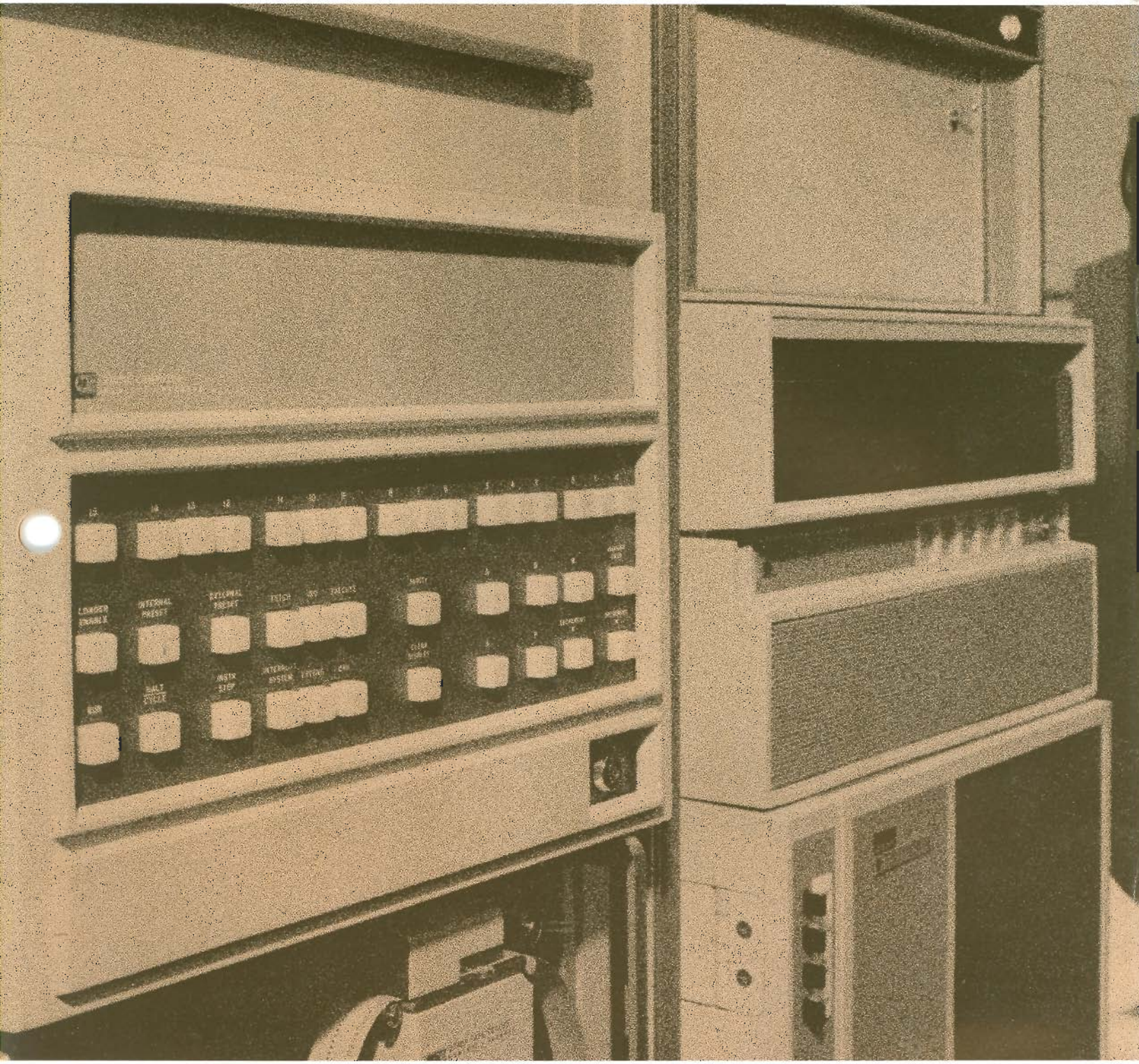
HP 9600E/F
Real-time executive systems



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ntroducing two new instrumentation-oriented Real

The 9600E Real Time Executive System (above) is based on two major, new-as-tomorrow capabilities from Hewlett-Packard . . . . The 2100A Computer (top left), also used in 9600F RTE systems, is a computer that comes equipped standard with most of the features required in an RTE – features like memory protect, hardware multiply-divide, parity checking with interrupt, and power fail/auto restart. Memory is plug-in expandable from the 16K used in the basic RTE systems on up to 24 or 32K in the mainframe. Direct memory access, which is part of all RTE systems, can be provided in the optional I/O extender, so program-assignable direct memory access can be used with any of the up to 45 I/O channels available with the system . . . . The 7900A moving head Disc Drive (top right) sets new records for access times – like 10 milliseconds, maximum, for head movement track-to-track; 35 milliseconds, average, over 67 tracks. This now-generation disc drive also features fast interchange of disc cartridges. The drive stops in only 25 seconds, restarts in only 30 seconds after the new cartridge is in. Storage capacity begins at 2.5 million 16-bit words, and three drive units can be added to expand storage capacity to 10 million words.

Time Executive Systems from Hewlett-Packard

These are multiprogramming, foreground-background systems, with priority scheduling, interrupt handling, and program load-and-go capabilities. The HP 9600E system is based on the new HP 7900A or 7901A moving-head Disc Drive, which provides large storage capacity for programs and data. The HP 9600F system uses a fixed-head-per-track disc.

In the 9600E and 9600F, the executive, operating in HP's new 2100A Computer, mobilizes disc storage, data acquisition subsystems, interfaced instruments, input/output peripherals and Real-Time Software modules into a powerful, real-time multiprogramming system. The executive operates in 16K of core, which is plug-in expandable to 24K or 32K whenever necessary to accommodate growth of system capabilities. With the executive controlling the computer, several user-prepared programs can be run in real time concurrently with general-purpose background programs.

In industry, the multiprogramming capability of HP 9600E/F systems can be used to coordinate computer control of sensor-based testing of engines, turbines, compressors, electric motors, and other complex products at multiple test stations. Sharing the control and mass storage capabilities of the system among several test stations minimizes the total cost of computer-automated checkout, with its benefits of increased speed, accuracy, and reliability. The executive administers concurrent execution of the individual programs serving the various test stations, applying test control signals and acquiring data, and returning appropriate test report printouts to the operating technicians at the test sites.

In the research lab, the executive shares system control and mass storage resources among multiple programs for controlling data acquisition subsystems and other instrumentation assigned to various projects, and for returning processed results to the researchers working on the projects.

Of particular value in these applications is the privileged interrupt capability designed into the 9600E/F system. Privileged interrupts bypass the normal interrupt processing of the executive to provide response in minimum time for critical programs.

The RTE schedules the running of programs on a priority basis under both time and event control. It supervises all interrupts, I/O operations, and bulk memory transfers plus the housekeeping necessary to a system where multiprogramming is performed. While the RTE is running multiple lab projects or test stations in the foreground, taking data on demand, members of your software development team can use the same computer during the day for program development. At night, background operations can be shifted to generation of long reports. The availability of background programming makes possible maximum utilization of hardware, providing a highly practical solution where separate computers are not economically feasible.

Programs for the 9600E/F systems can be written using HP Real Time Assembly Language, HP Real Time FORTRAN IV, or FORTRAN II, or HP Real Time ALGOL. These systems provide comprehensive memory protection for the system exec and for your vital programs, both in core and on the disc. Core memory requirements are minimized by configuring a tailored system from standard modules. The RTE is configured on the same computer system in which it will operate.

Programs can be added, replaced, or deleted while the computer is always on-line (operating in real time). This allows the system to be modified to meet changing requirements, or to perform new functions without interrupting existing operations or defaulting on existing commitments.

This brochure describes the system, its features, and capabilities. System support information is presented at the back. Ordering information for the various RTE systems, notes on RTE and other computer system applications, and detailed hardware information are presented in separate HP publications.

Features

- **Multiprogramming Capability** – Interleaved execution of programs for maximum processor utilization.
- **Load and Go Capability** – Minimizes bothersome paper tape handling.
- **File Manager Option** – Allocates and controls system mass storage.
- **Privileged I/O** – Provides for a class of interrupts that are processed faster than normal interrupts.
- **On-Line Modification** – Allows modification of disc-resident real time and background programs without stopping operation of the system.
- **Time-Out** – Provides a valuable check on I/O operations.
- **Foreground and Background Processing** – Operation of real-time processes and conventional background programs.
- **Swapping** – Grants processing time to higher priority programs without waiting for completion of lower priority programs.
- **HP Real-Time Software** – Complete programming systems, including HP Assembler, HP FORTRAN IV, FORTRAN II, ALGOL, Symbolic Editor, Debug, Library and Loader.
- **Easy Configuration on Same System.**
- **Modular System Organization** – Tailors a system to user's requirements and gets him "on-line" fast.
- **Flexible Program Priority Structure** – Up to 99 priority levels, changeable during system operation.
- **Dynamic System Protection** – Memory protect of both core and bulk memory.
- **Plug-in Adaptability** – Peripherals interfaced simply with plug-in cards.
- **Switchable Memory Access** – Two direct memory access channels, either one assignable to any I/O channel.
- **Reliability and Support** – System incorporates proven reliability of HP Computers, backed by sales and service offices throughout the free world.

A new standard in computer efficiency

Central Control

Using experience gained in other real-time systems, Hewlett-Packard developed the 9600E and 9600F Real-Time Executive Systems. These systems are designed to provide for monitoring and controlling all aspects of the operating environment. Central control is maintained through interrupt processing and scheduling of program execution and input/output processing. Inputs are accepted, processed, and returned fast enough to influence system environment. Processor time is granted to the highest priority program or function. Critical real-time functions may be assigned highest priority to assure optimum response and service.

Priority Structure

The priority structure defines the relationship among the real-time and supervisory segments of the system. Levels of priority (i.e., 1 to 99) are used rather than distinct classes. Multiprogramming capability permits many concurrent Real-Time programs and Background programs to be in the process of executing. A higher priority program can interrupt a running program and gain program control.

USER PROGRAM TYPES

The system defines two types of user programs, Real-Time (foreground) and Background, each of which is subdivided into two classes. The core allocations of these programs are shown at the right.

Real-Time Core-Resident Programs

Real-Time core-resident programs are always stored in core with the Real-Time Executive. This class is intended for high-priority programs requiring quick response to real-time conditions.

Real-Time Disc-Resident Programs

These programs are resident on disc and are transferred to the Real-Time disc-resident area in core to be executed. This class is provided for generally lower-priority programs whose response time can allow for a disc transfer (average disc hardware access time 8.7 milliseconds in 9600F system, 47.5 milliseconds in 9600E system). The real-time resident area of core holds one program at a time, but with swapping the program currently in core may be dumped out onto the disc and a higher priority program may be loaded into core and initiated before the program currently in core has run to completion.

Background Core-Resident Programs

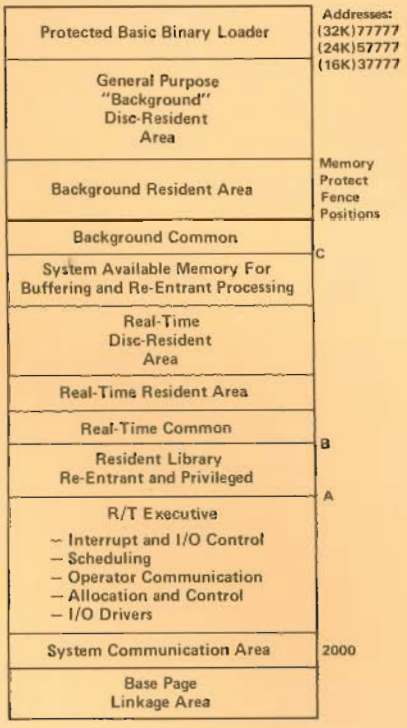
Background Core-Resident Programs are parallel with the real-time core-resident class, but are located at the start of the background region of core.

Background Disc-Resident Programs

Background Disc-Resident Programs are transferred from disc to the background disc-resident area of core to be executed. While the priority levels of these programs are not restricted, they would generally be assigned low priority. Background programs may be segmented and each segment transferred to core memory when needed. However, a program in this class cannot be swapped out, but usually runs to completion before a new background program can be loaded. The principal RTE programs in this class and their background area core requirements are:

Assembler	5K
FORTRAN II	5K
FORTRAN IV	5K
ALGOL	8K
FMGR (part of File Manager)	5K

Core Allocations in a Configured Real-Time System



MEMORY PROTECT

Dynamic and Fixed Protection

Dynamic memory protection is provided by the system for core and disc memory. The disc memory also has a hardware memory protect for specified tracks which protects the Real-Time Executive and the user's program library.

Memory Protect Fences

The core memory protect uses a hardware fence register. Its position is set by software. The protected core memory area is the area with addresses below (less than) the address in the fence register.

The memory protect fence is dynamically changed by the Executive to the locations A, B, and C as shown on the Core Allocation Diagram. The Executive is protected from errors in user programs. A program being executed in the background area of core is isolated from other areas of core so that the real-time user programs and the RTE are not altered due to an error in a background program.

Disc Protection

Disc memory tracks are dynamically assigned to a user program upon request. These tracks are protected from being overwritten by other programs until released by the requesting program. For flexibility, tracks can also be made accessible, without restrictions, to many programs.

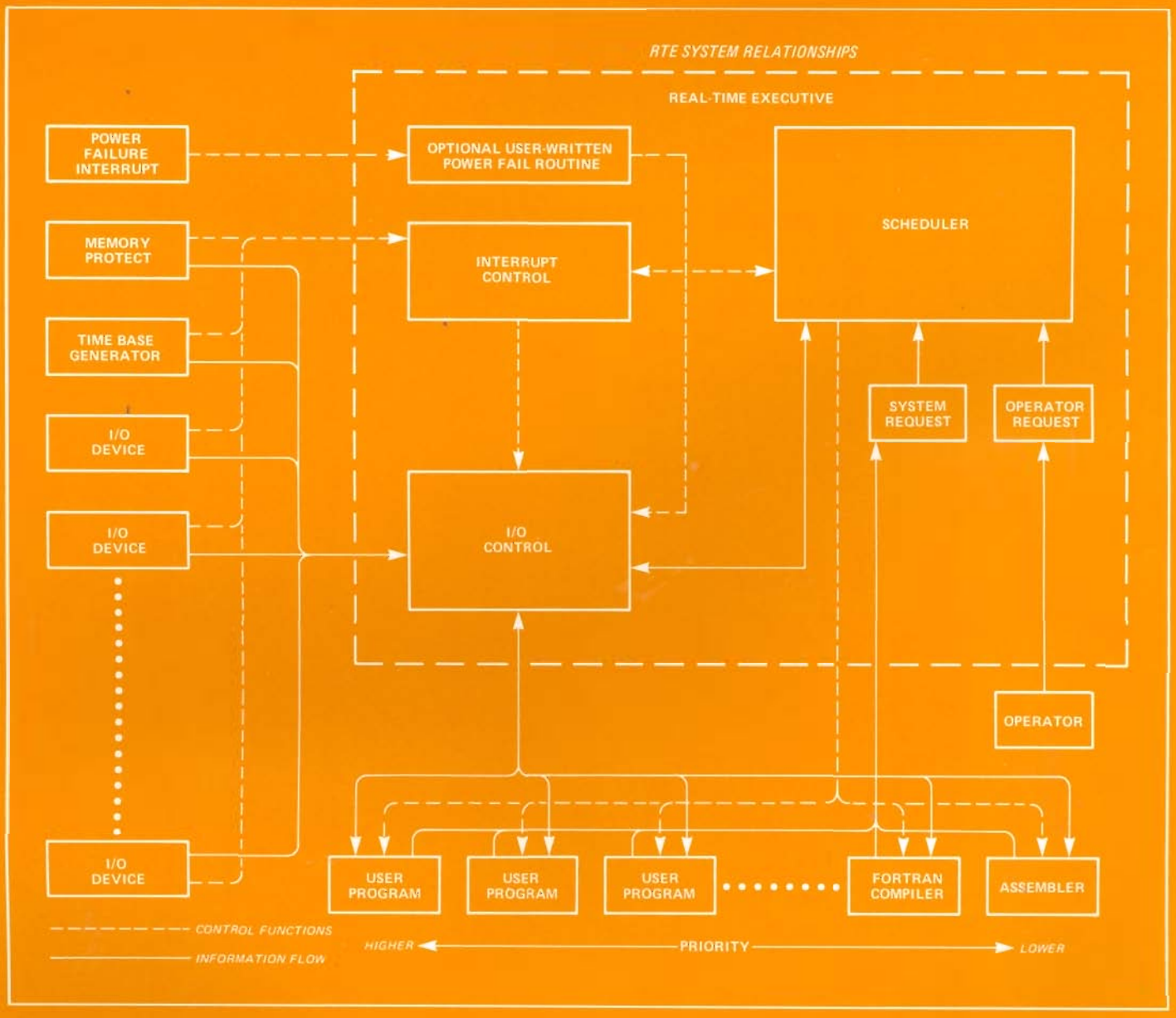
Specified tracks on the disc memory, which contain the RTE and user programs, can be hardware protected on the disc. This prevents these tracks of the disc from being overwritten and destroying the integrity of the system.

NOTE: The Real-Time Executive software is supplied with 9600E/F Systems under limited rights that do not include the right to copy the software for use on other systems or the right to disclose the software to any third parties.

System generation

User real-time programs, user background programs and Real-Time Executive Modules are incorporated into a configured real-time system. Since HP real-time software is modular and of a general nature, the user simply configures his particular programs and I/O device drivers into a real-time system tailored to his specific needs. The relationship of these elements to the Real-Time Executive are shown in the diagram below. A configured real-time system dynamically incorporates new user programs to the maximum number of programs specified at system generation.

Using the Real-Time Generator (RTGEN), a Real-Time Executive System can be configured in a matter of minutes. The user's computer or any other Hewlett-Packard computer with 16K memory, the necessary mainframe options, disc or drum memory, and ASR-33 Teleprinter may be used. The RTGEN converts relocatable software modules and user programs into a Configured Real-Time System in absolute binary format. The remaining disc storage is dynamically allocated by the Configured System to user programs or is utilized by the scheduler for swapping operations.



Operating characteristics

Program scheduling provides for dynamic allocation of the system facilities in a real-time environment. Processor time is granted dynamically to the highest priority program scheduled for execution. The RTE permits assignment of program priority either during system configuration or dynamically by the operator with the system online. Priorities of foreground and background programs can be intermixed although real-time programs normally require the highest priority. User priority levels may range from 1 to 99. It is possible for more than one program to be at the same priority level.

Programs may also be scheduled online or set to execute at periodic time intervals. Overall the RTE includes the following functions:

- Program Scheduling
- Interrupt Processing
- Input/Output Processing
- System Requests
- Operator Requests

The following software modules (or programs) are included:

- Real-Time Assembler
- Real-Time FORTRAN IV Compiler
- Real-Time FORTRAN II Compiler
- Real-Time ALGOL Compiler
- Real-Time Symbolic Editor
- Real-Time Debug
- Real-Time Relocating Loader
- Library and Utility Subroutines

Software modules

The software modules are in general disc-resident programs which are called by the system teleprinter to be executed in the background area of core. These programs run in the background disc-resident area at the same time real-time programs are being executed in the foreground in the real-time core-resident area. A description of each of the modules included in the HP real-time package is given below.

File Manager (Optional)

Allocates and controls system mass storage in named files. This option consists of:

FMGR – Operator command interface
D.RTR – Directory supervisor
Library – Supports user program access to files

Built-in multiprogramming safeguards keep programs from destructively interfering with each other's files. Up to seven programs can have access to the same file at one time.

The file manager handles any subset of disc packs on any combination of system, auxiliary, or peripheral discs. It can store programs in easily-retrievable source, relocatable, absolute, or load module form. It handles random-access, fixed length records, or sequential access, random length records.

Users can designate hardware devices as files, using file manager commands to a punch, magnetic tape unit, or other device.

The manager provides two levels of security. A master code can be required for a listing of the file directory that includes security codes of the individual files.

Housekeeping includes purging and repacking of files on command.

Real-Time Assembler

Accepts source input written in HP Assembly Language and outputs a relocatable binary program. If there is room to store the source program on the disc, only one pass of the source tape is made through the input device.

Real-Time FORTRAN IV Compiler

Accepts both FORTRAN IV and HP Basic FORTRAN (FORTRAN II) programs and provides a relocatable binary program. Includes special statements for real-time control.

Real-Time FORTRAN II Compiler

Accepts HP Basic FORTRAN plus additional statements for real time control.

Real-Time ALGOL Compiler

Accepts HP ALGOL plus additional statements for real time control. (Requires at least 24K of core and an 8K background disc area.)

Real-Time Symbolic Editor

Edits and updates symbolic source language programs or files on disc or paper tape.

Real-Time Relocating Loader

Provides for loading user-generated programs on-line into the foreground or background area for general purpose processing or for debug of programs which are ultimately to be included as real-time programs in the system.

Real-Time Library

Consists of routines found in the relocatable Library. These programs are designed for the real-time environment and classified or structured as:

Re-entrant
Privileged
Utility

The classification of a specific program is based on its functions, length, and execution time. A re-entrant or privileged program may be included in the resident library area of the absolute system and shared by all programs. A utility program is not designed for sharing among several programs, so a copy of the utility program is appended to the absolute version of each calling program that uses it.

System functions

PROGRAM SCHEDULING

Time Base Generator

The Time Base Generator generates an interrupt every ten milliseconds and updates the current time values. Programs can be initiated on resolutions of hours, minutes, seconds, or even tens of milliseconds. A list of time-scheduled programs is checked whenever current-time is updated.

Scheduled List

The scheduled list contains all programs in order of priority that are ready for execution. Programs are placed in this list when it is time for them to run, when requested by another program or by an operator, or when an event occurs. The program at the top of this list is the highest priority program for that time period, and is therefore, placed in the execution state.

Program Initiation

A program is initiated immediately if it is in core memory. Real-time resident programs are normally given highest priority. If the program is on disc and is to be executed in the real-time disc-resident area, and an uncompleted program already occupies that space, the uncompleted program is transferred out to disc and saved in its uncompleted and modified state. Then the new program is transferred into core. This swapping feature grants processing time to higher priority programs without waiting for the completion of the interrupted program. In the 9600F system, transfers are made from a high-speed disc which has an average hardware access time of only 8.7 milliseconds. During the transfer a check is made to see if work can be done in other areas of core. I/O operations can continue simultaneously. Transfers in the 9600E system with its greater storage capacity take somewhat longer (disc hardware access time averages 47.5 milliseconds).

INTERRUPT PROCESSING

The Real-Time Executive utilizes the multi-priority level interrupt system for power failure, memory protect violation and the time base generator, as well as for peripheral I/O and user-interfaced equipment. When one or more interrupts occur simultaneously, the interrupt with the highest hardware priority is recognized, but the hardware also remembers the other interrupts.

Since all responses to interrupts require some housekeeping, such as register storage, program control is transferred to the Central Interrupt Control Routine (except in case of power fail or privileged interrupt). After the housekeeping chores, this routine decides what action should be taken. It will initiate routines to handle memory protect violations, time keeping, I/O operations, and requests for program execution. Depending upon the complexity and the state of the system, response to an interrupt, from stimulus to initiation of the corresponding program, requires 1 to 3 milliseconds.

PRIVILEGED INTERRUPT

Both RTE systems offer a special feature, known as privileged interrupt, which is based on the hardware priority structure of the computer. Privileged interrupts bypass the normal interrupt processing of the system to achieve ultra-fast response (typically less than 100 microseconds to start of initiation of the privileged routine). This feature accommodates the needs of interrupts having the greatest urgency and also makes possible data acquisition at throughput rates in excess of 5kHz without the use of Direct Memory Access.

INPUT/OUTPUT PROCESSING

The I/O Scheduling and Control Monitor (IOC) is responsible for allocating the use of the DMA channels and all standard devices in the system. It provides for referencing I/O devices by a logical unit number rather than by the actual physical channel. It provides for stacking of I/O requests by priority of the calling program and allows for an automatic memory buffering of output directed to low or medium speed devices.

All input/output operations are performed concurrently with program computation in the overall system. One I/O driver is used for each group of like devices, but each device has a table associated with it to store the variable information required.

When a request is made for action by a busy device, the request is placed in a waiting list according to the priority of the requesting program. This keeps each device continually busy until the device's associated list becomes empty.

At the user's option, operation of any or all I/O devices can be timed out. This provides a check on operation. An I/O device that has not completed a directed action within the timeout period is put on 'down' status by the system and a 'timed-out' message on the teleprinter or keyboard-display unit notifies the operator.

System requests

User programs contact the Real-Time Executive by system requests to initiate input/output operations, schedule program execution and allocate system resources. System requests are made by an assembly language subroutine call or by a standard FORTRAN or ALGOL statement. The request processor routines operate as self-contained units within the RTE. Functions handled by the standard system requests are as follows:

1. Read from any input device or disc.
2. Write to any output device or disc.
3. Control functions on devices such as magnetic tape.
4. Check the status of an I/O device.
5. Schedule programs to be run.
6. Turn off running program when it is completed.
7. Request the current time and day of the year.
8. Request program retiming.
9. Request disc track allocations.
10. Make 'global' tracks available to all programs.
11. Release disc tracks.

Operator requests

The operator may monitor and control RTE operation via the system teleprinter. The operator may:

1. Start or terminate any user program.
2. Change priority and timing of any non-scheduled user program.
3. Initialize time.
4. Suspend any user program which is executing or scheduled and activate it upon request.
5. Request current status of any user program.
6. Specify timeout of any I/O device.
7. Request loading and execution of background programs (Assembler, FORTRAN IV, FORTRAN II, or ALGOL Compilers, etc.)
8. Load relocatable programs and subroutines into the foreground disc resident area and into the background area.
9. Alter I/O logical unit assignments.
10. Control I/O device availability.
11. Release program tracks.

Additional information on Hewlett-Packard Real-Time Systems, software, subsystems, and related instruments and interfaces is provided in the following literature, which is available through Hewlett-Packard field sales offices.

Request No.	TITLE
5952-1608	9600 Computer Systems Configuring Guide
5952-1590	AN135-4 Closed Loop Production Testing*
5952-1595	AN135-6 Computer Analysis Aids Battery Testing*
5952-1612	AN 135-11 Stable Measurements on the High Seas*
5952-1630	AN 135-15 Minicomputer System Benefits Fuel Cell Technology*
5952-1634	AN 135-16 Minicomputer Systems Aid Military Vehicle Testing*
5952-1631	AN 135-17 Testing Ovonic Read-Mostly Memories*
5952-1601	9600 Computer Systems for Data Acquisition and Control
5951-1354	Preface to Programming
5950-9226	Program Catalog
5950-8313	A Pocket Guide to HP Computers
5950-8718	A Pocket Guide to Interfacing HP Computers
5952-4376	The Thoroughly Modern Mini (2100A Computer)
5952-4377	Processor Description (2100A Computer)
5952-4396	2100A Computer (data sheet)
5952-4430	2100A Floating Point Hardware (12901A)
5952-4438	7900A Cartridge Disc Subsystem
5952-4471	7901A Cartridge Disc Subsystem
5952-4384	Disc and Drum Memories (2766A/2773A/2774A)
5952-4334	Buffered Teleprinter Input/Output (2752A/2754B)
5952-4346	Keyboard-Display Terminal (2600A)
5952-4339	High Speed Punched Tape Reader (2748A)
5952-4344	High Speed Punched Tape Output (2753A)
5952-4400	Punched Tape Output (2895A)
5952-4441	132-column Line Printer (2610A)
5952-4351	80-column Line Printer (2767A)
5952-4439	7970B Digital Magnetic Tape Units
5952-4440	7970E Digital Magnetic Tape Unit
5952-4302	Parallel Output Optical Mark Reader (2761A-007)
5952-4458	Card Reader (2892A)
5952-1627	12-Bit, 45 kHz Data Acquisition Subsystem
5952-1607	10-Bit, 100 kHz Analog-to-Digital Subsystem
5952-1609	14-Bit, 18 kHz Analog-to-Digital Subsystem
5952-1508	Data Acquisition Subsystem (2320A)
5951-1510	Data Acquisition Subsystem (2323A)
5952-1527	Dual-Channel System Data Amplifier (2471A)
5952-4367	Relay Output Register (12551B)
5952-4320	16/8-Bit Duplex Registers (12554A/12597A)
5952-4429	Dual 8-Bit Digital-to-Analog Converter (12555B)
5952-1606	40-Bit Output Register (12556B)
5952-4468	16-Bit Microcircuit Interface (12566B)
5952-1507	General-Purpose Data Source Interface (12604B)

**This note covers a Real-Time Executive application.*

For more information, call your local HP Sales Office or East (210) 265-5000 Midwest (312) 677-0400 South (404) 436-6181 West (213) 877-1282. Or write: Hewlett-Packard, 974 E. Arques Ave., Sunnyvale, CA 94086. In Europe: P.O. Box 85, CH-1217 Meyrin 2, Geneva, Switzerland. In Japan: YHP, 1-59-1, Yoyogi, Shibuya-Ku, Tokyo, 151.

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HP 9600E/F Real Time Executive Systems brochure, change 1

Effective March 5, 1973, the components used in HP 9600E/F RTE Systems differ from the items noted in this brochure. The correct listings of components are:

HP 9600E RTE System Components

1. HP 2121A Microprogrammable Disc-Based Systems Building Block, with:
   a. HP 2100S Microprogrammable Systems Computer with 16K memory, Direct Memory Access, Time Base Generator, Teleprinter Communications Channel (current loop), and Floating Point Hardware.
   b. 2.47 million word Cartridge Disc Memory Subsystem (2121A option 060) with HP 12869A Disc Cartridge.
   c. HP 2752A Teleprinter.
   d. One-Bay, 56-inch Cabinet with Base Extension.
   e. HP 12575C Cordless Electric Paper Tape Winder.
   f. HP 12925A Paper Tape Reader Subsystem.

HP 9600F RTE System Components

1. HP 2100S Microprogrammable Systems Computer with 16K memory, Direct Memory Access, Time Base Generator, Teleprinter Communications Channel (current loop), and Floating Point Hardware.
2. HP 2752A Teleprinter.
3. HP 12925A Paper Tape Reader Subsystem.
4. HP 2766A Disc Memory (262,144 words).
5. Two-Bay, 56-inch Cabinet with Base Extension.
6. HP 12575C Cordless Electric Paper Tape Winder.

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