REFERENCE
MANUAL

RPC-4000 COMPUTER SYSTEM

COMMERCIAL COMPUTER DIVISION/
GENERAL PRECISION, INC.

RPC 4000

COMPUTER SYSTEM

REFERENCE MANUAL

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RPC-4000 COMPUTER SYSTEM

ILLUSTRATIONS

INTRODUCTION

The RPC-4000 is a compact, general purpose computer system which is capable of meeting most scientific, engineering and business data processing requirements. The basic system (Figure 1) consists of the RPC-4010 computer and a Tape Typewriter/Reader-Punch unit for input and output. The RPC-4000 system can accomodate up to 45 input and output units on-line which may be operated simultaneously under program control. If desired, this capacity can be extended -- with minor modifications -- to 60 input/output devices.

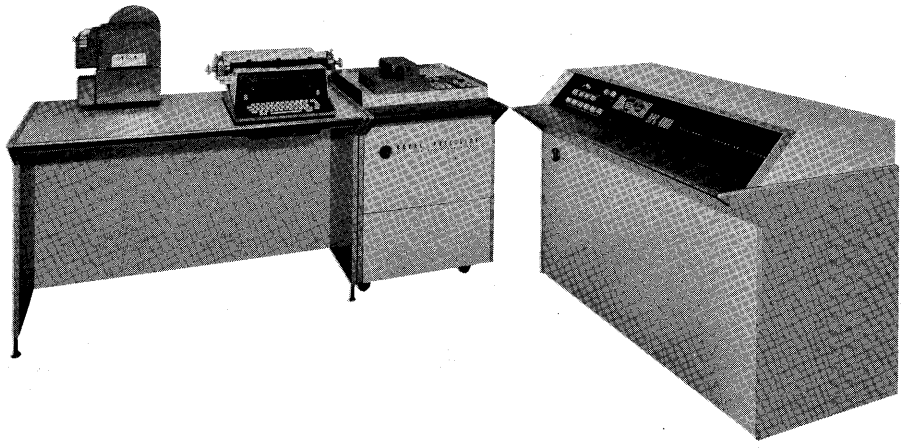

FIGURE 1 — RPC-4000 System

The computer unit is fully transistorized for maximal reliability and compactness. Although it is only desk-sized, it provides operating speeds, memory capacity, automatic operation features and other capabilities which are normally associated with larger, more expensive systems. The computer operates on an internally stored program and uses a "one-over-one" address system . It can perform 230, 000 operations per minute, with a minimum access time of 1 millisecond (8. 5 msec average).

To assure accurate performance, the RPC-4010 is equipped with a parity checking device. Parity is tested during input and generated during output. The computer stops automatically when an error is detected, so that corrections can be made.

In addition to the basic RPC-4000 system, a variety of auxiliary devices are available for users whose applications require greater input or output speeds. For example, a 500 character-per-second reader and a 300 character-per-second punch may be used instead of or in addition to the standard reader/ punch unit.

MEMORY

The memory unit of the RPC-4010 is a cylindrical drum which is housed in a metal case for protection against dust or accidental damage. This drum is used for information storage and can accomodate a total of 8008 computer words. Information is deposited as magnetized spots on the drum surface and can be read back during program operation. These "reading" and "writing" processes are carried out by a series of read/write heads. When the machine is idle, the drum rests away from the head to prevent damage from physical contact. When the power is turned on, air pressure raises the drum to the correct operating position.

The memory drum revolves at the rate of 3600 rpm. Thus, one drum revolution requires about 17 milliseconds. Since the drum speed determines how fast information can be read from the various locations on the drum, "one word time" for the RPC-4010 -- or the time required for one computer word to pass under the proper read head -- is about 0. 26 ms.

The circumference of the memory drum (Figure 2) is divided into parallel bands which are referred to as tracks. Above each track is a magnetic read/write head, except for the double access tracks which have two read/write heads each.

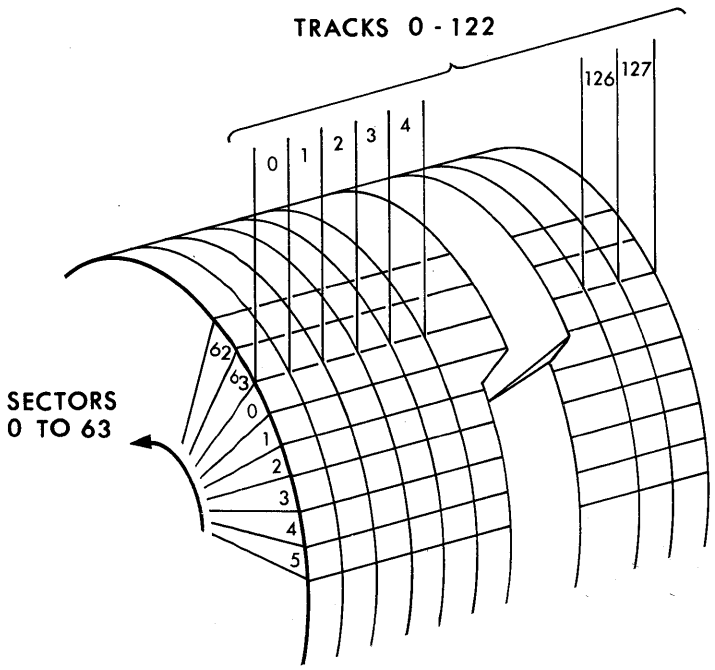

FIGURE 2—Memory Drum

The RPC-4010 memory consists of 128 tracks, which, in turn, are divided into 64 sectors each. This total storage area of 8008 locations accomodates 7872 words of main memory with an average access time of 8. 5 milliseconds; 128 words of dual access; and 8 words of high-speed storage with an access time of 1 millisecond average, 2 milliseconds maximum.

The location of any word in memory is specified by its track and sector number. This number is the address of the word. Since the main memory portion of the drum contains 123 tracks which are numbered 000 through 122, and 64 sectors per track, numbered 00 through 63, a word address designated as 01723 would refer to the word in track 17, sector 23; or the address 10961 would refer to the word in track 109, sector 61.

WORD STRUCTURE

A computer word is the basic unit of information on which a computer operates. The RPC-4000 word consists of 32 binary digits or "bits", which may represent a numerical value (data) or an instruction to the computer (see Figure 3).

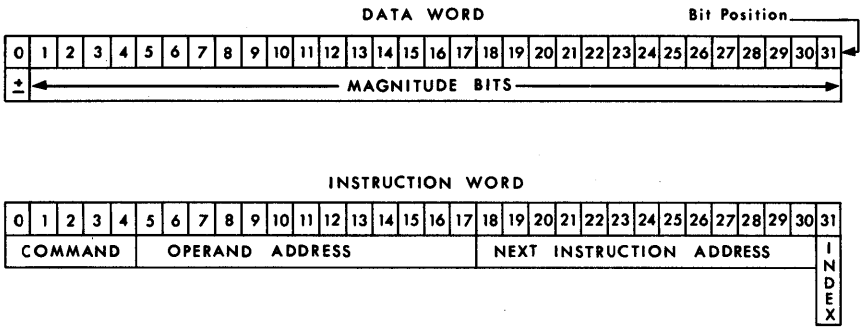

FIGURE 3 — Word Structure

The programmer normally prepares his information input in decimal or hexadecimal format. As this material enters the computer, it is converted to the binary format in which the RPC-4000 processes all information internally. Nevertheless, the programmer needs to be familiar with the binary representation of his information, so he can correctly interpret the binary displays in the oscilloscope which indicate the status of his program.

When a computer word is used for storing data, it contains the algebraic sign (plus or minus) in the left-most bit position and the data, which may represent up to 9 significant decimal digits in the next 31 positions.

When the computer word is used to represent an instruction, it may contain one command (5 bits), an operand or operand address (13 bits), a next-instruction address (13 bits), and an index tag (1 bit). Each part of the word provides the computer with specific information as follows:

Command -- determines the type of operation to be performed, such as addition, subtraction, division, etc.

Operand Address -- for most instructions, contains a value to be acted upon; or serves to identify the location of quantities related to the operation. For transfer instructions which cause an active transfer, it will contain the address of the next instruction.

Next-Instruction Address -- identifies the location of the instruction to be executed next, except for active transfer instructions.

Index Tag -- specifies whether an instruction is to be executed as it is recorded in memory, or if it is to be modified first. If the index tag position contains a 0, the Index Register has no effect on the instruction; i. e. , it is executed as recorded. If this position contains a 1, the operand address of the instruction is modified by having the operand address in the Index Register added to it. Thus, a programmer can modify an address by merely changing the contents of the Index Register.

Double Access Storage

In addition to the main memory section, the drum contains two tracks with double access to the data in each track. Each of these tracks has two read/write heads, addressed by individual track numbers. The heads addressed as Track 123 and 125 have common track storage. The Track 125 head reads 16 sectors later than head 123. For example, assume the number 357 is stored in Location 12300 (Figure 4).

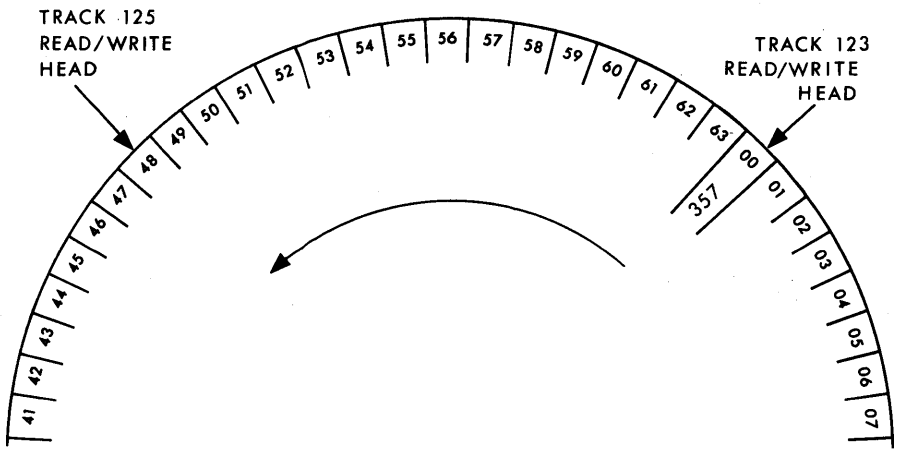

FIGURE 4 — Double-access Tracks 123/125

That value could be read 16 word-times later via the Track 125 read head if the address 12516 is used (Figure 5).

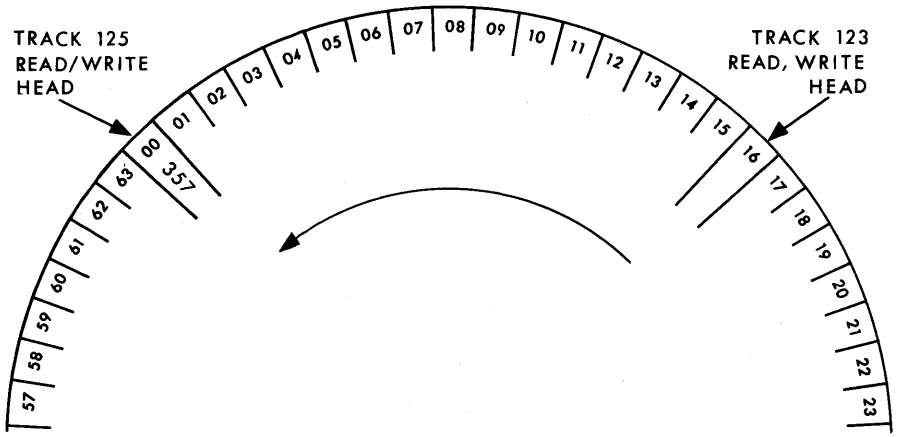

FIGURE 5 — Example of Using Tracks 123/125

The Double-access Tracks have an initial access time of 8.5 milliseconds (average). However, a second access to the same item of information requires only about 4 ms. for Track 123/125 or 6 ms. for Track 124/126. Total Double-access storage capacity is 128 words.

Note that although Sector 00 is shown at the Track 125 read head, the correct address to retrieve the number is 12516. This is true because the Track 123 read/write head is in phase with the Sector Reference Timing Track, and Sec-

tor 16 is currently under that head. As a further example, assume the number 892 is stored on the Double-access Track using the address 12500 (i. e., Track 123 read/write head is at Sector 00, and Track 125 write head is activated). See Figure 6.

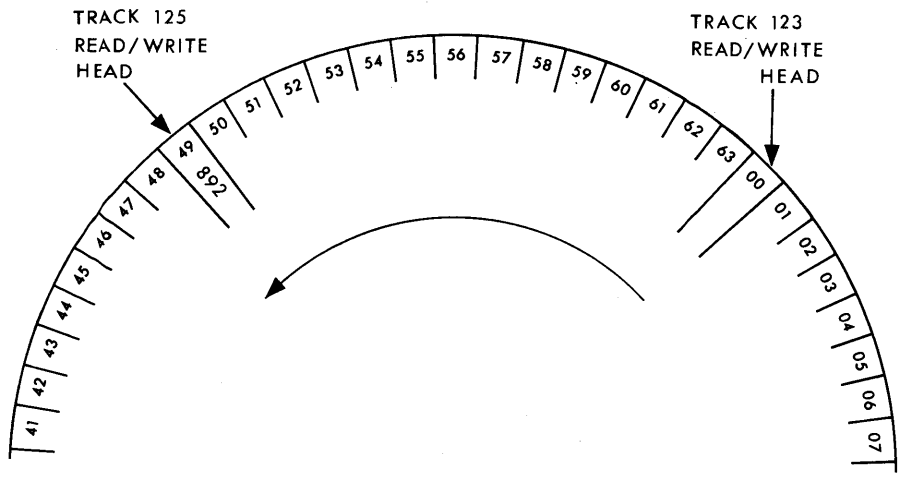

FIGURE 6 — Example of Using Tracks 123/125

Then that number—892—can be retrieved 48 word-times later via the Track 123 read head by using the address 12348 (Figure 7). Thus, any word on the track may be retrieved by either head.

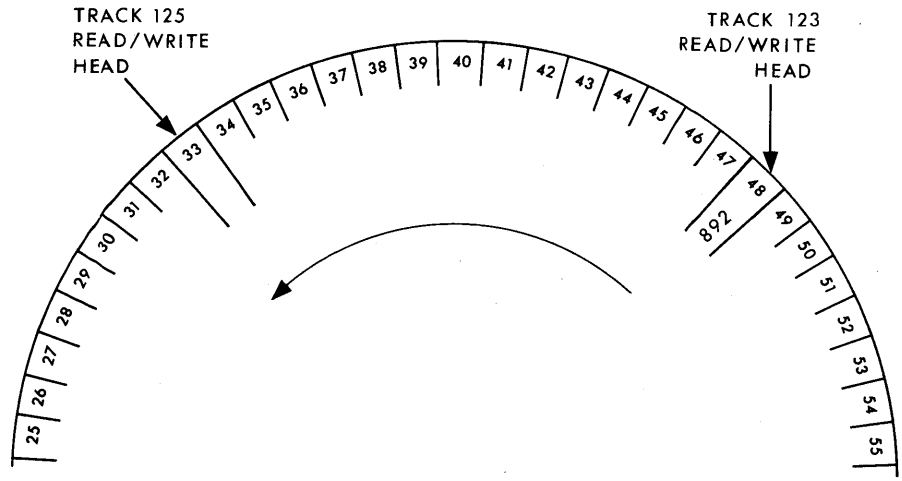

FIGURE 7 — Example of Using Tracks 123/125

The second Double-access Track is similar, with head 126 reading exactly 24 word-times later than head 124. For example, a word originally addressed as 12400 may be retrieved 24 word-times later by using the address 12624 (Figure 8).

In addition, a word addressed 12638 may be retrieved 40 word-times later as 12414 (Figure 9).

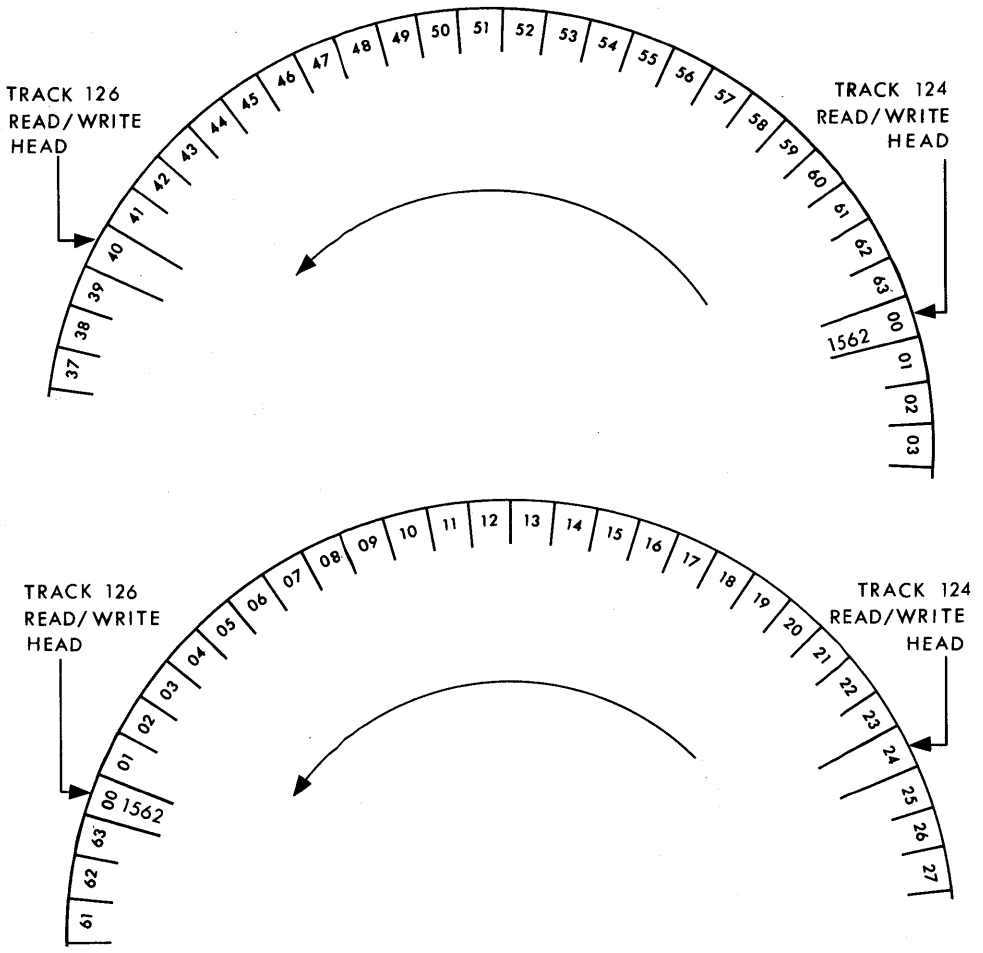

FIGURE 8—Double-access Tracks 124/126

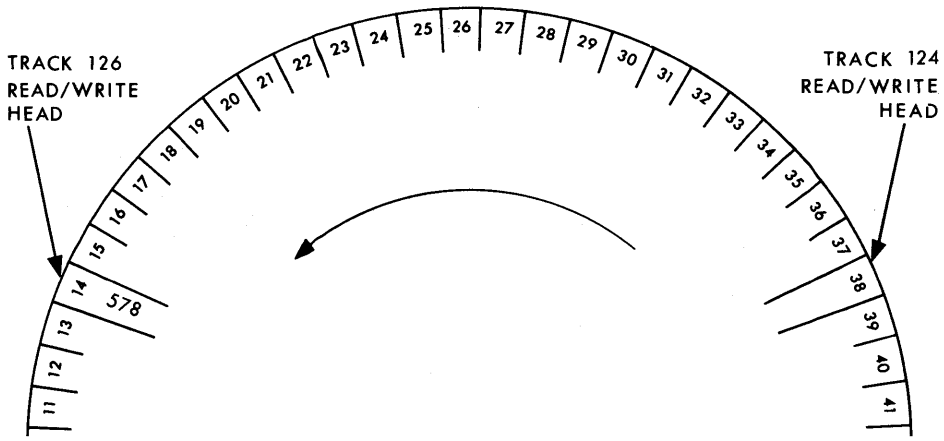

FIGURE 9—Example of Using Tracks 124/126

Figure 9 Continued on Next Page.

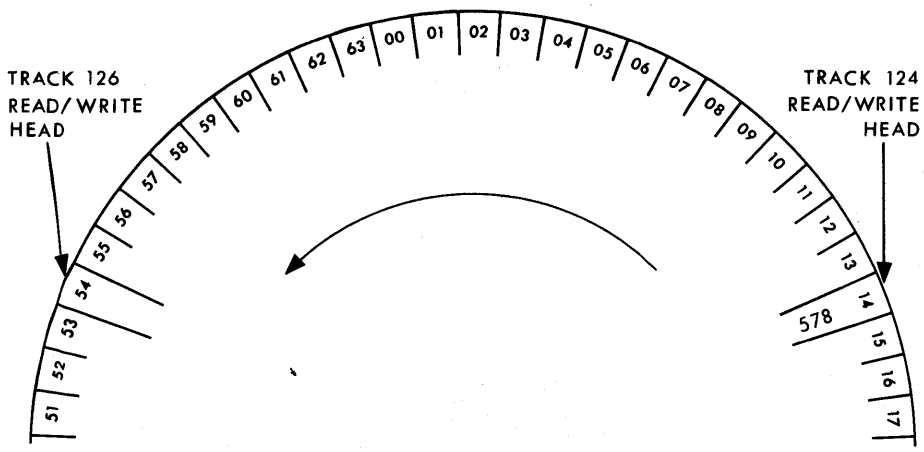

FIGURE 9—Example of Using Tracks 124/126

Recirculating Track

There is one track on the memory drum which duplicates the same word eight times around the drum. It is known as the Recirculating Track (Figure 10). This track has one associated read/write head which is in phase with the main memory for data insertion and retrieval. In addition, an individual read-head and write-head are employed for the recirculating process only. The Recirculating Track address is 127 with the sectors addressed modulo 8. Thus sector addresses 0, 8, 16, 24... 56 all apply to the same word (see Figure 11). This high-speed storage affords an access-time of 1 ms (average) to any of the eight words on the track. Its primary value is to provide quick access to data which is referred to many times in a program.

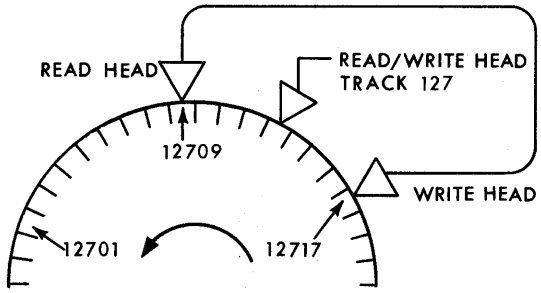

FIGURE 10—Recirculating Track

RECRC0 or RECRC8	00	08	16	24	32	40	48	56
RECRC1	01	09	17	25	33	41	49	57
RECRC2	02	10	18	26	34	42	50	58
RECRC3	03	11	19	27	35	43	51	59
RECRC4	04	12	20	28	36	44	52	60
RECRC5	05	13	21	29	37	45	53	61
RECRC6	06	14	22	30	38	46	54	62
RECRC7	07	15	23	31	39	47	55	63

FIGURE 11—Modulo-8 Table

COMPUTER CONTROL

All computer functions are controlled by the arithmetic and computing control elements, which are comprised of four registers and their associated circuitry. The registers are recirculating tracks on the memory drum. Internal calculations are accomplished by directing information from memory to the arithmetic element, processing it, and directing it either back to memory or to an output device. The four registers are designated: Upper Accumulator (U), Lower Accumulator (L), Command Register (C), and Index Register (X). The first two registers form the arithmetic element and the latter two the control element (Figure 12).

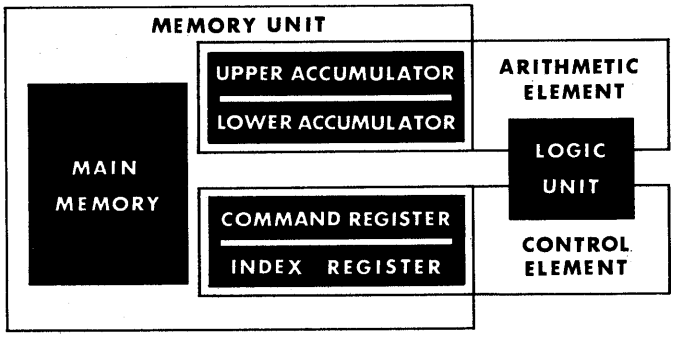

FIGURE 12 — Computer Control Elements

The contents of the registers and accumulators are displayed on the oscilloscope which is located on the control panel of the computer. (See Figure 13.)

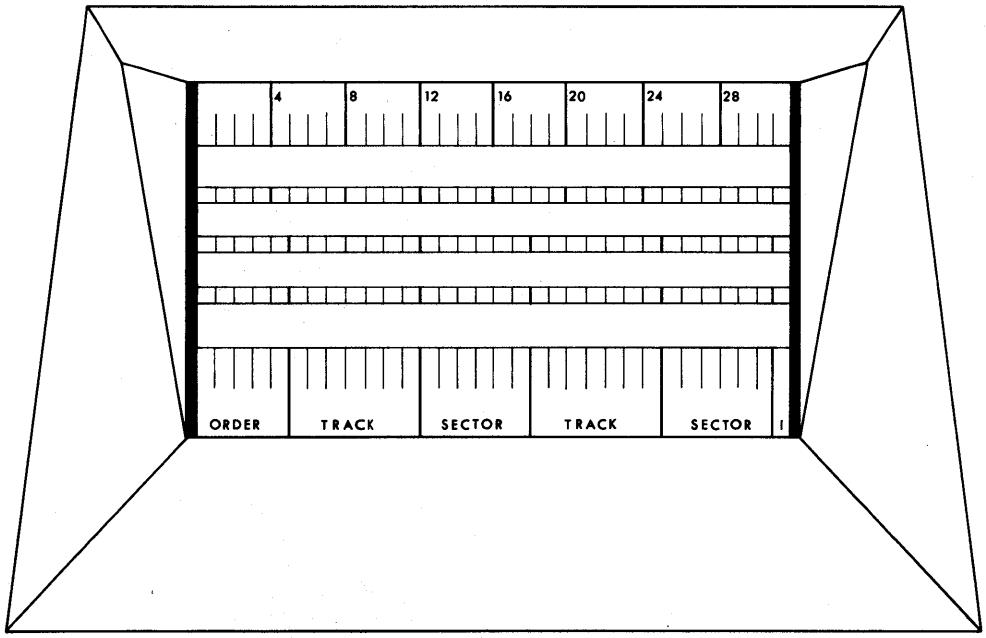

FIGURE 13 — Oscilloscope

Upper Accumulator

The Upper Accumulator may contain the result of addition or subtraction, the quotient of a division process, or the sign and most significant half of the product following a multiplication process. It is also used in comparisons. Prior to the execution of a command pertaining to this register, it will contain one of the operands, the location of the other operand being specified by the instruction. The Upper Accumulator can receive information from, or send information to, any location in memory, the Lower Accumulator, and the Index Register.

Lower Accumulator

The Lower Accumulator may be used in one of two ways: as an extension of the Upper Accumulator or as an individual register. When used as an extension of the Upper, the Lower Accumulator may contain the remainder in a division process or the least significant half of the product following a multiplication process. Also, information may be shifted from the Lower to the Upper or from the Upper to the Lower on a bit-by-bit basis. When used as an individual register, the Lower Accumulator may contain the results of an addition or subtraction process and serve for making comparisons. Prior to the execution of a command pertaining to this register, it will contain one of the operands, the location of the other being specified by the instruction.

Under program control, the Lower Accumulator may be extended to 8 one-word accumulators. This effectively divides the recirculating track of this register into 8 blocks of 8 words each. Consequently, up to eight words may be manipulated as a block by means of the LDC command. The position of each block of 8 words is identified as L_0, L_1, L_2 . . . or L_7 and is determined by the sector part (modulo 8) of the operand address (Figure 14).

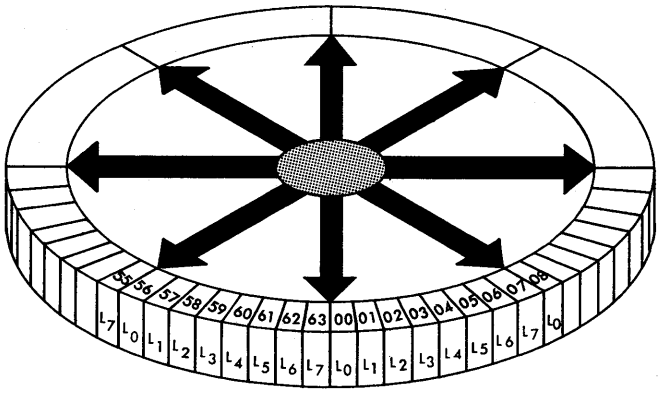

FIGURE 14 — Eight-Word Lower Accumulator

Command Register

The Command Register contains the instruction to be or being executed. Every instruction consists of four fields; the Command Field (bit positions 0 through 4), the Data-address Field (bit 5 through 17), the Next-address Field (bits 18 through 30), and the Index Tag Field (bit 31). See Figure 15.

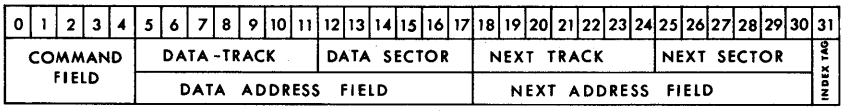

FIGURE 15 — Instruction Word Fields

Index Register

The Index Register (Figure 16) performs 3 basic functions. It

1. holds a value for address modification;
2. controls the number of repetitious of an instruction; and
3. contains the sector portion plus 1 of the location of the operand following a successful comparison.

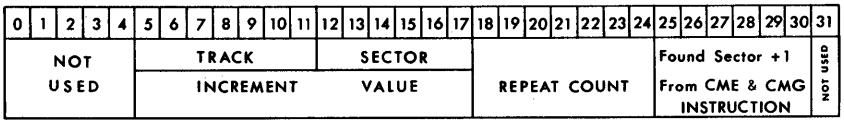

FIGURE 16 — Index Register Format

When used for address modification, bits 5 through 17 of the Index Register hold a value which is added to any instruction which contains a 1-bit in the Index Tag position. Only the Data-address field (bits 5 through 17) of the instruction will be incremented. When an indexed instruction is to be executed, the sum of the increment value in the Index Register and the instruction from memory is placed in the Command Register. The value in the Index Register and the instruction in memory are left unaltered.

Bits 18 through 24 of the Index Register hold the repeat count for any instruction which is to be executed in Repeat Mode.

Bits 25 through 30 of the Index Register are used in conjunction with the Compare Memory Equal and the Compare Memory Greater instructions, when executed in Repeat Mode. Following the execution of a repeated instruction, the Next-address track portion of the Index Register will contain the value 127 (all 1's). If the comparison was successful, the Next-address sector portion will contain a value one sector greater than the sector location of the memory word. If the comparison was not successful, the Next-address sector portion will contain a value one sector greater than the sector location of the memory word last compared. The remaining portions of the Index Register remain undisturbed.

In addition to these functions the Index Register may be used as a rapid-access storage location, and its contents may be exchanged with or may replace that of the Upper Accumulator.

BRANCH CONTROL

Although it is not a register, the Branch Control unit is another information-handling device within the computer which should be mentioned here. The Branch Control is an internal flip-flop. It is automatically turned on when an overflow condition occurs (a quantity larger than the capacity of the register has been generated), or when successful comparisons have been made according to prescribed instructions. The Branch Control can be examined and, depending on its state, a transfer made to one of two alternate locations.

REPEAT MODE

The repeat execution feature is a programmable, operating mode in which the instruction is executed and then repeated a specified number of times (from 0 through 127). The Repeat Mode is primarily used with the arithmetic instructions which process or effect transfers of blocks of data, and with the compare instructions for table search.

The Repeat Mode is initiated by a Load Count instruction which places the repeat count in bits 18-24 of the Index Register (without interfering with the ad-

dress modification portion, if present). Only the instruction immediately following the Load Count instruction will be repeated. (The exception, an active transfer instruction, is explained below). An instruction to which the Repeat Mode is applied begins execution at its operand address and continues for the appropriate number of sectors within the addressed track. That is, no change of track number occurs, but sectors are considered in turn regardless of the starting point. Any command may be repeated, whether it is meaningful or not. However, the multiply, divide, and shift instruction, when executed in Repeat Mode, produce results which are not true repetitions of the execution phase and should therefore not be used in this mode.

A special case occurs when a conditional transfer instruction is operated in Repeat Mode. If the transfer is inactive, no action is taken and the execution of the succeeding instruction is delayed until the repeat count is completed. If the transfer is active, the repeat count causes the repetition of the instruction to which the transfer is made. This is the only instance in which the repeated instruction does not immediately follow the Load Count Instruction.

INSTRUCTION TIMING AND SEQUENCE

The sequence in which instructions are executed is controlled by the addresses contained within the instruction word. The time required for completing the operation specified is likewise dependent, in part, on the addresses. A complete instruction cycle begins with the memory search for the instruction word and ends with the commencement of the search for the next instruction word.

The complete cycle consists of four phases:

Phase 1 - Search for memory location specified in Next-address field of Command Register. Requires 1 to 64 word-times.

Phase 2 - Transfer content of this location to the Command Register. Requires 1 word-time.

Phase 3 - Search for memory location specified in Data-address field of Command Register. Requires 1 to 64 word-times.

Phase 4 - Execution of operation. Requires basically 1 word-time but some instructions require additional Phase 4 cycles to complete the operation.

Basically the computer requires a complete cycle—a minimum of 4 word-times —to obtain and execute an instruction. However, not all instructions require a memory search for data (phase 3); some instructions require an extended Phase 3; and some, an extended Phase 4.

The following instructions do not require a memory search for data and require only 1 word-time in Phase 3:

Halt	Shift Right or Left
Sense	Shift Left and Count
Compare Index Equal	Input
Load Index Register	

Print instructions require only 1 word-time in Phase 3 except when the input/output interlock holds the computer in that phase, indicating non-readiness to output. As soon as the interlock releases, the output command is executed.

The Exchange and Multiply by Ten instructions do not require a memory search for data either. However, their Phase 3 time depends on the value in the Data-

sector field of the instruction word. For example, the Data-sector value may specify that the operation is to be performed on a particular word of the 8-word Lower Accumulator. Consequently, a Phase 3 wait for the required word in the Lower may be necessary.

Some instructions require an extended Phase 4 to complete their operations. The total Phase 4 time for these is as follows:

Divide Upper	67 word-times
Divide	67 word-times
Shift Right or Left	4 word-times plus 1 word-time for each bit position shifted
Shift Left and Count	4 word-times plus 1 word-time for each bit position shifted
Multiply	67 word-times

The Phase 4 time required for the Input and Print instructions depends on the speed of the selected input/output devices.

There are two instructions which do not follow the normal phase sequence: Transfer on Minus and Transfer on Branch Control. When a successful test is made during Phase 3 of a transfer instruction, Phase 4 and Phase 1 for the next cycle are by-passed, and the computer advances directly to Phase 2. Thus, these instructions may require as little as 2 word-times. Unsuccessful tests require completion of all 4 phases.

COMPUTER CONTROL PANEL

Operational control of the computer is effected through the control panel, which contains a set of indicators and manually operated switches (Figure 17). All components of the panel are identified by function or related action.

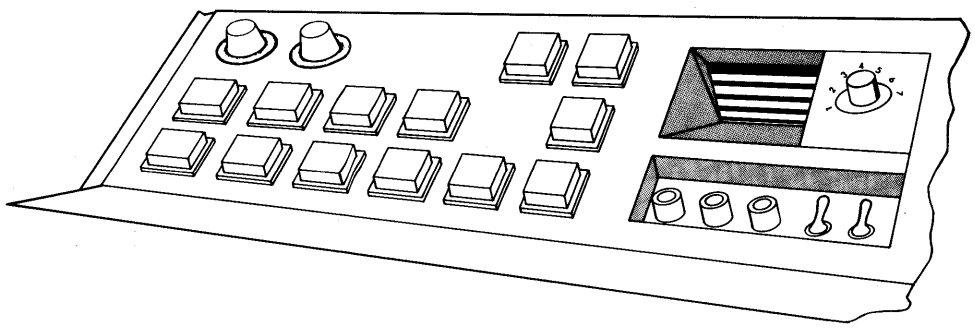

FIGURE 17 — RPC-4010 Control Panel

Control or Indicator	Function
STOP	An indicator lamp which is lighted when the computer is halted by either a programmed instruction or manual intervention.

Control or Indicator	Function
COMPUTE	An indicator lamp which is lighted when the computer is executing instructions.
POWER ON	A momentary switch which turns the electrical power ON and stays lighted while power is ON.
POWER OFF	A momentary switch which turns the power OFF.
START COMPUTE	A momentary switch which initiates computer operation. It is lighted when power is ON.
ONE OPERATION	A two-position switch which, when depressed, will cause the computer to halt after the execution of one instruction. When the computer is in One Operation mode, one instruction is executed each time START COMPUTE is depressed. With ONE OPERATION raised, the computer operates in the normal instruction-execution mode. Depressing this switch will allow the activation of the SET INPUT MODE and EXECUTE LOWER ACCUMULATOR switches.
SET INPUT MODE	A momentary switch used in conjunction with the ONE OPERATION switch. When ONE OPERATION is depressed, SET INPUT MODE is lighted, and depressing it will cause the Lower Accumulator and the data-track portion of the Command Register to be set to zero, the Lower Accumulator to be set to one-word length, and a four-bit input order to be initiated. Execution of the four-bit input order is contingent on manual selection of an input device and depression of START COMPUTE. With ONE OPERATION raised, depressing SET INPUT MODE has only one effect: to set the Lower Accumulator to zero.
EXECUTE LOWER ACCUMULATOR	A two-position switch which is active (and lighted) only when the ONE OPERATION button is depressed. When both EXECUTE LOWER ACCUMULATOR and ONE OPERATION are depressed and a start signal is received, the word contained in the Lower Accumulator is transferred to the Command Register. START COMPUTE must be depressed before the instruction will be executed. Sound practice demands that EXECUTE LOWER ACCUMULATOR be raised during operation in normal mode. If the operator is unaware of the fact that EXECUTE LOWER ACCUMULATOR is depressed and he depresses ONE OPERATION, the resulting program output may be invalid.

Control or Indicator	Function
BRANCH CONTROL	A momentary switch which is lighted when the Branch Control flip-flop is ON. With ONE OPERATION depressed, depressing the BRANCH CONTROL switch will turn OFF the Branch Control flip-flop.
BRANCH SWITCHES	Six 2-position switches, labeled 1, 2, 4, 8, 16, and 32, which are used in conjunction with the Sense instruction. Each switch is lighted when depressed. Depressed switches are ON; raised switches are OFF.
OSCILLOSCOPE	A cathode ray tube used for digital display. It is masked to designate the sweeps which show the contents of the Upper Accumulator, Lower Accumulator, Command Register, and Index Register.
L-DISPLAY	An eight-position rotary switch whose setting determines which record will be displayed in the Lower Accumulator when it is in 8-word mode.
VERT. POS., HORIZ. POS., WIDTH	Three knobs which allow the operator to adjust the four oscilloscope sweeps in their windows.
RECORD 0-15, 16-32	Two toggle switches which make it possible to permanently store information in computer memory. When turned to OFF, each switch inhibits recording in the tracks indicated.

INPUT/OUTPUT SYSTEMS

Communication between the computer and the operator may be through either of two input/output systems: the RPC-4500 Tape-Typewriter System, composed of the RPC-4480 Typewriter and the RPC-4430 Reader/Punch, or the RPC-4510 Tape-Typewriter System, composed of the RPC-4480 Typewriter and the RPC-4435 Reader/Punch (Figure 18). In each system the typewriter and the reader/punch are connected to form a multiple-function system capable of a wide variety of operations, both on-line and off-line.

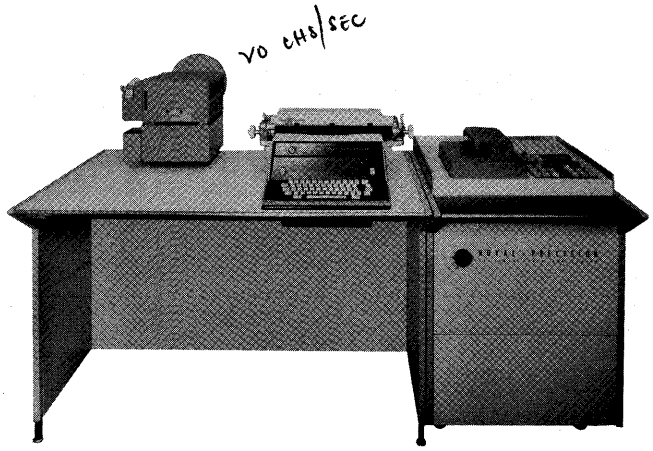

FIGURE 18 — RPC-4510 Input/Output System

RPC-4480 Typewriter

The RPC-4480 Typewriter has been designed specifically for the RPC-4000 System. The typing speed is 10 characters-per-second under automatic control. The RPC-4480 and the RPC-4430 (or 4435) are interconnected so that any combination of devices may be used to produce paper tapes and/or hard copy proofs. The effective speed of any combination is that of the slowest unit. Keyboard operation of the typewriter is identical to that of conventional machines except for the addition of a SPECIAL bar. When the typewriter is used with the RPC-4430, the SPECIAL bar allows the operator to backspace the typewriter carriage and the paper tape in the punch unit simultaneously and to produce a code delete in the tape. When the typewriter is used with the RPC-4435, the SPECIAL bar is used only to produce a code delete in the tape.

RPC-4430 Reader/Punch

The RPC-4430 Reader/Punch provides communication with the computer via perforated paper tape. The reader portion is capable of operating at a speed of 60 characters-per-second, while the punch operates at 30 characters-per-second. The Reader/Punch unit may be operated on-line (under computer control) or off-line (independent of the computer).

60|30

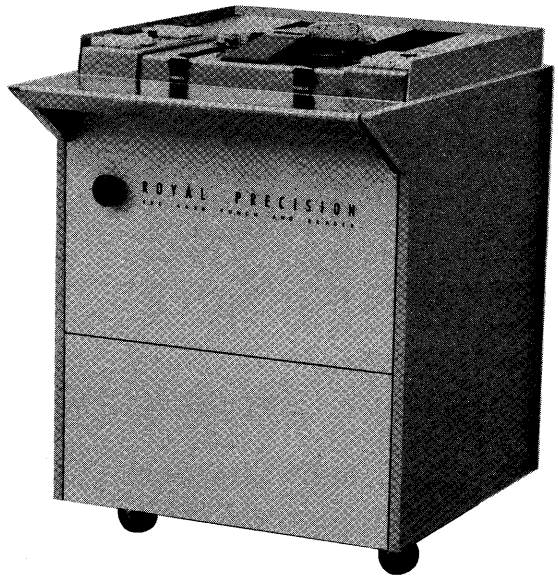

FIGURE 19 — RPC-4430 Reader/Punch

RPC-4435 Reader/Punch

The RPC-4435 Reader/Punch also reads and/or produces perforated paper tape. Its reader operates at 200 characters-per-second, while the punch operates at 20 characters-per-second. Like the unit described above, the RPC-4435 may be operated on-line or off-line.

SYSTEM CONTROL SECTIONS

When either reader/punch is operated on-line, the master control section functions as an interpreter between the computer and the input/output devices; no electrical signals pass directly between the computer and any device. This section controls the input/output interlock (i. e. , synchronizes the activities of the simultaneously operating output devices and/or the single input device with the computer). It also controls the automatic (programmed) selection of input and output devices. To insure maximum accuracy, the master control section

performs a parity check (for even parity) on all information passing through it. Different modes of operation can be effected by program control or through manipulation of the primary control panel. These various modes are handled by the master control section so that any device installed in the system can operate in alternate modes. Up to 60 input/output units may be connected to the computer through the reader/punch.

The off-line control section is completely independent of the master control section, although it performs similar functions. This section does not communicate with the computer, and the modes of operation must be manually selected. No parity check occurs off-line. All necessary tape preparation and editing modes are provided.

Reader/Punch Control Panels

The RPC-4430 control switches and indicator lights are mounted in two panels (Figure 20). The RPC-4435 has the same control switches and indicator lights; except the two panels are positioned side-by-side (Figure 21). The right or primary control panel is concerned exclusively with on-line operation. The left panel is actually in two sections: the upper one (auxiliary control panel) is concerned basically with on-line operation, but may affect off-line operation, and the lower section (off-line control panel) is concerned basically with off-line operation, but may have a decided effect on on-line operation. (See "Selection On-Line and Off-Line"). The following is an explanation of the functions of these indicators and switches:

Primary Control Panel

Control or Indicator	Function
CHARACTER INDICATOR LIGHTS	Seven lights which glow to indicate the bit-pattern of the next tape character to be read into the system by the tape reader.
SYSTEM POWER	A two-position switch which is ON and lighted when depressed. This switch controls the electrical power for input/output devices in the system. Individual power switches of each device are connected in series with this switch so both must be ON to make a unit operable.
SINGLE CHARACTER MODE	A two-position switch which is active and lighted when depressed. In Single Character Mode all tape characters enter the accumulator. Input will be one character at a time, with a start signal sent to the computer after each character is read. In Normal Mode (SINGLE CHARACTER MODE raised) only tape codes 16 through 62 enter the computer, and a start signal is sent only when a stop code is detected or START COMPUTE is depressed. Single Character Mode cannot be controlled by programming and, because of the timing involved, cannot be used when the Lower Accumulator is in 8-word mode.
PARITY MONITOR RESET	A momentary switch which is lighted when the computer is halted because of a parity error (an uneven number of bits in all 7 channels). Depressing this switch will reset the parity error stop switch which halted the computer and will allow operation to continue.

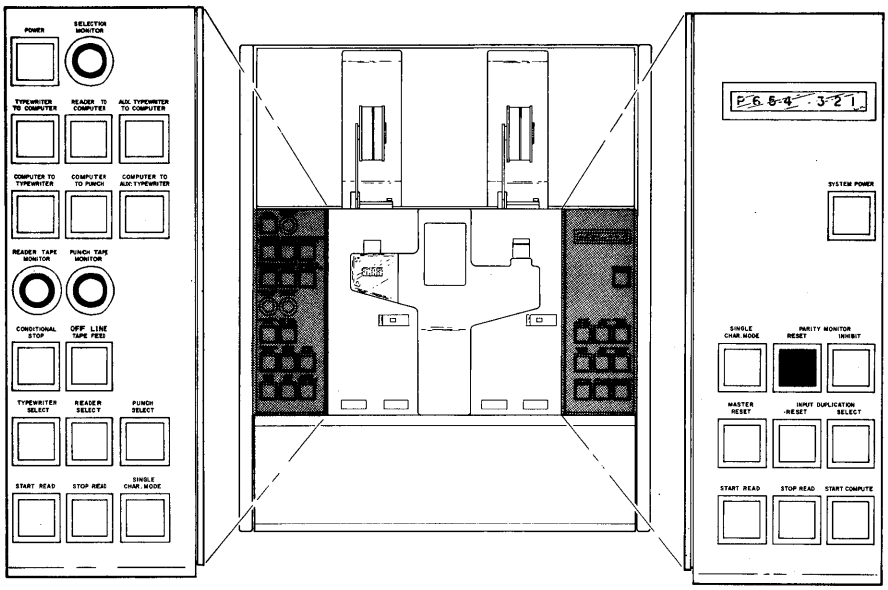

FIGURE 20 — RPC-4430 Control Panel

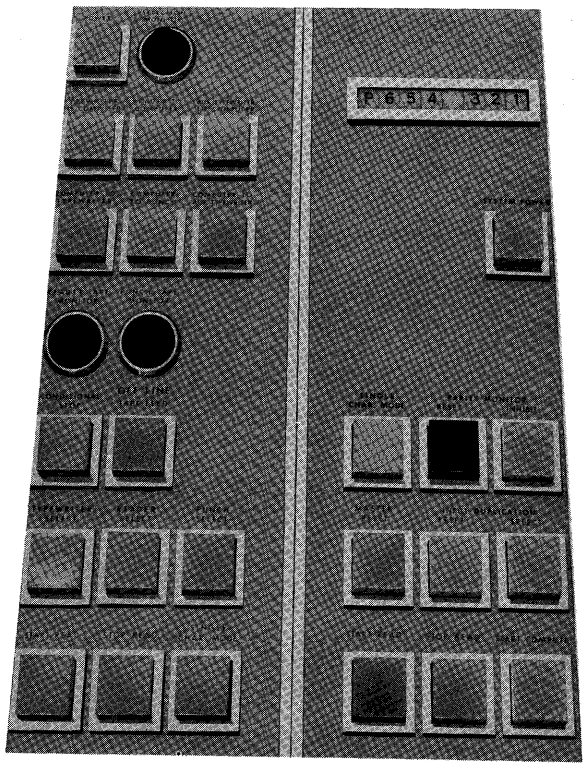

FIGURE 21 — RPC-4435 Control Panel

Control or Indicator	Function
PARITY MONITOR INHIBIT	A two-position switch which, when depressed, is lighted and will inhibit parity checking. When raised, it enables parity checking.
MASTER RESET	A momentary switch which, when depressed, deselects all input/output units selected on-line. If depressed while the computer is executing an input instruction, the read signal is terminated. When an input device is subsequently selected, depressing START READ will allow the computer to continue operation. This switch is lighted when the system power is ON.
INPUT DUPLICATION RESET	A momentary switch which inhibits input duplication. This switch is lighted when the reader/punch power is ON, and copy mode is off.
INPUT DUPLICATION SELECT	A momentary switch which is lighted when active. When depressed, this switch turns ON Copy Mode whereby all selected output devices duplicate the input data as it enters the computer. Copy Mode can be controlled by programming. NOTE: This duplication of input data as it enters the computer, provides a valuable and unique verification aid.
START READ	A momentary switch which causes the selected input device to be activated. This switch is lighted when the reader/punch power is ON.
STOP READ	A momentary switch which stops operation of the selected input device. Depressing START READ will resume input without interrupting the input sequence. This switch is lighted when the reader/punch power is ON.
START COMPUTE	A momentary switch which initiates program execution. Depressing this switch is the same as depressing START COMPUTE on the computer console. This switch is lighted when the system power is ON.
Auxiliary Control Panel	
POWER ON	A two-position switch which controls the electrical power of the input/output system. It is active and lighted when depressed. This switch must always be depressed after SYSTEM POWER is turned ON and raised before SYSTEM POWER is turned OFF.
SELECTION MONITOR	An indicator lamp that is lighted when an input/output unit selected off-line is subsequently selected on-line.

	Control or Indicator	Function
	TYPEWRITER TO COMPUTER	A momentary switch which is lighted when the typewriter has been selected as the input device. This selection may be controlled by programming.
	READER TO COMPUTER	A momentary switch which is lighted when the reader has been selected as the input device. This selection may be controlled by programming.
	AUXILIARY TYPEWRITER TO COMPUTER	A momentary switch identical to TYPEWRITER TO COMPUTER for selecting the auxiliary typewriter of the system as the input device. This selection may be controlled by programming.
	COMPUTER TO TYPEWRITER	A momentary switch which is lighted when the typewriter has been selected as an output device. This selection may be controlled by programming.
	COMPUTER TO PUNCH	A momentary switch which is lighted when the punch has been selected as an output device. This selection may be controlled by programming.
	COMPUTER TO AUXILIARY TYPEWRITER	A momentary switch identical to COMPUTER TO TYPEWRITER for selecting the auxiliary typewriter of the system as an output device. This selection may be controlled by programming.
	READER TAPE MONITOR	An indicator lamp which is lighted when the reader is out of tape or the tape is jammed.
	PUNCH TAPE MONITOR	An indicator lamp which is lighted when the punch is out of tape or the tape is jammed.
Off-Line Control Panel	CONDITIONAL STOP	A two-position switch which is active and lighted when depressed. When raised, the switch permits recognition of a stop code sensed by any selected input device and thereby terminates off-line operation. When depressed, the switch suppresses recognition of stop codes, and they are read in the same way as other characters. Operation will continue until STOP READ (off-line) is depressed.
	TAPE FEED	A momentary switch which when depressed, after the punch is selected off-line, will punch sprocket holes in blank tape. This switch is lighted when the POWER ON switch is depressed.
	TYPEWRITER SELECT	A two-position switch which when depressed will de-select the typewriter if it is selected on-line and will select it for off-line operation: for input if no other input device is selected off-line or for output if another input device is selected off-line. This switch is lighted when depressed.

Control or Indicator	Function
READER SELECT	A two-position switch which when depressed will de-select the reader if it is selected on-line and will select it for off-line operation. While the reader is selected off-line, the typewriter may not be used for off-line input to the punch. This switch is lighted when depressed.
PUNCH SELECT	A two-position switch which when depressed will de-select the punch if it is selected on-line and will select it for off-line operation. This switch is lighted when depressed.
START READ	A momentary switch which, when depressed, connects the device selected for off-line input to the device selected for off-line output and activates the input device. This switch is lighted when the POWER ON switch is depressed.
STOP READ	A momentary switch which, when depressed, terminates off-line input. This switch is lighted when the POWER ON switch is depressed.
SINGLE CHARACTER MODE	A two-position switch which, when depressed, will limit off-line input to one character at a time. This switch is lighted when depressed. If CONDITIONAL STOP is depressed, SINGLE CHARACTER MODE will have no effect, even though it will appear to be active.

In addition to the controls listed above, the RPC-4435 has two switches and a know located on the punch (Figure 22).

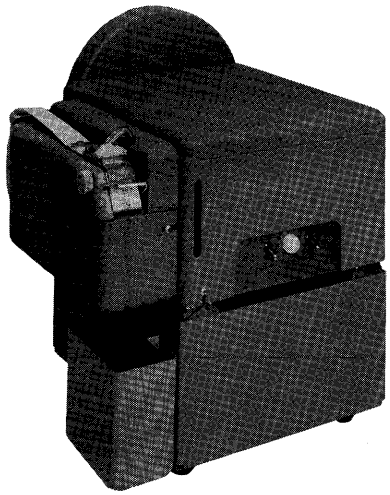

FIGURE 22 — RPC-4435 Punch Controls

RPC-4435 Punch Controls

Control or Indicator	Function
POWER	A two-position toggle switch which is in series with the POWER ON switch located on the RPC-4435 auxiliary control panel. The POWER switch may always be left in the ON position since operation of POWER ON will then control the power supply. When power is supplied to the punch, the indicator light adjacent to the POWER switch will glow. The punch will not function when this switch is OFF.
TAPE FEED	A momentary toggle switch which is active only when the RPC-4435 Punch is selected off-line. When it is active and depressed, the punch will produce sprocket holes in blank tape. This switch is convenient to use when loading a new roll of tape in the punch. When a leader of tape is to be punched, the TAPE FEED switch on the RPC-4435 off-line control panel should be used.
TAPE BACKSPACE KNOB	A round, knurled knob which may be rotated counterclockwise to backspace the tape. Rotating this knob clockwise will advance the tape. The device is designed so that the tape cannot be positioned between tape characters. An audible click occurs each time a character is moved under the punching station.

Character Deletion on the RPC-4435

Each time a character is punched on tape, the punch punches the code which corresponds to the character then advances the tape one character position. In order to delete the last code punched on tape, turn the TAPE BACKSPACE KNOB counterclockwise one character position, then depress the SPECIAL bar on the typewriter and type an X. When the character to be deleted is not the last one punched, position the incorrect code so that it can be seen just ahead of the punching station; then rotate the TAPE BACKSPACE KNOB counterclockwise one character position, depress the SPECIAL bar and type an X.

Selection On-Line and Off-Line

Selection of any unit off-line takes precedence over on-line selection of that unit. That is, selection of a device off-line will de-select that unit if it was previously selected on-line. If a unit is selected off-line and subsequently selected on-line, the light under the on-line selection button will turn ON and the SELECTION MONITOR indicator will glow to indicate the error. The computer will be unable to use the units selected both on-line and off-line. However, they may be used off-line in this condition. Only one input device should be selected at any one time.

PERIPHERAL EQUIPMENT

The RPC-4000 System may be augmented with specially designed optional input/output devices. Up to 45 input/output devices may be used on-line concurrently; and, with minor modifications, up to 60 devices may be connected, such as:

RPC-4290	Translator
RPC-4410	High Speed Reader
RPC-4431	Auxiliary Reader/Punch
RPC-4436	Auxiliary Reader/Punch
RPC-4440	High Speed Punch

RPC-4480	Auxiliary Typewriter
RPC-4600	Auxiliary Tape-Typewriter System
RPC-4610	Auxiliary Tape-Typewriter System

The RPC-4010 Computer may be programmed to control the selection of the input and output devices. Also, the computer may select four- or six-bit input as well as provide for typed copy and/or duplicate tapes to be made from input.

All input is parity checked for code validation. Output contains proper parity bits in the seventh tape channel for subsequent accuracy control.

RPC-4290 Translator

The RPC-4290 Translator converts code configurations employed by other systems to that used by the RPC-4000 System and, conversely, changes the code configuration of the RPC-4000 System to that of other systems. The same basic device is used for either input or output translation, but not both; if both input and output information is to be translated, two devices must be installed. The device(s) will be installed in the RPC-4430 (or 4435) Reader/Punch unit, and the control panel will be modified to accommodate the control switches for the translator(s).

RPC-4410 High Speed Reader

The RPC-4410 High Speed Reader is a photo-electric input device for the RPC-4000 System. Capable of reading perforated paper tape at 500 characters-per-second, this unit is separately packaged in a matching cabinet and provides additional tape-handling facilities for the computer. Tape may be read in forward or reverse direction. Also, the Photo Reader can search for a special code while the computer accepts input from another device, emits output, or computes.

The speed and bi-directional reading and searching features of the Photo Reader plus the ability of the RPC-4010 Computer to handle numerous input/output devices offer an unusual facility for applications wherein paper tape may be used for unlimited storage to augment the internal memory of the computer.

FIGURE 23 — RPC-4410 High Speed Reader

RPC-4431 Auxiliary Reader/Punch

The RPC-4431 Auxiliary Reader/Punch may be used (on-line or off-line) as a separate optional input/output device as well as a component of the RPC-4600 Auxiliary Tape-Typewriter System. The electro-mechanical perforated paper-tape reader and paper-tape punch provide additional computer input at 60 characters-per-second and computer output at 30 characters-per-second. Safety interlocks are provided to assure proper operation of reader and punch.

RPC-4436 Auxiliary Reader/Punch

The RPC-4436 Auxiliary Reader/Punch is a component of the RPC-4610 Tape-Typewriter System, or it may also be used as a separate optional input/output device. This device is the same as the RPC-4435 except that it does not have the primary control panel. The photo-electric reader and the paper-tape punch provide additional input at 200 characters-per-second and output at 20 characters. This device may be operated both on-line and off-line.

RPC-4440 High Speed Punch

The RPC-4440 High Speed Punch is capable of perforating paper tape at the rate of 300 characters-per-second. It is designed for on-line operation under control of the RPC-4010 Computer. When applications require high-volume output, one or more of the paper-tape punches will easily obtain the results desired.

FIGURE 24 — RPC-4440 High Speed Punch

RPC-4480 Auxiliary Typewriter

The RPC-4480 Auxiliary Typewriter is an optional input/output device for on-line operation. It may be connected as part of an RPC-4500 System, an RPC-4510 System, an RPC-4600 System, or an RPC-4610 System. Under program control, the typing speed is 10 characters-per-second. The control switches for the auxiliary typewriter are among those in the auxiliary control panel on the reader/punch unit of the system to which it is connected.

RPC-4600 Auxiliary Tape-Typewriter System

The RPC-4600 Auxiliary Tape-Typewriter System functions as an optional input/output system for the RPC-4000 System. It is identical to the RPC-4500 System except that it does not have the master input/output controls (primary control panel). The RPC-4600 System consists of an RPC-4431 Auxiliary Reader/Punch and an RPC-4480 Auxiliary Typewriter.

RPC-4610 Auxiliary Tape-Typewriter System

The RPC-4610 Auxiliary Tape-Typewriter System functions as an optional input/output system for the RPC-4000 System. It is identical to the RPC-4510 System except that it does not have the primary control panel. The RPC-4610 System consists of an RPC-4480 Auxiliary Typewriter and an RPC-4436 Auxiliary Reader/Punch.

RPC-4000 PROGRAM LIBRARY

A comprehensive library of general purpose, utility, and automatic programming routines, designed specifically to reduce programming time, expense, and effort, is available to all RPC-4000 System users. These routines, reflecting many years of programming experience, include:

COMPACT — a FORTRAN-language compiler complete with a large collection of subroutines.

ROAR — the RPC-4000 Optimizer and Assembly Routine which assigns optimum locations to symbolically-coded instructions, producing a machine-language program.

Basic Arithmetic Routines - trigonometric functions, exponentials, logarithms, roots, floating-point and fixed-point programs.

Utility Routines - program storage, input/output conversion routines, program test and correction routines.

Table Generator

Conversion Routines

COMPUTER COMMANDS

The following is a list of the numeric and mnemonic designations for the commands which control computer operation along with a brief description of each command and the functions pertaining to it.

(00) HLT — Halt

The HLT instruction causes the computer to halt in Phase 3 of an instruction cycle and wait for a start signal before proceeding to Phase 4. The track portion of the Data-address field of this instruction must always be zero, as a non-zero track address produces a Sense instruction.

(00) SNS — Sense

The SNS instruction turns OFF the Branch Control if it is ON. Then, if the track portion of the Data-address in the instruction contains a value which corresponds with one or more depressed Sense Switches, the instruction will turn the Branch Control ON. A Data-track value 64 in the SNS instruction is a non-readiness query which will turn the Branch Control ON if the selected input or output device is not ready to operate.

(01) CXE — Compare Index Equal

The CXE instruction turns the Branch Control OFF if it is ON, then compares the Data-address field of the instruction with the Data-address portion of the Index Register. If their contents are equal, the Branch Control is turned ON; if not, the Branch Control remains OFF.

(02) RAU — Reset and Add to Upper

The RAU instruction replaces the contents of the Upper Accumulator with the contents of the memory location specified by the Data-address field of this instruction.

(03) RAL — Reset and Add to Lower

The RAL instruction replaces the contents of the Lower Accumulator with the contents of the memory location specified by the Data-address field of this instruction.

(04) SAU — Store Address from Upper

The SAU instruction stores the Data-address portion of the Upper Accumulator into the corresponding portion of the memory location specified by the Data-address field of this instruction. The rest of the memory word is unaltered.

(05) MST — Masked Store

The MST instruction stores selected bits, as masked by the Upper Accumulator, from the Lower Accumulator into the memory location specified by the Data-address field of this instruction. Where the Upper contains 1's, the corresponding bits from the Lower will be stored into the memory location; where the Upper contains 0's, the corresponding memory-word bits will remain unaltered.

(06) LDC Load Count and Repeat

The LDC instruction places the contents of the track portion of the Next-address field of the memory location specified by the Data-address field of this instruction into the corresponding portion of the Index Register. The remainder of the Index Register is unaltered. The next instruction, indicated by the Next-address field of the LDC instruction, is then executed in Repeat Mode; i. e., the next instruction specified will be executed one time in Normal Mode and will be repeated as many times as indicated by the Repeat Count (the number now contained in the track portion of the Next-address field of the Index Register).

(07) LDX Load Index

The LDX instruction replaces the contents of the Data-address portion of the Index Register with the contents of the Data-address field of this instruction. An indexed LDX instruction adds the contents of the Data-address field of this instruction to the Data-address portion of the Index Register. The remainder of the Index Register remains unaltered.

(08) INP Input

The INP instruction sends a signal to the master control section of the input/output unit calling for input of information. If the track portion of the Data-address field of this INP instruction contains 000, only the least significant four bits of each character will be read in; if this Data-track contains 064, all six bits of each character are read in. If this Data-track contains other than 000 or 064, the character which enters the Lower will be the logical sum of the incoming character and the contents of the Data-track portion of the INP instruction.

If the Lower Accumulator is in 1-Word Mode, the characters are read into the combined (double-length) Upper and Lower Accumulators; if the Lower is in 8-Word Mode, the characters are read into the Lower only.

(09) EXC Exchange

The EXC instruction controls the length of the Lower and effects full-word exchanges among the Upper Accumulator, Lower Accumulator, and Index Register. The functions of this instruction are determined by the track portion of its Data-address field. The basic Data-track settings are listed below:

Data-track Address	Function	
0	No effect	
1	U ⟶ L	(Replace contents of Lower with contents of Upper Accumulator)
2	L ⟶ U	(Replace contents of Upper with contents of Lower Accumulator)
4	U ⟶ X	(Replace contents of Index Register with contents of Upper Accumulator)
8	X ⟶ U	(Replace contents of Upper with contents of Index Register)
16	L ⟶ 8	(Set Lower to 8-word length)
32	L ⟶ 1	(Set Lower to 1-word length)
64	(Reserved)	(If used, has no effect)

Note that any combination of functions can be achieved with one instruction. For example, a track number of 3 reverses the contents of the Upper and Lower Accumulators; a track number of 10 results in a number in the Upper that has 1's wherever either the Lower or the Index or both have 1's (a logical "OR" operation), effecting a pack or merge into the Upper Accumulator; and, a track number of 48 results in reversing the state of the Lower Accumulator, whatever it was.

(10) DIV Divide

The DIV instruction divides the sign and first 62 bits of the Double-length Accumulator by the contents of the memory location specified by the Data-address field of this instruction. The quotient is held in the Upper; and the remainder, after the Upper is cleared, is in the Upper/Lower Accumulator at the same q as the divident. Overflow will turn the Branch Control ON.

(11) DVU Divide Upper

The DVU instruction divides the contents of the Upper Accumulator by the contents of the memory location specified by the Data-address portion of this instruction. The quotient is left in the Upper; and the remainder, which is automatically zero, is left in the Lower Accumulator. Overflow will turn the Branch Control ON.

(12) SRL Shift Right or Left

The SRL instruction shifts the contents of the Double-length Accumulator to the right if the track portion of the Data-address field of this instruction is zero; or shifts it left if the Data-track portion is a 1. The number of bit positions shifted depends upon the number in the sector portion of the Data-address field of this instruction. The Branch Control is turned ON if overflow occurs during a shift left.

(13) SLC Shift Left and Count

The SLC instruction shifts the contents of the Double-length Accumulator left until bit position 1 contains the first significant magnitude bit, or until the sum of the Data-sector value of the instruction word and the number of bit positions shifted equals 64. Following the shift, the Lower Accumulator will be cleared to zero, and the number of bit positions shifted will be loaded into its Data-address field.

(14) MPY Multiply

The MPY instruction multiplies the contents of the Upper Accumulator by the contents of the memory location specified by the Data-address field of this instruction. The resulting double-length product is held in the Double-length Accumulator.

(15) MPT Multiply by Ten

The MPT instruction multiplies the contents of either the Upper or the Lower Accumulator by 0, 2, 8, or 10. The value in the track portion of the Data-address of the MPT instruction determines the multiplier and which accumulator will be affected. These values and their effects are listed on the following page:

Data-track value	Effect on Upper	Effect on Lower
0	Multiply by 10	None
1	Multiply by 8	None
2	Multiply by 2	None
3	Multiply by 0	None
64	None	Multiply by 10
65	None	Multiply by 8
66	None	Multiply by 2
67	None	Multiply by 0

It should be noted that left shifts of the contents of a single accumulator can be accomplished with these instructions and that such shifts require less time than the normal shift commands. For example, a multiply by 8 followed by a multiply by 2 will shift the contents of the designated accumulator left 4 places in 8 word-times instead of the 11 word-times an SRL instruction would require.

Use of Data-track values other than those specified is not recommended since unusable results may be produced.

(16) PRD Print From Data-Address

The PRD instruction presents the contents of the track portion of its Data-address field as binary output to an output device. Track numbers 0 through 63 represent characters to be printed or punched, while numbers 64 through 127 represent control functions. (See Alphanumeric Code Table, Appendix B; and Input/Output Selection Codes, Appendix C.)

(17) PRU Print From Upper

The PRU instruction presents the most significant four or six bits of the Upper Accumulator as binary output to an output unit, depending on the value in the track portion of the Data-address. For track numbers 0 through 63, the result is a four-bit output; for track numbers 64 through 127, the result is a six-bit output. When the four-bit output is indicated, the complete configuration for the character is composed of bits 6 and 7 from the instruction word and the high order four bits of the Upper Accumulator.

(18) EXT Extract

The EXT instruction produces, in the Upper Accumulator, the logical product of the contents of the Upper Accumulator, and the contents of the memory location specified by the Data-address field of this instruction. The resultant product will contain 1's in only those bit positions which contained 1's in both the Upper Accumulator and the memory word.

(19) MML Masked Merge Lower

The MML instruction combines the contents of the memory location specified by the Data-address field of this instruction with the contents of the Lower Accumulator through a mask in the Upper Accumulator. In those bit positions where the Upper contains 0's, the contents of the Lower is retained. In those bit positions where the Upper contains 1's, the contents of the memory word replace the contents of the Lower Accumulator.

(20) CME Compare Memory Equal

The CME instruction turns the Branch Control ON prior to performing the specified comparison. The contents of the Upper Accumulator are compared with the contents of the memory location specified by the Data-address field of this instruction, through a mask in the Lower. If both are identical in the bit positions where the Lower contains 1's, the Branch Control remains ON; otherwise it is turned OFF. When this instruction is executed in Repeat Mode, the sector number following the last sector compared or the sector following that of the successful comparison is placed in the Next-address, sector portion, of the Index Register.

(21) CMG Compare Memory Greater

The CMG instruction turns the Branch Control ON prior to performing the specified comparison. The contents of the Upper Accumulator are compared with the contents of the memory location, specified by the Data-address field of this instruction, through a mask in the Lower. If the word in memory is equal to or greater than the contents of the Upper in the bit positions where the Lower contains 1's, the Branch Control remains ON; otherwise, it is turned OFF. When this instruction is executed in Repeat Mode, the sector number following the last sector compared or the sector following that of the successful comparison is placed in the Next-address, sector portion, of the Index Register.

(22) TMI Transfer on Minus

The TMI instruction tests the sign of the Upper Accumulator. If it is negative, the Data-address field of this instruction defines the address of the next instruction to be executed; if it is positive, the Next-address field of this instruction is used to indicate the next instruction.

(23) TBC Transfer on Branch Control

The TBC instruction tests the Branch Control flip-flop. If it is ON, the Data-address field of this instruction defines the address of the next instruction to be executed, and the Branch Control is turned OFF. If the Branch Control is OFF when tested, this instruction has no effect, and the next instruction is that specified by the Next-address field.

(24) STU Store Upper

The STU instruction stores the contents of the Upper Accumulator into the memory location specified by the Data-address field of this instruction, leaving the Upper unaltered.

(25) STL Store Lower

The STL instruction stores the contents of the Lower Accumulator into the memory location specified by the Data-address field of this instruction, leaving the Lower unaltered.

(26) CLU Clear Upper

The CLU instruction stores the contents of the Upper Accumulator into the memory location specified by the Data-address field of this instruction, and then sets the Upper to zero.

(27) CLL — Clear Lower

The CLL instruction stores the contents of the Lower Accumulator into the memory location specified by the Data-address field of this instruction, and then sets the Lower to zero.

(28) ADU — Add to Upper

The ADU instruction adds the contents of the memory location specified by the Data-address field of this instruction to the contents of the Upper Accumulator, the sum being held in the Upper. Any overflow turns the Branch Control ON.

(29) ADL — Add to Lower

The ADL instruction adds the contents of the memory location specified by the Data-address field of this instruction to the contents of the Lower Accumulator, the sum being held in the Lower. Any overflow turns the Branch Control ON.

(30) SBU — Subtract from Upper

The SBU instruction subtracts the contents of the memory location specified by the Data-address field of this instruction from the contents of the Upper Accumulator, the remainder being held in the Upper. Any overflow turns the Branch Control ON.

(31) SBL — Subtract from Lower

The SBL instruction subtracts the contents of the memory location specified by the Data-address field of this instruction from the contents of the Lower Accumulator, the remainder being held in the Lower. Any overflow turns the Branch Control ON.

SUMMARY

RPC-4000 COMMANDS

HLT	00	HALT (TRACK 0)
SNS	00	SENSE
CXE	01	COMPARE X EQUAL
RAU	02	RESET, ADD UPPER
RAL	03	RESET, ADD LOWER
SAU	04	STORE ADDRESS FROM UPPER
MST	05	MASKED STORE LOWER
LDC	06	LOAD COUNT AND REPEAT
LDX	07	LOAD X
INP	08	INPUT 4 BIT (TRACK 0)
INP	08	INPUT 6 BIT (TRACK 64)
EXC	09	EXCHANGE
DVU	10	DIVIDE UPPER
DIV	11	DIVIDE
SRL	12	SHIFT RIGHT (TRACK 0)
SRL	12	SHIFT LEFT (TRACK 1)
SLC	13	SHIFT LEFT AND COUNT
MPY	14	MULTIPLY
MPT	15	MULTIPLY UPPER BY TEN (TRACK 0)
MPT	15	MULTIPLY LOWER BY TEN (TRACK 64)
PRD	16	PRINT DATA ADDRESS
PRU	17	PRINT FROM UPPER

Continued on next page

EXT	18	EXTRACT
MML	19	MASKED MERGE LOWER
CME	20	COMPARE MEMORY EQUAL
CMG	21	COMPARE MEMORY GREATER
TMI	22	TEST MINUS
TBC	23	TEST BRANCH CONTROL
STU	24	STORE UPPER
STL	25	STORE LOWER
CLU	26	CLEAR UPPER
CLL	27	CLEAR LOWER
ADU	28	ADD TO UPPER
ADL	29	ADD TO LOWER
SBU	30	SUBTRACT FROM UPPER
SBL	31	SUBTRACT FROM LOWER

APPENDIX B

ALPHANUMERIC CODES

The following list gives the tape codes and the computer's internal configurations of the typewriter keyboard.

NUMERIC	DEFINITION		BINARY	NUMERIC	DEFINITION		BINARY
00	Tape feed		000 000	32	g	G	100 000
01	Carriage return		000 001	33	h	H	100 001
02	Tab		000 010	34	i	I	100 010
03	Backspace		000 011	35	j	J	100 011
04			000 100	36	k	K	100 100
05	Upper Case		000 101	37	l	L	100 101
06	Lower Case		000 110	38	m	M	100 110
07	Line feed		000 111	39	n	N	100 111
08	*Stop Code		001 000	40	o	O	101 000
09			001 001	41	p	P	101 001
10			001 010	42	q	Q	101 010
11	End of Block		001 011	43	r	R	101 011
12			001 100	44	s	S	101 100
13	Photo-Reader EOM		001 101	45	t	T	101 101
14			001 110	46	u	U	101 110
15			001 111	47	v	V	101 111
16	0	)	010 000	48	w	W	110 000
17	1	°	010 001	49	x	X	110 001
18	2	"	010 010	50	y	Y	110 010
19	3	#	010 011	51	z	Z	110 011
20	4	Σ	010 100	52	,	$	110 100
21	5	Δ	010 101	53	=	:	110 101
22	6	@	010 110	54		;	110 110
23	7	&	010 111	55		%	110 111
24	8	'	011 000	56			111 000
25	9	(	011 001	57			111 001
26	a	A	011 010	58	—	?	111 010
27	b	B	011 011	59	-	_	111 011
28	c	C	011 100	60	.	.	111 100
29	d	D	011 101	61	Space		111 101
30	e	E	011 110	62	/		111 110
31	f	F	011 111	63	Code Delete		111 111

APPENDIX C

INPUT/OUTPUT SELECTION CODES

D TRACK	INPUT SELECTED	OUTPUT SELECTED
64	4500/4510 Reader	
65	4500/4510 Reader	4500/4510 Punch
66	4500/4510 Reader	4500/4510 Typewriter
67	4500/4510 Reader	4500/4510 Punch & Typewriter
68	4500/4510 Typewriter	
69	4500/4510 Typewriter	4500/4510 Punch
70	4500/4510 Typewriter	4500/4510 Typewriter
71	4500/4510 Typewriter	4500/4510 Punch & Typewriter
72	4410 Photo--fwd & Search	
73	4410 Photo--rev & Search	
74	4410 Photo--fwd	
75	4410 Photo--rev	
76-79	Available	
80	4600/4610 Reader	
81	4600/4610 Reader	4600/4610 Punch
82	4600/4610 Reader	4600/4610 Typewriter
83	4600/4610 Reader	4600/4610 Punch & Typewriter
84	4600/4610 Typewriter	
85	4600/4610 Typewriter	4600/4610 Punch
86	4600/4610 Typewriter	4600/4610 Typewriter
87	4600/4610 Typewriter	4600/4610 Punch & Typewriter
88-94	Available	
95	Master Reset--Reset all units	
96	Available	
97		4500/4510 Punch
98		4500/4510 Typewriter
99		4500/4510 Punch & Typewriter
100	Available	
101		4500/4510 Punch
102		4500/4510 Typewriter
103		4500/4510 Punch & Typewriter
104	Search Mode	
105	Search Mode	
106		4440 Punch
107-112	Available	
113		4600/4610 Punch
114		4600/4610 Typewriter
115		4600/4610 Punch & Typewriter
116	Available	
117		4600/4610 Punch
118		4600/4610 Typewriter
119		4600/4610 Punch & Typewriter
120-124	Available	
125	Copy Mode ON	
126	Copy Mode OFF	
127	Reset output units	

APPENDIX D

TABLE OF POWERS 2

2^N	N	2^{-N}
1	0	1. 0
2	1	0. 5
4	2	0. 25
8	3	0. 125
16	4	0. 062 5
32	5	0. 031 25
64	6	0. 015 625
128	7	0. 007 812 5
256	8	0. 003 906 25
512	9	0. 001 953 125
1 024	10	0. 000 976 562 5
2 048	11	0. 000 488 281 25
4 096	12	0. 000 244 140 625
8 192	13	0. 000 122 070 312 5
16 384	14	0. 000 061 035 156 25
32 768	15	0. 000 030 517 578 125
65 536	16	0. 000 015 258 789 062 5
131 072	17	0. 000 007 629 394 531 25
262 144	18	0. 000 003 814 697 265 625
524 288	19	0. 000 001 907 348 632 812 5
1 048 576	20	0. 000 000 953 674 316 406 25
2 097 152	21	0. 000 000 476 837 158 203 125
4 194 304	22	0. 000 000 238 418 579 101 562 5
8 388 608	23	0. 000 000 119 209 289 550 781 25
16 777 216	24	0. 000 000 059 604 644 775 390 625
33 554 432	25	0. 000 000 029 802 322 387 695 312 5
67 108 864	26	0. 000 000 014 901 161 193 847 656 25
134 217 728	27	0. 000 000 007 450 580 596 923 828 125
268 435 456	28	0. 000 000 003 725 290 298 461 914 062 5
536 870 912	29	0. 000 000 001 862 645 149 230 957 031 25
1 073 741 824	30	0. 000 000 000 931 322 574 615 478 515 625
2 147 483 648	31	0. 000 000 000 465 661 287 307 739 257 812 5
4 294 967 296	32	0. 000 000 000 232 830 643 653 869 628 906 25
8 589 934 592	33	0. 000 000 000 116 415 321 826 934 814 453 125
17 179 869 184	34	0. 000 000 000 058 207 660 913 467 407 226 562 5
34 359 738 368	35	0. 000 000 000 029 103 830 456 733 703 613 281 25
68 719 476 736	36	0. 000 000 000 014 551 915 228 366 851 806 640 625
137 438 953 472	37	0. 000 000 000 007 275 957 614 183 425 903 320 312 5
274 877 906 944	38	0. 000 000 000 003 637 978 807 091 712 951 660 156 25
549 755 813 888	39	0. 000 000 000 001 818 989 403 545 856 475 830 078 125
1 099 511 627 776	40	0. 000 000 000 000 909 494 701 772 928 237 915 039 062 5
2 199 023 255 552	41	0. 000 000 000 000 454 747 350 886 464 118 957 519 531 25
4 398 046 511 104	42	0. 000 000 000 000 227 373 675 443 232 059 478 759 765 625
8 796 093 022 208	43	0. 000 000 000 000 113 686 837 721 616 029 739 379 882 812 5
17 592 186 044 416	44	0. 000 000 000 000 056 843 418 860 808 014 869 689 941 406 25
35 184 372 088 832	45	0. 000 000 000 000 028 421 709 430 404 007 434 844 970 703 125
70 368 744 177 664	46	0. 000 000 000 000 014 210 854 715 202 003 717 422 485 351 562 5
140 737 488 355 328	47	0. 000 000 000 000 007 105 427 357 601 001 858 711 242 675 781 25
281 474 976 710 656	48	0. 000 000 000 000 003 552 713 678 800 500 929 355 621 337 890 625
562 942 953 421 312	49	0. 000 000 000 000 001 776 356 839 400 250 464 677 810 668 945 312 5
1 125 899 906 842 624	50	0. 000 000 000 000 000 888 178 419 700 125 232 338 905 334 472 656 25
2 251 799 813 685 248	51	0. 000 000 000 000 000 444 089 209 850 062 616 169 452 667 236 328 125
4 503 599 627 370 496	52	0. 000 000 000 000 000 222 044 604 925 031 308 084 726 333 618 164 062 5
9 007 199 254 740 992	53	0. 000 000 000 000 000 111 022 302 462 515 654 042 363 166 809 082 031 25
18 014 398 509 481 984	54	0. 000 000 000 000 000 055 511 151 231 257 827 021 181 583 404 541 015 625
36 028 797 018 963 968	55	0. 000 000 000 000 000 027 755 575 615 628 913 510 590 791 702 270 507 812 5
72 057 594 037 927 936	56	0. 000 000 000 000 000 013 877 787 807 814 456 755 295 395 851 135 253 906 25
144 115 188 075 855 872	57	0. 000 000 000 000 000 006 938 893 903 907 228 377 647 697 925 567 626 953 125
288 230 376 151 711 744	58	0. 000 000 000 000 000 003 469 446 951 953 614 188 823 848 962 783 813 476 562 5
576 460 752 303 423 488	59	0. 000 000 000 000 000 001 734 723 475 976 807 094 411 924 481 391 906 738 281 25
1 152 921 504 606 846 976	60	0. 000 000 000 000 000 000 867 361 737 988 403 547 205 962 240 695 953 369 140 625

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