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The HP 3000 is Hewlett-Packard's most powerful business computer product line. At the top of the line is the HP 3000 Series III, a step ahead of its predecessor, the Series II. Under control of the advanced MPE-III Multiprogramming Executive operating system (an operating system is the master program that gives a computer its basic personality), the Series II/III can run multiple concurrent application programs written in six high-level languages and handle up to 64 user terminals. These systems offer on-line transaction processing, data base management with HP's IMAGE software, virtual memory, and networking capability.

However, this issue isn't about the Series II/III. Most of it is about a brand-new HP 3000 Computer System, the Series 33, that costs only about half as much as its big brothers. It's a real HP 3000 that runs under the same MPE-III operating system and will run the same application programs as the Series II/III (except those written in the APL language). It'll handle up to 32 terminals and large computer peripherals like those shown on the cover—tape drives, large-capacity disc memories, and line printers. On the other hand, it doesn't have networking capability and isn't quite as fast as the larger HP 3000s.

The main reason we can offer an HP 3000 at the System 33's low price is an advance in technology, HP's silicon-on-sapphire integrated circuit process. Most of the Series 33's central processing unit is on three SOS chips, the same three chips, in fact, that made the new HP 300 Computer possible (see our recent June and July issues). The chips are wired differently to run the different HP 300 and HP 3000 operating systems.

Also in this issue is an article on HP's automated pulmonary function test system (page 20). The main contribution of this system is its desktop computer. By controlling all valving, measuring, computing, printing, and plotting, checking the hardware, and cueing the operator, the computer greatly reduces the chances of error in lung-function measurements and gives the operator more time to concentrate on the patient.

The article on page 25 describes a new option for one of HP's storage oscilloscopes. Usually an oscilloscope is used to show how some changing voltage (Y) varies as a function of time (X), and there are built-in facilities to select the time window that the user wants to look at. The new option gives the user a similar select-the-window capability when another voltage, rather than time, is the X-axis variable.

-R. P. Dolan

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SOS Technology Yields Low-Cost HP 3000 Computer System

The new Series 33 is software compatible with the Series II and Series III, HP's most powerful computer systems. Thanks to silicon-on-sapphire technology, its cost is surprisingly low for HP 3000 performance.

by Richard C. Edwards

HEWLETT-PACKARD'S new HP 3000 Series 33, Fig. 1, is a powerful, multiple-terminal, interactive business data processing system designed for use as an organization's complete EDP system. The HP 3000 Series 33 is the first application of HP's silicon-on-sapphire (SOS) technology to the top of the HP computer systems product line. The use of three proprietary large-scale-integrated SOS chips enabled the system designers to produce the HP 3000 CPU (central processing unit) on two printed circuit boards, a major reduction from the nine boards in the HP 3000 Series II/III. A new desk-sized mainframe package was made possible because of the SOS circuits' low power consumption, low heat dissipation, and small size.

Since the HP 3000 was first introduced in 1972, more advanced HP 3000 systems (HP 3000CX, Series II, Series III) have been introduced with successively higher performance. In contrast, the main design objective for the Series 33 was to deliver HP 3000 performance at a greatly reduced price. Fig. 2 illustrates price/performance curves for the HP 3000 for the past five years. The computer industry in general has been able to deliver either more performance at the same price or the same performance for a lower price each year (in contrast with the persistent inflation in the world economy over the past few years). At Hewlett-Packard we have been able to deliver equivalent HP 3000 performance at a price approximately 25% less each year for the past five years. The Series 33 accelerates this trend in the direction of greatly lowered price, yet this entry-level HP 3000 has many of the features of its larger relatives and is software compatible with them.

Like other HP 3000 Systems, the Series 33 runs under the Multiprogramming Executive (MPE III) operating system, including the recent additions of a new, friendlier user interface and private disc volumes. A new, easy-to-use data entry subsystem, VIEW/3000, is supported on both the HP 3000 Series 33 and the HP 3000 Series II/III.

All non-privileged HP 3000 Series II and Series III programs—both source code and object code—written in COBOL, RPG, BASIC, FORTRAN, or SPL will run without any modification on the new HP 3000 Series 33. The Series 33 runs all HP 3000 Series II/III software subsystems except APL/3000 and the data communications subsystems (DS/3000, RJE/3000, MRJE/3000, and MTS/3000), which are not offered on the Series 33.

The basic HP 3000 Series 33 consists of a central processing unit (CPU), cartridge disc storage of 20 megabytes, a double-sided flexible disc drive with a capacity of 1.2 megabytes, and a microprocessor-based system console/maintenance console. It also includes 262,144 bytes of fault

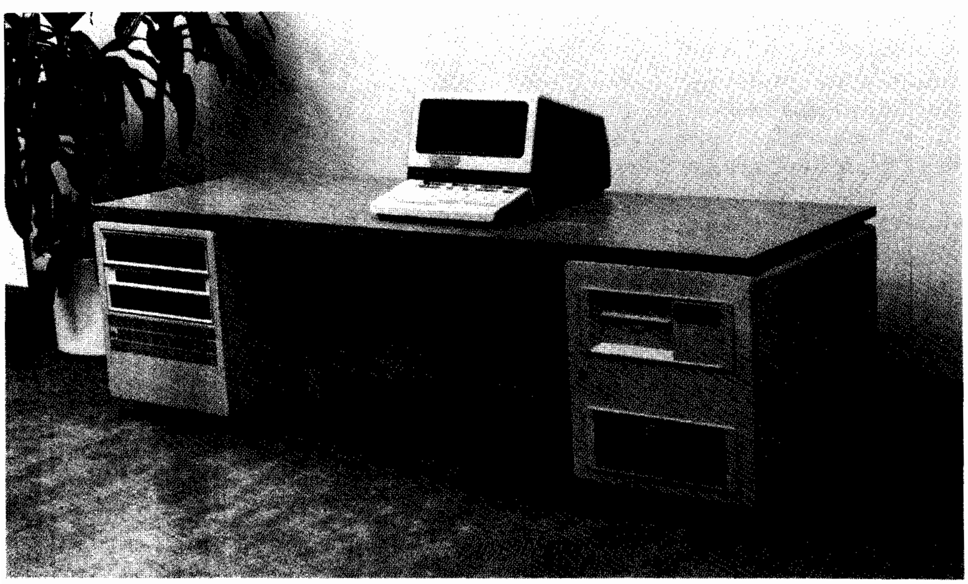

Fig. 1. *HP 3000 Series 33 Computer System. Base model includes a 20M-byte cartridge disc drive, 256K bytes of fault-control memory, seven ports for 2400-baud asynchronous terminals, two general I/O channels, and a one-megabyte double-sided flexible disc drive. The Series 33 runs the same Multiprogramming Executive operating system (MPE III) as the more powerful HP 3000 Series II and Series III systems, and will execute Series II and Series III application programs without changes or recompilations.*

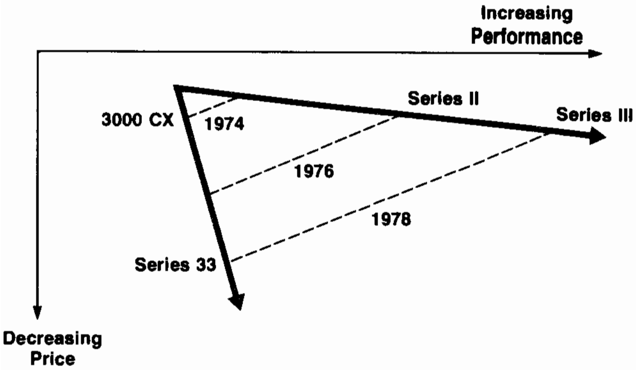

Fig. 2. *HP 3000 Computer systems have steadily increased in computing power and decreased in price. Series 33 is designed to deliver HP 3000 performance at a dramatic reduction in price.*

control main memory, two general I/O channels, and two asynchronous data communications controllers (one main, one extender) for connecting the hardwired system console and up to seven asynchronous terminals (hardwired or connected through modems). Remote diagnostic capability is also standard.

The basic HP 3000/33 can be expanded at the factory or in the field up to 1,024,000 bytes of fault control main memory, 960 megabytes of disc storage, three general I/O channels, and eight asynchronous data communications controllers that support up to four terminals each.

A Series 33 can support up to two line printers, either HP 2631A serial printers or HP 2608A line printers or both. Up to four 1600-bpi magnetic tape drives can also be attached.

The HP 3000/33 supports all CRT terminals in Hewlett-Packard's 2620 and 2640 families, including the HP 2647A and HP 2648A Graphics Terminals with automatic plotting of columnar data. Also supported is the HP 2635A printing terminal. Each terminal operator independently has full access to all system resources. Data entry, data base updates and retrievals, interactive program development, data communications, and batch programs can all be supported simultaneously on the system.

Design Objectives

In addition to the main objective of delivering HP 3000 performance at a greatly reduced price, several other design objectives were set at the beginning of the Series 33 project. These included:

- Complete MPE (operating system) compatibility with Series II/III
- Complete user application software compatibility with Series II/III
- Incorporation of the new HP I/O interface based on ANSI/IEEE standard 488-1978, known as the HP-IB (Hewlett-Packard Interface Bus)
- Designing the system to be friendly and easy to use.

CPU Hardware

HP's complementary-metal-oxide-semiconductor silicon-on-sapphire (CMOS/SOS) process,[1] developed as a large-scale integrated circuit technology, was chosen for the CPU design. The benefits of using the CMOS/SOS process for the HP 3000 CPU included:

- Small CPU size. The equivalent functions in a Series III CPU occupying 4500 square centimetres are reduced to less than seven square centimetres on the Series 33 three-chip CPU set (see Fig. 3).
- High-speed circuits. The system clock period is 90 nanoseconds.
- Low power consumption. The three CPU chips with approximately 25,000 transistors consume only one watt.
- Lower cost, the combined result of small size, low power consumption, and good manufacturing yields.
- Very high component reliability.

The three CMOS/SOS chips used in the Series 33 CPU are the same chips that are used in the CPU of the HP 300, another new HP computer system.[2,3] In the HP 3000 Series 33, one pin of each chip is wired to a different voltage than in the HP 300, and the microprograms executed by the CPU are different.

Operating System

MPE III, Hewlett-Packard's Multiprogramming Executive operating system for the HP 3000 product line, is a general-purpose, disc-based operating system that makes possible concurrent execution of many programs (transaction processing, timesharing, and batch) in a multilingual environment. MPE III virtual memory provides a total memory space that far exceeds the maximum main memory of one megabyte on the HP 3000/33. MPE provides these major capabilities on the HP 3000 Series 33:

- Multiprogramming: concurrent transaction processing, timesharing, and batch processing
- Virtual memory
- Stack architecture: separation of code and data, variable length segmentation, data stacks
- Concurrent multilingual capability: COBOL, RPG,

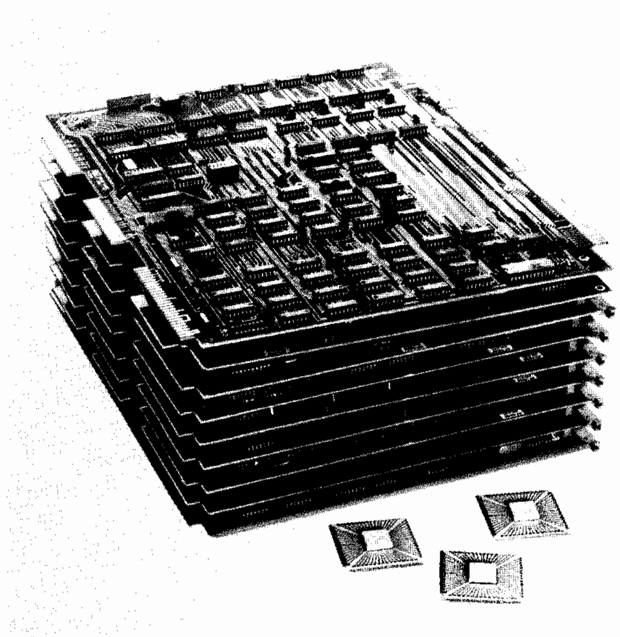

Fig. 3. *Silicon-on-sapphire technology makes the Series 33 possible, reducing 4500 cm^2 of HP 3000 components on portions of nine circuit boards to the three SOS chips in the foreground.*

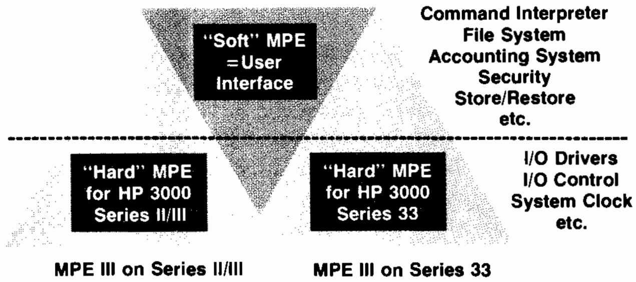

Fig. 4. *Series 33 architecture differs from that of Series II and Series III. The MPE III operating system was divided into machine-dependent (hard) and machine-independent (soft) parts, and only hard MPE was modified, so all HP 3000 systems under MPE III have an identical user interface and compatible software.*

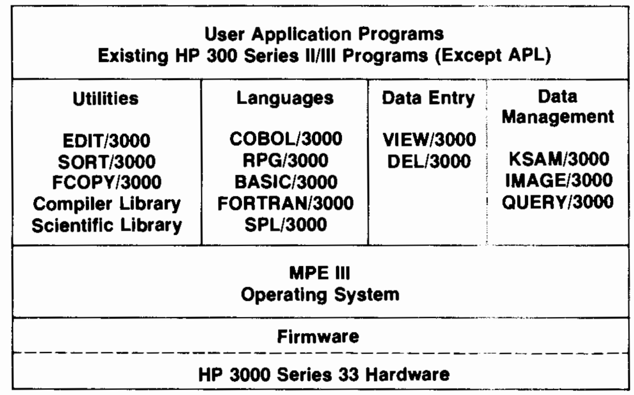

Fig. 5. *User application programs written for the Series 33 can use all HP 3000 utilities, languages, data entry facilities, and data management software except APL.*

BASIC, FORTRAN, and SPL

- A uniform, device-independent and language-independent file system with file backup and security
- System security and complete accounting of resources
- Dynamic resource control
- Friendly but powerful command language, including user-defined commands, conditional job control, on-line HELP facility, and meaningful error messages
- Device and file independence
- Input/output conveniences: spooling of input and output, private disc volumes, magnetic tape labels
- Complete and automatic terminal management, local and remote
- Automatic scheduling (under the control of the installation's management)
- System tailoring (under the control of the installation's management)
- Power-fail/auto-restart.

Because the Series 33's hardware, especially the CPU, is related more closely to the HP 300 than to other HP 3000 systems, changes had to be made to be able to run the Series 33 under MPE. MPE was divided into two sections, one that was hardware dependent, that is, unique to Series 33 or Series III, and one that was not hardware dependent, that is, identical for both Series 33 and Series III. We call these "hard" MPE and "soft" MPE, respectively (Fig. 4). The non-hardware-dependent section (soft MPE) is the user interface known as MPE III. This division enabled our designers to change only those sections that were affected by changing to the common HP 300 and HP 3000/33 hardware. The major sections changed were the input/output drivers

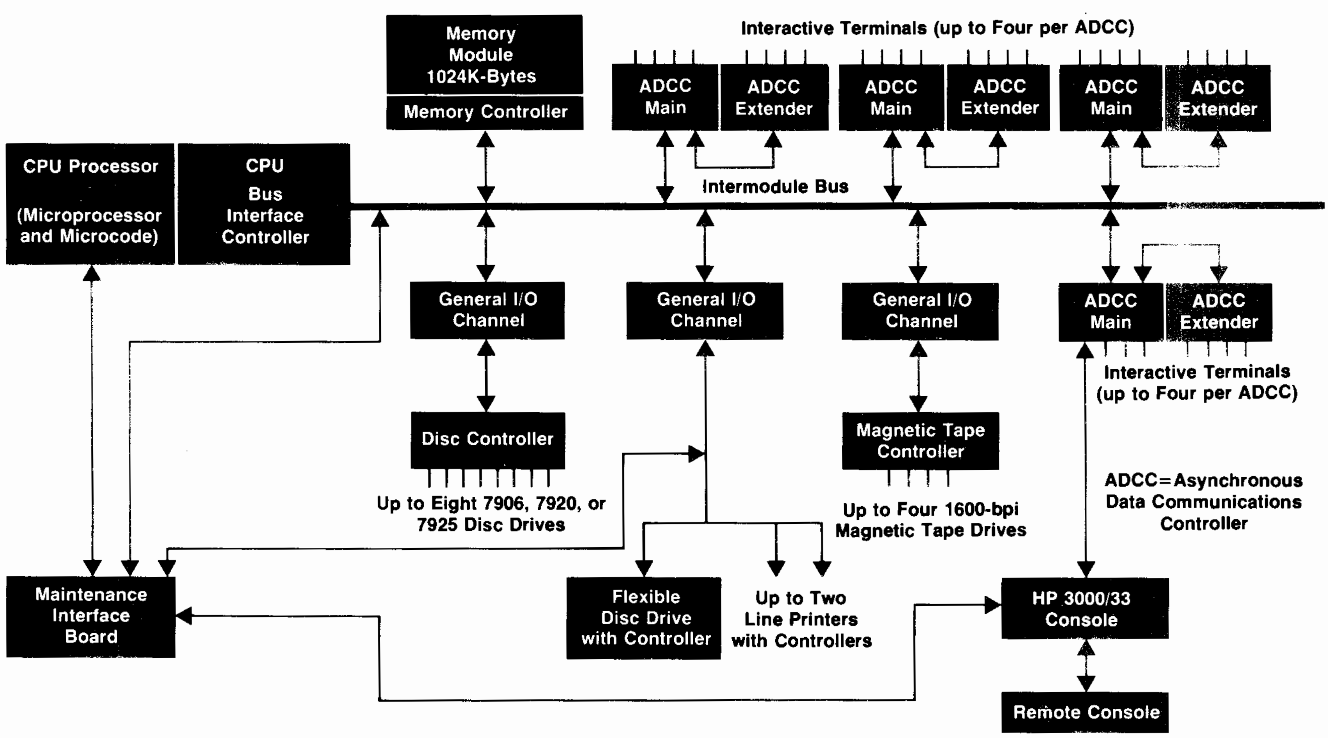

Fig. 6. *HP 3000 Series 33 maximium configuration block diagram. The general I/O channels use HP-IB (ANSI/IEEE 488-1978) protocol.*

for peripherals and the system clock. This amounted to about 15-20% of MPE.

The article on page 7 explains in greater detail how the changes in system microcode and hard MPE allowed the Series 33 to meet its design objective of MPE compatibility and complete user application software compatibility with HP 3000 Series II and III (see Fig. 5).

Architecture

Because it uses the HP 300 CPU chip set, the Series 33's architecture is markedly different from other HP 3000 systems. The HP 3000 Series 33 is designed around independent elements that are connected by a central bus structure (see Fig. 6). The elements of the system consist of a central processor that operates through a bus interface controller, memory arrays with a memory controller, general I/O channels, asynchronous data communications channels, and a bus system for communication between the I/O elements. Also, the system includes a system console, a system front panel, and a maintenance facility. Peripheral elements attach to the system through the general I/O channels. Interactive terminals attach to the system through the asynchronous data communications controllers.

When an I/O request is issued, the device driver in the CPU assembles the channel program, then issues a start I/O program (SIOP) instruction to one of two types of channels on the intermodule bus. These are the general I/O channel (GIC) and the asynchronous data communications controller (ADCC). The GIC is the hardware I/O channel that provides the electrical interface between the computer system and peripheral devices connected to the Hewlett-Packard Interface Bus (HP-IB). The HP-IB is HP's implementation of ANSI/IEEE standard 488-1978, and is used on the Series 33 to connect peripheral devices. The HP-IB consists of eight data lines and eight control lines. The ADCC provides a bit-serial data interface between the computer system and terminals. The two channels operate in a similar manner, but the GIC has a DMA facility to permit high-speed transfer of large blocks of data, while the ADCC can transfer data only one character at a time.

This I/O structure is similar to the HP 300's. Its major benefit is that it is easy to add new HP peripherals designed with the standard I/O interface (HP-IB), so that customers have a wide choice of peripherals for future system growth.

Packaging and Service

The Series 33 is the first HP 3000 to be designed for the office environment. Along with a pleasant and functional desk package for the mainframe (see article, page 9) the designers have created a system that is friendly and easy to use. It is possible to configure the CPU, one megabyte of memory, I/O control for all permissible input/output peripherals, and terminal controllers for up to 24 terminals within a single 24-slot card cage. Fig. 7 illustrates the com-

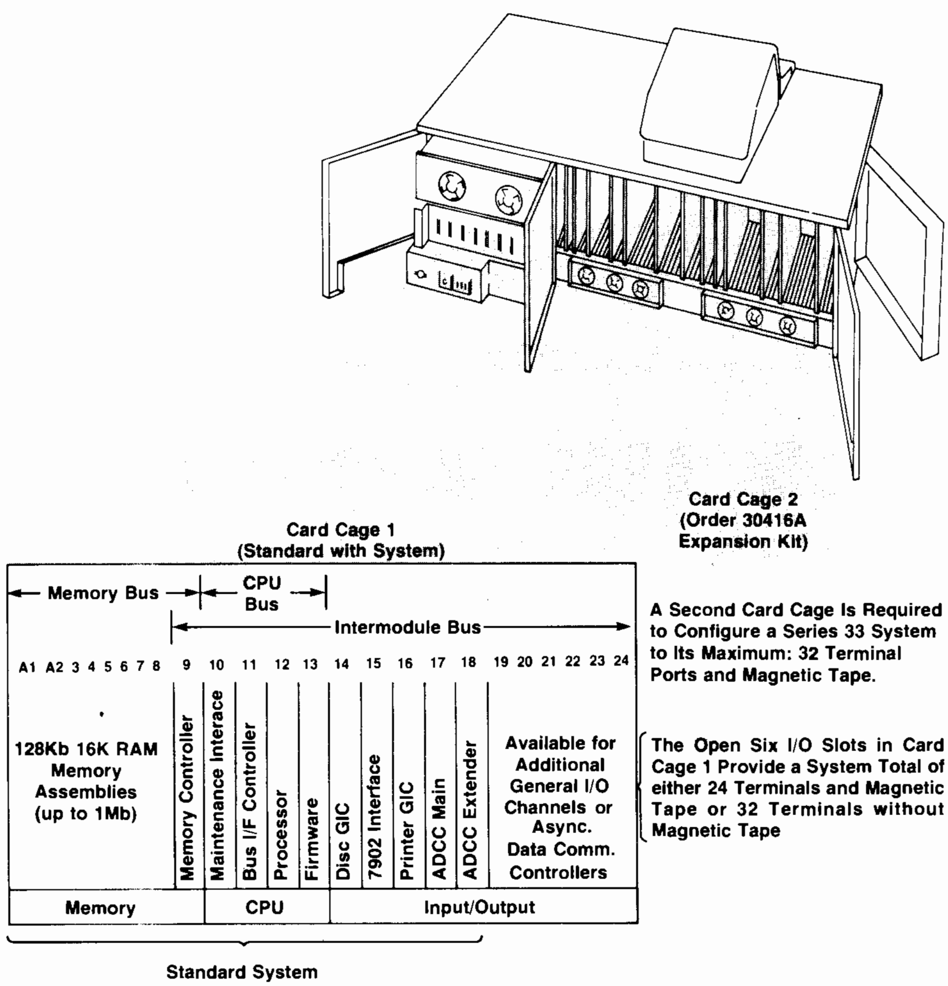

Fig. 7. *Series 33 base system can be expanded within the same cabinet.*

Adapting the Multiprogramming Executive to a New Hardware Environment

by Claude Robinson, Jr.

The HP 3000 Series 33 is first and foremost a member of the HP 3000 family. It is designed to be software compatible with the HP 3000 Series II and Series III and to run the same MPE (Multiprogramming Executive) operating system.

Adapting MPE to run on the new Series 33 was a nontrivial problem because of the Series 33's use of different hardware and a different I/O protocol from other HP 3000s, as explained in the accompanying article. The first task of getting MPE to run was to microprogram the new hardware with a subset of the existing HP 3000 instruction set. Since the Series 33 uses a different I/O protocol, the I/O instructions were redone. Along with new I/O instructions, some new instructions were coded to facilitate handling new features in the operating system and to handle the system clock on the Series 33.

To prepare for running MPE on the new hardware with the new I/O protocol, the MPE project team divided MPE into two portions, one hardware dependent and the other hardware independent. The hardware dependent portion, hard MPE, consists mostly of drivers, I/O system control modules, system clock handler, external and internal interrupt handlers, and some miscellaneous modules. The hardware independent portion, soft MPE, contains all the modules that nonprivileged users interface to.

MPE is a modular system divided into many segments. This new division meant rearranging segments so that they are either all hard MPE or all soft MPE. This task was complicated by the desire to maintain segmentation that would cause a minimum of absent-segment faults. Once the division was made, we were well on our way to getting MPE to run on the new hardware by changing only hard MPE. Since soft MPE was not changed, all user-mode and most privileged programs can be run on Series II, III, and 33 without changes, even at the object code level.

Because the system was intended as a low-price entry into the HP 3000 family, it was desirable to make the system functional without magnetic tape. The challenge was to do this in a manner that would not require retraining of current users of HP 3000s if they purchased a Series 33 to complement existing systems. We also wanted to accommodate the less-sophisticated user that we expect to encounter with this entry-level system.

Our solution was to design a serial disc interface. This capability is invisible to users except when a disc is declared as a serial disc. The serial disc interface allows the user to store files, back up the system, and do other serial, tape-like operations on the disc without additional effort on the user's part. HP 7905 cartridges on Series II and III, HP 7906 cartridges and flexible discs on Series 33, and HP 7920 and 7925 disc cartridges on Series II, III, and 33 may be used as serial devices.

The serial disc interface allowed us to make the flexible disc the backup device for Series 33 systems. It also gives great flexibility of files backup on the HP 3000: the user now has a choice of magnetic tape, serial disc, and private volumes for system backup.

New I/O protocol

The I/O bus used by the Series 33 (and the HP 300) is the HP-IB (ANSI/IEEE 488-1978). This standard, along with some system requirements on peripherals to be interfaced to the HP 300 and the HP 3000 Series 33, results in an I/O protocol that we refer to as the Amigo protocol (Amigo is the nickname used in the lab for the HP 300 system). The remainder of this article will address some of the differences in running MPE using the Amigo I/O protocol instead of the I/O protocol used on Series II and III.

The Amigo protocol requires more memory reserved for I/O programs—on the average, about 100 words per device controller on the system. This means that, for initialization of I/O, more variables have to be set up. However, I/O programs can be (and are on Series 33) designed so that nearly all of these variables need to be set up only once after the system is up. This is done by initialization routines that are called by the system progenitor when the system first comes up.

The Amigo protocol requires more investigation by the driver on completion of I/O. This is in many cases an advantage, because it allows the designer of a driver to supply specialists and knowledgeable users with more information on I/O completion and to distinguish between various I/O failures, such as device failures, I/O channel failures, I/O programming errors, memory wraparounds, and DMA (direct memory access) aborts. This information can be determined and logged by the system. The overhead required for this benefit is minimal.

Here is an example of how this feature can help the specialists. When the 7925 disc drive was being interfaced to the Series 33, we decided to increase the size of the free space table on the disc. A problem was introduced that caused memory wraparounds on writes to the disc. Because of new features in the hardware and the Amigo protocol, the error was reported as soon as it occurred. In the past, this error would not have been noticed until much later (possibly days), long after the fact. It often takes weeks to determine where this type of problem originated. But with this new feature, we found and corrected the problem within hours.

Another difference of the Amigo protocol is that peripherals are not allowed to interrupt the CPU directly. Instead, peripherals are required to enable channel service request lines to indicate that they are ready for service. An interrupt to the CPU is caused only when the I/O program interpreter encounters an INTERRUPT instruction.

This is an advantage because the system designer has more control over when and how the CPU is interrupted. Also, the designer can supply more information along with the interrupt. The protocol requires reserving seven words per channel (called the channel program variable area, or CPVA) for interrupt information. The first four words of the CPVA are used with the INTERRUPT I/O instruction. The programmer may use any of the four words to put parameters in the CPVA to describe the cause of an interrupt. When DMA aborts, a known parameter is placed in CPVA0, and the memory address where the abort occurred is stored in CPVA4 and CPVA5.

The HP 3000 has automatic volume recognition for certain devices

Claude Robinson, Jr.

Chuck Robinson received his BS degree in mathematics from Morehouse College in Atlanta in 1970. With HP for nine years, he's worked in quality assurance, helped develop MPE C and the HP 3000 Series II, and served as project manager for HP 3000 Series 33 system software. He's currently section manager for MPE data access software. Outside of working hours, Chuck serves on the board of trustees of his church, coaches a youth soccer team, and enjoys tennis, golf, basketball, and woodworking. He's married, has two sons, and lives in San Jose, California.

when they are mounted. This requires running an I/O program to be able to see devices come on-line or taken off-line. The Amigo protocol allowed the system designer to have an I/O program in a WAIT state, requiring CPU or I/O program interpreter service only when the device in question enables the channel service request line (e.g., coming on-line).

Probably the greatest advantages of the new I/O protocol are a unified standard for all peripherals to be interfaced to the family of computers, and the new terminal controller, the asynchronous data communications controller or ADCC. The unified standard means that peripherals developed for one system in the new family can be easily interfaced on all. It also means fewer specialists are needed for peripheral support.

The new terminal controller is probably the most significant advantage. Even with a CPU of slightly more than half the speed of the Series III, MPE on the Series 33 reads/writes a character from/to a terminal, on the average, in about the same time as the Series II/III. This is very important to an interactive transaction system such as the HP 3000.

Acknowledgments

Phil Ho developed the terminal I/O system for the Series 33. Rich Pearson and Dan Lundberg developed the peripheral access method.

pact internal layout of the Series 33.

The Series 33 does not have the traditional computer system front-panel lights and switch registers. Total system control has been built into the system console. The CRT console, employing a specially microcoded microprocessor, is used for starting the system as well as receiving the traditional console messages. The user knows the status of the system from a status line on the console that displays either RUN or HALT and shows CPU utilization as a percentage from 0 to 100.

The system console also serves as the system maintenance console. Users are given a system diagnostic program that runs unattended in less than two minutes, displaying results on the console CRT screen. The diagnostic program checks out all hardware components involved in a system cold-load. Faults are isolated to the module level and concise, easy-to-understand messages are printed on the CRT.

Users can run the system self-test before calling Hewlett-Packard for hardware maintenance. If a service call is necessary, HP customer engineers and operating system specialists can use the console CRT display to inquire into the status of diagnostics initiated from the console system and even into the status of hardware registers for detailed troubleshooting.

Making this new maintenance console even more valuable is the ability to transmit the display and control functions to a remote HP 2645 terminal via a modem and telephone link. With this facility, the customer engineer on site can call the HP service office and have a specialist check out the system over the telephone using a remote system console/maintenance console. The customer engineer loads the remote maintenance code data cartridge into the console, then switches the modem (user-supplied) to the console using a switch built into the terminal junction panel to establish the telephone link. The specialist now has a duplicate display of the Series 33 system console/ maintenance console display, with the ability to send the customer engineer and/or system manager messages that are not transmitted to the computer. This remote maintenance console facility is a standard part of all Series 33 systems. It is described in more detail in the article on page 13.

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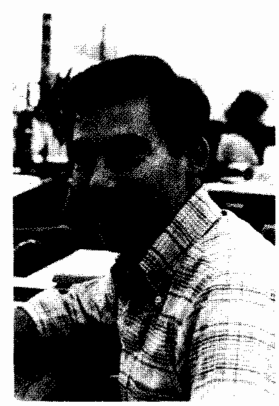

Richard C. Edwards

Rich Edwards received his BSE degree in electrical engineering from Princeton University in 1969 and his MBA degree from Stanford University in 1976. He's been with HP since 1976, serving as product marketing engineer for KSAM/3000, HP 3000 Series II Models 6 and 8, and HP 3000 software policy, and as product manager for the HP 3000 Series 33. He's now product manager for all HP 3000 systems. Rich served in the U.S. Navy from 1970 to 1974. As assistant director of the U.S. Naval Nuclear Power School, he taught mathematics, nuclear physics, and nuclear reactor operation. A member of IEEE, he's been selected as one of the "Outstanding Young Men of America" by the group of the same name. Born in Jacksonville, Florida, Rich is married to an attorney, has a son, and now lives in Oakland, California. He enjoys swimming, jogging, cooking, photography, skiing, and traveling.

SPECIFICATIONS

HP 3000 Series 33 Computer System

HARDWARE SUPPLIED

- Central processing unit (CPU)
- 214 firmware instructions
- System clock
- 8 asynchronous terminal ports via two asynchronous data communications controllers (ADCCs)
- Modem support (for type 103/212/202S)
- General I/O channel for discs
- General I/O channel for line printers and flexible disc
- 256Kb fault control memory with memory controller
- System desk mainframe, one card cage, and power supplies
- System console/maintenance console
- 7906 19.6Mb disc with controller
- 1.2Mb flexible disc with controller (double-sided)
- 6 spare I/O slots and space for 1024Kb memory
- Room for 31 terminals plus system console
- Built-in isolation transformer

SOFTWARE SUPPLIED: HP 3000 Series Fundamental Operating Software, which includes:

- Multiprogramming Executive III operating system (MPE III)
- Text editor (EDIT)
- File-copying utility (FCOPY)
- Sort and merge package (SORT)
- IMAGE/3000
- QUERY/3000
- KSAM/3000
- HP VIEW/3000
- Facility to execute compiled programs without the source-language compiler on the system (except for programs written in APL 3000)

ENVIRONMENTAL

TEMPERATURE (OPERATING): 50°-104°F (10°-40°C)

RECOMMENDED TEMPERATURE RANGE FOR MOST RELIABLE OPERATION: 68°-86°F (20°-30°C)

RELATIVE HUMIDITY: 30-80% non-condensing. 60% optimal. Maximum wet bulb temperature, 78°F (26°C).

LINE VOLTAGE: 200/210/220/230/240 V +4%, −10% single phase.

LINE FREQUENCY: 50 or 60 Hz ±0.5 Hz.

MAXIMUM RATE OF TEMPERATURE CHANGE: 18°F/hr (10°C/hr).

PRICE IN U.S.A.:

HP 3000 Series 33 Standard System, $58,500.

MANUFACTURING DIVISION: GENERAL SYSTEMS DIVISION
19447 Pruneridge Avenue
Cupertino, California 95014 U.S.A.

A Friendly, Easy-to-Service Computer

by Yas Matsui and Manmohan Kohli

THE DESK-LIKE DESIGN of the HP 3000 Series 33 (see Fig. 1) puts a lot of computing power into a very small space, allowing it to fit easily into most business office environments. Visual compactness, low profile, low audio noise level and operator oriented design combine to achieve friendliness and space effectiveness.

The large desktop allows the operator to place the system console where convenient, and provides work space. Ample leg and knee space is provided under the desktop for comfortable seating, and all necessary controls are within reach of the operator.[1,2]

A welded steel frame optimizes strength-to-weight ratio

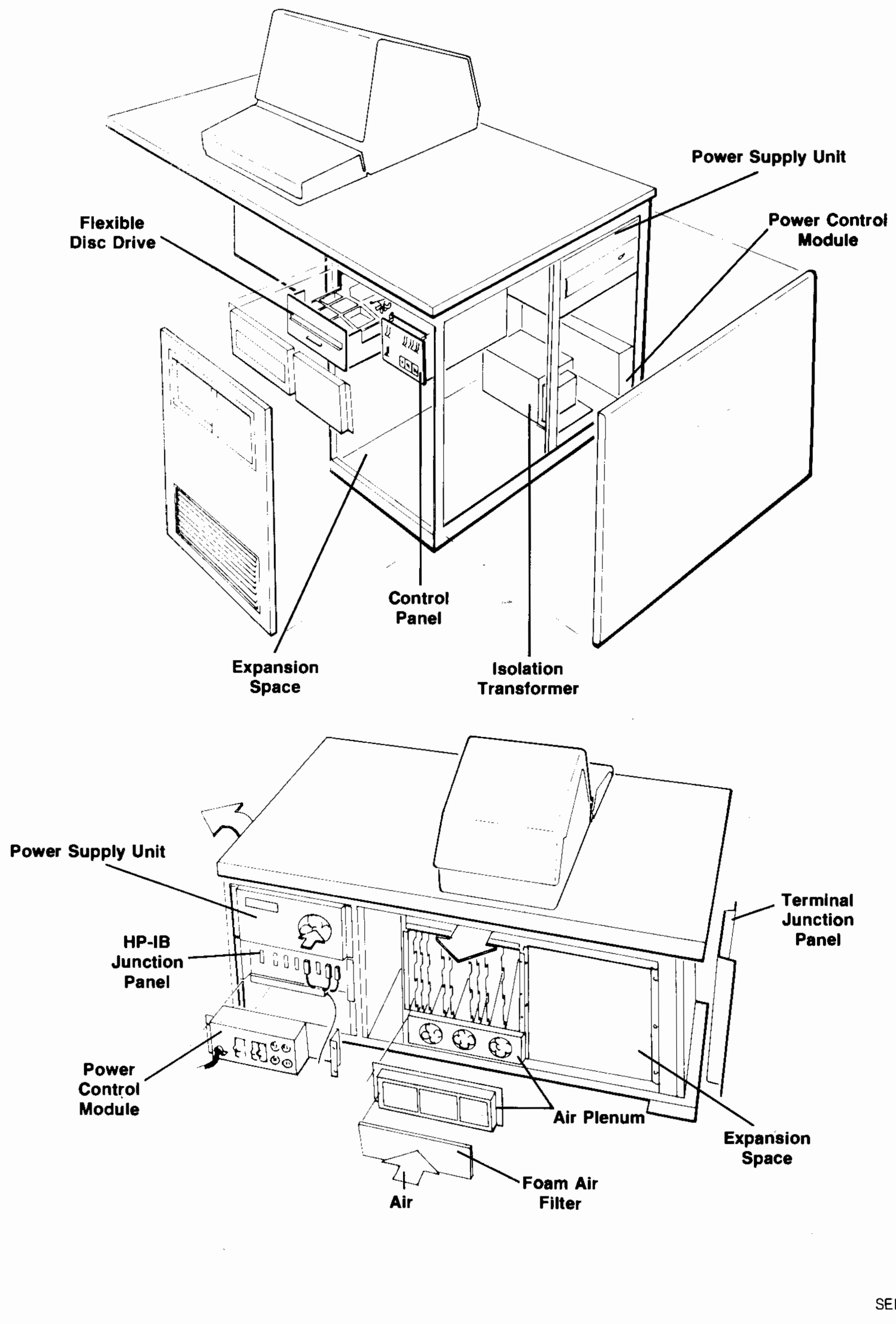

Fig. 1. *HP 3000 cabinet design.*

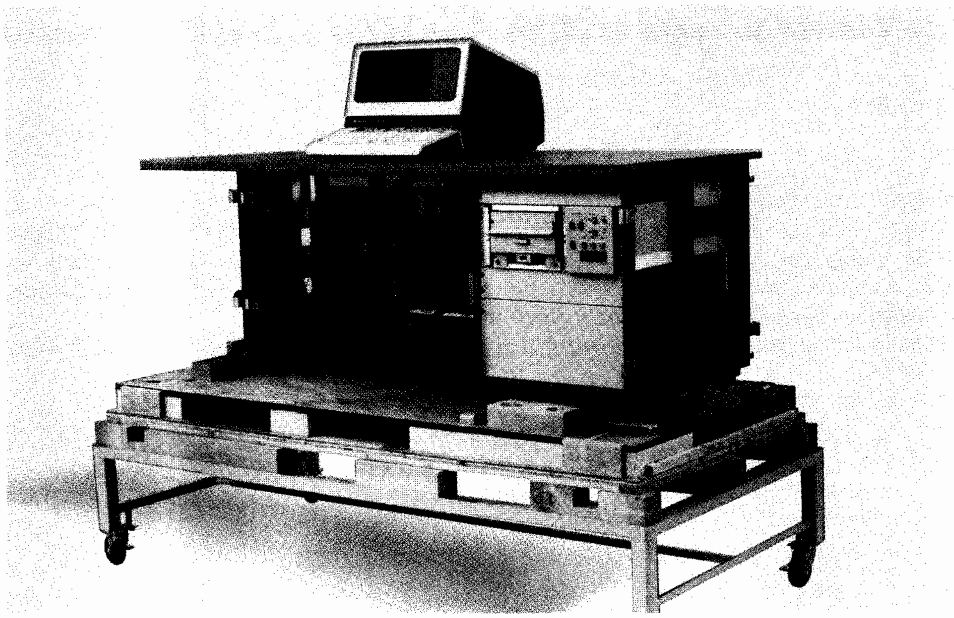

Fig. 2. *Series 33 mainframe is mounted on a wooden pallet and placed on an elevated pedestal for ease of handling and assembly on the production floor. After final system assembly, the same pallet is used as the base for the shipping container.*

and ensures structural integrity under various environmental load conditions (Fig. 2). This approach provides dimensional stability to the card cage, where 4250 individual contact points between printed circuit boards and the backplane must be kept free from undue stresses. The doors and panels are made of steel sheet because it offers easy fabrication, low tooling costs, and excellent shielding for electromagnetic interference (EMI).

Two types of locks provide two levels of access security for the cabinet. The operator has access to the flexible disc unit and a backup control panel through the front door (Fig. 3) and to the terminal junction panel through the side door (Fig. 4). These doors use one type of lock assembly. All other doors use another type of lock assembly and are accessible only to service personnel.

The easily removable desktop is made of steel and laminated plastic veneer. It is reinforced with a spot-welded steel stiffener to prevent deflection due to large loads on the cantilevered portion. Plastic veneer was selected as the surface material for its scratch resistance, dimensional stability under severe environmental conditions, and ease of maintenance. The mainframe cabinet passes the HP class C

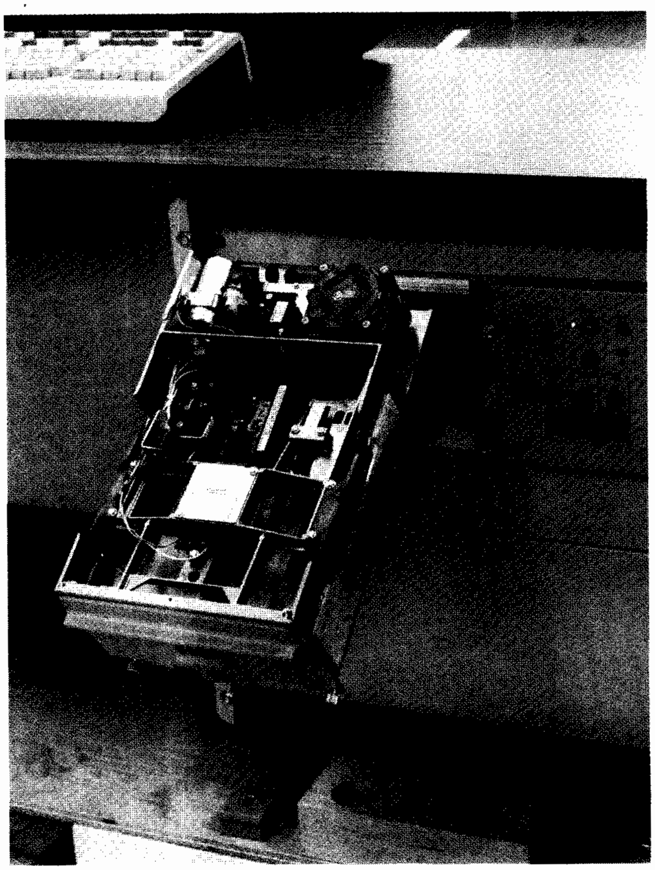

Fig. 3. *Flexible disc is mounted on slides that extend and rotate to provide easy access to the top and bottom for service.*

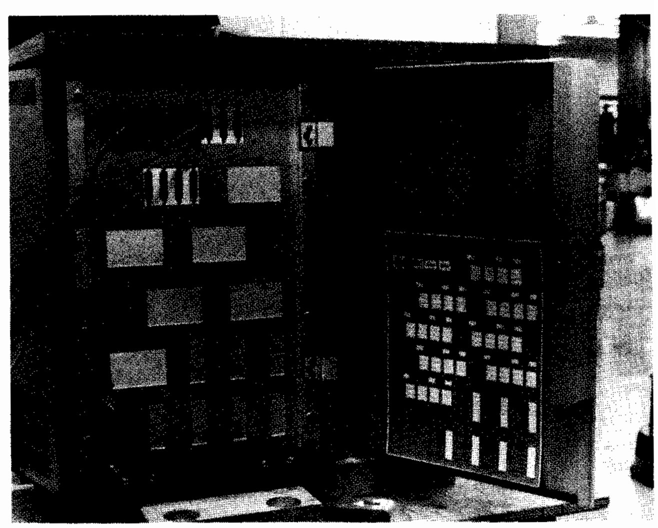

Fig. 4. *Junction panels are accessible through the side door and are mounted with quick-disconnect fasteners for easy removal.*

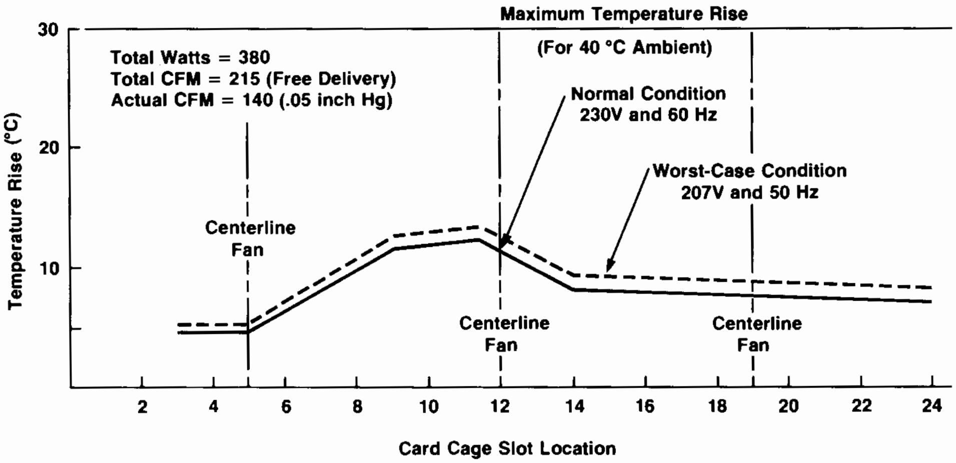

Fig. 5. *Temperature profile at the card cage exhaust opening shows an average temperature rise of 10°C under normal operating conditions, leaving a 20°C margin for worst-case voltage, frequency, and altitude.*

vibration test, an unpackaged drop test from three-inch height, a packaged drop test from 24-inch height, and a repetitive shock test to simulate transportation hazards.

The package consists of three modules: card cage module, power supply module, and desktop. They are bolted together and placed on a movable pedestal (Fig. 2) for ease of installation of subassemblies, making the mainframe fully accessible from all sides. After assembly, parts of the platform are used as a shipping container.

For a complex computer, the Series 33 is very serviceable. With seven access doors and two removable panels, access and removal of 90% of the subassemblies can be achieved within 10 minutes. Instrument slides are used for the heavy power supply unit and for a dirt and temperature sensitive flexible disc drive unit, enabling debugging and servicing without removal from the mainframe cabinet. Keyed connectors for all ac and dc power and dc signal cable harnesses ensure correct and quick system cabling.

Cooling

A concerted effort was made to maximize available internal space for cooling while keeping the audio noise generated by cooling fans within requirements for an office environment.[3] Cooling was designed to meet the following primary objectives:

- Quiet enough for an office environment. Audio noise level not to exceed 60 dBA.
- Temperature rise to be kept within 10°C of ambient for system reliability.
- Air intake and exhaust to be kept away from operator.

To achieve these objectives, cooling for the system was separated into three areas: card cage cooling, flexible disc drive cooling, and power supply unit cooling. The card cage cooling was accomplished by using an air plenum with a built-in deflector to distribute the air flow evenly. The fans are mounted away from a foam air filter and the cabinet surface to minimize back-pressure buildup and radiated audio noise.

The peak velocity of air at a fan blade is directly proportional to the fan blade's diameter and rotational speed. Since peak velocity contributes to noise level, three smaller fans (4.50-in diameter, 75 ft^3/min capacity) are employed rather than fewer higher-capacity fans.[4] This results in lower fan noise and even distribution of air across the card cage. In normal operating mode the average temperature rise has been measured to be 6°C while the noise level of the mainframe cabinet is held to 52.5 dBA. The temperature profile of the system is shown in Fig. 5 for normal operating conditions and for worst-case line voltage and frequency (207V at 50 Hz).

EMI and ESD

EMI shielding was accomplished by using commercially

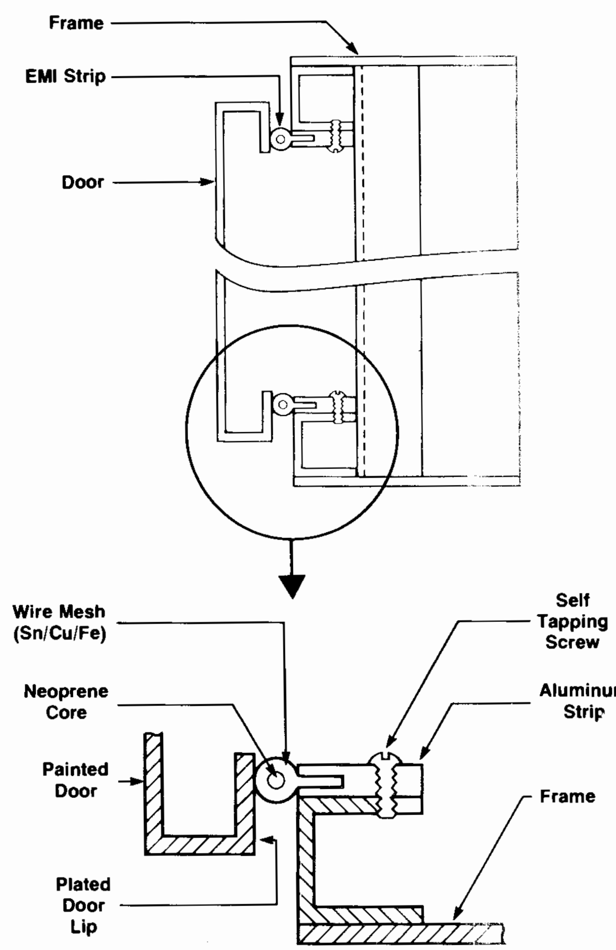

Fig. 6. *EMI (electromagnetic interference) shielding detail.*

available EMI gasket, a continuous strip of fine Fe-Cu-Sn alloy wire mesh wrapped around elastomer and mounted on an extruded aluminum strip.[5] The aluminum strip is attached to the mainframe at front and rear door openings using self-tapping screws to create electrical bonding with the painted frame. The wire mesh gasket makes contact with the plated door lips when closed (Fig. 6) to provide EMI shielding at the frame and access doors. This scheme also provides electrostatic discharge (ESD) protection for the cabinet doors by a low-impedance path through the plated lip, EMI gasket, aluminum strip, and self-tapping screw to the cabinet frame. Additional ESD protection was achieved by providing good electrical bonding between the mainframe and all the subassemblies. Where there is no metal to metal contact available (painted-metal to non-painted metal or painted metal to painted metal contacts), stainless steel grounding buttons are press-fitted into painted metal surfaces to make low-impedance paths (Fig. 7). The final measurements indicate that the mainframe cabinet provides EMI shielding for radiated energy 15 dB below the level B requirement of VDE for the office environment, and the mainframe assembly is able to withstand a 20-kV discharge when tested with the Hish Model ESD-254, a widely used ESD tester.

Acknowledgments

The development of the mechanical parts of the HP 3000 Series 33 required significant contributions by many people at HP's General Systems Division. We would like to give special recognition to Gary Lepianka for his card cage and other mechanical package designs, George Canfield, who designed the power control module and the system cable harnesses, Steve Spelman, who designed molded plastic parts, Brock Dagg for doing the lion's share of the drafting, Vince Roland for hardware QA, Ron Morgan for product safety and for taking us through UL and VDE certifications, Jack Barbin, Steve DePaoli, and Dave Jones for providing us with production engineering support, Jerry Curran of HP's Santa Clara Division for providing product manufacturing support, and Lou DeWitt, Mike Borg, and Rich Edwards for constant marketing inputs. Special thanks to Tom Whitney and Matt Schmutz for their guidance and patience throughout the development of the product.

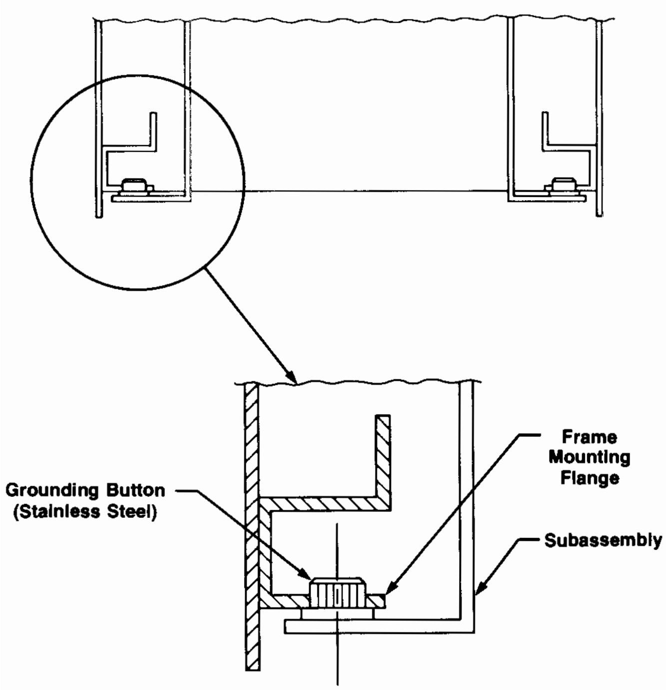

Fig. 7. *ESD (electrostatic discharge) grounding detail.*

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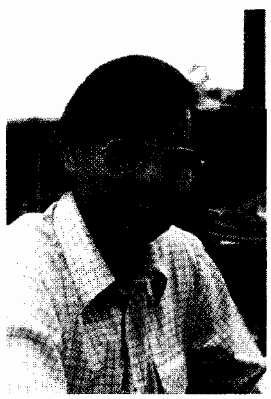
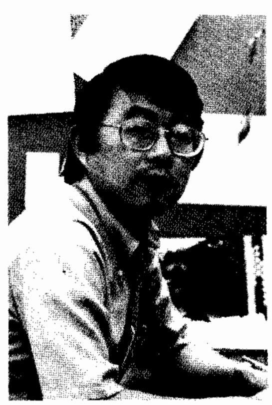


Manmohan Kohli

Manny Kohli designed the cabinets for the HP 3000 Series 33 Computer. A native of Punjab, India, he received his BSME degree in 1964 from Punjab University and his MSME degree in 1967 from the University of California at Berkeley. He's done mechanical design for impact printers and high-speed cameras, and stress analysis and galley design for commercial aircraft. With HP since 1974, he's designed thermal printers for the HP-91 and HP-97 Calculators and is now a project leader for computer cabinet design. Manny is married, has two children, and lives in San Jose, California. He spends his spare time gardening, working on his cars and house, and managing his investment property.



Yas Matsui

Yas Matsui is industrial design and product design manager for the HP 3000 product line. With HP since 1969, he's also done industrial design for signal generators, network analyzers, microwave systems, and passive components. He received his BS degree in industrial design from Carnegie-Mellon University in 1967, his MS in industrial design from the Univesity of Illinois in 1969, and his MBA from Santa Clara University in 1976. Born in Tokyo, Yas is married, has two children, and lives high up in the Santa Cruz Mountains near Los Gatos, California, in a house of his own design. He enjoys skiing, backpacking, and furniture and jewelry design, and is currently designing solar heating and greenhouse systems for his home.

A Remote Computer Troubleshooting Facility

by David L. Nelson

SPECIAL MAINTENANCE TOOLS have been integrated into the HP 3000 Series 33 to aid in diagnosing and repairing the system when hardware or software failures occur. These tools allow the system engineer (SE) and the customer engineer (CE) to investigate the situation from their office. Hardware failures must ultimately be fixed by the CE on-site, but the SE can help the customer with software problems with almost the convenience of being on-site, and with the advantage of immediate response. The HP 3000 Series 33's remote console/maintenance facility has immediate benefits because it reduces the HP response time and eliminates unnecessary visits to the customer's site.

The remote console facility can also be used when the system engineer is at the site and wishes to consult on a problem with an expert, either in a field support office or at the factory, to help solve a particularly difficult problem.

The remote facility is not intended just for use by HP personnel. It is equally useful for any central office in a large corporation to assist operators of HP 3000s at other sites. Large corporations typically develop a significant amount of specialized software to fit their particular needs, and as a result must support those programs just as HP supports its operating system and subsystems. The remote console facility provides a convenient way for users of the software in a distributed system to demonstrate problems to the corporate personnel who support their applications and get immediate help in finding solutions to their problems.

The HP 3000 Computer System, including peripherals and software, is undoubtedly the most complex system that Hewlett-Packard produces. Consequently, it presents significant challenges in terms of system support and maintainability. The HP 3000 is typically used in interactive data base management activities, and customers often cannot carry out their business if the system is not operational. Thus system availability is very important. Since no hardware or software is perfect, it is necessary to have an effective means of maximizing availability of the system despite occasional hardware and software failures. Series 33's remote console/maintenance facility has been designed to meet this need.

Remote Console Implementation

To provide remote diagnostic capabilities it is necessary to have a smart device independent of the system CPU (central processing unit). This is because a significant amount of system hardware must be operational for the CPU to work, yet any hardware in the system might have failed. The system console contains a microprocessor that allows it to act as the independent smart device. To avoid transferring the diagnosis problem from the CPU to the console, the

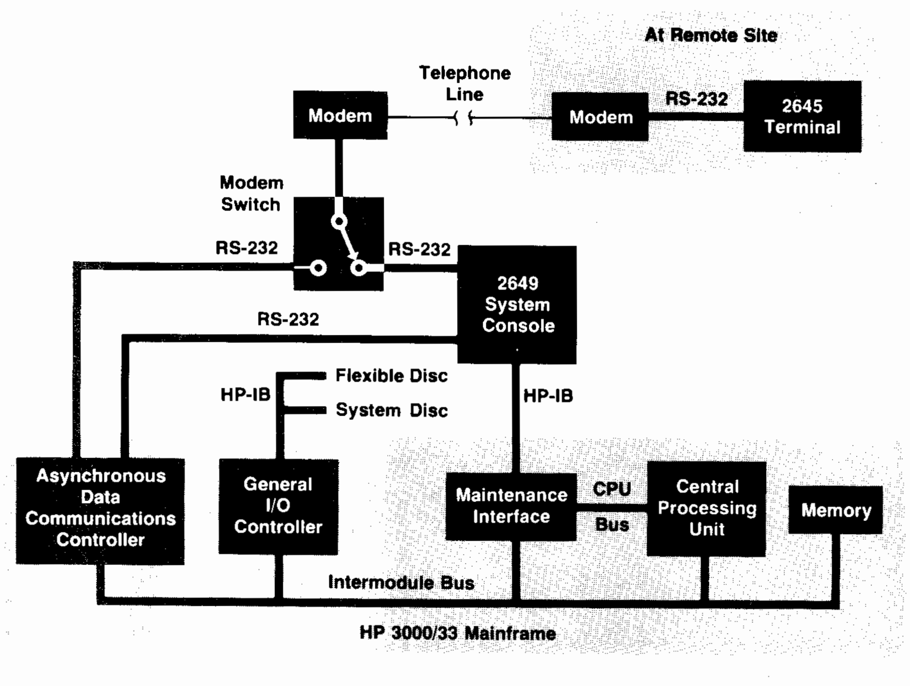


Fig. 1. *HP 3000 Series 33 maintenance hardware includes the system console, a remote console, and the maintenance interface. The MI provides access to the CPU and the intermodule bus.*

console has a self-test capability that is easily used by the customer. If the console fails, any other terminal can replace the console and the system will still be operational, although all remote diagnostic capabilities will be lost.

The system console is an HP 2649 Terminal that has been specially microcoded for this application. The firmware in the console is composed of the standard HP 2645A Terminal firmware plus custom firmware for the special console functions. Since no 2645A firmware was removed, the console can perform all 2645A functions in addition to its console functions. Essentially the console is an independent computer system containing the following items:

- Two RS-232 ports
- Dual cartridge tape drives
- CRT display
- Keyboard
- 8080 microprocessor
- 26K bytes of read-only memory
- 16K bytes of read-write memory
- HP-IB (ANSI/IEEE standard 488-1978) interface to special interface hardware within the HP 3000.

When a failure occurs within the HP 3000, the system console and the remote diagnostic capability can still be used. The only common failure within the system for which remote diagnosis is not very effective is a power supply failure. This causes the interface between the console and the system (called the maintenance interface, or MI) to stop operating, so the console can't get any response from the system whatsoever. For this case, power supply status LEDs are mounted behind a door on the system for examination by the customer.

Fig. 1 shows the maintenance hardware and the interconnect paths between the maintenance hardware and the rest of the system. The 2649 system console is the controller of all the maintenance hardware. It is connected to the modem via an RS-232 cable. All the information on the 2649 console screen can be displayed on the remote console, and console commands can be entered at the remote console. The modem switch allows the modem to be used either for remote maintenance or for dial-in sessions. Thus the customer can use the modem conveniently for regular business. The modem switch also provides security for the local system, since the remote console facility is disabled when the modem is not connected to the system console.

Another RS-232 cable connects the 2649 console to the asynchronous data communications channel (ADCC). This allows the 2649 to be used as a system console by the operating system when the system is operating normally. An HP-IB cable connects the 2649 to the maintenance interface (MI). This connection allows the 2649 to access the CPU via the CPU bus and access the other boards of the system via the intermodule bus (IMB). Fig. 2 is a diagram of the maintenance interface.

Using the Remote Console Facility

To activate the remote console facility, the customer calls the HP system engineer and then loads the remote console/maintenance facility cartridge tape into the 2649 system console. The cartridge tape contains the code for controlling the modem. Next the user sets the modem switch to connect the 2649 to the modem. Both the user and the remote system engineer then set the data keys on their modems. The link is then established and the remote terminal becomes a system console. Both system consoles are effectively tied in parallel such that both users can enter commands to the HP 3000 or the 2649 system console. The information displayed at the remote console is identical to the information displayed at the local console. This allows the remote operator, in effect, to look over the local operator's shoulder to see exactly what the symptoms of the problem are. Also, the remote operator has the ability to demonstrate how to work around the problem if a workaround exists. Both operators can cold-load the system, dump memory, run diagnostics, and examine the internal state of the HP 3000. However, because of the low baud rate of the modem, all programs that reside on flexible disc or

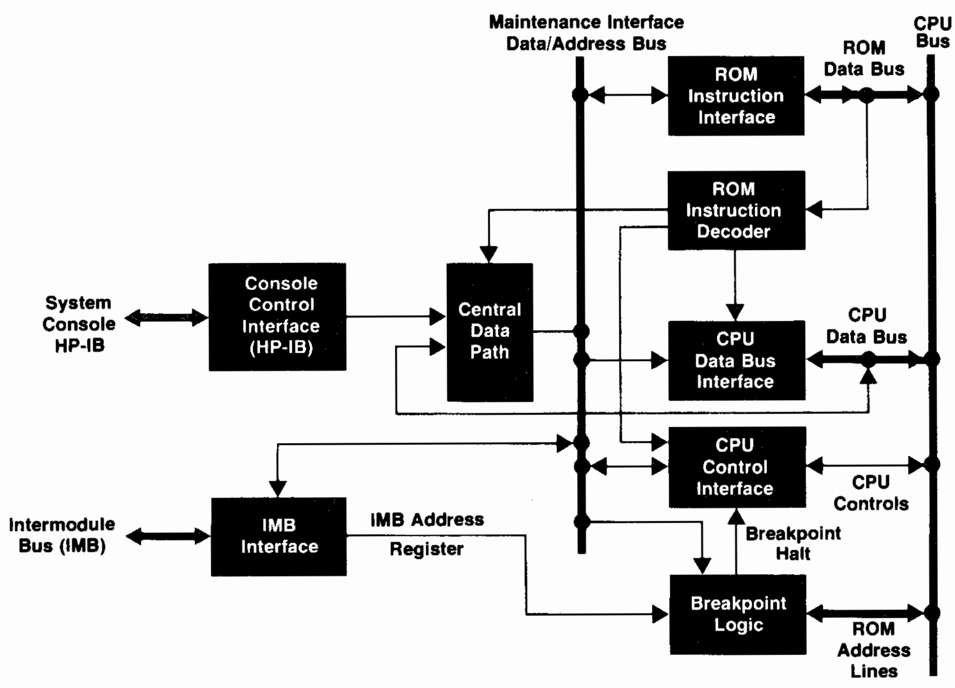


Fig. 2. *Maintenance interface block diagram. The MI is connected to the system console by an HP-IB (ANSI/IEEE 488) cable.*

Philosophy of HP 3000 Series 33 Diagnostics

by James H. Holl

One of the appealing features of the HP 3000 Series 33 is that it allows maintenance to be done with a minimum number of site visits from the customer engineer (CE). This saves the user both time and money. The system includes new self-test features that allow the user to start diagnosing problems before calling for help. If the user does require assistance, the system can be diagnosed remotely.

Tests the user can perform fall into two categories. If the operating system is running and one of the peripheral subsystems (flexible disc, line printer, or terminal) is suspected, the user can perform a self-test on the subsystem. If the user is willing to suspend job execution or if the system stops working, the user can be told over the phone how to run off-line diagnostics.

Peripheral self tests consist of steps that test data paths within the subsystem, verify read-only memory via a checksum test, test any random-access memory, test the microprocessor, and test the peripheral itself. Each peripheral subsystem contains a self-test key, button, or switch and a means of reporting the results of the self test (light-emitting diodes, paper, or CRT). The hard discs and magnetic tape do not have this capability. The user thus performs the same initial test that the customer engineer (CE) would perform. When an error is detected by a self-test program, the user can provide this information to the CE when the user requests service. The user may also run on-line programs that exercise the line printers and verify the data paths between the computer and the printers.

The user who has suspended job execution can run the Diagnostic and Utility system (DUS). The DUS is described in detail later in this article. Once the DUS is run, the CE knows what device is not working and what function within the device is failing. Because the CE will bring the proper service kits and tools, the percentage of successful first-time calls is increased and the mean time to repair is reduced.

If the user wishes to have the CE run the DUS, the user loads the REMOTE program into the 2649 system console from the console's cartridge tape unit and connects the console through the modem switch to a Bell 103-compatible modem. The CE can then connect a remote HP 2645 terminal through a matching modem to the customer's modem (using a phone line between modems). The CE obtains a duplicate copy of the system console on the remote terminal. The CE's keyboard and the user's keyboard are both active at this time, and all keyboard input appears on both screens. While the user watches on the system console, the CE runs the diagnostics from the remote site.

Both the REMOTE program and the system maintenance display can be installed without disturbing the system. The system maintenance display loads in the same way as the REMOTE program and uses part of the 2649 screen for its display.

When the user can not cold load the operating system, there is another set of options. First, self tests can be performed on the applicable peripheral subsystems as described earlier. This will not always isolate the problem. Second, the DUS can be used to help isolate the problem, but sometimes this system won't cold load either.

There is yet another set of tests. Two programs can be loaded into the 2649 system console. Together these programs execute inside the system console and test the system parts that are used to perform a cold-load operation. The first program is the diagnostic for the maintenance interface (MI) board. This board provides the console with the ability to monitor and control the central processing unit (CPU). The board is also used by the maintenance display mentioned earlier. The MI provides access to the intermodule bus (IMB) and the general I/O channel (GIC) to which the cold-load device is connected. This program is executed first to insure that the results of the next program are valid.

The second program is the cold-load self test. This program tests all parts of the system that are needed to cold load except the actual cold-load device and the media containing the program to be loaded. The CPU, first bank of memory, cold-load GIC, cold-load device controller (the controller is identified and a loopback procedure is used to check the data path), and the system console's asynchronous data communication channel (ADCC) are tested. The CPU tests are actually part of the CPU microcode. The system console causes them to run and obtains their results.

By running these two programs, the user acquires specific information about the problem. By relaying this information to the HP CE, the user can again save time and money. These programs can also be run remotely from the CE's office if the user desires.

Diagnostic and Utility System

The DUS is a random-access file system that resides entirely on a single flexible disc. The DUS contains diagnostic programs for discs, magnetic tape, memory, the GIC channel, and the ADCC channel. It also includes the IOMAP utility and the SADUTIL utility. IOMAP shows the system configuration and has the ability to invoke a peripheral subsystem's self-test sequence and read back the self-test results. IOMAP also has the ability to perform a loopback test on a device controller. SADUTIL recovers disc files, condenses the data on a disc volume, and modifies the contents of a disc volume. Without precluding component repair, each diagnostic attempts to identify the field-replaceable assembly that is failing. Error messages are friendly, nonambiguous and contain both the stimulus and all symptom information. By running selected diagnostics or utilities, the user can provide more detailed information to the CE. The HP 3000 Series 33 DUS is similar to the DUS provided with the HP 300 Computer System.

The diagnostics that are part of the DUS are written either in AID (an interactive language) or in systems programming language (SPL-II). The diagnostics for the memory, the GIC, and the ADCC are written in SPL-II to provide maximum control during board repair (usually not done at the customer's site). The diagnostics for the peripherals are written in AID, are easily modified, and are self listing. A simulator for SLEUTH (an HP 3000 Series III troubleshooting language) has been written in AID and is provided as part of the DUS. SLEUTH is a powerful interactive language that can exercise any peripheral with

James H. Holl

Jim Holl received his BSEE degree from the University of California at Berkeley in 1966, then worked as a programmer for three years before joining HP in 1969. He's developed diagnostics for several disc drives and served as peripheral lab software manager and as diagnostic coordinator for the HP 300. Along the way, he picked up an MSEE degree from the University of Santa Clara in 1971. Currently he's project manager for HP 3000 serviceability. Jim is a member of IEEE, a long-distance runner, and a third-generation native Californian, born in Palo Alto and now living in Cupertino. He's married and has two sons.

high-level commands such as SEEK, READ and REW(ind). Peripherals of various types may be exercised concurrently. SLEUTH is used to troubleshoot both peripherals and the I/O system.

For the first time on a Hewlett-Packard system, there is built-in hardware to enable a utility program (IOMAP) to determine what channels are present and what Hewlett-Packard Interface Bus (HP-IB) devices are connected to the system. The system may contain as many as fifteen channels. Each channel responds to a roll call request by answering on the line corresponding to its channel number (set by a thumbwheel switch on each channel). Each channel contains an identification register that is read to determine the channel type (GIC or ADCC). Each device connected to the GIC over the Hewlett-Packard Interface Bus responds to an identify request with a sixteen-bit code. This code is used by the utility to identify each peripheral subsystem.

Acknowledgments

The following individuals contributed to the design of the service package: Jim Chiochios, Jim Coffron, Dave De Lano, Curt Gowan, Tony Hunt, Carson Kan, Chuck Leis, Jim Lewis, Slava Mach, Dan Mathias, Dave Nelson, Wil Pomeroy, Peter Rosenbladt, Russ Scadina, and Fred White.

cartridge tape must be manipulated by the local operator. Bell 103-compatible (300 baud) modems were chosen as the primary modems because of their low cost, although the Bell 212 (1200 baud) modem also can be used.

Because the local 2649 system console has some specially defined keys while the remote terminal is a standard 2645 terminal, the remote operator must enter special escape sequences to cause a cold load, a warm start, or a memory dump of the local system.

Diagnosis

The remote modem driver is not the only code loaded into the console from cartridge tape. The maintenance interface diagnostic and the cold-load self test are used to test the basic hardware needed to perform a cold load of the system. Cold load means starting up the system by loading software from the flexible disc or the optional magnetic tape drive. Because the diagnostics that run within the HP 3000 must be cold loaded, the system console is the only means of finding a failure that prevents the cold loading of diagnostics. The maintenance interface diagnostic and the cold-load self test are described in more detail on page 15.

A maintenance display program can also be loaded into the console from cartridge tape. The maintenance display for earlier HP 3000s was a hardware panel containing lights and switches and mounted inside a suitcase. The CE would carry the maintenance panel to the customer's site and plug it into the HP 3000. The maintenance display program for the Series 33 is stored on a cartridge tape and can be used remotely as well as on site. Because the display shows all the registers on the console and accepts verbal commands, it is much easier to use than the lights and switches of the old switch panel.

The maintenance display program allows the CE or SE to check the state of the CPU and memory. By checking the CPU and memory, the system engineer can determine where in the cold-load operation an error occurred. Although primarily used as a development tool in the factory, the maintenance display gives an experienced CE or SE a great deal of flexibility in diagnosing hardware problems. Fig. 3 shows the maintenance display that appears on the local and remote consoles. The hardware display shows all the CPU registers and flags. The software display shows the registers that are important when the CPU is running software, along with a memory window. The maintenance display allows the SE to change the contents of CPU registers and memory.

Fig. 3. *Maintenance displays on local and remote consoles show CPU registers, flags, and memory information.*

Acknowledgments

I am grateful to Dan Lee, Jim Coffron, Slava Mach, and Bob Saunders for their contributions to the console project.

David L. Nelson

Dave Nelson designs development and service tools for HP 3000 systems. Raised in Spokane, Washington, he received his BSEE degree from Washington State University at Pullman in 1976 and joined HP the same year. He's a member of IEEE, and is currently completing work for a master's degree in computer science at Santa Clara University. Dave enjoys backpacking, hiking, raising houseplants, and reading, especially science fiction. He's single and lives in Santa Clara, California.

Controlling Electromagnetic Interference Generated by a Computer System

by Daniel T. Y. Wong

ELIMINATION OF EXCESSIVE electromagnetic interference (EMI) has long been a prime design consideration for electronic engineers. As electronic devices are being used in ever-widening range of applications, EMI control assumes even greater importance. For example, EMI suppression was a major factor in the design of the Hewlett-Packard System II instrument enclosure system,[1] which made its first appearance in 1973.

In the interest of maintaining a clean EMI environment as sources of EMI proliferate, many regulatory agencies around the world are imposing stricter and stricter rules governing EMI emissions from various types of equipment. At the present time, the most comprehensive set of regulations regarding EMI emission limits has been established by the Verband Deutscher Elektroniker (VDE), an independent association of electrical engineers in West Germany that prepares regulations and conducts tests for equipment safety, EMI emissions, and so on. Various countries have established their own regulations regarding EMI and the European Economic Community (EEC) is working toward a common set of regulations for its member countries. Since these will most likely be similar to the VDE regulations, it was deemed appropriate to design the HP 3000 Series 33 Computer and its peripherals to meet the VDE EMI requirements and to obtain an FTZ (West German Bureau of Telecommunications Technology) license as proof of performance. The pertinent VDE specifications[2,3,4] are diagrammed in Fig. 1.

Designing for Quiescence

In designing equipment to meet EMI standards, two basic types of EMI emissions are considered: conducted and radiated. Conducted emissions consist of radio noise conducted through the ac power line. Radiated emissions consist of electromagnetic energy radiated from the equipment and connecting cables.

In the design of the HP 3000 Series 33, conducted emissions were minimized by filtering the ac line, shielding assemblies and cables, minimizing cable-to-cable and field-to-cable coupling, and special grounding techniques. To minimize cable-to-cable coupling, the cable bundles that distribute dc power from the power supplies in the right-hand equipment bay to the other bays are run along the bottom of the cabinet close to the steel members and away from the ac and data cables. Where feasible, the wires inside the cables are twisted to reduce differential-mode coupling.

A logic/signal ground point tightly coupled to the dc power supply return was established in a ground plane on the six-layer main mother board which is solidly grounded to the card cage in the center bay. The ac line safety ground is connected to the framework where the ac line enters the system. The coupling between logic/signal and safety grounds is thus relatively loose to minimize coupling of common-mode noise from the logic/signal ground to the ac line.

The ac input is effectively filtered by a double-shielded isolation transformer that supplies all the ac power for the system including the two dc power supplies, a number of cooling fans, and the flexible disc drive motor (the isolation provided by the transformer also performs a safety function). The transformer attenuates common-mode noise coupled from the internal ac lines to the main power line by

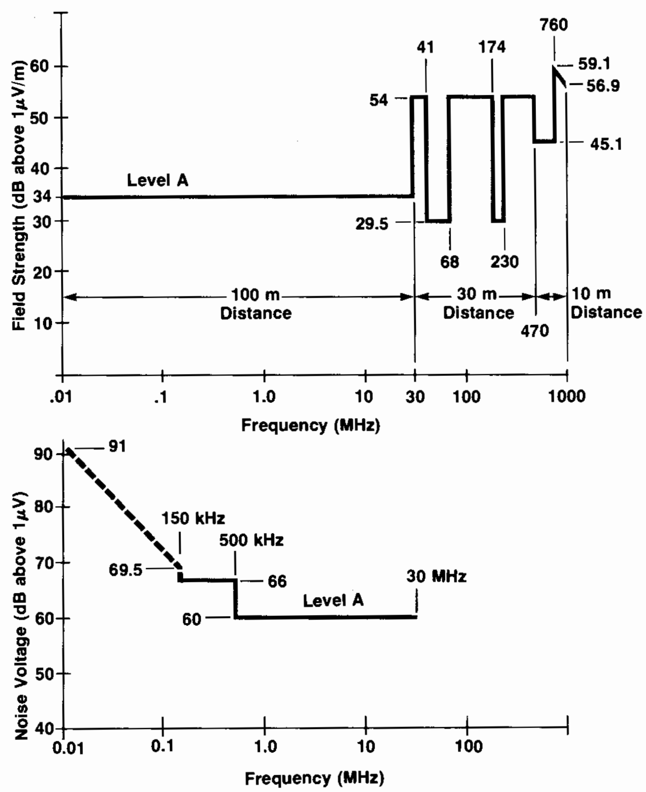


Fig. 1. *Radiated and conducted emission limits specified by VDE 0871/6.78.*

140 dB and differential noise by 70 dB. It is positioned at the ac input to make the primary ac leads within the system as short as possible, minimizing any direct coupling of noise to the ac line. The primary side of the transformer is protected by a circuit breaker but the system power on-off switching takes place on the secondary side so there is no need to run the unfiltered ac mains to the power switch at the front.

Shielding is effected by enclosing the sub-units, such as the power supplies and the card cage, with aluminum panels. Data is transmitted between units either on shielded cables or flat cables. The flat cables are as short as possible, routed close to the chassis or cabinet surface, and the wire assignments are ground-signal-ground-signal-etc. The connector shells of shielded cables are connected to the cable shields and the shells of the mating connectors are solidly grounded to the mounting panel. All this shielding prevents radiated interference from getting into the ac mains.

Radiated Emissions

Radiated emissions were controlled primarily by establishing an electrically "leakproof" cabinet. The system cabinet, made of steel not only for EMI control but for economic and structural reasons as well, is in two parts. One frame houses the power supplies, the isolation transformer, the control panel, and the flexible disc drive. The other frame houses the card cages. Electrical bonding between the two frames is assured by steel buttons on one that butt against plated mating surfaces on the other when the two are bolted together. The buttons are spaced about six inches (150 mm) apart, which is approximately one-tenth the wavelength of the highest frequency (200 MHz) that measurements showed were radiated by the system. Subsequent measurements confirmed that this spacing is effective in preventing the cabinetry from functioning as a radiator for system-generated interference. The card cages and the peripheral I/O junction panel at the left-hand end of the cabinet are also mounted to the frame against grounding buttons.

Electrical continuity around the cabinet doors is maintained by metallic mesh gaskets. The door surfaces that contact the gaskets are plated and then masked during painting to leave the metallic surface exposed. Electrical continuity is maintained not only between parts of the mainframe cabinet but also to the shields of the cables that interconnect the mainframe and the peripherals, thereby assuring continuity of the shielding throughout the entire system. As noted above, the cable shields are attached solidly to the connector shells, which are mounted to the junction panel of the mainframe. The logic ground return for each peripheral is handled separately on one of the cable conductors.

EMI Evaluations

During the design phase, radiated emissions from the various units that make up the computer system were evaluated initially with a spectrum analyzer (HP Model 8552B/8554B) connected to a broadband biconical antenna. Most of this work was done in a large shielded enclosure. Because of the possibility of standing waves within the enclosure, results were considered simply as relative values for evaluating various design fixes. Once a problem frequency was identified, electric-field and magnetic-field probes were used with the spectrum analyzer to pinpoint the source of the radiation. An RF current probe was also used; clamped to an I/O cable, it helped determine the frequencies radiated by the cable.

When these tests indicated that an acceptable level of EMI performance had been achieved, quantitative measurements were made outdoors in an open field. A 52×60-metre elliptical area, oriented at right angles to nearby commercial radio transmitters, was cleared of all objects that could affect the electromagnetic fields. The equipment was placed at one focus of the ellipse and the measuring antenna was at the other. Tuned dipole antennas and tuned radio receivers of the VDE-recommended type were used to measure the electric field strength in the 30-to-1000-MHz range. The magnetic field strength was measured in the 10-kHz-to-30-MHz range using loop antennas and a tuned receiver. Analyses were then made on the nature of detected signals, the type of modulation, the polarity of the radiated signals, the orientation of the cables with respect to the equipment, and whether or not the radiations were a function of the type of data activity going on in the computer.

Measurements of Conducted EMI

Conducted emission measurements were initially performed in the shielded enclosure with the spectrum analyzer and a line impedance stabilization network (LISN), a device that inserts an RF transformer in series with any of the ac power line conductors for detecting the presence of EMI on the conductors. The LISN was mounted directly to the wall of the shielded enclosure for good RF grounding, and care was taken to assure a good impedance match between the RF transformer and the spectrum analyzer.

During these tests, the unit under test was operated as it

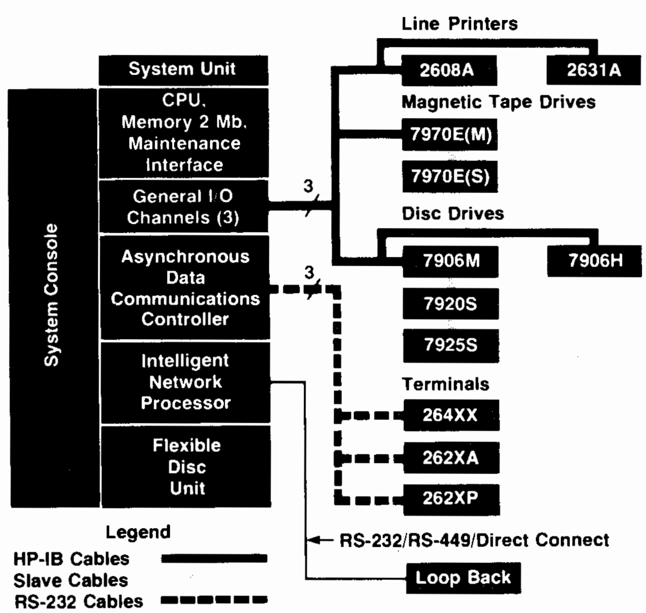


Fig. 2. *HP 3000 Series 33 mainframe configuration and peripherals tested for VDE type-certification.*

would be during normal operations. For example, for testing the flexible disc unit a looping program was written that caused data transfer in both directions between the disc and the CPU. Since the current levels encountered during write operations are different from those during read operations, all possible operations characteristic of normal activity were programmed so emission levels could be evaluated as a function of program activity.

The smallest operational assemblies were tested first and results were documented. From these results it was deduced what the total emissions would be. Then two or more assemblies were checked together, and finally an entire system was checked as a unit. Then, all practical combinations of the mainframe and various peripherals were checked. In cases where a system exceeded desired emission goals, peripherals and sub-units were individually powered off or electrically and physically removed to help trace the problem frequency. (The EMI emissions of the various peripherals had been controlled by the personnel of the relevant manufacturing divisions using techniques similar to those used for the mainframe.)

As a result of these tests, it was observed that conducted emissions that have frequencies below 1 MHz or so can be traced to the effectiveness of the line filtering. Emissions above 1 MHz, which were largely program dependent, are affected by grounding, shielding, and couplings between cables.

As with the radiated emission tests, once acceptable conducted EMI levels were achieved, quantitative measurements were made with tuned receivers of the type recommended by VDE.

Certification

In September 1978, VDE representatives measured the conducted and radiated EMI emissions of an HP 3000 Series 33 and peripherals, in the configuration shown in Fig. 2, using their measuring equipment according to prescribed procedures. As a result, the Series 33 was certified under VDE 0871/6.78 Level A specifications for ISM (industrial, scientific, and medical equipment). Table I lists the units licensed by FTZ as a result of the VDE certification.

Table I. Equipment licensed by FTZ.

System Unit	32413A
Line Printer	2608A
	2631A
Data Terminals	2621A, B, P
	2622A, B, P
	2623A, B, P
	2640B, F, K, N, R, S
	2641A, B, F, K, N, R, S
	2645A, B, F, K, N, R. S
	2646A, B, F, K, N, R, S
	2647A, B, F, K, N, R, S
	2648A, B, F, K, N, R, S
	2649A, B, C, D, F, K, N, R, S
Disc Drives	7906H, M, S
	7920H, M, S
	7925H, M, S
Mag Tape, Master	7970E
Mag Tape, Slave	7970E

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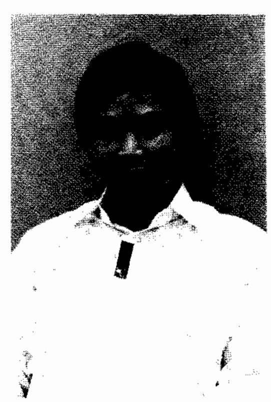
Daniel T.Y. Wong



Danny Wong functioned as the catalyst for the HP 3000 Series 33 System EMI design and certification. He joined HP in June 1976, and was involved in several areas of Series 33 mainframe design in addition to EMI control. Before joining HP he was a research associate at the University of Missouri, where he spent four years leading a group of students working on a fast, large-scale (7,000 IC) hybrid computer for simulating electric power systems. The computer is used by the electric power industry for operator training today. Danny is a member of IEEE and the IEEE Computer Society, and has contributed many technical papers in the field of hybrid computation of power systems. He is now doing memory systems design. He obtained his BS, MS, and PhD degrees from the University of Missouri at Columbia in 1971, 1972, and 1976 respectively, all in electrical engineering. He and his wife enjoy travelling and outdoor activities, and spend much of their spare time improving their home in San Jose, California.