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This profile of RCA's new time sharing system and other recent developments in the Spectra 70 line is extracted from a new 250-page analysis of the RCA Spectra 70 hardware and software in AUERBACH Standard EDP Reports, an analytical reference service published by AUERBACH Info, Inc., of Philadelphia.

time sharing spectra 70 style

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When the RCA Spectra 70 series of computers was announced in December 1964, RCA entered head-to-head competition with IBM and

its System 360. From the beginning, RCA promised to provide more computing power per dollar than IBM.

Spectra 70 indeed offered much: a family of five generally compatible computer systems, a high degree of source and object program compatibility with the IBM System 360, extensive use of monolithic integrated circuitry, three levels of integrated operated systems, and an extensive line of peripheral equipment.* But the System 360 offered more—a greater variety of hardware and, especially, more “third generation” software facilities, such as random-access-oriented operating systems, source-language control of random access devices, automatic data management systems, comprehensive data communications control systems, and support of time-shared processing.

Recognizing these problem areas, RCA quietly set about closing the “facilities gap” between itself and IBM. During the past year RCA has added new and impressive peripheral units to its Spectra 70 line and has greatly increased the capacity and scope of its software systems. Most recently, on May 4, 1967, RCA announced the long-rumored Spectra 70/46 Time Sharing System, a development that serves to plug the only remaining gap of any significance in RCA's battle to match the processing capabilities of IBM in the small-to-medium-scale computer market.

Spectra 70/46

The Spectra 70/46 Time Sharing System includes a new Spectra 70/46 central processor, a new 70/567 high-speed magnetic drum unit, and a specially-designed software system called the Time Sharing Operating System (TSOS). Both hardware and software for the Spectra 70 Time Sharing System are scheduled for first delivery during the third quarter of 1968.

The 70/46 marks RCA's entry into the time-sharing computer market, joining such competition as the GE-645, IBM System 360/Model 67, and SDS Sigma 7 computer systems. However, RCA has designed its time-sharing system with more modest goals than those

of GE and IBM. RCA's apparent intention is to remain competitive in all areas of the small-to-medium scale commercial computer market without enduring the frustrations of the more ambitious pioneers in the large-scale commercial time-sharing business.

The monthly rental of an RCA Spectra 70/46 Processor with 262,144 bytes of core storage is \$14,125. RCA estimates that typical 70/46 system configurations will rent for between \$25,000 and \$30,000 per month. Contributing to the relatively modest prices of planned Spectra 70/46 systems are the facts: (1) that the 262K-byte 70/46 Processor is basically an expanded version of the \$11,125-per-month Spectra 70/45 262K-byte Processor, (2) that only single-processor systems have been announced to date, and (3) that a maximum of 48 on-line remote terminal units can be controlled by the system.

According to its design goals, the Spectra 70/46 Time Sharing System will be an efficient batch processing system with advanced multiprogramming capabilities; remote, conversational time-shared operations in time-sliced mode will be a powerful available facility that may, in some installations, consume only a limited amount of the system's total processing capacity. The more expensive GE-

*For a detailed review of the Spectra 70 family of computer systems, see “RCA Spectra 70—A Compatible Competitor,” by J. B. Totaro, *Data Processing Magazine*, June 1966, pages 54-61.

645 and IBM System 360/Model 67 systems, by contrast, are designed primarily for time-shared processing.

Noteworthy features of the 70/46 Time Sharing System include:

- Hardware logic within the processor to facilitate program paging and segmentation, providing simultaneous system access for up to 48 users at remote terminals.

- Up to 2,097,152 bytes of virtual memory available to programmers.

- A fast associative memory for translation of all virtual memory addresses to real core storage addresses.

- A conversational FORTRAN IV compiler with interpretive execution capability.

- Full compatibility with the systems programs and language processors of the RCA Spectra 70 general-purpose Tape Operating System (TOS) and Tape/Disc Operating System (TDOS), both of which are used with Spectra 70/35, 70/45, and 70/55 computer systems.

Configurations

Spectra 70/46 system configurations (and their costs) will closely approximate those of Spectra 70/45 systems. Any Spectra 70 peripheral device that can be used with the 70/45 can also be used with the 70/46 (and in generally the

same numbers). The few configuration differences include the 70/46's required use of a 70/567 Drum Memory Unit and, if remote terminals are expected to be used on-line, a multi-line communications controller. Spectra 70/46 systems are currently restricted to the use of a single processor and 262K bytes of core storage.

In addition to the 70/567 Drum Memory Unit, a minimum Spectra 70/46 configuration will include at least two 70/564 Disk Storage Units and two magnetic tape units for use by the system's software. The 70/46 Time Sharing System is designed to take advantage of the processing efficiencies made possible through the use of a hierarchy of system storage devices that range from magnetic tape units to disks, drums, and finally to main core memory.

Storage

Spectra 70/46 magnetic core memory is available in a single block of 262,144 bytes. Memory cycle time is 1.44 microseconds per 2-byte access. Each byte consists of eight data bits and one parity bit. Bytes can be grouped into 4-byte, 32-bit binary words. This data structure is identical with that of the Spectra 70/35, 70/45, and 70/55 systems (and, therefore, with the IBM System 360).

A major feature of the Spectra

70/46 Processor is its read-only control memory unit. This unit has a memory cycle time of 480 nanoseconds per 54-bit access. Read-only memory (ROM) is provided in three banks, each of which contains 2,048 54-bit words (or "Elementary Operations"). The Spectra 70/45 Processor, by contrast, provides only a single bank of read-only memory, which is used exclusively for the emulation of other computers, such as the IBM 1401 or RCA 301.

Spectra 70/46 systems cannot use the emulation technique. Read-only memory in 70/46 systems is instead used to implement several features that facilitate time-shared operation. The first bank of read-only memory is used to provide the microprogrammed routines that will permit the 70/46 to operate in the Spectra 70/45 processing mode. The second bank is used to implement an address translation table (in a section called the Translation Memory), an interval timer, and other hardware features used by the 70/46 in its paging and time-sharing operations. A portion of the second bank and all of the third bank are used to implement specialized functions, such as translation table manipulation, paging interrupt handling, etc., that would normally be performed by software. A special Spectra 70/46 processor instruction, Function Call, is provided to call for and execute these microprogrammed routines.

The new 70/567 Drum Memory Unit is currently offered for use exclusively with the 70/46 Time Sharing System. In this system, pages of user programs will be stored in on-line disk storage units, from which they will be called to main memory for execution. Once in main memory, program pages that must be temporarily dumped to make room for higher-priority pages are sent to the Drum Memory Unit, where they await rapid retransmission to core when main memory space again becomes available. Also residing in the Drum Memory Unit will be the most frequently used control routines of the 70/46 Time Sharing Operating System (TSOS).



DEBUGGING AT THE console of a prototype Spectra 70/46 Time Sharing System.

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Vital statistics on the new drum include a storage capacity that ranges between 4.1 and 16.4 million bytes, an average access time of 8.6 milliseconds, and a peak data transfer rate of 333,333 bytes per second.

70/46 Processor

The RCA Spectra 70/46 Processor is basically a 70/45 Processor with additional features to facilitate time-shared operations. All features of the 70/45 Processor are also included in the 70/46. The principal features added to the 70/45 in designing the 70/46 Processor include:

- Two additional banks of read-only memory.
- Virtual-to-real address translation logic.
- An interval timer with a 100-microsecond resolution.
- Hardware control of paging and segmentation.
- Interrupt capabilities for interval timer run-out, paging errors, and page queuing.
- Six microprogramed operators to control use of the translation Memory, interval timer, and page queuing.
- Capacity to add up to four high-speed selector I/O channels (as compared to a maximum of three medium-speed selector channels with the 70/45).
- Memory protection that includes both Store and Fetch Protect features. The Spectra 70/46 Processor has been designed to facilitate serving multiple users with multiple programs. To understand this design, it is necessary to consider the concept of paging.

Paging

The Spectra 70/46 core storage unit is divided into many blocks of equal size called "pages." The basic page size is 4,096 bytes, but 2,048-byte page lengths can also be specified through the software. Spectra 70/46 programs are compiled in blocks of 4,096-byte pages, and only a limited number of pages of each program need be in core storage at any given instant of program execution.

The purpose of so fragmenting core storage and programs is to permit a large number of programs (or program segments) to reside concurrently in core storage in a manner that permits execution control to be passed easily between the resident programs, either on an interrupt basis or a time-slicing basis. Thus, even modest-sized core memories can accommodate the processing needs of a large number of users, since only a limited number of pages of each requested program require use of core storage at any one time.

Program pages not immediately required for execution in a Spectra 70/46 system are stored in random access secondary storage—typically a 70/564 Disk Storage Unit. When these program pages are called for execution, they are relocated by the Time Sharing Executive routine to any available page in core storage. If active resident pages must be displaced by higher-priority program pages, they are temporarily dispatched to the system drum unit, from which they can be quickly called and re-instated in any available page of core storage.

The 512-word Translation Memory is used by the software when assigning and relocating program pages to specific blocks of core storage. The Translation Memory sets a limit of 512 pages as the maximum number of uniquely addressed program pages that any program can contain. This means that every Spectra 70/46 program can be written as if 2,097,152 bytes of core storage were available for its use, even though the actual core storage unit provides only 262,144 bytes of real storage. The Spectra 70/46's provision of about two million bytes of virtual core storage could be expanded to eight million bytes without substantial hardware change, but RCA has not indicated that such an expansion is forthcoming.

Address Translation

Before executing instructions in program pages that are dispersed randomly through core storage, the 70/46 Processor must translate each non-I/O instruction and op-

erand address from its virtual address form to the corresponding real address that is relative to the current location of the page in core storage. Virtual-to-real address translation takes place automatically in the Spectra 70/46 Processor, and generally without any increase in instruction execution time. (Instruction execution times for the 70/46 Processor are generally equal to those of the 70/45 Processor.)

When the Spectra 70/46 Processor is operating in the time-sharing mode, 24-bit virtual addresses are translated to 18-bit real addresses by means of an associative table-lookup search through the Translation Memory portion of read-only memory. The 12 low-order bits (i.e., the "displacement" field) of the virtual address are used intact as the 12 low-order bits of the real address. The next 11 bits of the virtual address represent the segment and page number of the program address. These bits are translated via the Translation Memory to a 6-bit real page address which is combined with the untouched 12-bit displacement field to form an 18-bit real address that is capable of directly addressing up to 262,144 bytes of core storage.

Processor Modes

Two processing modes are available for users of the 70/46 Time Sharing System. If a specific bit is set in the processor's Interrupt Status Register and a corresponding bit is set within the virtual address of an instruction or operand, automatic virtual-to-real address translation takes place and the various microprogramed operations of the Function Call instruction can be utilized. This processing mode is called the 70/46 or time-sharing mode. All user programs compiled by the Spectra 70/46's Time Sharing Operating System (TSOS) software include virtual addresses with the translate bit set.

The other processing mode is called the 70/45 mode. In this mode all object program addresses are treated as direct addresses, and no address translation occurs.

It will be possible to execute all Spectra 70/45 object programs, including the TOS and TDOS software control routines, in a Spectra 70/46 Processor operating in the 70/45 mode, with results identical to those obtained in a 70/45 Processor.

Instruction Set

The Spectra 70/46 Processor includes the full instruction repertoire of the Spectra 70/45 Processor, plus two new instructions; Test and Set, and Function Call. The Test and Set instruction can be executed in either the 70/45 or 70/46 mode. This instruction is used for bit-testing anywhere in main memory. The Function Call and its several microprogramed operations (called Special Functions) can be executed only in the 70/46 processing mode, and an attempt to execute them in the 70/45 mode results in an interrupt.

The purpose of the Special Functions is to reduce overhead times normally associated with time-sharing systems by implementing in hardware (i.e., read-only memory) functions which are usually performed by relatively slow software control routines. This approach to reducing the overhead delays associated with software operating systems has been widely discussed but rarely used to date. A similar use of read-only memories to implement emulators for

achieving program compatibility with unlike computers has been successfully accomplished by RCA and IBM, and is currently being developed by several other manufacturers.

I/O Capacity

Like the Spectra 70/45 system, the 70/46 Time Sharing System can concurrently execute one machine instruction, one input-output operation on each of the installed selector channels, and one data transfer operation on each of the eight subchannels included in the standard multiplexor channel. Up to 256 low-speed I/O devices can be connected to a 70/46 system via the multiplexor channel.

Selector channels are optional equipment, and two, three, or four such channels can be installed. Each selector channel has two trunks, permitting two I/O control units to be connected. Input/output data is transferred into and out of core storage in 2-byte blocks over the Selector Channels, and the 70/46 Processor is delayed a maximum of 1.44 microseconds for each block transferred. Thus, the I/O throughput capacity of the 70/46 system is 1.4 million bytes per second. (The 70/45 Processor, by contrast, is delayed 1.44 microseconds for each single-byte I/O transfer, resulting in an I/O throughput capacity that is half that of the 70/46.) The maximum data rate possible over a single se-

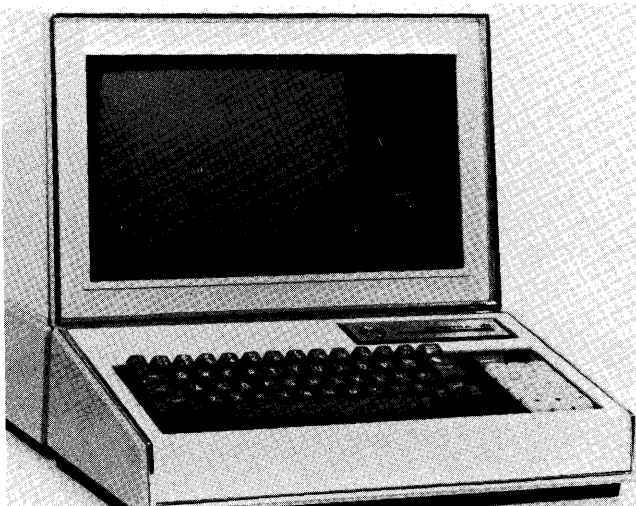
lector channel is 465,000 bytes per second.

Time-Sharing Software

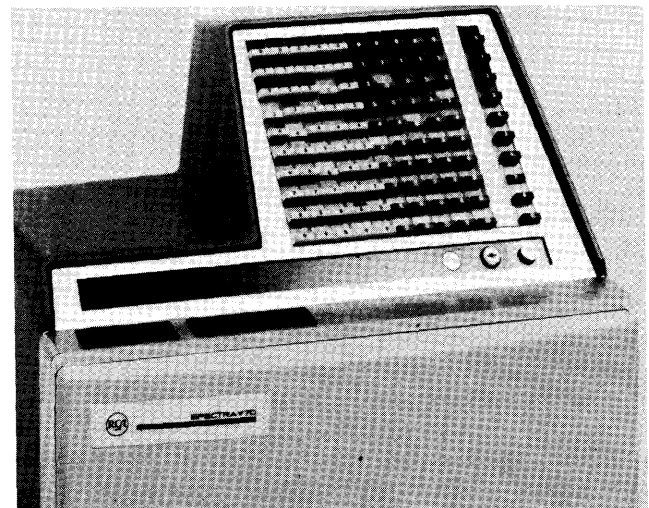
To complement the promising hardware design of the Spectra 70/46, RCA has announced an impressive software package called the Time Sharing Operating System. TSOS promises an efficient random-access-oriented multiprogramming operating system plus capabilities for providing up to 48 users at remote terminals with immediate, conversational access to the central 70/46 computer. Included in the software package will be a complete range of batch and conversational language processors, remote syntax checking, debugging and file editing systems, an extensive data management system, and a powerful executive control program. RCA plans to deliver the entire Time Sharing Operating System during the third quarter of 1968.

The nucleus of TSOS is its network of system control programs used in the "privileged" mode by the central Spectra 70 system. The principal control programs include: the resident Executive program; the File Control Processor (FCP) for catalog, file, and data management; an interactive data communications input-output system; an interactive software debugging system; and hardware diagnostic routines.

The chief components of the



RCA's NEW SPECTRA 70/552 Alphanumeric Video Data Terminal provides keyboard input and CRT output facilities.



THE SPECTRA 70/630 Data Gathering System transmits data from input stations such as this to a Spectra 70 computer.

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Executive program will be the following:

- Task Scheduler, to maintain a single task queue from multiple input sources, including remote terminals, and to schedule on a priority basis the concurrent execution of as many programs as the system resources will allow. The Task Scheduler will also include a time-sharing algorithm to control responsive time-shared operations.

- Memory Manager, to control the dynamic allocation of program pages and to manage the use of the more than two million bytes of virtual storage available to the programmer.

- Device Allocator, to manage the pool of input-output devices available to the system, and to assign free I/O devices to the programs' device-independent I/O requests.

- Peripheral Input-Output, to provide optional buffering of punched-card input files and printer-destined output files on random access devices or magnetic tape units.

- Job Control, to accept user-specified Job Control Language statements used to enter and define batch processing jobs at the central 70/46 computer center.

- Command Language Control, to enable users at remote terminals to communicate with the central system in either conversational or batch mode. The Command Language is an extension of the Job Control Language. It permits the users at remote terminals to identify themselves, to specify the tasks the system is to perform, and to monitor the execution of these tasks. Command Language procedures can be prestored for efficiency of operation.

Data Management

A major system control program in the Time Sharing Operating System is the File Control Processor (FCP). The FCP provides comprehensive file management and data management systems. In the area of file management, the FCP

maintains catalogs of all files in the system and provides facilities for indexed sequential access to files stored on random access devices. Options available to the user include the capability to specify file names and characteristics at execution time rather than at assembly or compilation time, and the capability to share files among users through the use of passwords.

Also controlled by the FCP is the TSOS Data Management System. Two types of file organization are supported: sequential and indexed sequential. The Data Management System provides facilities for manipulating either type of file by means of the following functions: describe, create, access copy, change, and delete. A file protection system prevents unauthorized reading and writing of files in a dynamic time-shared environment.

Processing Programs

In addition to the network control programs, TSOS provides a large set of processing programs available for use by the system and problem programmers. The TSOS processing programs include language processors and utility or service programs. Both the processing programs and the users' programs are executed in the "non-privileged" mode under control of the TSOS control programs.

Language processors are supplied in conversational and batch form. The conversational language processors include an interpretive FORTRAN compiler that uses a FORTRAN subset language, and syntax checking programs for source-level FORTRAN, COBOL, and assembly-language programs. The more conventional language processors that operate in batch mode are a FORTRAN IV compiler, a COBOL compiler, a Macro Assembler, and a Report Program Generator.

Utility programs are also provided in both conversational and batch modes. The two conversational service programs are the Desk Calculator and Text Editor programs. Using the Text Editor, the remote user can create, modify, and display files on a line-at-a-time

(i.e., single record) basis. The Text Editor should prove of great value in maintaining symbolic programs and their associated data files. The batch utility programs include a sort/merge program, a file maintenance routine for system and user programs, and a test data generator.

All software comprising the Time Sharing Operating System is currently scheduled for delivery during the third quarter of 1968.

In summary, the Time Sharing Operating System and its many components represent RCA's answer to the large-scale, random-access-oriented software systems offered by IBM with its Operating System 360 and the Model 67's Time Sharing System. TSOS supplants the long-discussed Disk Operating System in the RCA Spectra 70 software line. Because TSOS includes not only time-sharing facilities, but also impressive multi-programming and data management facilities, it is likely that the Spectra 70/46 Time Sharing System (including TSOS) will prove attractive to some users whose processing requirements do not include remote, time-shared processing.

Compatibility

The Spectra 70/46 Time Sharing System is compatible with the RCA Spectra 70/35, 70/45, and 70/55 systems to the extent that all instructions, character codes, interrupt facilities, and special features available in the nontime-sharing systems are also available in the 70/46 system and function in the same manner. Therefore, when operating in the 70/45 mode, the 70/46 system will be able to use the TOS and TDOS software systems and execute object programs compiled for 70/35, 70/45, and 70/55 systems, provided that the programs are timing-independent and system optional features are identical.

Functioning in the 70/46 mode under the specialized Time Sharing Operating System, the 70/46 will be able to compile all source programs originally written to function under TOS or TDOS in 70/35, 70/45, or 70/55 systems.

The Job Control Language (JCL) used with the Spectra 70/46 Time Sharing Operating System is an expanded version of JCL as used with the Tape and Tape/Disc Operating Systems, but is not fully compatible with the latter.

Because of the high degree of compatibility between the 70/46 and the general-purpose Spectra 70 computer systems, users of the 70/35, 70/45, and 70/55 systems should be able to upgrade to the more advanced facilities of the Time Sharing System with a minimum of conversion-time difficulty.

Like the RCA Spectra 70/35, 70/45, and 70/55 systems, the Spectra 70/46 in 70/45 mode is largely compatible (both in terms of programs and data) with the general-purpose models of the IBM System 360 computers.

Performance

A prototype Spectra 70/46 system is currently operational and being used by RCA for software development, but no detailed performance estimates are available to date. As a preliminary performance indication, RCA states that

the system will provide a maximum response time of eight seconds for each of 48 interactive remote terminals, assuming that all terminals are concurrently active and that four background programs are also being processed concurrently.

The Spectra 70/46 hardware/software combination as specified is impressive and deserving of further scrutiny by the industry as its implementation progresses. The 70/46 Time Sharing System is not startlingly revolutionary in its design nor extravagantly bold in its goals (and, as such, may not appeal to the industry's confirmed innovators). Yet, the 70/46 may work. It appears to combine the better features of efficient multiprogramming systems with more advanced remote data communications and time-sharing facilities. Its approach to time-sharing is evolutionary—a natural, continuous progression from the time-tested batch processing facilities to those that may be better suited to cope with the processing needs of the future.

New Hardware and Software

In addition to the 70/46 Time Sharing System, RCA has expanded and improved its product line in other areas during the past year. New hardware products include a controller for Burroughs, IBM, or NCR MICR sorter-readers, a high-speed (1,000 cps) paper tape reader, "quietized" printers with 96-character sets, an improved CRT display device, and 7-track magnetic tape units that provide tape compatibility with earlier RCA 301 and 501 systems.

More specialized hardware systems of recent development are the Spectra 70/510 Voice Response System, which delivers recorded human-voice responses to on-line inquirers at Bell System Touch-Tone telephones, and the Spectra 70/630 Data Gathering System (DGS), designed to gather information at remote, point-or-transaction input stations (such as badge readers, card readers, etc.) and transmit it to a central Spectra 70 computer system.

Software improvements have centered on adding random access device capabilities to the Spectra 70 language processors and expanding the support of data communications devices. Also, the Spectra 70 Basic Time Sharing System (BTSS) is being developed as an all-software approach to limited time-shared processing with Spectra 70/45 systems.

By means of these developments, RCA has improved its position as a worthy competitor of IBM in all areas of the small-to-medium scale computer market. RCA has accomplished this feat with the aid of a maturing market and product planning philosophy that does not attempt to match in every detail the vast facilities of the IBM System 360, but instead attempts to analyze the demands of the market place and to implement whatever facilities are required to remain competitive, but on a scale that is feasible and potentially profitable. The hardware and software design of the new Spectra 70/46 Time Sharing System is an excellent case in point.

Table 1. Profile of the RCA Spectra 70/46 Processor

Core storage cycle time, microseconds	1.44
Bytes accessed per cycle	2
Core storage capacity, bytes	262,144
Selector channels	0, 2, 3, or 4
Multiplexor channels	1
Selector channel capacity, bytes per second	465,000
Multiplexor channel capacity, bytes per second	465,000
Maximum combined I/O data transfer rate, bytes per second	1,388,888
Processor speeds, microseconds*	
Fixed-point binary	
$c = a + b$	25.2
$c = a \times b$	81.9
Fixed-point decimal	
$c = a + b$	42.2
$c = a \times b$	127.0
Floating-point (short)	
$c = a + b$	37.4
$c = a \times b$	67.6
Floating-point (long)	
$c = a + b$	52.6
$c = a \times b$	211.5

*The fixed-point binary and short floating-point operations use 32-bit binary operands; long floating-point operations use 64-bit binary operands. The fixed-point decimal times are based on signed 5-digit (3-byte) decimal operands.