent until all processes are reduced to their minimum working sets, below which they are incapable of executing any instructions without demanding a new page. Thereafter, any increase in load causes the system to spend almost all of its time in disk transfers. At this point, essentially no work is performed. The BTI 8000 modifies the conventional demand-paging alogrithm to prevent thrashing. When a demand occurs, the operating system selects the "least valuable process," based on a number of criteria, including the distinction between interactive and batch processes, and strips this process of the least recently used page of its working set, overlaying that memory page with the one demanded. As the overall load grows, this procedure is repeated until all processes are reduced to working sets close to minimum. At this stage, prior to the thrash point, the operating system identifies the process that is the most critical "troublemaker"—normally the one with the largest current working set. It then suspends this process for a certain period of time, rolling out its entire working set to free up memory for the rest of the load. The BTI 8000 process management algorithm avoids thrashing by making a dynamic transition from demand-paging to a modified multiprogramming technique.

There are no preset, conventional priorities in this scheduling technique, although the system operator can modify certain scheduling parameters (e.g., to favor batch processing). The operating system automatically favors processes that are currently interactive on the assumption that a user at a terminal requires service as soon as possible after entering a message. Processes that are not currently interactive can relinquish their demands for system resources, including CPU's, in favor of interactive processes, although a "fairness" algorithm ensures that batch processes are not totally locked out of execution. Process scheduling operates with dynamic priorities according to the recent behavior and current characteristics of the processes. On a heavily loaded system, with all other considerations equal, the most efficiently written programs—those with compact working sets—will be favored for execution over potential troublemakers.

LANGUAGES: The BTI 8000 supports four programming languages: COBOL 74, FORTRAN 77, PASCAL/8000, and BASIC/8000. All four have the following concepts in common:

- Program development may occur in an interactive mode. Programs may be written, compiled, and linked from a terminal, and test files can be defined, built, and dumped from a terminal. Programs can be tested at a terminal with the aid of an interactive, symbolic level debugging facility.
- All languages support terminals as standard I/O devices. A terminal can be accessed by the operating system without special telecommunications software.

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BTI 8000 COBOL is a high intermediate implementation of the 2 ANSI COBOL X.3.23-1974 standard. An interactive Debug replaces the standard Debug module. It also includes full indexed I/O support, transaction handling and an extended *Accept* and *Display* for terminal handling.

BTI 8000 FORTRAN is a full implementation of FORTRAN 77, ANSI standard FORTRAN X3.9-78. This language allows the programmer to concentrate on the algorithm instead of its implementation. Support of upper/lower case symbolic data names is one of the language's features. Debugging statements (identified by a "D" in column 1) can be included in the compilation or interpreted as remarks, depending upon a selected compiler option. A fully interactive debugging facility aids in program test and verification.

BTI 8000 FORTRAN places the full power of the operating system in the hands of the programmer through the use of extended I/O facilities. Files may be created, attached, interrogated, and destroyed under program control using the OPEN, CLOSE, and INQUIRE statements. Data transfer to and from files may be formatted, unformatted, or list-directed. Files may be direct access or sequential and may contain variable length records. In addition, data may be transferred to and from character strings by using statements which are similar to regular I/O statements. Character strings may be concatenated and assigned to variables. Strings may be compared with other strings. Substrings may be extracted with a convenient subscript-like notation. Numeric data types (Real, Integer, and Complex) have over 15 digits of significance; Double Precision Real supports 34 digits of significance. Variables of any type may be subscripted, and an array may have up to seven dimensions with no restrictions on upper and lower bounds.

BTI 8000 FORTRAN extends the ANSI FORTRAN-77 standard with the following features:

- Debugging statements can be easily eliminated for compilation of production program version.
- Array subscript and computed GO TO expressions of real, double precision, or integer type.
- Interactive debug support.
- Symbolic names, 1 to 30 characters in length, in upper and lower case.
- Subexpression optimization.
- Variable length record I/O support.

BTI 8000 PASCAL/8000 includes all the features of standard PASCAL, and is a valid superset of standard PASCAL. The BTI 8000 PASCAL/8000 adds the following features to standard PASCAL:

- Full support for string data type,
- Loop state allows the user to accomplish repetition and decision in the same statement,
- Support of multi-keyed indexed sequential and relative file access methods,
- Case labels arranged in ranges,
- Compile-time expression evaluation for "CONST" declarations,
- Spawning and management of concurrent processes and generation and control of underprograms, and
- An interprocess communication capability.

BTI BASIC/8000 is an extended version of Dartmouth BASIC designed for creating, compiling, executing, and debugging programs. Important features offered by the extensions include improved file handling, string handling, and subrouting. The BASIC/8000 programming language includes the following:

- Function calls as a series of statements,
- String arrays,
- String handling,
- Subprogram calls with arguments,
- Variable names to 30 characters,
- Support of multi-keyed indexed sequential and relative files, and
- Interactive debugging.

APPLICATION SOFTWARE: BTI does not generate applications software, but assists in the marketing of selected user-generated packages. A unique feature of the BTI operating system permits applications software to be installed on a system where it may be used in the execute-only mode by the system owner. It can, however, be accessed for updates and maintenance by the software vendor through a special "proprietary software account." Under this feature, the system owner and users are permitted access to the program and to all system management privileges except the proprietary source code. The vendor, however, given telephone access to his proprietary software, can update and correct the package without the need of sending copies or interrupting users.

PRICING

POLICY: BTI offers the 8000 system on a purchase-only basis. The base system configuration is complete and includes the operating system, Control Mode, the utilities package, a file system, and one programming language. BTI warrants all hardware for 90 days. Software is licensed for use on one system, but discounts are offered for multiple installations by one customer. BTI-furnished software is maintained free for one year, and continuing maintenance is available on a yearly contract basis. Upgrades of BTI software are offered for a nominal handling fee to customers using the existing software.

SUPPORT: BTI features a unique customer-participation service and support system that combines human resources and hardware features of the 8000 system. The 8000 contains integrated maintenance aids for automatic fault diagnosis by a remote computer located at BTI's factory service center. BTI customer engineers can gain access to the operating system through a user port and exercise various system components. Customer cooperation, in the form of a person standing by the system to perform specified actions, may be required to aid the BTI engineer in testing and evaluating a failed system. The customer's responsibility to provide such assistance is noted in BTI's corrective maintenance contract.

Under the contract terms, BTI furnishes both parts and labor to correct all failures and to provide 7-day, 24-hour telephone service. Replacement parts are shipped from the factory by air freight, scheduled airline, or package express service to users, who replace them and return the failed

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parts. A BTI systems engineer is dispatched from Sunnyvale to any site where telephone consulting and testing cannot correct the malfunction.

BTI Corrective Maintenance Plan charges are based on the hardware configuration. Typical monthly charges covering both preventive and corrective maintenance are less than 1 percent of the purchase price.

System purchase prices include training by BTI personnel. Training includes both operation and maintenance procedures.■

EQUIPMENT PRICES

		Purchase Price	Monthly Maintenance
BASE SYSTEM			
8000	Includes Computational Processing Unit, Memory Control Unit, 512K bytes of memory, Peripheral Processing Unit, 67M-byte disk drive and controller, 10M-byte magnetic tape cartridge drive and controller, asynchronous communications controller, 8-port interface, System Services Unit, double-bay system cabinet with bus backplane, operator control panel, and system power supply	$107,000	$827
SYSTEM RESOURCE MODULES			
8110	Computational Processing Unit (CPU)	16,000	96
8130	Memory Control Unit (MCU)	5,000	30
8170	Peripheral Processing Unit (PPU)	8,000	48
8190	System Services Unit (SSU)	5,000	30
MEMORY			
8142	Memory module, 512K bytes of semiconductor memory	16,000	120
8144	Memory module, 1M bytes of semiconductor memory	28,000	210
8154	Memory power supply, supports up to 2M bytes of one MCU	7,500	56
MASS STORAGE			
8205	Disk controller for up to four 8215, 8225 disk drives (in any combination)	10,000	60
8215	67M-byte disk drive with one removable disk pack	13,500	135
8225	254M-byte disk drive with one removable disk pack	30,000	300
MAGNETIC TAPE EQUIPMENT			
8305	Magnetic tape controller for up to four 8310 or 8315 magnetic tape cartridge drives	4,000	22
8310	Single magnetic tape cartridge drive and housing with one magnetic tape cartridge (supports up to three additional 8315 drive units)	3,000	38
8315	Additional magnetic tape cartridge drives, installs in 8310 unit (up to three additional units can be installed)	2,500	30
8320	Magnetic tape controller for up to four 8330 drives	5,000	50
8330	9-track, reel-to-reel magnetic tape drive, 800/1600 bpi	9,000	120
TERMINALS			
1410	CRT terminal, 80 characters x 24 lines, 5x7 character matrix, 64 displayable characters, TTY-style keyboard with numeric keypad, transmission rates to 19.2K bps	900	—
1420	CRT terminal, 80 characters x 24 lines, 5x8 character matrix, 94 displayable characters (including lower case), dual intensity, typewriter-style keyboard with numeric keypad, transmission rates to 19.2K bps	995	—
1500	CRT terminal, 80 characters x 24 lines, 7x10 character matrix, 94 displayable characters, dual intensity and reverse video, ANSI standard keyboard with numeric keypad, serial printer interface, transmission rates to 19.2K bps	1,225	—
1510	CRT terminal, 80 characters x 24 lines, 7x10 character matrix, 94 displayable characters, dual intensity, reverse video, screen protect and block transmission, ANSI standard keyboard with numeric keypad, serial printer interface, transmission rates to 19.2K bps	1,395	—
1800	Printing terminal, 9x7 character matrix, 132 columns, 150-cps impact printer, full ASCII 128-character keyboard, transmission rates from 110 to 9600 bps	2,395	—
PRINTERS			
8415	Line printer controller for 8420, 8425, 8430 printers	5,000	30
8420	Line printer, 300 lpm	10,000	125
8425	Line printer, 600 lpm	13,000	163
8430	Line printer, 900 lpm (includes quietized cabinet)	18,700	234
8435	96-character set for 8420, 8425, 8430 printers	1,500	—
8440	Quietized cabinet for 8420 or 8425 printers	800	—
COMMUNICATIONS			
8510	Asynchronous communications controller, supports up to eight 8515 8-port interfaces	8,000	48
8515	8-port interface, EIA RS-232-C, at rates to 19.2K bps	2,000	12
ACCESSORIES			
8815	Cabinet extension (extends 8810 cabinet to a triple-bay configuration)	2,000	—
8816	Side cover	800	—
8850	System power supply (one included in 8810 cabinet furnished with base system)	3,000	30

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SOFTWARE PRICES

		License Fee*
8910	PASCAL/8000, on cartridge tape	$5,000
8911	PASCAL/8000, on reel-to-reel tape	5,000
8920	ANS 77 FORTRAN, on cartridge tape	5,000
8921	ANS 77 FORTRAN, on reel-to-reel tape	5,000
8930	BASIC/8000, on cartridge tape	5,000
8931	BASIC/8000, on reel-to-reel tape	5,000
8940	ANS 74 COBOL, on cartridge tape	5,000
8941	ANS 74 COBOL, on reel-to-reel tape	5,000

**Discounts are offered for multiple installations by one customer.*