an output buffer, the number of columns can be increased.

The magnetic tape equipment is attached to the 2002 in a similar way. The tape control unit contains one or two buffers with a capacity of 1290 × 6 bits (one character per column).

The next record on tape is read into the buffer storage (the contents of the buffer storage are written on the tape) by read (write) instructions while calculating. If two buffers are installed, two records can be transferred simultaneously to or from two tape units. Up to 10 tape units can be connected with the tape control unit.

The instructions for reading data out of the tape buffer into the accumulator and for filling the tape buffer from the accumulator are the same as for the punched card buffers. The execution time for reading 12 columns is 270 μsec. Because of the length of the tape buffer, four block transfer instructions are provided which transfer the next n columns of tape buffer k into the core memory, beginning with memory location x, or the data stored in the core memory beginning with memory location x, into the next n columns of tape buffer k; two instructions serve the transfer of alphanumerical and two instructions the transfer of numerical data.

Physical Construction

For the most important physical characteristics see Table II. The circuitry in the arithmetic and control unit is of the dynamic type using gates and delay-lines. The circuitry in the memory units is of the static type. All circuits are composed of 16 types of different units which are dip soldered into etched circuit boards of the plug-in type (size 6.5 × 4 inches), one of which is shown on Fig. 1. Fig. 2 shows a central processing unit. The control and arithmetic units are of five different types, the logical configuration of two of them is reproduced on Figs. 3 and 4. The output of the circuit boards is delayed by 1.25 μsec. Up to 8 inputs can be driven by an output of one of the circuit boards.

On Fig. 5 a part of the rackmounted transistorized core memory unit (1,000 words) together with the read and write amplifiers are to be seen. The 52 matrices are combined within two blocks of 26 matrices each, Fig. 6. In the case of the 2,500-word memory, 160 plug-in units with 1,057 transistors are built into the memory unit (excluding buffer registers).

Fig. 7 gives a general view of the 2002 computer (punched paper tape input and output).

Conclusions

The 2002 has been working since November 1, 1958. A prototype has been operating successfully since October 1956. The 2002 is an enlargement of this prototype.

Discussion

E. Goldstein (Bell Telephone Laboratories): Are parity bits included in the core memory?

What checks are made to insure accuracy during data transfers between cores and drum, etc.?

Dr. Gumin: One parity bit per word in core memory; and four parity bits per word in drum memory. Data transfers are checked by means of "pseudo tetrads" (forbidden combinations of four bits).

J. Reitman (Teleregister Corporation): Please describe the size of the input and output punch paper tape buffers.

Dr. Gumin: The prototype has punched paper tape buffer of one word (input, one word; output, one word).

J. D. Babcock (The Rand Corporation): Has an assembler-compiler system been devised for the 2002? If so, would you please give a short description of it?

Dr. Gumin: An assembler-compiler system will be available during the summer of 1959. This will be a generalized formula translating system.

G. M. Wilson (United Shoe Machinery Corporation): What is the card-per-minute speed of reading and punching? Also, what are the read-write speeds of the magnetic tape?

Dr. Gumin: Siemens does not manufacture punched card equipment. Punched card machines and printers of various manufacturers can be attached to the 2002 computer. The system is designed to permit the use of either International Business Machines Corporation or Bull peripheral equipment.

W. R. Haber (Remington Rand Univac): What is the drum speed in milliseconds, and how many drum bands are there?

Dr. Gumin: A drum revolution requires 23 milliseconds, and there are 40 bands each containing 50 words per band.

Design of the RCA 501 System

J. G. Smith T. M. Hurewitz

The RCA Corporation of America (RCA) 501 System (Fig. 1) was designed specifically for a wide range of data processing applications. This paper describes the system and relates specific functional characteristics of the requirements that are found in data processing activities.

System Highlights

Some of the outstanding features of the RCA 501 Electronic Data Processing System are mentioned here to provide a framework of reference for the remainder of the discussion.

Solid State Technology

The RCA 501 Data Processing System is comprised entirely of solid-state devices. The logic of the system is implemented with transistors, over 90% of which appear in the basic "Nor" circuit configuration. There are approximately 17,000 transistors in a typical system. During the first 6 months of 3-shift operation involving more than forty-four million transistors hours, there were only three transistor failures. These initial data indicate an expected failure rate of less than one transistor failure during 1,000 hours of system operation. The use of transistors has had a potent impact on design particularly in the area of reliability.

Variable Data Length

In keeping with the emphasis on data processing, the 501 system retains the RCA-developed concept of variable word length. This concept of information organization on magnetic tape lends itself naturally to the types of data encountered in processing applications and results in minimum processing times.

Building Block Expandability

Another highlight of the RCA 501 system is its expandability features. The high speed magnetic core storage of the computer may be expanded from a minimum of 16,384 characters (a character

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From the collection of the Computer History Museum (www.computerhistory.org)
being 7 bits) to a maximum of 262,144 characters. The expansion occurs in increments of 16,384 characters. The number of magnetic tape mechanisms directly under program control may expand from one (1) to a total of 63. Finally, peripheral equipment may be used on-line or off-line as dictated by machine loads.

For reasons of economy, particular emphasis was given to reducing, or in some cases eliminating, the need for special control devices for operation of peripheral equipment.

POWERFUL FILE HANDLING CAPABILITIES

The computer records on magnetic tape at the rate of 33,300 alphanumeric characters per second. The information can be read from the tape while it moves in either direction.

To add to the file handling capabilities of the 501 system, the computer performs certain combinations of operations simultaneously. These combinations are read-compute, write-compute, and read-write. The simultaneity is handled by an interrupt technique which will be discussed in greater detail.

ACCURACY CONTROL

Again consistent with the data-processing emphasis, the 501 system incorporates a thorough system of wired-in checks which monitor and safeguard the processing of data. Among these checks are provisions for performing each arithmetic step twice and a complete parity preserving system of information transfer and modifications.

BASIC CIRCUIT

Fig. 2 is the so-called "Nor" circuit which is the basic circuit used repeatedly in the over-all system. (The SM2 is the RCA designation for this submodule.) The operation of this basic circuit is as follows: If both inputs are sitting high, the emitter-base junction is reverse-biased and hence the transistor is cut-off. This causes the output to be clamped to ground. When either one of the inputs goes low, the divider network yields a potential which is below the emitter potential and the transistor turns on. The output rises to 6.5 volts, less whatever drop occurs through the transistor, which in this case is a maximum of 0.3 volt. This basic circuit is used to achieve signal standardization and to accomplish all logic. The basic logic, in terms of the "Nor" circuit, can be described by a truth table. Using inputs A and B, and letting "0" represent ground potential and "1" represent +6.5 volts, then when either one of the inputs is at ground the output remains high. Only when both inputs are high does the output go to ground. When both inputs are at +6.5 volts the output is at ground potential. By cross coupling two of these circuits so that the output of one is the input to the other, a flip-flop results. Negative pulses are used to set and reset the circuit.

SYSTEM EQUIPMENT

RCA 501 systems are tailored to specific applications by adroitly choosing "equipment modules." A brief description of the items from which this choice may be made will serve to indicate the degree of flexibility available in arranging system configurations. For purposes of this description equipment is classed into three major types: Computer, magnetic tape, and input-output.

COMPUTER

The basic computer is composed of the following elements: program control, operating console, paper tape reader, monitor printer, high-speed core storage (16,384 alphanumeric characters minimum), controls (switching and buffering for eight magnetic tape stations), and power supply.

The high-speed storage unit, Fig. 3, starts with a basic building block of 16,384 characters. It contains a stack of planes, 28 deep, with each plane having 64X64 cores to give 4,096 cores in a plane.

Fig. 1. The RCA 501 system expanded

Fig. 2. Basic transistor circuit

Fig. 3. High-speed memory (32,768-character capacity shown)

Since one character consists of 7 bits, this stack of 28 planes represents a 4 character-deep array. Hence, information is called from the storage unit in groups of 28 bits or 4 characters in parallel. The method of using these 4 characters will be described in greater detail in the discussion of the block diagram of the computer. Memory access time, the time for retrieving or storing four characters, is 7.5 microseconds (μsec). A complete memory cycle requires 15 μsec.

The storage unit may be increased in as many as fifteen steps of 16,384 characters to a maximum of 262,144 characters (2^18). The addition of a bank of memory in no way affects previously written programs. Further, the only distinction between individual banks are the addresses, which for purposes of programming are considered to be continuous. The unit depicted contains two stacks of memory or a total of 32,768 characters. The same unit can be expanded to a total of 65,536 characters. Four such expanded units may be added to the program control.

The order code consists of 49 instructions covering input-output, data handling, arithmetic, and decision and control. The instruction format, Fig. 4 is as follows: One character is designated the operation code, three characters (18 bits) specify the A address; the N character specifies the index register to be used as a modifier for either the A or B address; three characters specify the B address. The N character is split into two groups of three bits each. The left-hand group specifies how the A address is to be modified and the right-hand group specifies how the B address is to be modified.
Particular characteristics of the computer of special interest to programmers will be discussed as a separate topic.

### MAGNETIC TAPE

Some specifications of the magnetic tape stations, Fig. 5 serve as an introduction to this topic. Gross data-transfer rate is $33 \frac{1}{3}$ thousand characters per second, achieved by recording $333 \frac{1}{3}$ characters per inch and moving tape at the rate of 100 inches per second. The tape is 3/4 inch wide, Mylar base. Reels accommodate up to 2,400 feet of tape. The gaps generated on magnetic tape are 0.35 inch. The tape start time is 3.5 milliseconds. The tape has a lock-out feature which provides for the safety of program and master file tapes. Characters are recorded twice on magnetic tape, substantially increasing reliability.

As many as 63 tape stations may be made available to the computer at one time. Expanding the number of tape stations is done as follows: eight tapes may be connected without any additional equipment. A B-level switching unit is substituted for one of the original eight tape mechanisms. This unit provides for connection of as many as eight additional tape stations. Thus, 15 tapes are available with one B-level switching unit, 22 with two B-level switching units, etc. Two B-level units, together with their power supplies are contained in a single cabinet.

### INPUT-OUTPUT EQUIPMENT

It has already been mentioned that a 1,000-character per second paper tape reader is available as an on-line device. Similarly, a monitor printer (10 characters per second), with a paper tape punch is on-line. High-speed output is also available on-line in the form of a 600-line-per-minute, 120-character-wide printer, Fig. 6. This printer uses the computer's electronics for most of the buffering and control functions.

Off-line devices are available which provide for card-to-tape conversion and high-speed printing. The card-feed rate on the card transcriber, Fig. 7 is 400 cards per minute. Characters are written on magnetic tape at a rate of 33,300 characters per second. The input and output hoppers hold up to 1,000 cards for continuous operation. For continuous operation beyond 1,000-card capacity, the cards may be loaded or unloaded during transcription. There is a considerable amount of editing that can be done through the use of the plugboard. As in all RCA 501 equipment, considerable care has been taken to ensure accuracy control. There is a dual sensing station. The card is read twice and the readings are compared. Overpunching which may represent three or more punches in a particular column is sensed and detected. Character parity is checked as is data format. Finally, when information is transferred from the cards to magnetic tape, the echo signal check is used.

Transcribing card punch, Fig. 8, features are as follows: A maximum of 80 columns can be punched in an 80-column operation. The card punching rate is 150 cards per minute and input-and output-hopper capacity is 1,000 cards each. Again there is extensive editing through the use of the plugboard, and accuracy control features similar to the card transcriber are included.

Off-line printing is accomplished with the Electro-Mechanical Printer, Fig. 6. This device operates with a standard tape station and prints at the rate of 600 lines per minute. Paper skipping can be done at a rate in excess of 70 lines per second. Editing can be accomplished through the use of a plugboard and a paper tape loop. Among the accuracy control provisions for the printer are print-
Many schemes for tape simultaneity were considered for inclusion in the computer. All of the schemes that were considered had their advantages and disadvantages. The one chosen was considered to be the most useful from the programmer's standpoint as well as the least costly in equipment. It is believed that this particular scheme eliminates the need for complex scheduling of special purpose buffer memories, hence, allowing the programmer maximum flexibility.

Simultaneity of tape operation is a demand-type function. The process is initiated when a tape instruction is received from storage. At the time of execution, three tests are made: 1. Is the instruction a type which is "potentially simultaneous?" 2. Is the simultaneous mode free, i.e., not already occupied? 3. Is the program-controlled gate to the simultaneous mode open? If the answer to all three of these questions is positive then the operation code and memory address are transferred to the simultaneous operation register (SOR) and the S-register, respectively, and the computer selects the next instruction sequence. Note that if the answer to any of these questions is negative, the instruction is accomplished in normal fashion.

When a tape operation is being performed in the simultaneous mode, buffering is such as to require the interruption of one 15-μsec memory cycle out of every eight. Thus computation can proceed for 7 cycles before being interrupted. Of course, no interruption is required while tapes are accelerating.

From the programmer's standpoint, it was deemed extremely desirable to include equipment in the computer for utmost flexibility in modifying instructions. For this reason a highly capable set of index registers are incorporated. There are seven index registers which may be used to modify instruction addresses. Of these, four are fixed high-speed memory locations which can be operated upon by any of the normal instructions. In addition, three of the index registers are registers which are dynamically used during the normal course of instruction execution. For example, the program register is also an index register. By this device, programmers may write completely self-relative routines in machine code. Two of the other registers, the A- and T-registers, are used normally for addressing
data in the high-speed memory. Hence, references can be made data-relative, tying-in with the use of variable length operations.

While it is impossible to describe completely the instruction complement at this time, a brief resume is in order. It is natural in a system such as the RCA 501, which has been designed primarily for data processing, that highly flexible use of magnetic tape be made. Some examples of the facilities available in the 501 for tape use can be cited. First, tape may be read in either direction. Those familiar with sorting will realize that by reading tape in reverse and writing forward on tape, rewind time can be eliminated. A second ability, important in data processing, is the provision for positioning tapes in either a forward or reverse direction by control symbols or by gaps. This last feature permits the scheduling of multiple files on the same reel of tape eliminating both tape costs and operating time. Lastly, data may be stored on tape in either program form or message form. Instructions have been scheduled to offer complete sets of functions for data no matter which of the forms are used.

Data-transfer functions are arranged for either address or symbol control, and either serial or parallel (4 character) operation. In addition, special functions deemed appropriate for data processing problems have been provided. Examples include an instruction which searches consecutive memory locations and stops on the nth occurrence of any prescribed character. Another example is an instruction which distributes incoming data to the maximum fields for each item. Its converse performs data compression prior to tape write-out.

Arithmetic instructions provide for the four basic decimal functions, in addition to binary and logical functions. The latter two categories are designed to work alphanumerical data as well as program data.

Decision and control functions include the ability to set or store the contents of all of the addressing registers. Conditional jumps can be based on the sign of previous arithmetic results, on tape status, or on the memory address register, prior to performing the jump. Construction of jump tables is accomplished by transferring the contents of the standard memory locations.

Summary

Many years of experience in engineering and in analysis of data processing requirements have been uniquely combined in the design of the RCA 501 system. Design emphasis has been dictated by the relative sensitivity of the criteria of data processing problems.

Discussion

Edwin Freeman (Remington Rand Univac): Since both the on-line and off-line printers operate at the same speed, it would seem unnecessary to use two printers in the system. Couldn't you use one printer that could be put on-line or off-line, depending on the program?

Mr. Smith: Yes.
The IBM 7070 Data Processing System

R. W. AVERY  S. H. BLACKFORD  J. A. MCDONNELL

The International Business Machines Corporation (IBM) 7070 is a high-speed solid-state data processing system designed for both commercial and scientific applications. Its versatility and range enables easy expansion from a basic card system to a tape or tape RAMAC system which incorporates the speed and capacity of many large-scale data processing systems.

In both commercial and scientific applications, it is becoming essential that the data processing system be flexible to meet both current and future requirements of the application. The IBM 7070 system has been designed with such flexibility in mind. A wide variety of configurations can be utilized to meet increasing customer needs.

Description of a Typical 7070 System

A typical 7070 system is composed of the machine units shown in Fig. 1. These units are:

- Console: This is a separate unit which includes the console typewriter and a small operator’s panel. The console unit is designed to simplify and expedite the operator’s tasks and insure maximum productive machine time.

- The typewriter is the principal operator’s tool, and replaces many of the indicator lights and control switches of previous data processing machines.

- Operator errors should be minimized by the computer’s ability to audit operator commands by a stored program, and by the existence of a printed record from the console typewriter.

- Magnetic Tape Units: Two different magnetic tape units are available. The Model 7291II reads or writes tape at a rate of 15,000 characters per second, while the Model 7291IV reads or writes at a rate of up to 62,500 characters per second. Any combination of up to 12 of these units can be employed in the 7070 system.

Each tape unit is attached to one of two independent tape channels. This enables the system to simultaneously read-write compute, read-read compute, or write-write compute.

To insure that the tape record is properly written, an additional set of magnetic reading heads is mounted in the tape drive adjacent to the writing heads, providing an immediate validity check of the written record.

- Disk Storage Units: The 7300 disk storage units consist of a magnetic disk storage array with a capacity of six million digits. Each record is 80 words in length, making a total of 600 digits and 60 signs.

- Records are read or written by a mechanical access mechanism containing a magnetic recording head. This mechanism moves rapidly to any record in the file. Three of these mechanisms are provided in each disk storage unit to minimize access time by overlapping the operation.

- Up to four disk storage units can be utilized in the system, providing a total storage capacity of up to twenty-four million digits. These units are attached to the system by the same two data channels as the magnetic tape units. Each of these data channels is connected to a disk storage unit by program control, thus enabling simultaneous read-write compute, read-read compute, or write-write compute on different disk storage units.

- Manual Inquiry Station: The 7900 manual inquiry station permits fast interrogation of the status of data stored in core storage, in a disk storage unit, or on magnetic tape. The station consists of a special typewriter equipped with a solenoid-driven key-board and transmitting contacts. A 16-channel punched Mylar tape provides format control.

Up to ten manual inquiry stations can be attached to the system, each one separately buffered, and designed for connection to the system by cable up to 2,500 feet long.

- Card Reader: The 7500 card reader operates at a rate of 400 cards per minute, with format control by means of a control panel mounted on the reader. Data from a full 80-column punched card may be transferred into the computer.

The card reader is equipped with a front-attended tray-feeding hopper and stacker.

As many as three 7500 card readers can be utilized for card input. Selected cards may be offset in the stacker as desired.

- Card Punch: The 7550 card punch operates at a punching speed of 250 cards per minute, with format controlled by control panel wiring. Front-attended hopper and stackers are used. Selected cards may be offset in the stacker.

- As many as three 7550 card punches can be utilized for card output.

- Printer: The 7400 printer operates at a speed of 150 lines per minute, with format control provided by the control panel. The printed line output consists of a span of 120 characters, spaced ten to the inch.

- As many as three 7400 printers can be utilized for printed output.

However, as printed and/or card output, a maximum of three 7550 card punches and 7400 printers can be used in any combination.

- Main frame: The main frame of the 7070 system contains most of the system electronics and consists of the following elements:

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