

RAYTHEON



COMPUTER

THE RAYTHEON 703 IC SYSTEMS COMPUTER

RAYTHEON HARDWARE

Raytheon Computer's 703 is a low-cost, 16-bit integrated circuit computer ideally suited to be the central control element in data acquisition, data processing, industrial, commercial, engineering and scientific control systems. It starts as a basic 4K configuration. Hardware and software permit the user to easily and economically expand the basic computer to meet application requirements.

Hardware can be expanded up to a 32K memory system with all major peripherals, including disk. Software includes Real-Time FORTRAN IV and conversational FORTRAN, a real-time monitor, an integrated executive system and advanced hardware diagnostic routines.

The low priced 703 is perfect for replacing core buffers and special logic in OEM equipment. In addition, the 703 provides design features, operating performance, and programming advantages that make it comparable to the more expensive computers.

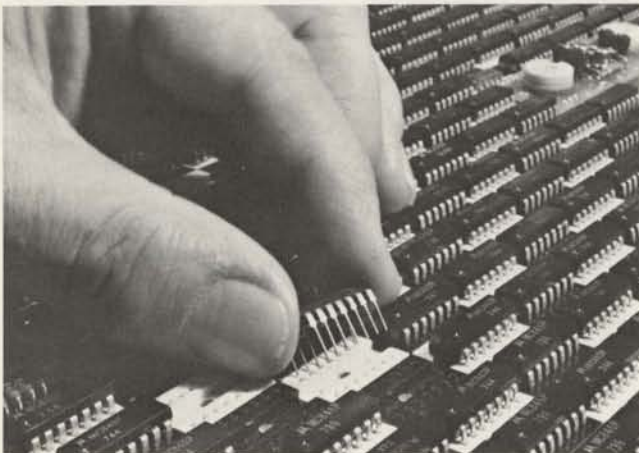
Included in the minimal central processor configuration are a 4K core memory, an ASR-33 Teletype, a Direct Input/Output bus, one level of Automatic Priority Interrupt and a cabinet complete with an operator's console.

PERFORMANCE

Word and byte manipulation instructions, a 1.75 microsecond memory, a real-time priority interrupt system and hardware multiply-divide make the 703 performance comparable to larger computers. Load word, load byte, add and subtract instructions execute in 3.5 microseconds. Hardware multiply-divide, available as an option, executes in 17.5 and 24.5 microseconds respectively.

FOURTH-GENERATION PACKAGING

Through the advanced 703 packaging concept, the user is offered initial low cost, accessibility for maintenance, reduced maintenance time and low cost spares.



703 computer packaging concept mounts all CPU IC circuitry on single motherboard. Diagnostic routine pinpoints faults to specific IC element which can be quickly replaced.

Logic for the entire 703 central processor is contained on a single master module or "motherboard" with 740 IC elements plugged into permanent socket units. Each IC can be quickly unplugged and replaced without damage to itself or adjacent circuit elements. Personnel without a high level of computer maintenance or technical training can maintain the 703. No soldering is required.

The motherboard approach means that 703 users need only a minimum inventory of \$1.50 spares instead of circuit modules costing \$50 or more. In addition, each 703 operator can make use of the SENSOR hardware diagnostic routine for troubleshooting. This routine enables the user to automatically and rapidly pinpoint an individual malfunctioning IC unit which can then be replaced as described above.

COMPATIBLE HARDWARE FOR EASY SYSTEMS DESIGN

For system expansion beyond standard peripherals, there's an almost endless line of compatible Raytheon M-Series IC analog and digital modules plus data acquisition and processing instruments made up from these modules. These instruments include the MINIVERTER™, available in 10 and 12-bit binary and 13-bit BCD, other ADCs and DACs, and the widely-used MULTIVERTER®, which offers the same functions as the MINIVERTER but with resolution up to 17 bits.

For users who might want to implement their own logic expansion, Raytheon will provide the basic master module boards. The user can then purchase the necessary IC elements from Raytheon or from some other source.

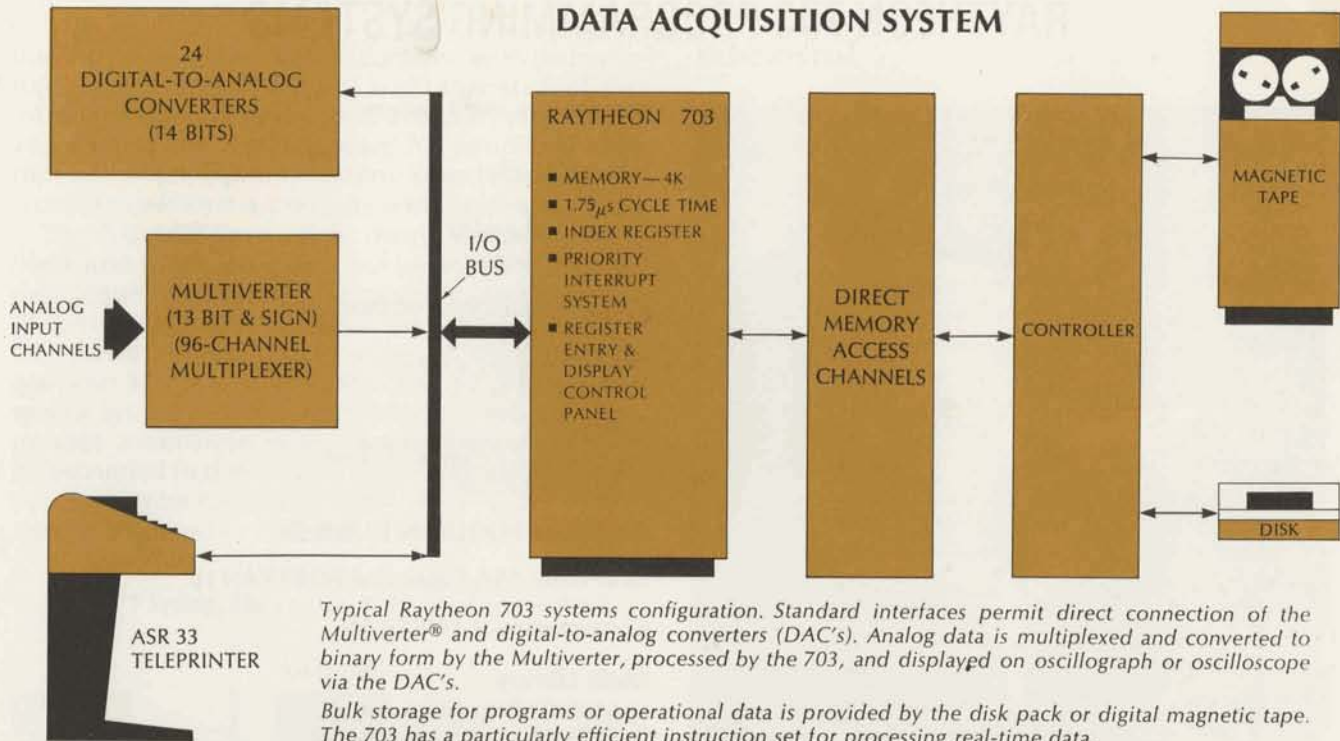
In addition to the compatible hardware, Raytheon Field Application Engineers provide application and systems design assistance. Raytheon Computer also offers automatic wire wrap service to user specifications so that systems are delivered assembled, wired and ready to use, usually at lower cost than if the user performed the assembling and wiring functions himself.

APPLICATIONS

Raytheon 703 computers are in use for applications such as radar data processing, aircraft and helicopter checkout systems and seismic data processing. The 703 is also being designed into systems for message switching, manufacturing test, engine test, signal processing and traffic control.

The Raytheon 703 provides the systems designer with more power, versatility and adaptability to changing requirements than is available with combinations of core buffers and special purpose logic. In addition, the low cost of the 703 enables Original Equipment Manufacturers to integrate the computer into a wide range of product systems for resale and maintain or even increase profit margins.

DATA ACQUISITION SYSTEM



FEATURES AND CHARACTERISTICS

- 16-bit word length
- 2's complement arithmetic
- 74 hardware instructions
- Direct and indexed addressing
- 4K to 32K Memory
- Byte and word addressing
- Byte manipulation
- Register entry and display control panel
- Programmed word transfer via 16-bit I/O bus
- 1.75 microsecond cycle time
- Real Time Priority Interrupt System
- Software Package — IC diagnostics, assembler, FORTRAN compiler, and executive routines

OPTIONS

Direct memory access channels; buffered/unbuffered
High-speed hardware multiply/divide
Real time clock

Peripherals include ASR33 or ASR35 with paper tape reader and punch, magnetic tape, line printer, paper tape reader and punch, card reader and punch, disk and Raytheon's line of data systems equipment.

CENTRAL PROCESSOR

The Raytheon 703 Computer has a set of 74 hardware instructions including 16 Skip instructions — power and speed for data acquisition applications, and a parallel arithmetic unit — power and speed for the scientific application. Byte manipulation, word manipulation, byte compare and word compare plus register transfers between the four hardware registers gives the 703 additional power and versatility. These particular commands, normally available only in large-scale computers, substantially increase the throughput of the processor where word and byte-oriented data must be input, output and manipulated.

INPUT/OUTPUT

The Raytheon 703 offers scientific and systems applications a versatile input/output structure. The basic I/O bus permits data transfers from 256 devices such as the teleprinter and paper tape equipment. High speed data transfers are handled via the direct memory access channel (DMA). The DMA channel allows six devices to actively input and output data simultaneously. For the systems user, the DMA channel is available fully buffered or unbuffered. With as many as six active devices on the DMA channel, data rates of 571,428 16-bit words per second can be accommodated.

PERIPHERAL EQUIPMENT

Magnetic tape — 7 and 9 track, 25, 36 or 75 ips, 200, 556 and 800 bpi, IBM-compatible.

Disk — maximum storage 6.4×10^6 bits; average access time 16.7 ms.

High-speed paper tape reader — 8 level, 300 characters per second.

High-speed paper tape punch — 110 characters per second, 8 level.

ASR33 and ASR35 teleprinter — with paper tape reader and punch.

Card reader — 400 or 1000 cards per minute.

Card punch — 100-400 cards per minute.

Line printer — 300/600/1000 LPM, 132 columns.

Digital plotter — 300 steps per second.

Raytheon Data Systems Hardware includes M-Series IC Digital Modules, digital-to-analog converters and the exclusive MINIVETER™ and MULTIVETER®. These units offer up to 256 multiplexer channels, a sample-and-hold amplifier and an analog-to-digital converter in a single chassis. Either can be connected to the 703 by a standard coupler to form data acquisition or logging systems.

RAYTHEON 703 PROGRAMMING SYSTEMS



RAYTHEON SOFTWARE

The Raytheon 703 is an integrated hardware/software system providing advance design in software as well as hardware. Hardware/software architecture was planned for modular growth from a 4,096 word processor with ASR 33/35 to a 32,768 word system with disk and other major peripherals. Real-time considerations strongly influenced the design of 703 programming systems. Features are incorporated for the programmer who is constructing real-time, time-sharing control programs. X-RAY EXEC, PREP, Symbolic Program Editor, TRACE and SYM I are innovations that provide a convenient man-machine interface in program preparation, debugging and execution.

All 703 programming systems were developed by Raytheon programming specialists working directly with the computer designers. As a result, the 703 customers benefit from reduced memory requirements, greater speed, efficient utilization, comprehensive diagnostics, and detailed documentation. ASA and industry standards were adopted wherever possible. Unique capability is presented in a specially developed package for detection and identification of hardware faults.

Raytheon 703 programming systems include the following elements for BASIC, STANDARD, and EXTENDED hardware configurations.

Assemblers and Loaders

- SYM I
- Basic Loader
- SYM II
- Record Loader
- Disk Loader

Executive and System Programs

- X-RAY EXEC
- Input/Output System
- TRACE
- PREP
- Symbolic Program Editor
- System Editor

Real Time FORTRAN IV Subset

Real Time ASA Expanded FORTRAN IV

Conversational FORTRAN

Math Library

- Math Subroutines
- Function Subroutines

Hardware Diagnostics

- SENSOR Package

MODULAR SYSTEMS

Raytheon 703 programming systems vary from the simple to the sophisticated, from BASIC to EXTENDED. Internal memories, mass memories, and peripherals establish the environment. As the system grows, the modular software expands. "Full utilization" is the guideline, even in the smallest systems. Each 703 software system contains an assembler (SYM), a system-fitted X-RAY EXEC and sub-programs; PREP, Symbolic Program Editor, TRACE, the Input/Output System and the System Editor.

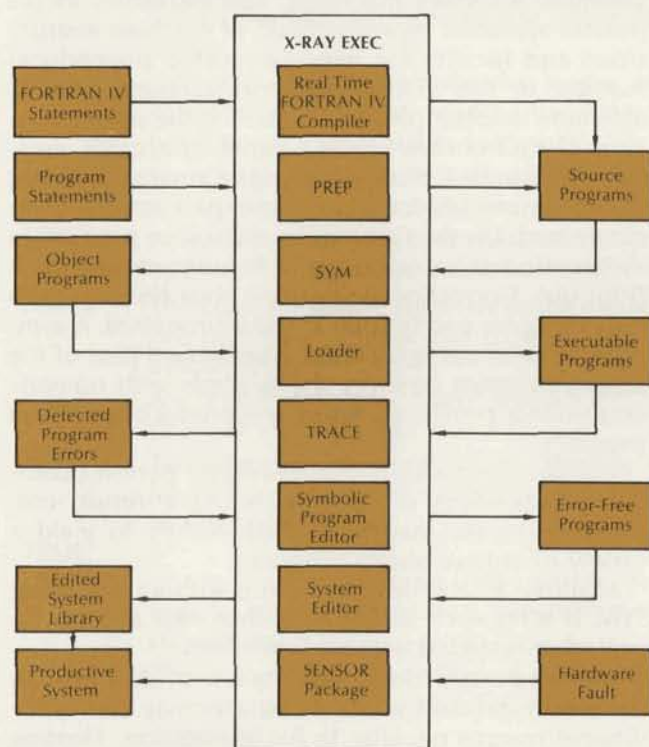
The X-RAY Executive and its sub-programs provide a unique new approach to program control within the system, to operator interaction and to system operation in a real-time environment. The X-RAY EXEC accepts directives from the user at the typewriter keyboard and sets up the system for operation with any of the sub-programs or user programs in the system. The various facilities available from the sub-programs can thus be readily utilized by the operator. One of the most important capabilities is the modification of source or object code from the keyboard under X-RAY supervision. In various operations X-RAY will output diagnostic references while its sub-programs are processing symbolic inputs.

The 703 is intended for use in systems where its sophisticated interrupt system and real-time instructions can be exploited. An input/output software system is provided as part of X-RAY EXEC to accommodate such environments. It features the ability to respond to priority interrupts by saving register contents and status automatically and by initiating a

transfer to the user function identified with that interrupt. Re-entrant subroutines and other state-of-the-art programming capabilities have been provided to accommodate not only standard 703 peripheral interrupt operation, but also custom, asynchronous interfaces with which the user may wish to communicate.

The 703 will be used in many situations where dedicated system programs will be written to provide data acquisition, information retrieval, data reduction or control functions. Raytheon has provided in X-RAY EXEC basic modules which can be utilized by the programmer to efficiently construct these programs for special system automation. These same sub-programs provide automation in the standard system and can be expanded in their use by the introduction of additional program modules. System flow under X-RAY EXEC is depicted in Figure 1.

Figure 1 System Flow under X-Ray Exec Supervision.

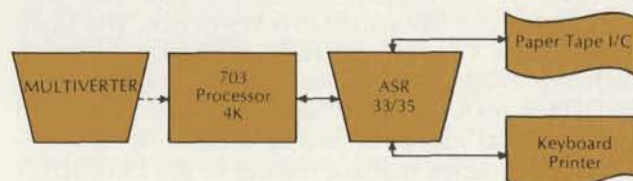


In addition to providing a library of math and function sub-routines for the scientific user, Raytheon has placed particular emphasis on hardware diagnostics. The 703 as a central element in sophisticated digital systems must have the ability to identify electrical malfunctions within itself and other parts of the system. Real-time systems by their nature demand high reliability and minimum mean-time-to-repair. Too little emphasis has been placed by contemporary designers on software for this purpose. Consequently, Raytheon developed SENSOR, the hardware diagnostic package, as an answer to this need. Many of its features are described later in this document.

BASIC SYSTEM

With emphasis on compactness of program components, BASIC is provided for 703 users with the minimum hardware configuration as depicted in Figure 2—4,096 words of memory and the ASR 33/35 with keyboard, paper-tape reader and paper-tape punch. System efficiency may be increased with the addition of magnetic tape and high-speed paper-tape reader and punch. BASIC consists of the SYM I assembler with the Basic Loader, X-RAY EXEC, Math Library, and SENSOR Hardware Diagnostic Package. A MULTIVERter® and coupler may be used as an optional input for analog data.

Figure 2 703 Basic Configuration

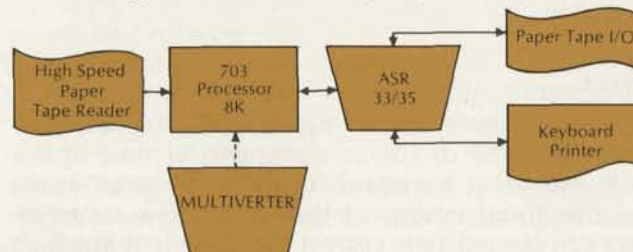


STANDARD SYSTEM

STANDARD is a system developed to fully utilize the addition of a high-speed paper-tape reader and memory expansion of 4,096 words to provide a total internal memory of 8,192 words. Optionally, a high-speed paper-tape punch may be added to accelerate program and data output to paper tape. The upward-compatible BASIC programs are combined with a powerful two-pass assembler, a Record Loader, and an expanded X-RAY EXEC. Magnetic tape may be added to the configuration for increased system efficiency. Programs on the optional magnetic tape may be updated by the System Editor. The system library paper tape may be modified by the System Editor if a high-speed paper-tape punch is present.

A MULTIVERter® and coupler may be used as an optional input for analog data. The STANDARD configuration with the optional MULTIVERter is illustrated in Figure 3. Peripheral independence is achieved by logical-unit assignment under program control. This large-scale system feature improves system flexibility and reliability.

Figure 3 703 Standard Configuration



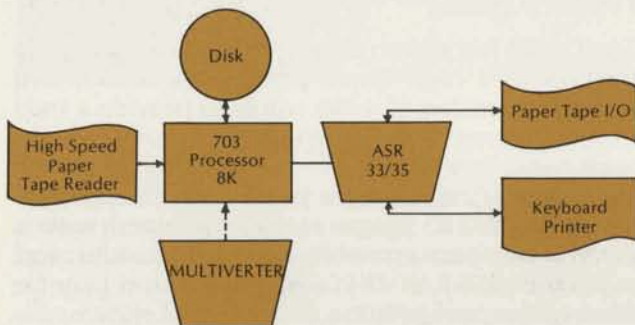
EXTENDED SYSTEM

The EXTENDED configuration is shown in Figure 4 and consists of 8,192 words of memory, disk and STANDARD system peripherals. SYM II and expanded X-RAY EXEC can be employed. Optionally, a high-speed paper-tape punch may be added to accelerate paper-tape throughput and magnetic tape units may be employed to increase system efficiency.

The system library resides on the disk; a unique method of identifying library programs was developed to allow rapid location and transfer from the random access disk. This circumvents other serial search methods and exploits disk speed. Conversation between keyboard and disk facilitates program and data retrieval.

The System Editor provides an automatic method for updating the library. Its system generator prepares the system library for disk residence. The Math Library, Disk Loader and fully expanded SENSOR Hardware Diagnostic Package are included in EXTENDED. A MULTIVERter® and coupler may be used as an optional input for analog data. Peripheral device independence is also a feature of the EXTENDED configuration.

Figure 4 703 Extended Configuration



ASSEMBLERS AND LOADERS

Raytheon 703 software includes two assemblers. A one-pass assembler, SYM I, is available for BASIC systems without mass storage. It provides direct on-line assembly using the ASR 33/35 as the primary input/output device. A more powerful two-pass assembler, SYM II, is available for STANDARD or EXTENDED systems. It includes procedural macro capabilities and other advanced features such as conditional processing. A SYM II assembler which operates on the Raytheon 520 computer system is also available.

SYM I

SYM I accepts symbolic paper-tape programs prepared by PREP or source statements entered at the ASR typewriter keyboard. In the latter case, errors are diagnosed on-line as they occur. The programmer can immediately correct the statement at which

time the assembler will accept and translate it to relocatable or absolute object code. SYM I is a one-pass assembler with a language subset of SYM II. Forward definitions are allowed. Statement error diagnostics are printed on the ASR 33/35.

Multiple assemblies can be run without reloading SYM I after each assembly. A special feature incorporated into SYM I permits the user to assemble a program directly into memory and execute immediately. Any combination of input/output assignments for ASR reader, ASR keyboard, ASR punch, High Speed punch or High Speed Reader may symbolically be made at the ASR keyboard under SYM I/X-RAY EXEC control. This versatility is provided during the initial phase of each assembly.

SYM II

SYM II design provides a fresh approach to macro assembly for small machines. The assembler incorporates symbolic representation of machine instructions and facility for user-generated procedural macros. In the STANDARD configuration, SYM II assembly is accomplished by reading the source program twice from any media—paper tape, cards, magnetic tape or disk. Slow punching of intermediate text which is normally found with two-pass assemblers is eliminated. On the first pass of the source program, a diagnostic test is performed with programming error print-out. Correction of errors is thus possible with only one pass and is done at the source level. A symbolic table is also generated. The second pass of the source program replaces the symbols with numeric equivalents, provides a listing and produces an object program.

Pseudo operations in the assembler permit conditional processing of statements. As a result, one source program may be altered slightly to yield a variety of unique object programs.

Multiple assemblies can be run without reloading SYM II after each assembly. Either pass can be repeated or restarted without limitations.

Extended instruction capability is provided through the use of standard macros. The user may define additional macros peculiar to his application. Floating point and mathematical operations are symbolically referenced at a macro level. An automatic call to the routine resident on the library is part of the macro sequence. A powerful, simplified input/output repertoire, especially developed for ease of communication, is provided by the assemblers. The two-pass operation produces documentation where lists of symbols and literals are made. Source data definition and transfer points labeled later in the program sequence (forward-defined equates) are permitted.

Object binary text is absolute or relocatable and can be output to paper tape, cards, magnetic tape or disk. Full flexibility of input/output is obtained by logical unit identification of peripherals and assignment under program control. The full capacity of

the 8,192 words of memory and high-speed devices of the 703 STANDARD and EXTENDED configurations is employed to allow the user utilization of the extensive features of SYM II.

In the EXTENDED configuration, the assembly process is further automated by reading the source program only once and recirculating its image via the mass storage device—disk or magnetic tape.

Symbolic data labeling is easily accomplished by directives that identify alphanumeric characters, special characters, decimal and hexadecimal constants. Thus the assembler exploits the unusual byte manipulation instructions in the 703 hardware. Linkages to and from user-generated and library routines are quickly established. Memory is allocated and the position of the program in absolute memory is established with additional directives. SYM II's pseudo operations are summarized below.

- DO The next statement is repeated under control of the DO variable and the specified range.
- BLK The BLK directive informs the loader of specified memory for loading the object program of a relocatable assembly.
- ORIG . . . The ORIG directive sets the location counter during absolute assemblies.
- END Assembly processing is terminated and an optional "start" address can be specified.
- LOAD . . . The LOAD directive specifies to the loader the named routines are to be loaded unconditionally.
- NTRY . . . An NTRY statement identifies an entry point of the program.
- LIBR . . . The LIBR directive generates identification labels for routines which are to be added to the system library.
- TRUE,
FALS These directives permit the programmer to specify conditional processing of statements.
- ENDC . . . The termination of conditional processing is accomplished by the ENDC pseudo operation.
- EQU The EQU directive equates a symbol to an expression.
- BYTE BYTE defines data that is to fill one memory byte.
- DATA . . . The DATA directive defines word-oriented data.
- TEXT A string of characters which fills consecutive bytes is defined by TEXT.
- RES The RES directive reserves a block of storage whose length is defined by the operand.
- PROC . . . A procedure is defined.
- ENDP . . . A procedure definition is terminated.

LOADERS

The Loaders accept multi-module binary text from SYM and X-RAY and load it into memory along with any required system library routines. All linkages to external references are automatically established. Either relocatable or absolute object text is acceptable from media such as disk, cards, paper tape or magnetic tape. External references not defined in the text signal the loader to scan the system library. Optionally, a memory map is listed. Validity checking is performed on all inputs. Memory efficiency can be increased by utilizing the area occupied by the loader for working storage after loading is accomplished.

Loaders are implemented for operation in BASIC, STANDARD, and EXTENDED software systems. The BASIC Loader operates conveniently under control of the user through X-RAY EXEC. It provides all of the facilities, including acceptance of relocatable binary text, of the loaders for STANDARD and EXTENDED configurations with the exceptions of loading FORTRAN programs and performing library searches. The Record Loader is provided for systems where a suitable library input device such as a high-speed paper tape reader or magnetic tape is available. It includes augmented memory allocation features, library search and FORTRAN loading capability. The EXTENDED configuration's Disk Loader utilizes a directory search technique to implement high speed library access. All loaders process the same type of loader text. The BASIC Loader merely accepts a loader text subset produced by SYM I assembler.

REAL TIME FORTRAN IV

To make the Raytheon 703 fully capable of dealing with real-time systems requirements, a comprehensive real-time ASA expanded FORTRAN IV compiler is provided to the user. A subset of the ASA standard is furnished for customers whose system configurations include smaller memories.

In addition to object programs running in a real-time priority interrupt environment, Raytheon FORTRAN IV includes:

- Intermixing FORTRAN statements and symbolic assembly language.
- Data types:
 - Logical
 - Integer
 - Double Integer
 - Real
 - Complex
 - Hollerith
 - Mid-precision
 - Double-precision
- Dynamic storage allocation of tables during compile phase provides optimized memory utilization and permits the compilation of large programs.

The FORTRAN IV library for the 703 is extensive and includes over 30 external functions and 35 intrinsic functions.

CONVERSATIONAL FORTRAN

Conversational FORTRAN is a one-pass compiler which compiles programs directly into memory providing rapid compile and go capabilities. In BASIC and STANDARD systems programs can be prepared and executed in four simple steps: load the compiler, input source statements, load the run-time library (the library overlays the compiler), and execute.

In the extended system the entire process is automated by batch control directives. The compiler includes a PREP option which allows the user to prepare his program on-line in the conversational mode. The run-time system includes a TRACE option to facilitate program checkout. Provisions are also included for interfacing machine language routines for data acquisition and real-time applications. The compiler is compact, requiring only 2750 locations including I/O.

EXECUTIVE AND SYSTEM PROGRAMS

X-RAY EXEC

X-RAY EXEC is a resident executive and utility system designed to facilitate automatic system operation in program preparation, debugging, execution, and construction of real-time, time-sharing control programs. Maximum use is made of the interrupt and status saving features of the 703. A central input/output sub-program, an input/output control sequence, is used by the system and accommodates concurrent I/O, priority interrupt and re-entrant programs.

File-oriented I/O schemes normally found in large scale computers are incorporated. Symbolic set up of real-time input/output is performed at the macro level, speeding program development. Thus, complex machine language and multi-level interrupt routines are utilized without cost to the user.

X-RAY EXEC assists the user in preparation and debugging of programs. Retrieval and updating system library programs is automatic upon request. X-RAY EXEC is the communicator between the user, the user's programs, basic peripherals, the loader and mass storage devices. It interprets program requests and takes necessary action. At all times memory usage is minimized.

On-line debugging is allowed by use of TRACE, a non-resident programming aid. Execution of each instruction or an entire program subsection may be monitored. Contents of memory and registers can be modified to correct the object program run.

X-RAY EXEC controls the absolute and relocatable loader which accepts binary text produced by SYM, or DUMP, an option of X-RAY. Object programs may be revised by typing changes in hexadecimal notation, in data or instruction format. X-RAY EXEC also permits the user to review programs by displaying memory.

A number of other utility operations is provided. X-RAY may be used to zero all or part of memory or to initiate jumps to any part of memory. Memory or

portions of memory may be dumped on any output media, including paper tape or magnetic tape. Break-points may be inserted in a program. Data words may be repeatedly stored in specified areas of memory.

The non-resident Symbolic Program Editor is controlled by X-RAY EXEC. It allows symbolic updates to source programs on paper tape, cards, magnetic tape or disk. Instructions, operands, constants, and test data can easily be modified to correct or improve performance of programs.

INPUT/OUTPUT SYSTEM

The Input/Output System is designed to allow the computer to be time-shared in a real-time interrupt environment. It exploits the sophisticated interrupt system and status save feature of the 703. As a result time for interrupt service and changes to higher priority programs is minimized. A file-oriented input/output structure is the heart of the input/output scheme. Facilities are provided for use of the File Input/Output Table (FIOT) which contains all information necessary to perform an I/O operation in a time-share situation with resident re-entrant programs.

Simultaneous I/O with more than one device is allowed. Input/Output macros and end-action control are available. As a result of the hardware/software I/O design, magnetic tapes may be kept in motion through record gaps during read/write operations while concurrent paper tape and ASR 33/35 operations continue.

All operations are controlled through the centralized I/O monitor and its device drivers. Device re-assignment is under program control. The physical device is assigned a logical unit number in the Peripheral Equipment Assignment Table, PEAT. The user can then perform an input/output operation by simply calling three subroutines.

OPEN
DOIO
STAT

To initiate an input/output operation, a call must be made to subroutine OPEN. It translates the arguments into the proper format and inserts them in FIOT. The physical device is assigned the logical unit specified in the Peripheral Equipment Assignment Table. The calling sequence format is:

OPEN FIOT, BUF, WC, UNIT, OPER, MODE
where,

FIOT is the location of the 8-word array for the file description.

BUF is the initial data buffer address.

WC is the address of the number of words to be transferred.

UNIT is the logical unit number.

OPER is the type of operation, for example, read or write.

MODE specifies binary or alpha mode.

After OPEN has been called, the actual operation is initiated with a call to DOIO. Once a file has been

opened, multiple DOIO's may be executed. DOIO interrogates its argument list, changes the FIOT table as required, starts the I/O operation and returns program control to the user. The calling sequence format is:

DOIO FIOT, BUF, WC

When the operation is completed, the user has the option of executing any end-action subroutine. It allows the user to deviate from normal flow of the program upon completion of the input/output function. The status of an input/output operation can be requested through the STAT routine whose calling format is:

STAT FIOT, ERR

where:

ERR is the address of an error routine to be executed if a fault occurs.

Raytheon 703 assemblers accept these macros directly and translate them into the appropriate calling sequences. When using DOIO, arguments not changed from the previous call or those established by OPEN need not be included. The subroutine, STAT, will loop until the operation is complete. A normal return will always be taken, if ERR is omitted.

TRACE

On-line program debugging is performed by TRACE, a compact and powerful programming aid which is loaded under supervision of X-RAY EXEC along with the program to be tested. A dynamic means of monitoring selected portions of program execution is utilized. TRACE options are selected on the ASR typewriter. Breakpoints may be inserted to trace sections of a selected program and selected memory may be searched for specified masked words.

Either mode of TRACE, Full or Partial, prints the program counter value and the value of any or all of the following: Accumulator, Index Register, and Machine Status. Thus the programmer dynamically monitors execution. The Full option traces all instructions while Partial traces only jump instructions. TRACE executes in coordination with X-RAY such utilities as memory alter, memory dump, jump and start execution, clear memory within limits, and set memory within limits. Program tapes may be read and compared with memory and discrepancies printed.

PREP PROGRAM

PREP is utilized when the operator wishes to construct a source program on-line from the ASR 33/35 keyboard with computer assistance. Symbolic statements are accepted from the ASR keyboard and buffered in the 703's memory. As each statement is typed, it is dynamically diagnosed on-line. Syntax errors are flagged and statements can be corrected immediately. After a block of source statements has been input, and buffered in 703 memory, it is punched onto paper tape. Symbolic output of PREP is acceptable to both SYM I and SYM II assemblers.

SYMBOLIC PROGRAM EDITOR

The Editor program under control of X-RAY EXEC, symbolically corrects, updates, and generates source programs. The user's program is read from paper tape, magnetic tape, or disk and stored in memory, whereupon instructions, constants and test data may be easily replaced, deleted or inserted. A new symbolic program, completely modified and error free, is then output from memory. Source statements are referenced by line number. A copy of the corrected program can optionally be listed. New sections may be added to yield expanded or mixed programs.

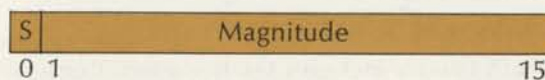
SYSTEM EDITOR

System Editor is used with systems whose configurations include high-speed paper-tape reader and punch, disk or magnetic tape. It facilitates the deletion, insertion or replacement of programs resident on magnetic or paper tape or on the System Library on disk. It also generates the installation's master file containing those elements required for the specific configuration. System Editor is a mandatory system component where system-oriented libraries are in use and corrections or updates must be made.

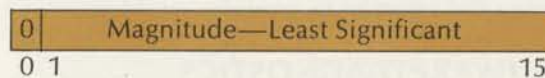
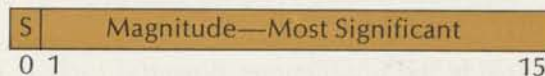
MATH LIBRARY

The Math Library is a comprehensive set of mathematical functions and subroutines available to users of all three systems—BASIC, STANDARD, and EXTENDED. Negative numbers are represented in two's complement notation, while floating point exponents are in Excess 200₈, or Excess 80₁₆. The numerical data formats utilized in the 703 are illustrated below.

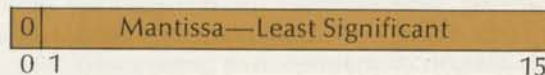
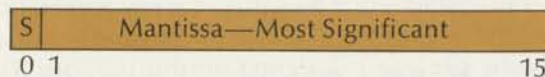
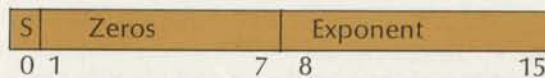
FIXED POINT SINGLE PRECISION FORMAT



FIXED POINT DOUBLE PRECISION FORMAT



FLOATING POINT FORMAT



MATH SUBROUTINES

The math subroutines provide the user with complete capabilities to perform floating point or fixed point double precision arithmetic. All negative numbers utilize two's complement notation. The table below summarizes these routines.

Subroutine

Mnemonic

Fixed Point Single Precision

Multiply	MPYS
Divide	DIVS

Fixed Point Double Precision

Double Precision LoadDLD

Double Precision StoreDST

Double Precision AddDAD

Double Precision Subtract DUSB

Double Precision 2's ComplementD2C

Double Precision Shift LeftDSL

Double Precision Shift RightDSR

Double Precision CompareDCM

Double Precision MultiplyDMP

Double Precision DivideDDV

Floating Point

Floating Load FLD

Floating Store FST

Floating AddFAD

Floating Subtract FSB

Floating CompareFCM

Floating MultiplyFMP

Floating DivideFDV

HARDWARE MULTIPLY/DIVIDE

Hardware multiply/divide is an option which performs a 16-bit, 2's complement multiply or divide. In each case, a two word result is produced. The operation mnemonics MPY and DIV are reserved for this optional hardware.

The hardware multiply has an execution time of 12.25 to 17.5 microseconds. The divide instruction executes in 24.5 microseconds.

FUNCTION SUBROUTINES

The Math Library includes the basic functions—SIN, COS, SQRT, ATAN, TANH, LOG, and EXP. These functions utilize the floating point data format. Fixed point routines are available for SQRT, SIN and COS which utilize the double precision format. These utilities provide the programmer powerful tools in developing the solution to complex problems.

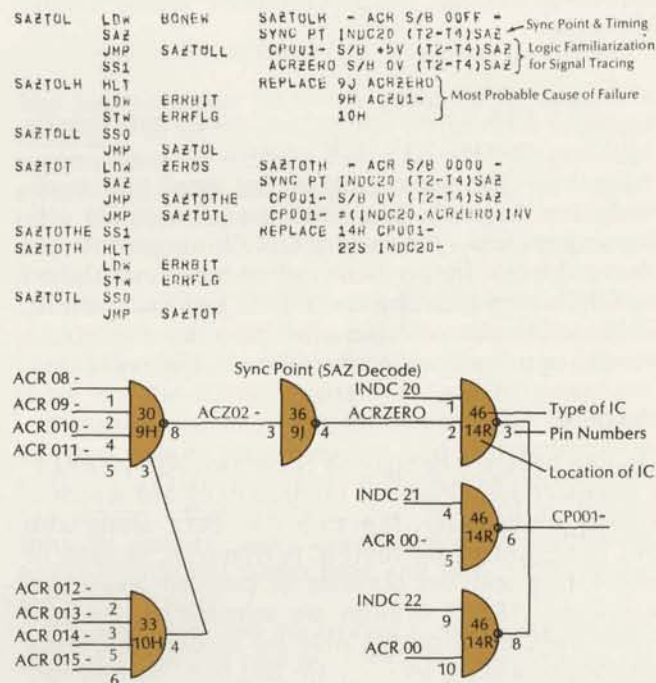
HARDWARE DIAGNOSTICS

Raytheon Computer has paid special attention to user need for monitoring and diagnosis of real-time computer system operation. The ability to quickly determine the status of hardware and identify the location of malfunctions is essential in many applications.

SENSOR is a package of more than twenty test and diagnostic programs designed for this purpose. Field Engineering objectives set for this package include organization and documentation that simplifies and speeds the job of maintenance personnel.

SENSOR tests and verifies the operational integrity of all functions contained in the Raytheon 703 system. When a malfunction occurs, whether it is major or minor, the problem can be quickly defined and isolated by typewriter SENSOR error messages and through use of technically annotated program listings and fault isolation flow diagrams (Fig. 5).

Figure 5. Sensor Sample Error Messages, Program Listing and Logic Flow Diagram.



If the typewriter or CPU is failing and error messages cannot be typed, a pre-bootstrap procedure is followed. Basic logic signals are checked utilizing SENSOR listings and flow diagrams in conjunction with the system console.

Typically, typewriter error messages direct the technician to logical faults by referencing Boolean equation names and IC locations. Figure 6 depicts sample SENSOR error directives where fault isolation is made within two integrated circuits. The Adder Carry Test found signals ADC02 and ADC01 to be in error. Further analysis by SENSOR determined the two most probable signals causing the failure and the physical locations of their origins—ADC02 at IC locations 1U and 5T.

Figure 6. Sample Sensor Typewriter Error Directives

```
ADC02- TEST -ERROR-
ADC01- TEST -ERROR-
ADC02- 1U
ADC02-T1 5I
```

The ability of SENSOR to list names of signals involved at the point at which the error occurred and sync point information supports fast and effective

maintenance techniques and in the majority of cases reduces down-time intervals to minutes. In most cases the diagnostic program will isolate the malfunction to six or less integrated circuits, many times to an individual integrated circuit. Corresponding documentation is annotated for short systematic checks of the designated signals to provide quick reference of detail logic flow. All integrated circuits in the central processor plug into individual receptacles. Therefore, the faulty component may be quickly removed and replaced without soldering or wiring changes.

The packaging of the 703 processor with dual in-line IC's plugged directly into a single mother board provides a unique capability. Any signal checking of the processor is limited to the standardized signals of the IC's themselves. The hundreds of unique signals associated with plug-in circuit cards and the tedious matching of test point to signal list is eliminated.

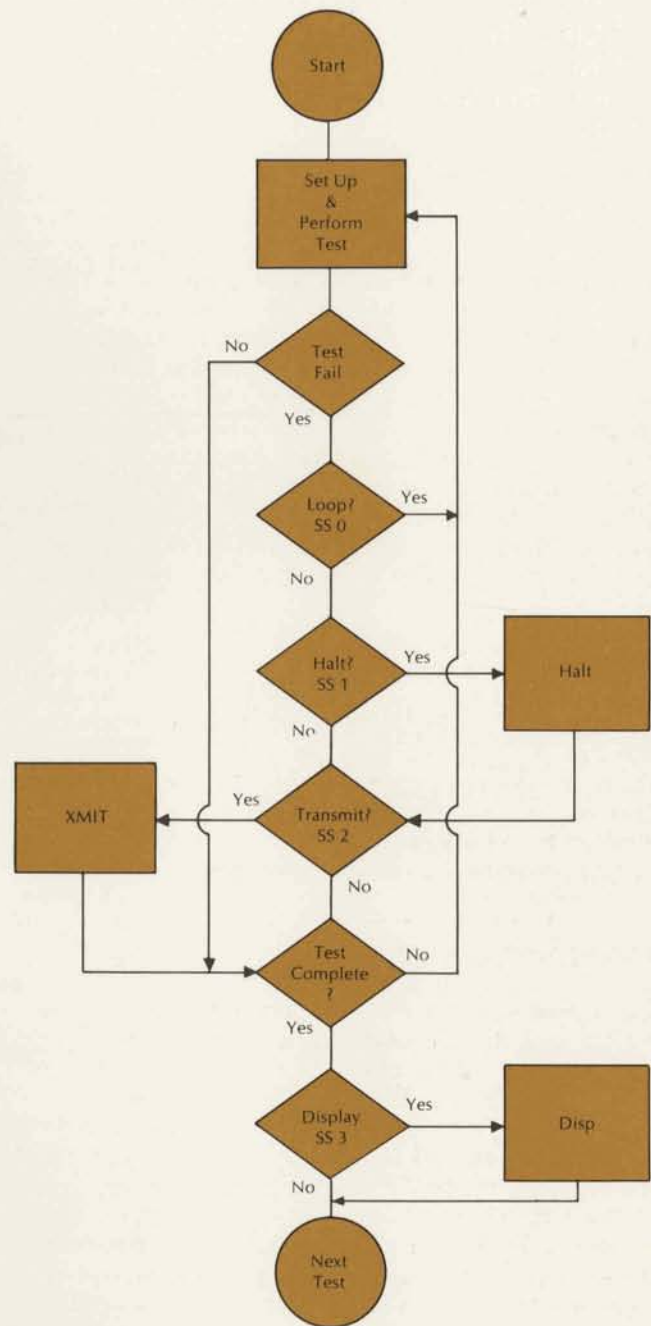
Test and diagnostic modules operate in a mode controllable by sense switch selection. Basic modes include: Halt (H), Executive (E), Loop (L), Display (D), and Transmit (T). Mode selection permits tests to be run automatically, manually, or in various combinations thereof. Module execution flow is illustrated in Figure 7.

SOFTWARE PERFORMANCE TEST

The software performance test is one of the most important programs in the library. It exercises X-RAY EXEC, I/O Drivers, and other basic software elements in the same way the operational software utilizes the system. Test programs in the 703 IC diagnostic library are listed below.

- Pre-test Program
- Primary Instruction
- BRAINWASH Memory
- Skip Instruction
- Single Word and Byte Shift
- Index Register
- Memory Extension
- Addressing
- Index Skip
- Byte Instruction
- Logical Instruction
- Overflow
- Double Word Shift
- Interrupt System
- Worst Case Timing and Reliability
- ASR 33/35
- High-speed Paper-tape Reader
- High-speed Paper-tape Punch
- Disk
- Software Performance
- 9-Track Magnetic Tape
- Incremental Magnetic Tape
- Line Printer
- MULTIVERter®

Figure 7 Test and Diagnostic Flow Chart



SERVICE AND SUPPORT

By developing 703 and other system programs in-house, Raytheon has developed a software organization with significant depth and technical capabilities. As a result, the customer can depend on better software support in areas such as training, warranty, documentation, systems programming and program library.

TRAINING

At regular intervals Raytheon offers 703 programming and maintenance factory training classes as part of the service provided to customers. These courses are conducted at the Raytheon Computer facilities in Santa Ana, California, and include instruction by experienced Raytheon personnel together with training manuals and supplies. Classes are confined to small groups assuring adequate individual attention to attendees. By conducting classes at Raytheon Computer's headquarters, the full resources of its technical staff and computer facilities are available to support training activities. Raytheon will also conduct classes at individual customer sites for a nominal retainer.

WARRANTY

Software for the 703 is warranted for a period of one year following shipment. Raytheon warrants that all standard software delivered with 703 computer systems is free from logical defects and performs to applicable published specifications. Any defective programs will be corrected or replaced.

DOCUMENTATION

A complete set of supporting documentation is delivered with the 703. All 703 software is thoroughly documented to the highest standards. Source listings are fully annotated. Detailed flow charts as well as complete operational and maintenance descriptions are available for all 703 software. With thorough documentation, the customer can take advantage of the full capabilities of the 703 programming systems. The documentation also provides the tools necessary to modify or expand the software to meet special requirements.

CONTRACT SOFTWARE SERVICES

Raytheon provides comprehensive programming systems with the 703 computer. These systems have been designed to be applicable to a broad spectrum of system applications. However, the scope of the general purpose software is almost never entirely sufficient to solve a dedicated system application. Many computer users and prospective computer users do not have or feel they do not have the in-house experience and capability to effectively implement the special programs that their applications require. As a result, many users are employing programming consultants to prepare their specific application programs.

Recognizing this requirement in today's market, Raytheon Computer will assume total systems responsibility for both hardware and software upon customer request. Dedicated system programs are quoted on a fixed price, or time and material basis according to individual customer requirements. The total system approach provides the customer the advantage of having a fully operational system delivered which is immediately ready to be used in its respective application. Furthermore, software costs will be fixed and delays caused by serial implementation of software following hardware will be avoided. Raytheon has an outstanding team of programming specialists who are intimately familiar with the 703 and its applications in a wide variety of system configurations.

PROGRAM LIBRARY

Raytheon maintains a complete 703 program library of tapes, card decks and documentation. With each system delivery, customers receive a copy of all programs which operate on their system as well as their associated documentation. Under "Limited Service" contract terms special arrangements are made for support.

Additional copies of programs and documentation are reproduced for a nominal service charge. In addition, users of Raytheon 703 have access to the growing Raytheon User's Group (RUG) program library. RUG was established to promote the exchange of programs and program information between Raytheon computer users. RUG also publishes a periodic newsletter to keep users informed of the latest ideas, techniques and program submittals.

703 INSTRUCTION SET

CLASS	MNEMONIC	OPERATION	TIME (μ s)	CLASS	MNEMONIC	OPERATION	TIME (μ s)
LOAD/STORE	LDB	Load Byte	3.50	CONTROL	HLT	Halt	1.75
	LDW	Load Word	3.50		INR	Interrupt Return	5.25
	LDX	Load Index	3.50		ENB	Enable Interrupt	1.75
	STB	Store Byte	5.25		DSB	Disable Interrupt	1.75
	STW	Store Word	3.50		SLM	Set Local Mode	1.75
	STX	Store Index	3.50		SGM	Set Global Mode	1.75
ARITHMETIC	ADD	Add	3.50		CEX	Copy Extension to Index	1.75
	SUB	Subtract	3.50		CXE	Copy Index to Extension	1.75
LOGICAL	ORI	Inclusive OR	3.50		SML	Select Memory Lower	1.75
	ORE	Exclusive OR	3.50		SMU	Select Memory Upper	1.75
	AND	Logical AND	3.50		MSK	Mask Interrupts	1.75
COMPARE	CMB	Compare Byte	3.50		UNM	Unmask Interrupts	1.75
	CMW	Compare Word	3.50	DATA	CLR	Clear Accumulator	1.75
JUMP	JMP	Unconditional Jump	1.75		CMP	Complement Accumulator	1.75
	JSX	Jump and Store Return in Index	1.75		INV	Invert Accumulator	1.75
SHIFT	SRA	Shift Right Arithmetic	3.50 - 8.75		CXA	Copy Index to Accumulator	1.75
	SLA	Shift Left Arithmetic	3.50 - 8.75		CAX	Copy Accumulator to Index	1.75
	SRA D	Shift Right Arithmetic Double	3.50 - 8.75	I/O	DIN	Direct Input	3.50
	SLA D	Shift Left Arithmetic Double	3.50 - 8.75		DOT	Direct Output	3.50
	SRL	Shift Right Logical	3.50 - 8.75	LITERAL	IXS	Increment Index and Skip if ≥ 0	1.75 - 3.50
	SLL	Shift Left Logical	3.50 - 8.75		DXS	Decrement Index and Skip if < 0	1.75 - 3.50
	SRL D	Shift Right Logical Double	3.50 - 8.75		LLB	Load Literal Byte	1.75
	SLL D	Shift Left Logical Double	3.50 - 8.75		CLB	Compare Literal Byte	1.75
	SRC	Shift Right Circular	3.50 - 8.75	SKIP	SAZ	Skip on Accumulator Zero	1.75
	SLC	Shift Left Circular	3.50 - 8.75		SAP	Skip on Accumulator Plus	1.75
	SRC D	Shift Right Circular Double	3.50 - 8.75		SAM	Skip on Accumulator Minus	1.75
	SLC D	Shift Left Circular Double	3.50 - 8.75		SAO	Skip on Accumulator Odd	1.75
	SRL L	Shift Right Logical Left Byte	3.50 - 8.75		SLS	Skip on Compare Less	1.75
	SLL L	Shift Left Logical Left Byte	3.50 - 8.75		SXE	Skip on Index Even	1.75
	SRL R	Shift Right Logical Right Byte	3.50 - 8.75		SEQ	Skip on Compare Equal	1.75
	SLL R	Shift Left Logical Right Byte	3.50 - 8.75		SNE	Skip on Compare Not Equal	1.75
	SRC L	Shift Right Circular Left Byte	3.50 - 8.75		SGR	Skip on Compare Greater	1.75
	SLC L	Shift Left Circular Left Byte	3.50 - 8.75		SLE	Skip on Compare Less Than or Equal	1.75
	SRC R	Shift Right Circular Right Byte	3.50 - 8.75		SNO	Skip on No Overflow	1.75
	SLC R	Shift Left Circular Right Byte	3.50 - 8.75		SSE	Skip on Sense External	1.75
					SS0	Skip on Sense Switch Zero False	1.75
					SS1	Skip on Sense Switch One False	1.75
					SS2	Skip on Sense Switch Two False	1.75
					SS3	Skip on Sense Switch Three False	1.75

703 COMPUTER CHARACTERISTICS

General

Number System	Binary
Cycle Time (μ s)	1.75
Data Word (bits)	16
Instruction Word (bits)	16
Negative Numbers	2's complement
Memory Type	Magnetic Core
Memory Capacity	4-32K
Memory Organization	Page Organization
Direct Addressing	2048 words
Means of Addressing	
Expanded Memory	Memory Extension Register

Registers

Addressable Registers	4
Hardware Index Registers	1

Instructions

Number of Instructions	74
Number of Memory Reference Instructions	15
Number of Index Instructions	9
Number of Shift Instructions	20
Number of Test/Jump Instructions	18
Number of Control, I/O and Data Generics	19

Other Instructions and Addressing

Byte Instructions	Yes
Number of Addressing Modes	3
Literal Instructions	4
Shift & Rotate	Accumulator right or left up to 16 bits
Logical AND	Logical product of accumulator and specified memory location

Logical OR	Exclusive/Inclusive OR between accumulator and specified memory location
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Input/Output

I/O Lines	Separate 16-bit parallel data I/O, and separate 8-bit parallel address
-----------	--

Interrupt System

Automatic Priority Interrupt	Yes
Maximum Number of Interrupts	16
Programmed Input/Output	Processor selects input/output, data transfers from accumulator to device or from device to accumulator
Interrupt Type	Jump to Interrupt Service Routine
DMA Type	Direct-device to Memory, fixed priority, interlaced
Real Time Clock	Optional

Display and Controls

Basic Display	P register, Index Register, accumulator, Memory Buffer, Memory Address, Control Status and Instruction.
Controls	RUN, HALT, RESET, Enter Data in Memory, Single Instruction, Single Cycle Step, Display Data in Memory, and four sense switches

Environmental

Power Requirements	110 Volts AC, 50-60 cycle
Air Conditioning	None required
Temperature	0-40°C

WORLD-WIDE SALES AND SERVICE

UNITED STATES

HOME OFFICE—Raytheon Computer

2700 South Fairview Street, Santa Ana, California 92704
Phone: (714) 546-7160 From Los Angeles phone: 625-7645
TWX: 910 595-1570

CALIFORNIA

Western District

Raytheon Computer
9550 Flair Drive - Suite 207
Flair Industrial Park
El Monte, California 91731
Phone: (213) 443-7181

Raytheon Computer
363 S. Taaffe, Suite 201
Sunnyvale, California 94086
Phone: (408) 736-2286, 2287

GEORGIA

Southern District

Raytheon Computer
1600 Tullie Circle, NE, Suite 109
Atlanta, Georgia 30329
Phone: 404-631-0091-92
TWX: 810-751-8447

ILLINOIS

Central District

Raytheon Computer
710 Higgins Road
Park Ridge, Illinois 60068
Phone: (312) 692-3325
TWX: 910-687-2266

MASSACHUSETTS

Northeastern District

Raytheon Computer
Box 184 - Fourth Avenue
Burlington, Massachusetts 01803
Phone: (617) 272-6400
TWX: 710-332-0313

TEXAS

West Central District

Raytheon Computer
6420 Hillcroft, Suite 215
Houston, Texas 77036
Phone: (713) 771-4449, -5851
TWX: 910 881-1795

WASHINGTON, D. C. Area

Mid-Atlantic District

Raytheon Computer
1316 Fenwick Lane, Suite A
Silver Spring, Maryland 20910
Phone: (301) 587-9110
TWX: 710 825-9762

INTERNATIONAL

ARGENTINA

Rayo Electronica
Belgrano 990
Buenos Aires, Argentina
Phone: 38-1779; 37-9476
Cable: RAYOTRONICA

AUSTRALIA

Datamatic Pty. Ltd.
90 Alexander Street
P.O. Box 171
Crow's Nest, N.S.W. 2065, Australia
Phone: 43-3333, 43-7125

BELGIUM

Koopman and Company Electronica N.V.
13 Avenue des Gaulois
Brussels, Belgium
Phone: 02. 35.80.65, Telex: 846-23616

DENMARK

Aage Hempel Teknik A/S
Longangstraede 16
DK 1468 Copenhagen K, Denmark
Phone: 01156801, Telex: 5231

ENGLAND

A. C. Cossor Limited, Data Systems Div.
Harlow, Essex, England
Phone: Harlow 26862, Telex: 851-81228
Raytheon Overseas, Ltd.
Shelley House-Noble Street
London E.C. 2, England
Phone: 01-606-8991, Telex: 851-25251

FRANCE

Imex, France
B.P. 93
(93) Montreuil, France
Phone: 808-1920, Telex: 22489

GERMANY

Dynatec Datenverarbeitung-
Elektrotechnik Vertriebs—GMBH.
Oberkassel Hansa Allee 159
4 Dusseldorf, West Germany
Phone: Dusseldorf 59 10 71
ERA—Elektronische Rechenanlagen
Postfach 465
51 Aachen, W. Germany
Phone: 02405-4444, Telex: 08-32-799

HOLLAND

Koopman and Company Electronica N.V.
Post Box 6049 (Stadhouderskade 6)
Amsterdam, Holland
Phone: 020-182821
Telex: 844-11273, Cable: KJOEBMAND

INDIA

Greaves & Cotton & Co., Ltd.
2 Palace Road, P. B. No. 13
Bangalore 1, India
Phone: 23873/26773,
Telex: 043-365

ISRAEL

Agentex, Ltd.
3 Bograshov Street T.A. Box 3308
Tel-Aviv, Israel
Phone: 233968
Cable: AGENTEX TELAVIVJAFFO

ITALY

Elettronucleonica
Pia de Angeli 7,
20146 Milano, Italy
Phone: 463 520/286

JAPAN

Japan Radio Co., Ltd., Mori Bldg. Fifth
25, Sakuragawa Cho, Shiba
Nishikubo, Minatoku,
Tokyo, Japan
Phone: (03) 591-3451
Telex: 781 0222-3068

KOREA

Korea Computers Corp.
Kurodong Industrial Estates
I.P.O. Box 3320
Seoul, Korea
Phone: 69-5187-7, Cable: KORAND

LEBANON

Triad International Marketing Co.
P.O. Box 4984
Beirut, Lebanon
Phone: 230091 or 230093
Telex: TRICORP, Cable: TRIMARK

NORWAY

Metric A. S.
P.O. 80 Bekkelagshgd
Oslo, Norway
Phone: (02) 28 26 24
Telex: Metrictrade Oslo

SOUTH AFRICA

Aerosignals Pty. Ltd.
P.O. Box 957
Johannesburg, South Africa
Phone: 836-6828/9
Telex: 43-0209JH, Cable: AEROSIGNALS

SPAIN

Neotecnica, S.A.E.
Marques de Urquijo 44
Madrid 8, Spain
Phone: 248 96 02, Cable: NEOTECNICA

SWEDEN

Scandia Metric AB
Dalvagen 12
Fack 171 03
Solna 3 Sweden
Phone: 08/820310
Telex: 10766 Metricade Stockholm

SWITZERLAND

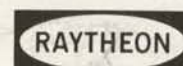
Computer AG Zurich
Badenerstrasse 551
8048 Zurich (Postfach 145) Switzerland
Phone: 051/52 42 50/51
Telex: PULP CH 52039

YUGOSLAVIA

Jugo Auto
Borisa Kidrica 6-1
Beograd, Yugoslavia
Phone: 336-503; 342-394

From other countries contact:

Raytheon International
141 Spring Street
Lexington, Massachusetts 02173
Phone: (617) 862-6600
TWX: 710-324-6568



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