### TABLE 1

**POWERS OF TWO**

<table>
<thead>
<tr>
<th>Positive Power (2^n)</th>
<th>(N) Power</th>
<th>Negative Power (2^{-n})</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>1.0</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>0.25</td>
</tr>
<tr>
<td>8</td>
<td>3</td>
<td>0.125</td>
</tr>
<tr>
<td>16</td>
<td>4</td>
<td>0.062 5</td>
</tr>
<tr>
<td>32</td>
<td>5</td>
<td>0.031 25</td>
</tr>
<tr>
<td>64</td>
<td>6</td>
<td>0.015 625</td>
</tr>
<tr>
<td>128</td>
<td>7</td>
<td>0.007 312 5</td>
</tr>
<tr>
<td>256</td>
<td>8</td>
<td>0.003 906 25</td>
</tr>
<tr>
<td>512</td>
<td>9</td>
<td>0.001 553 125</td>
</tr>
<tr>
<td>1024</td>
<td>10</td>
<td>0.000 976 562 5</td>
</tr>
<tr>
<td>2048</td>
<td>11</td>
<td>0.000 488 281 25</td>
</tr>
<tr>
<td>4096</td>
<td>12</td>
<td>0.000 244 140 625</td>
</tr>
<tr>
<td>8192</td>
<td>13</td>
<td>0.000 122 670 312 5</td>
</tr>
<tr>
<td>16384</td>
<td>14</td>
<td>0.000 641 085 156 25</td>
</tr>
<tr>
<td>32768</td>
<td>15</td>
<td>0.000 320 517 578 125</td>
</tr>
<tr>
<td>65536</td>
<td>16</td>
<td>0.000 161 255 789 062 5</td>
</tr>
<tr>
<td>131072</td>
<td>17</td>
<td>0.000 807 629 394 031 25</td>
</tr>
<tr>
<td>262144</td>
<td>18</td>
<td>0.000 403 314 197 266 625</td>
</tr>
<tr>
<td>524288</td>
<td>19</td>
<td>0.000 201 907 948 632 125</td>
</tr>
<tr>
<td>1048576</td>
<td>20</td>
<td>0.000 100 453 674 316 406 25</td>
</tr>
<tr>
<td>2097152</td>
<td>21</td>
<td>0.000 501 907 837 158 200 125</td>
</tr>
<tr>
<td>4194304</td>
<td>22</td>
<td>0.000 251 294 418 679 101 562 5</td>
</tr>
<tr>
<td>8388608</td>
<td>23</td>
<td>0.000 125 217 513 439 250 25</td>
</tr>
<tr>
<td>16777216</td>
<td>24</td>
<td>0.000 62 108 864 177 590 625</td>
</tr>
<tr>
<td>33554432</td>
<td>25</td>
<td>0.000 31 541 432 522 997 695 312 5</td>
</tr>
<tr>
<td>67108864</td>
<td>26</td>
<td>0.000 16 253 101 901 151 195 947 656 25</td>
</tr>
<tr>
<td>134217728</td>
<td>27</td>
<td>0.000 8 102 450 450 590 966 923 828 125</td>
</tr>
<tr>
<td>268435456</td>
<td>28</td>
<td>0.000 4 51 226 226 290 998 461 914 062 5</td>
</tr>
<tr>
<td>536870912</td>
<td>29</td>
<td>0.000 2 25 113 113 145 454 149 238 857 031 25</td>
</tr>
<tr>
<td>1073741824</td>
<td>30</td>
<td>0.000 1 126 532 532 574 615 478 515 625</td>
</tr>
<tr>
<td>2147483648</td>
<td>31</td>
<td>0.000 0 63 266 266 287 307 739 257 812 5</td>
</tr>
</tbody>
</table>

---

**LGP-30**  
**THE ROYAL PRECISION**  
**DIGITAL**  
**COMPUTER**
This manual describes the operation of the LGP-30 Digital Computer. It is intended for the reader who has some knowledge of computer techniques but wishes to know just how the LGP-30 operates.

The success of the desk-size digital computer is attributed to its wide range of applications. It makes it possible for small business operation to use automatic data processing techniques economically; to operate as larger computing installations with less “waiting time” and consequently quicker evaluation. It can be used in conjunction with large scale installations or in place of large scale installations where the latter are not economically justified.

When used with large scale computers, it serves to eliminate the bottleneck by decentralizing operation. The LGP-30 makes it possible to quickly evaluate trial ideas associated with more complex engineering designs, before putting the over-all problem on the larger computer.

When used alone, it permits the smaller company to obtain realistic answers to problems quickly and reduces the lengthy manual calculations from man-weeks to a few man-hours.

For the first time small business can justify the cost of the computer since it may be operated with no additional electrical service, ventilation, or cooling and requires a minimum of floor space.

HEXDECIMAL EQUIVALENTS OF TRACK AND SECTOR LOCATIONS:

<table>
<thead>
<tr>
<th>Decimal</th>
<th>Hexadecimal</th>
<th>Instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>z 0000</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>b 0001</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>y 0010</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>r 0011</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>i 0100</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>d 0101</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>n 0110</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>m 0111</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>p 1000</td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td>e 1001</td>
</tr>
<tr>
<td>10</td>
<td>f</td>
<td>u 1010</td>
</tr>
<tr>
<td>11</td>
<td>g</td>
<td>t 1011</td>
</tr>
<tr>
<td>12</td>
<td>h</td>
<td>h 1100</td>
</tr>
<tr>
<td>13</td>
<td>k</td>
<td>c 1101</td>
</tr>
<tr>
<td>14</td>
<td>l</td>
<td>a 1110</td>
</tr>
<tr>
<td>15</td>
<td>m</td>
<td>s 1111</td>
</tr>
</tbody>
</table>

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APPENDIX B

SCALING

The operation of scaling is performed by the programmer to eliminate overflow or underflow in precision computations.

Before programming a problem on a computer, a technique for scaling the data must be employed. Various techniques may be used depending on the number system. In the decimal system 10 is the basic number. However, the LCP-30 is designed about the binary system, using a base of 2. In scaling data, the binary point, "a", represents the number of places from the extreme left of the data word, where the radix point is located. (The radix point indicates the separation between the integral and fractional portions of a data word.) Given a data word, its "a" is determined from the table of Powers of Two, Table I. For example, number 256 must be held at least a "a" of 8. In representing a word of 30 bits, excluding the sign bit to the left. See Figure A below, "q" is considered to be at the extreme left.

Example:

Figure A

The rules for scaling in arithmetic operations of the LCP-30 are the same as those in other computer devices. To add or subtract two numbers, they must be held at the same "a". (In a decimal calculator, this is equivalent to lining up the decimal points.) The result of such addition or subtraction is a number at the same "a".

In multiplication, the "a" of the two numbers need not be the same. The product of two such numbers is a number at q = q1 - q2, where q2 is the binary point of the multiplier and q1 is the binary point of the multiplicand. In division, the quotient of two numbers has a q = q1 - q2 where q1 is the binary point of the dividend, and q2 is the binary point of the divisor. In multiplication, q's are added, in division, the q's are subtracted.

Since the purpose of scaling is to shift data into such favorable locations to eliminate loss of precision, it is important to determine how shifts are made without altering the value of the data. Any number multiplied by the integer 1, results in the same number. But any number multiplied by the integer 1 at q = n shifts the number in the accumulator by n places to the right. This will place the number in the required location. For example, to add 5 at q = 10 to 10 at q = 12, the 5 at q = 10 must be multiplied by 1 at q = 2 to obtain 5 at q = 12, or shift 6 to location q = 12 in accumulator. Then, we can add the result in the accumulator. Thus, we shift the contents of the accumulator to the right so that the radix point is located at the required q = 12.

It is sometimes required to shift left to scale a number to q smaller than that given. In this case, divide the number to be scaled by the integer 1 at q = n, and thus shift it in the accumulator by n places to the left. For example, 7 at q = 4, divided by 1 at q = 2 equals 7 at q = 2. However, it must be noted that 7 cannot be located at q = 2 since the last remaining digit to the left will overflow and stop the computer. A mental check is necessary to determine the "a" of the quotient in the accumulator before dividing. In this case, it is possible only to divide 7 at q = 4, by 1 at q = 1 to obtain 7 at q = 3, which will "fit" into the accumulator.

Another method of shifting left utilizes the "N" multiply instruction. This instruction retains the least significant half of the product in the accumulator. To shift a number left n places, "N" multiply the number by 1 at q = (31-n). For example, to shift 7 at q = 6, we want 7 at q = 4, therefore, shift left by 2 places. To do this, "N" multiply 7 at q = 6, by 1 at q = (31-2) to obtain 7 at q = 8. This is equivalent to 7 at q = 4 as can be illustrated below.

From the following illustration, we note that the 31st bit of the total product is in the sign bit of the accumulator.

Figure B

track containing 64 sectors. Punched paper tape is the permanent file of information for the LCP-30. The interface patterns of sectors on each track of the drum makes for shorter access time. The drum will retain its memory when power has been turned off.

Input-Output System

The primary input-output device to the LCP-30 is the Tape Typewriter. It has a standard typewriter key and a switch, as shown in Figure 2, and a paper tape reader and punch which are integral parts of the input-output unit.

Input information to the LCP-30 is transmitted from the Tape Typewriter or from the paper tape reader on the typewriter.

Output information from the LCP-30 is recorded on the typewriter or the typewriter and paper tape punch simultaneously. Maximum typewriter speed for input and output is 10 characters per second. Higher speed input and output devices are available, such as a photographic reader which reads input at 200 characters per second and an output device which punches 20 characters per second.

One of the primary considerations in designing the LCP-30 was to minimize the number of components, thus increasing its reliability and limiting its size and cost. The computer is internally binary. Many components of the LCP-30 are used on a time-sharing basis. Input-Output is normally done with the LCP-30 doing the binary computation and input and output time.

Programs are usually punched on a tape by means of the Tape Typewriter and then read into the computer. However, the LCP-30 may be stopped at any time, to enter information manually from the Tape Typewriter.

Word Structure

The basic unit of information is defined as a word. The LCP-30 word contains 30 binary digits plus a sign bit and spacer bit. The 30 binary bits and sign position may be recorded as "0" or "1" on the magnetic drum. The spacer bit is used to separate adjacent words on the drum and is always recorded as "0." As many as 9 decimal digits may be represented in one data word. A word may be used to store data or an instruction as shown above. Negative numbers are represented as two's complement.

Addressing Systems

The 4096 words of the LCP-30 are addressed in terms of tracks, sectors, and words. This convention has also been adopted to facilitate optimum programming which will be described later. Other addressing methods could be adopted and are perfectly feasible, such as addressing memory 0000 through 4095; however, in this manual, manual addressing is identified in terms of track and sector. Each track is addressed 00 through 63 and each sector is addressed 00 through 63. There is no break in continuity of addresses from one sector to the next or from one track to the next; 1723 represents the word whose address is track 17, sector 23. Consecutive addresses are then labeled 0000, 0001, 0002, ... 0063, 0100,
Computing Unit

Internal calculation is accomplished by directing information to the computer section from memory, processing it, and directing it back to memory. The computing section consists of three working registers: the counter register (C), the instruction register (I), and the accumulator register (A). The three registers are located on three separate recirculating tracks on the LSP-30 drum, in addition to the 64 tracks of memory. The accumulator, A, is the working register. It contains the results of addition, subtraction, multiplication, etc., as these operations occur. It also contains one of the operands, prior to execution of an arithmetic instruction; the second operand is in memory at the word location specified by the address part of the instruction.

The instruction register, I, contains the instruction being executed. Both the operation and the address or the instructions are located in this register. Words are transmitted from memory to this register. Generally, these words are instructions of a program stored in memory. The instruction register may be interrogated to determine the operation to be performed.

The counter register, C, contains the location of the next instruction to be executed, i.e., if the counter register reads 242, the next instruction to be executed is stored at 2418 or track 24, sector 256. This register contains only the address part of a word. The address part of the instruction register may be transferred to the counter register. The address part of the counter register may be transferred into a plus 1 address to memory by use of the B command. During the execution of every operation, I is added to the counter register automatically, so it will be ready to search for the next instruction, after it finishes the one being executed.

The flow of information between the memory and the memory is shown in Figure 4. The solid lines indicate the flow of information from the memory to the instruction register, the dotted lines indicate the flow from the instruction register to the memory.

Oscilloscope

The scope furnishes the operator with a visual representation of the three registers as a means of checking or debugging his program. Three windows, one below
Timing on Output

When the Tape Typewriter is used as the Output device of the LGP-30 it is a very pleasant experience to see the Tape Typewriter at top speed, approximately ten characters per second. This means that there are approximately 5½ drum revolutions of useful calculation between printing each character on the Tape Typewriter. This time is normally spent converting the next character to be printed on the Tape Typewriter. This is especially true if a binary to decimal conversion is required.

After the "P" instruction supplies the typewriter unit with the required information to execute a print or a control function, control is transferred to the instruction following the "P" instruction. The programmer may use any instruction except another "P".

The other, display in binary the Counter Register, C, the Instruction Register, R, and the Accumulator Register, A, from top to bottom, as shown in Fig. 6.

![Figure 6: Oscilloscope showing three registers](image)

The Counter Register, C, contains the address, or location (track and sector) of the next instruction to be executed. The Instruction Register, R, contains the last instruction executed and during multiplication or division, holds the second operand. The Accumulator Register, A, contains the results of the execution of the last instruction.

**CONTROL BUTTONS**

**Power On And Off Buttons**

The "Power On" and "Power Off" switches are the main power switches.

It is good practice to be sure that the "Manual Input" button is depressed before depressing the "Power Off" switch. If it is not depressed when the computer is turned on, the computer will remain in "Stand By" state. If it is not depressed when the power is turned off, some of memory may be erased.

**Stand By**

When the "Stand By" button is depressed, after the "Power On" button is depressed, a red light behind it lights up. This turns off the high voltage.

**Operate**

Depress this button to prepare the computer for operation.

**Stand By To Operate**

This is an indicator, not a button and cannot be depressed. It indicates that the computer is in one phase of its warm-up cycle.

**Mode Buttons**

The following buttons select one of the three modes of operation but do not cause the machine to operate.

- **Manual Input**—This is not the same as the Manual Input button on the Tape Typewriter. Depressing this button connects the computer to the keyboard of the Tape Typewriter. All data typed on the keyboard appears in the accumulator register.

- **If the "Start" button is depressed, the contents of the word whose address is in the counter register is displayed in the instruction register and the counter register is increased by one. The accumulator register is unchanged since no instruction is executed. This enables the operator to "step through" a section of memory and examine the contents of each word as it appears in the Instruction Register.

- **One Operation**—Depressing this button prepares the computer for executing one instruction at a time and halting. Depressing the "start" button executes only the instruction whose address is in the counter register and stops the computer. The counter register is then increased by one, unless a transfer instruction, T or U is executed. In this case, the counter register contains the address of transfer instruction, the instruction register contains the instruction just executed (except for multiply and divide instructions).

- **Normal**—Depressing this button sets the computing mode to execute the stored program automatically.

**Operation Buttons**

The Start, Clear Counter, Fill Instruction, and Execute Instruction buttons interlock with the Mode selection buttons. To simplify computer operation, a light under each button indicates when that button is operable; the lights are not lit when buttons are inoperative. For example, the execute instruction light is lit only when the One Operation button is depressed, depressing this button in any other mode does not activate the computer.

- **Start**—This button must be depressed to execute stored instructions. It is used with One Operation and Manual Input as explained previously.

- **Clear Counter**—Depresses this button to reset the counter register to zero to restart a program. This switch is used only in the Manual Input and One Operation modes.

- **Fill Instruction**—Depresses this button to transfer the contents of the accumulator to the instruction register after it has been typed into the accumulator from the keyboard. This button is used only in the Manual Input and One Operation modes of operation.

- **Execute Instruction**—Depresses this button to execute the instruction in the instruction register. This button is used only in the One Operation mode.

- **Stop**—The "Stop" light will remain red to indicate when computer has stopped.

- **Compute**—The "Compute" light panel will light green when computer is computing.

The bottom row of buttons on the console panel displays:

- **Break Point Switches**—The 4 breakpoint switches BP-32, BP-16, BP-8, and BP-4 are used with the track portion of the address of a stop order. When the breakpoint switch is depressed, the computer ignores the "stop" instruction in the program and executes the following instruction. One depression latches the breakpoint in the down position, a second depression releases the latch. Lights under the breakpoint buttons are lit when switch is down, in latched position. The Z command will be explained later.

- **6-bit Input**—This button, when depressed during Input, permits all six channel bits of each typewriter character to enter the accumulator—instead of the usual 4 channels when button is up.

- **Transfer Control**—This button provides the operator another means of manually controlling the machine. It is used with a Test instruction (T) to
Timing and Optimizing

Optimum programming is the technique by which data and instructions are located on the drum of the computer to minimize non-productive searching time. Before describing the optimum technique used in the LGP-30, it should be emphasized that the savings in machine time should be compared with the cost of the programmer's time before deciding to optimize a program.

LGP-30 Design

An interface pattern of sectors around the drum has been provided on the LGP-30. The track portion of all locations and addresses has no effect on optimizing; only the sector portion determines whether an order is optimum or non-optimum. Fig. 9 shows a cross-section of one track on the drum, divided into 64 sectors or words. Since a word time is the time it takes for one word or sector to pass under the read head and the drum revolves at 4000 revolutions per minute, one word time is 0.23 milliseconds.

Table I shows the complete sequence of sectors around the drum for one track. Consider the following program:

<table>
<thead>
<tr>
<th>Location</th>
<th>Op.</th>
<th>Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>B</td>
<td>1945</td>
</tr>
<tr>
<td>0002</td>
<td>C</td>
<td>1943</td>
</tr>
</tbody>
</table>

The instructions, B 1945, A 2181, C 1943, must be brought into the instruction register before they can be executed and this can only happen when locations 0000 0001 0002 respectively are under the read head. Assume the read head is over sector 00 and in placing the instruction B 1945 in the instruction register. If this instruction, B 1945, can be executed before the drum turns around to sector 01 it will be an optimum instruction. Figure 9 shows sector 43 is between sector 00 and sector 01 and is within the portion which is optimum for sector 00. The same logic applies to the next instruction A 2181 at location 0001. Sector 01 lies between sector 01 and sector 02 and lies within the portion that is optimum for sector 00. The same logic applies to the remaining instructions are optimum. The next instruction C 1943 at location 0002 will not be optimum because sector 43 does not lie between sector 02 and sector 03.

Table I

<table>
<thead>
<tr>
<th>Sequence of sectors around the Drum for one Track</th>
</tr>
</thead>
<tbody>
<tr>
<td>00 01 02 03 04 05 06 07</td>
</tr>
<tr>
<td>00 01 02 03 04 05 06 07</td>
</tr>
</tbody>
</table>

Table II shows the 16 commands the LGP-30 performs and the number of word times after the location of the instruction, the address of the operand must be in order for the instruction to be optimum. For example Table II shows that for a divide instruction, if the address of the operand is in 2-8 word times after the location, the instruction will be optimum. If the divide instruction were placed at sector 51, Table I will give the sector addresses of the 2 through 5 word times following sector 51.

Table II

<table>
<thead>
<tr>
<th>Order</th>
<th>No. of Word Times</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bring, Add, Subtract</td>
<td>2 to 7</td>
</tr>
<tr>
<td>Hold, Clear, Store</td>
<td>2 to 8</td>
</tr>
<tr>
<td>Return Address, Extract</td>
<td>2 to 6</td>
</tr>
<tr>
<td>Print, Input, Stop</td>
<td>2 to 5</td>
</tr>
<tr>
<td>N multiply</td>
<td>4 or more</td>
</tr>
<tr>
<td>M multiply</td>
<td>4 or more</td>
</tr>
<tr>
<td>And, divide</td>
<td>4 or more</td>
</tr>
</tbody>
</table>

Timing on Input

The only timing problems that occur in Input are with the Tape Writer. If a P 0000 instruction is initiated, an instant 10000 instruction must follow before any information reaches the read portion of the Tape Writer. In some instances, however, it may be desirable to have the LGP-30 send a P 0000 instruction to start the tape in motion on the Tape Writer. The Tape Writer could then type a title or heading while the LGP-30 continued to compute.
Photoelectric Reader is not available until the LGP-30 power is turned on. The power for the Photoelectric Reader should not be turned on until the LGP-30 is inoperable status.

Reader Stop
This button is used to stop the transport of paper tape through the Photoelectric Reader. There is no manual "start read" switch on the Photoelectric Reader.

Punch Power
This switch turns the power on in the Paper Tape Punch. The Punch may be operated without the reader power switch on. This switch should not be turned on until the LGP-30 is inoperable status.

Tape Feed Switch
This switch feeds the tape to the punch unit. Only the sprocket holes are punched.

Input
This switch selects the Tape Typewriter or the Photoelectric Reader as the Input device for the LGP-30.

Output
This switch selects the Tape Typewriter or the Photoelectric Reader as the Output device for the LGP-30.

Operation of Photoelectric Reader
To operate reader:
1. Turn Computer on and make ready to operate by warming up.
2. Depress Reader Power switch.
3. Place tape face down in Reader starting with 6 in. leader.
4. Locate tape inside guide pins under reader head and snap clamps on tape.
5. Set Input switch to Reader.

The Computer is now ready to accept information from the Photoelectric Reader.

Operation of Computer and Reader
A P0000 instruction is ignored by the Reader, when the Computer is connected, but a F0000 instruction activates Input when the Tape Typewriter is used.

An F0000 instruction starts the Reader, reading all characters into the Computer. A Conditional Step code (V) stops the Reader.

Only those characters read into the Computer by the Tape Typewriter may be read in by the Reader. A stop code generates a "Start Compute" signal to the Computer and stops the tape.

Operation of Tape Punch
To operate the Tape Punch:
1. Turn Computer "on" and make it ready to operate by warming up.
2. Depress "Punch Power" switch once. (It lights up.)
3. Set Output switch to "Punch".
4. Depress "Tape Feed" switch and hold depressed long enough to obtain at least a 3 inch leader.
5. Tape starts punching.
6. Direct long tapes into chute, through slot in Punch Reader console to bin inside cabinet.

Operation of Punch with the Computer
A P0000 code starts the Tape Typewriter. Any one of the other 63 codes (01 through 63) are possible.

A P000 instruction from the computer punches the character represented in binary in the track portion of the instruction.

At the end of each punching cycle, a "Start Compute" signal is generated similar to the punching operation of the Tape Typewriter.

Since the punch operates approximately twice as fast as the Tape Typewriter, there is consequently less time for calculation between punch cycles. The timing using the punch will be further discussed in timing and optimizing.

The description of the Photoelectric Reader and the Tape Punch only describes the difference between programming with these units and with the Tape Typewriter. For more information, see Programming Input and Output of the Tape Typewriter.

INPUT-OUTPUT OPERATIONS
Print
P n
Print a Tape Typewriter symbol. The n address does not refer to one of the 4096 addresses, instead the track portion is a code to print or punch a character on the Tape Typewriter. The sector part of the address is irrelevant with respect to the function of the operation, but it does affect the timing and will be further explained in timing and optimizing. A further discussion of the print P order will be found in the Input-Output components section.

Input
I n
This command enters information from the Tape Typewriter into the accumulator. An Input order is always preceded by a print order, but not necessarily immediately. The n address does not refer to one of the 4096 addresses and will normally be zero. The sector part of the address is irrelevant with respect to the function of the command, but it does affect the timing of the instruction. The track portion of the address indicates the first four bits to enter the accumulator. If the 6-bit switch is depressed, all six bits enter the accumulator.
Input-Output Components for the LQP 30

The Tape Typewriter, Photoelectric Paper Tape Reader, and high-speed Paper Tape Punch are the Input-Output devices for the LQP 30. All of these are controlled directly by the program stored in the computer.

Tape Typewriter

The tape typewriter is a typewriter with the paper tape reader and paper tape punch attached as integral parts of the unit. As shown in Fig. 7, it may be operated independently of the computer as a reading and punching device. Information is fed to the computer via the typewriter keyboard or via punched tape in the paper tape reader, depending on the typewriter used.

Information passing through the paper tape reader or paper tape punch will also create a typewritten copy. These units may not be operated independently of the typewriter.

Typewriter Controls Switches, Lights, and Manual Controls

The tape typewriter has a standard typewriter keyboard, as shown in Fig. 8, modified to use the LQP 30 codes shown in Appendix A. These keys that represent the commands are a different color from those on the rest of the keyboard. One extra code key, Conditional Stop, is added to the typewriter keyboard.

- **Conditional Stop Code (1)**
  - This key establishes a code in paper tape. When this code is read, it has two functions:
    1. stop the paper tape reader
    2. send the stop code to the computer
- **Punch On—Punch Off Switch**
  - This switch, in the lower right hand corner of the typewriter, adjacent to the keyboard, turns the power to the typewriter on or off. It is independent from the LQP 30 power switch and may be turned on when punching tape or printing typewritten copy.

Connect Switch

This switch allows start signals to pass from the tape typewriter. If the switch is in the "On" position, the "start" signal, originating from the Start button on the tape typewriter or from reading a conditional stop code on the paper tape, will pass to the LQP 30. If the switch is "Off," all start signals originating from the tape typewriter are blocked.

- **Start Compute**
  - When depressed, sends a start signal to the LQP 30, to start computing. It duplicates the function of the "Start" switch on the keyboard. It is independent from the LQP 30 power switch and may be turned on when punching tape or printing typewritten copy.

- **Manual Input**
  - No connection with the Manual Input on the computer.

The Manual Input on the tape typewriter determines whether information from the tape typewriter to the computer is transmitted from the keyboard or from the paper tape reader. If the switch is down, the information is received from the keyboard. If the switch is up, the information is received from the paper tape reader.

- **Code Delete**
  - This lever is operative only when the "Punch On" switch is depressed. It is used to delete an error punch in the paper tape by punching holes in the 4 channels 1 through 6 after tape has been rolled back to the error position. Then the correct code may be punched.

- **Tape Feed**
  - This lever regulates the amount of paper feed to the paper tape. It functions from the sprout feed holes only. It is operative only when the "Punch On" switch is depressed. The "Tape Feed lever" springs upward when released. The "Punch On" lever is used to obtain a letter at the beginning and a trailer at the end of the tape.

Punch On Switch

The "Punch On" Switch turns the Paper Punch "on" so that any characters being typed from the keyboard or read from the Paper Tape Reader, will be reproduced on the Paper Tape.

- **Stop Read**
  - Depressing this lever will stop the Paper Tape Reader and the tape typewriter from reading any more characters. It also extinguishes the Manual Input light on the tape typewriter.

- **Start Read**
  - Depressing this lever will start the Paper Tape Reader, reading from the keyboard. When a "Start Input" code appears on the Paper Tape or when the Stop Read lever is depressed, the reading is stopped.

- **Conditional Stop (not the same as Conditional Stop Code (1) key)**
  - This lever (on the upper frame of the typewriter), when depressed, will cause the Paper Tape Reader to ignore a Conditional Stop Code (1).

- **Gauges and Indicators**
  - Guides and indicators on both the Paper Tape Reader and the Paper Tape Punch feed the paper tape to the Tape Typewriter. If the tape breaks, the interlock is tripped and the tape typewriter automatically stops.

- **Tape Carriage Returns**
  - Controls for manually setting tabs and carriage returns are located on the rear of the carriage.

Operation of the Tape Typewriter

Output information is transmitted from the computer to the tape typewriter, and P Punch instruction has a specific binary code for the track portion of the address. The code used to activate the characters on the tape typewriter are the same type as used in the computer. For example, if the instruction "P 1300" is given, the Tape Typewriter types the letter "R." Track 13, in binary, is written 0010110, the code for the letter "R." To print any of the alpha-numeric characters or control commands, the same techniques are used. When there is a possibility of the LQP 30 sending 64 distinct codes to the tape typewriter, the tape typewriter is limited to 128 different code combinations. If any of the remaining 12 codes are given, the typewriter will ignore them.

- **Manual Input Switch**
  - When the 6-bit stop code (1) is read on the tape, a stop signal is given to the computer. The computer then operates on the next instruction.

- **From the Keyboard**
  - When information to the computer is transmitted via Paper Punch, the "Start Compute" lever is depressed to supply the computer with the start signal. The "Start Compute" lever is depressed by the user; it is not controlled by any signal from the tape typewriter. This lever is independent from the LQP 30 power switch and may be turned on when punching tape or printing typewritten copy.

Output

When the character is punched on paper tape the channels on the tape are numbered.

When the character punched on the tape are in channels 1, 2, 3, 4, 5, from left to right, the computer enters characters into the accumulator in the order of 1, 2, 3, 4, 5.

If the bit 6 input switch is not depressed, only channels 1 through 4 on the tape are transferred to positions 38 through 31 in the right hand end of the accumulator. If the bit 6 input switch is depressed, all 6 channels of each character code are filled, 6 bits at a time, into positions 36 through 31 of the accumulator. The accumulator is shifted 4 or 6 positions before each character is entered.

- **Punch On Switch**
  - When a conditional stop code (1) on the tape, a stop signal is given to the computer. The computer then operates on the next instruction.

When the character is punched on the tape, the character is entered into the accumulator. If the character is less than 128, the accumulator is shifted 4 or 6 positions before each character is entered.

When a conditional stop code (1) is read on the tape, a stop signal is given to the computer. The computer then operates on the next instruction.

2. From the Keyboard

When information to the computer is transmitted via Paper Punch, the "Start Compute" lever is depressed to supply the computer with the start signal. The "Start Compute" lever is depressed by the user; it is not controlled by any signal from the tape typewriter. This lever is independent from the LQP 30 power switch and may be turned on when punching tape or printing typewritten copy.

PHOTOELECTRIC READER AND PAPER TAPe PUNCH

A high-speed Photoelectric Reader and high-speed Paper Tape Punch may be attached to the LQP 30 as an accessory Input-Output equipment. The Photoelectric Reader as shown in Fig. 8 is capable of reading 200 characters per second. The Paper Tape Punch operates at a speed of 20 characters per second. The combination of Reader and Punch as a unit is identified as Model No. 542, the Reader alone as Model No. 541. Using the Photoelectric Reader and Paper Tape Punch, there is no typewritten copy as a by-product of the Input or Output.

Manual Controls

Switches are operated, a light behind them lights up, as shown in Fig. 8.

- **Reader Power Switch**
  - This switch on the console of the Photoelectric Reader turns the power on. The power required to operate the...
The Tape Typewriter is a typewriter with the Paper Tape Reader and Paper Tape Punch attached as integral parts of the unit, see Fig. 7. It may be operated independently of the computer as a reading and punching device. Information is fed to the computer via the typewriter keyboard or via punched tape in the Paper Tape Reader attached to the Tape Typewriter.

Information passing through the Paper Tape Reader or Paper Tape Punch will also create a typewritten copy. These units may not be operated independently of the typewriter.

Typewriter Controls Switches, Lights and Manual Controls

The Tape Typewriter has a standard typewriter keyboard, see Fig. 2, modified to use the LCP-30 codes shown in Appendix A. The keys that represent the commands are a different color from those on the rest of the keyboard. One extra code key, Conditional Stop, is added to the typewriter keyboard.

- **Conditional Stop Code (1)**
  
  This key has no code in paper tape. When this code is read, it has two functions:
  1. To stop the paper tape reader and puncher by punching the "OFF" code into the computer.

- **Punch On—Punch Off Switch**

  This switch, in the lower right hand corner of the Tape Typewriter, adjacent to the keyboard, turns the power to the typewriter "on" or "off." It is independent of the LCP-30 computer power switch and must be turned on when punching tape or printing typewritten copy.

- **Connect Switch**

  This switch allows start signals to pass from the Tape Typewriter. If the switch is in the "On" position, the "start" signal, originating from the Start button on the Tape Typewriter or from reading a conditional stop on tape, will pass to the LCP-30. If the switch is "Off," all start signals originating from the Tape Typewriter are blocked.

- **Start Compute**

  The "Start Compute" lever on the Tape Typewriter, when depressed, sends a start signal to the LCP-30, to start computing. It duplicates the function of the "Start" switch on the typewriter, and indicates the reading of the "start" function of a Conditional Stop code (1) on tape. It also turns out the manual input light on the Tape Typewriter.

- **Manual Input (no connection with the Manual Input on Computer Console)**

  The Manual Input lever on the Tape Typewriter determines whether information from the Tape Typewriter to the Computer is transmitted from the keyboard or from the Tape Tape Reader. If the switch is down, the information is received from the keyboard. If the switch is up, the information is received from the Paper Tape Reader.

  - **Code Delete**
    This lever is operative only when the "Punch On" switch is depressed. It is used to delete an error punch in the paper tape by punching the "punch" code into the tape in a 4-6 punch position after the tape has been pulled back to the error position. Then the correct code may be punched in.

  - **Tape Feed**
    The Tape Feed lever, when depressed, feeds tape into the Tape Punch. It punches the spurred feed holes only. It is operative only when the "Punch On" switch has been depressed previously. The Tape Feed lever springs up into place, when released. This lever is used to obtain a leader at the beginning and a trailer at the end of the tape.

- **Punch**

  The "Punch On" Switch turns the Paper Tape Punch "on" so that any characters being typed from the keyboard or read from the Paper Tape Reader, will be reproduced on the Paper Tape.

- **Stop Read**

  Depressing this lever will stop the Paper Tape Reader and the Tape Typewriter from reading any more characters. It also extinguishes the Manual Input light on the Tape Typewriter.

- **Start Read**

  Depressing this lever will start the Paper Tape Reader, reading from the "stop" instruction. When in "start" condition, Stop code appears on the Paper Tape or when the Stop Read lever is depressed, the reading is stopped.

  - **Conditional Stop (not the same as Conditional Stop Code (1) key)**

  This lever (on the upper frame of the typewriter), when depressed, will cause the Paper Tape Reader to ignore a Conditional Stop Code (1).

  - **Guides and Interlocks**

    Guides and interlocks on both the Paper Tape Reader and the Paper Tape Punch feed the paper tape to the Tape Typewriter. If the tape breaks, the interlock is tripped and the Tape Typewriter automatically stops.

  - **Tape and Carriage Returns**

    Printed on the typewriter, these are used for manually setting tabs and carriage returns are located on the rear of the carriage.

### Operation of the Tape Typewriter

#### Output

Output information is transmitted from the Computer to the Tape Typewriter by the "P" instruction with a specific binary code for the track portion of the address. The code used to activate the characters on the Tape Typewriter are given in Table 1, Appendix A.

- **For example, if the instruction "P 1380" is given, the Tape Typewriter types the letter "R." Track 13, in binary, is written 01110, for the letter "R."**

To print any of the alpha-numeric characters or controls from 1 to 4, the "Q" instruction is used. While there is a possibility of the LCP-30 sending 64 direct codes to the Tape Typewriter, the Tape Typewriter is limited in its description code codes, as in Table 1. If any of the remaining 13 codes are given, the Tape Typewriter will ignore them.

After the print command, P, is given, the LCP-30 does not stop but may continue computing.

The Tape Typewriter can accept only 10 characters per second. If two print commands are given in succession, the second one will not be executed because the Tape Typewriter has not completed executing the first.

### Guide Select

Two solutions are suggested:

1. Expand the computing time between the two print orders so that one order has finished its print cycle before the second order is given. The minimum time between print instructions should be 0.1 second (400 print revolutions). This will be discussed further under Timing and Optimizing.

2. The Tape Typewriter always sends a start signal to the computer after it finishes printing a character. Place a Stop instruction after each Print Instruction. This stops the computer after the character has been printed, and prohibits computing between print instructions. A start signal from the Tape Typewriter is required again.

Many output programs use the combination of the two suggestions executing instructions and following them by a "Stop." However, this may not be taken as an example since it is not to execute too many instructions before a stop order. If this occurs, the Tape Typewriter sends a "start" signal before the "stop" instruction is given. Then, when the computer stops there is no start signal transmitted to get it started again.

### Input

Information is transmitted to the Computer from the Tape Reader by methods, either by reading the information from punched paper tape by means of the reader unit, or by accepting information directly from the keyboard.

- **From the Keyboard**

  When information to the Computer is transmitted via paper tape, the computer is started as supplied to the computer by depressing the "Start Compute" lever on the Tape Typewriter, or the computer console.

### Photoclectric Reader and Paper Tape Punch

A high-speed Photoclectric Reader and high speed Paper Tape Punch may be attached to the LCP-30 as an auxiliary paper output device. The Photoclectric Reader shown in Fig. 6 is capable of reading 200 characters per second. The Paper Tape Punch operates at a speed of 20 characters per second. The combination of Reader and Punch as a unit is identified as Model No. 543, the Reader alone as Model No. 541. Using the Photoclectric Reader and Paper Tape Punch, there is no typewritten copy as a by-product of the Input or Output.

### Manual Controls

The switches are operated, a light behind them lights up, see Fig. 8.

- **Reader Power Switch**

  This switch on the console of the Photoclectric Reader turns the power on. The power required to operate the...
Output
This switch selects the Tape Typewriter or the Photoelectric Reader as the Output device for the LGP-30.

Operation of Photoelectric Reader
To operate reader:
1. Turn Computer on and make ready to operate by warming up.
2. Depress Reader Power switch.  
3. Place tape face down in Reader starting with 6 in. leader.
4. Locate tape inside guide pins under reader head and snap clamps on tape.
5. Set Input switch to Reader.

The Computer is now ready to accept information from the Photoelectric Reader.

Operation of Computer and Reader
A P0000 instruction is ignored by the Reader, when the Computer is connected, but a F0000 instruction activates Input when the Tape Typewriter is used.

An E0000 instruction starts the Reader, reading all characters into the Computer. A Conditional Stop code (=) stops the Reader.

Only these characters read into the Computer by the Tape Typewriter may be read in by the Reader. A stop code generates a "Start Compute" signal to the Computer and stops the tape.

Operation of Tape Punch
To operate the Tape Punch:
1. Turn Computer "on" and make it ready to operate by warming up.
2. Depress "Punch Power" switch once. (It lights up.)
3. Set Output switch to "Punch."
4. Depress "Tape Feed" switch and hold depressed long enough to obtain at least a 6 inch leader.
5. Tape starts punching.
6. Direct long tapes into chute, through slot in Punch Reader console to bin inside cabinet.

Operation of Punch with the Computer
A P0000 code starts the Tape Typewriter. Any one of the other 63 codes (01 through 63) are possible.

A Pn00 instruction from the computer purchases the character represented in binary in the track portion of the instruction. At the end of each punching cycle, a "Start Compute" signal is generated similar to the punching operation of the Tape Typewriter.

Since the punch operates approximately twice as fast as the Tape Typewriter, there is consequently less time for calculation between punch cycles. The timing using the punch will be further discussed in timing and optimizing.

The description of the Photoelectric Reader and the Paper Tape Punch only describes the difference between programming with these units and with the Tape Typewriter. For more information, see Programming Input and Output of the Tape Typewriter.

Input
This command enters information from the Tape Typewriter into the accumulator. An Input order is always preceded by a print order, but not necessarily immediately. The n address does not refer to one of the 4096 addresses and will normally be zero. The sector part of the address is irrelevant with respect to the function of the command, but it does affect the timing of the instruction. The track portion of the address indicates the first four bits to enter the accumulator. If the 6-bit switch is depressed, all six bits enter the accumulator.

FIGURE 6. Photo-Electric Reader Model 342

FIGURE 7. Paper Tape Reader and Punch on Tape Typewriter
determine which of two paths to follow in a program. One depression latches the button in down position (depressed), a second depression releases the latch. The T command will be explained later.

**Operation Codes**

The operations of the LGP-30 are grouped under arithmetic, logical, and input-output. In general, arithmetic operations are those that operate on a full 30-bit plus sign word; logical operations are those that affect only the address portion of the word.

**ARITHMETIC OPERATIONS**

*Bring* B m
Replace the contents of the accumulator with the contents of the memory location specified by the address, m.

*Add* A m
Add the contents of m to the contents of the accumulator and retain the sum in the accumulator.

*Subtract* S m
Subtract the contents of m from the contents of the accumulator and retain the difference in the accumulator.

*Hold* H m
Store the contents of the accumulator in m, retaining the contents of the accumulator in the accumulator.

*Clear* C m
Store the contents of the accumulator in memory location m, clearing the accumulator to zero.

*Extract* E m
The Extract order or "logical product" is a bit by bit product of the contents of the accumulator by the contents of m. The order may also be explained in this way: if there is a '1' in a bit position of the accumulator and a '1' in the corresponding bit position of the m word, the E order places a '1' in the corresponding position of the accumulator; otherwise it places a zero in the accumulator. This order makes it possible to "mask out" parts of a word.

*Divide* D m
Divide the number in the accumulator by the number in memory location m, retaining the quotient (rounded to 30 bits) in the accumulator. The absolute value of the contents of m must be greater than the absolute value of the contents of the accumulator.

*Multiply* M m
Multiply the number in the accumulator by the number in memory location m, retaining the most significant half of the product (30 binary places) in the accumulator.

*Logical operations* Store Address S m
Store only the address portion of the word in the accumulator in memory location m, leaving the rest of the word in m undisturbed.

*Return* R m
Add "one" to the address held in the accumulator, C, and record it in the address portion of the word in memory location m. The counter register, C, normally contains the address of the next instruction to be executed. This command is used in setting a subroutine exit.

**Unconditional Transfer** U m
Transfer control to m unconditionally i.e., get the next instruction from memory location m.

---

*If an ADD or SUBTRACT order results in a number which is too large for the 30-bit accumulator, overflow will occur and the computer will stop.*

*In the multiply and divide orders, the contents of (m) are used for repetitive additions or subtractions and must be available many times. Since the instruction register is used for this purpose, it is required that (m) be present in the instruction register before execution of the operation.*

*When two 30-bit binary words plus sign are multiplied the result is a 60-bit product plus sign. In the M multiply order, only the sign and the most significant 30 bits appear in the accumulator. The least significant 30 bits of the product appear in the sign position through bit position 30 of the accumulator, generally 0. It will not be zero only when the sign bit is one and the sign is not preserved in the multiplication.*

*If an error occurs in the divide operation, the digit in the error register is set to zero. The divide order is not executed in the case of a divide by zero.*

*Remember: when debugging a program, if overflow results during division, the counter register indicates where, in the program, the computer has stopped. The instruction register will not contain the actual instruction being executed.*

*The instructions, B 1945, A 211, C 1943, must be brought into the instruction register before they can be executed and this can only happen when locations 0000 0001 0002 respectively are under the read head. Assume the read head is over sector 00 and in placing the instruction B 1945 in the instruction register, if this instruction, B 1945, is executed before the drum turns around to sector 01 it will be an optimum instruction. Figure 9 shows sector 4 is between sector 00 and sector 01 and is within the portion which is optimum for sector 00. The same logic applies to the next instruction A 211 at location 0001. Sector 41 lies between sector 01 and sector 02 and lies within the portion which is optimum for sector 00. Both the preceding instructions are optimum. The next instruction C 1943 at location 0000 will not be optimum because sector 43 does not lie between sector 02 and sector 03.*

---

**TABLE I**

<table>
<thead>
<tr>
<th>Sequence of Sectors around the Drum for One Track</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
</tr>
<tr>
<td>07</td>
</tr>
</tbody>
</table>

Table II shows the 16 commands the LGP-30 performs the number of word times after the location of the instruction, the address of the operand must be in order for the instruction to be optimum.

*For example Table II shows that for a divide instruction, the address of the operand is in 2 words after the location of the instruction so this instruction will be optimum. If the divide instruction were placed at sector 51, Table II will give the sector addresses of the 2 through 6 word times following sector 51.*

---

**TABLE II**

<table>
<thead>
<tr>
<th>Order</th>
<th>No. of Word Times</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bring, Add, Subtract</td>
<td>2 to 7</td>
</tr>
<tr>
<td>Hold, Clear, Store</td>
<td>2 to 8</td>
</tr>
<tr>
<td>Return Address, Extract, Print, Input, Stop</td>
<td>2 to 6</td>
</tr>
<tr>
<td>N multiply</td>
<td>2 to 5</td>
</tr>
<tr>
<td>M multiply</td>
<td>2 to 5</td>
</tr>
<tr>
<td>Divide</td>
<td>4 or more</td>
</tr>
</tbody>
</table>

**Timing on Input**

The only timing problems that occur in Input are with the Tape Writer. If a P0000 instruction is initiated, an 10000 instruction must be placed after any information reaches the read portion of the Tape Writer. On some instances, however, it may be desirable to have the LGP-30 send a P0000 instruction to start the tape in motion on the Tape Writer. Tape Writer could then type a title or header while the LGP-30 continued to compute.
Timing on Output

When the Tape Typewriter is used as the Output device of the LGP-30 it is necessary to take the Tape Typewriter at top speed, approximately ten characters per second. This means that there are approximately 9½ drum revolutions of useful calculation between printing each character on the Tape Typewriter. This time is normally spent converting the next character to be printed on the Tape Typewriter. This is especially true if a binary to decimal conversion is required.

After the "P" instruction supplies the typewriter unit with the required information to execute a print or a control function, control is transferred to the instruction following the "P" instruction. The programmer may use any instruction except another "P".

The other, display in binary the Counter Register, C, the Instruction Register, R, and the Accumulator Register, A, from top to bottom, as shown in Fig. 6.

![Figure 6: Oscilloscope Showing Three Registers](image)

The Counter Register, C, contains the address, or location (track and sector) of the next instruction to be executed.

The Instruction Register, R, contains the last instruction executed and during multiplication or division, holds the second operand.

The Accumulator Register, A, contains the result of the execution of the last instruction.

**CONTROL BUTTONS**

Power On and Off Buttons

The "Power On" and "Power Off" switches are the main power switches.

It is good practice to be sure that the "Manual Input" button is depressed before depressing the "Power Off" switch. If it is not depressed when the computer is turned on, the computer will remain in "Stand By" state. If it is not depressed when the power is turned off, some of memory may be erased.

Stand By

When the "Stand By" button is depressed, after the "Power On" button is depressed, a red light behind it lights up. This turns off the high voltage.

Operate

Depress this button to prepare the computer for operation.

Stand By to Operate

This is an indicator, not a button and cannot be depressed. It indicates that the Computer is in one phase of its warmup cycle.

Mode Buttons

The following buttons select one of the three modes of operation but do not cause the machine to operate.

- Manual Input—(This is not the same as the Manual Input button on the Tape Typewriter.) Depressing this button connects the computer to the keyboard of the Tape Typewriter. All data typed on the keyboard appears in the accumulator register. If the "start" button is depressed, the contents of the word whose address is in the counter register is displayed in the instruction register and the counter register is increased by one. The accumulator register is unchanged since no instruction is executed. This enables the operator to "step through" a section of memory and examine the contents of each word as it appears in the Instruction Register.

- One Operation—Depressing this button prepares the computer for executing one instruction at a time and half. Depressing the "start" button executes only the instruction whose address is in the counter register and stops the computer. The counter register is then increased by one, unless a transfer instruction, TO U is executed. In this case, the counter register contains the address of transfer instruction, the instruction register contains the instruction just executed (except for multiply and divide instructions).

- Normal—Depressing this button sets the computing mode to execute the stored program automatically.

Operation Buttons

The Start, Clear Counter, Fill Instruction, and Execute Instruction buttons interlock with the Mode selection buttons. To simplify computer operation, a light under each button indicates when that button is operable; the lights are lit when buttons are inoperable. For example, the execute instruction light is lit only when the One Operation button is depressed, depressing this button in any other mode does not activate the computer.

- Start—This button must be depressed to execute stored instructions. It is used with One Operation and Manual Input as explained previously.

- Clear Counter—Depress this button to reset the counter register to zero to restart a program. This switch is used only in the Manual Input and One Operation modes.

- Fill Instruction—Depress this button to transfer the contents of the accumulator to the instruction register after it has been typed into the accumulator from the keyboard. This button is used only in Manual Input and One Operation modes of operation.

- Execute Instruction—Depress this button to execute the instruction in the instruction register. This button is used only in the One Operation mode.

- Stop—The "Stop" light panel will light red to indicate when computer has stopped.

- Compute—The "Compute" light panel will light green when computer is computing.

The bottom row of buttons on the console panel displays:

- Break Point Switches—The 4 breakpoint switches BP-32, BP-16, BP-8, and BP-4 are used with the track portion of the address of a stop order, Z. When the break point switch is depressed, the computer ignores the "stop" instruction in the program and executes the following instruction. One depression latches the breakpoint in the down position, a second depression releases the latch. Lights under the breakpoint buttons are lit when switch is down, in latched position. The Z command will be explained later.

- 6-bit Input—This button, when depressed during Input, permits all six channel bits of each typewriter character to enter the accumulator—instead of the usual 4 channels when button is up.

- Transfer Control—This button provides the operator another means of manually controlling the machine. It is used with a Test Instruction (T) to
Computing Unit

Internal calculation is accomplished by directing information to the computing section from memory, processing it, and directing it back to memory. The computing section consists of three working registers; the counter register (C), the instruction register (R), and the accumulator register (A). The three registers are located on three separate recirculating tracks on the LGP-30 drum, in addition to the 64 tracks of memory. The accumulator, A, is the working register. It contains the results of addition, subtraction, multiplication, etc., as these operations occur. It also contains some of the operands, prior to execution of an arithmetic instruction; the second operand is in memory at the word location specified by the address part of the instruction.

The instruction register, R, contains the instruction being executed. Both the operation and the address of the instruction are located in this register. Words are transmitted from memory to this register. Generally, these words are instructions of a program stored in memory. The instruction register may be interrogated to determine the operation to be performed.

The counter register, C, contains the location of the next instruction to be executed, i.e., if the counter register reads 243, the next instruction to be executed is stored at address 243 or track 24, sector 23. This register contains only the address part of a word. The address part of the instruction register may be transferred to the counter register. The address part of the counter register may be transferred to a register by use of the R command. During the execution of every operation, 1 is added to the counter register automatically, so it will be ready to search for the next instruction, after it finishes the one being executed. The flow of information between the registers and memory is shown in Figure 4. The solid lines indicate information being passed as a whole word. The dotted lines indicate information affecting the address portion only. A typical instruction affects the registers as follows:

1. The word, whose address is in the counter register, is placed in the instruction register.

2. The word in the instruction register is then executed and information flows along one of the lines represented in the diagram depending on the instruction. During this time, the counter register is increased by 1. This completes an instruction cycle and the counter starts to look again for the word whose address is now in the counter register.

Control Panel

The LGP-30 control panel is designed for simplicity of operation. It displays, see Figure 5, the Oscilloscope in the upper right hand corner of the panel and the translucent control buttons. These buttons, when lighted, indicate the operating status of the computer. The patterns on the Oscilloscope indicate the contents of the three working registers.

OSCILLOSCOPE

The scope furnishes the operator with a visual representation of the three registers as a means of checking or debugging his program. Three windows, one below
APPENDIX B

SCALING

The operation of scaling is performed by the programmer to eliminate overflow or underflow of precision.

Before programming a problem on a computer, a technique for scaling the data must be employed. Various techniques may be used depending on the number system. In the decimal system 10 is the basic number. However, the LPG-30 is designed about the binary system, using a base of 2. In scaling data, the binary point, "q", represents the number of places from the extreme left of the data word, where the radix point is located. (The radix point indicates the separation between the integral and fractional portions of a data word.) Given a data word, its "q" is determined from the table of Powers of Two, Table I, for example number 200 must be held at least a "q" of 4. In representing a word of 30 bits, excluding the sign bit to the left. See Figure A below, q is considered to be at the extreme left.

Example:

\[
2 \quad 1 \quad 1 \quad 1 \quad 1 \quad 0 \quad 1 \quad 0 \quad 1 \\
\]

FIGURE A

The rules for scaling in arithmetic operations of the LPG-30 are the same as those in other computing devices. To add or subtract two numbers, they must be held at the same "q". (In a de-cennial code, this is equivalent to lining up the decimal points.) The result of such addition or subtraction is a number at the same "q".

In multiplication, the "q"s of the two numbers need not be the same. The product of two such numbers is a number at q = q₁ - q₂, where q₂ is the binary point of the multiplier and q₁ is the binary point of the multiplicand. In division, the quotient of two numbers has a q = q₁ - q₂, where q₁ is the binary point of the dividend, and q₂ is the binary point of the divisor. In multiplication, q₁s are added, in division, the q₁s are subtracted.

Since the purpose of scaling is to shift data into such favorable locations to eliminate loss of precision, it is important to determine how shifts are made without altering the value of the data. Any number multiplied by the integer 1, results in the same number. But any number multiplied by the integer 1 at q = q shifts the number in the accumulator by q places to the right. This will place the number in the required location. For example, to add 5 at q = 10 to 10 at q = 12, the 5 at q = 10 must be multiplied by 1 at q = 2 to obtain 5 at q = 12, or shift 6 to location q = 12 in accumulator. Then, we can add the result in the accumulator. Thus, we shift the contents of the accumulator to the right so that the radix point is located at the required q = 12.

It is sometimes required to shift left to scale a number to a q smaller than that given. In this case, divide the number to be scaled by the integer, 1 at q = q, and thus shift it in the accumulator by q places to the left. For example, 7 at q = 4, divided by 1 at q = 2 equals 7 at q = 2. However, it must be noted that 7 cannot be located at q = 2 since the last remaining digit is the left will overflow and stop the computer. A mental check is necessary to determine the "64" of the quotient in the accumulator before dividing. In this case, it is possible only to divide 7 at q = 4, by 1 at q = 1 to obtain 7 at q = 3, which will "fit" into the accumulator.

Another method of shifting left utilizes the "N" multiply instruction. This instruction retains the least significant half of the product in the accumulator. To shift a number left n places, "N" multiply the number by 1 at q = (31-n). For example to obtain 7 at q = 6, we want 7 at q = 4, therefore, shift left by 2 places. To do this, "N" multiply 7 at q = 6, by 1 at q = (31-2) to obtain 7 at q = 8. This is equivalent to 7 at q = 4 as can be illustrated below.

From the following illustration, we note that the bit of the total product is in the sign bit of the accumulator.

![Figure 2. Standard Keyboard of Tape Typewriter](image)

Addressing Systems

The LPG-30 is a tape reader and has a tape reader is a standard typewriter key. It has a board and control switch as is shown in Figure 2, and a paper tape reader and punch which are integral parts of the input-output unit.

Input information to the LPG-30 is transmitted from the Tape Typewriter or from the paper tape reader on the typewriter.
TABLE I
POWERS OF TWO

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LGP-30
THE ROYAL PRECISION DIGITAL COMPUTER
This manual describes the operation of the LGP-30 Digital Computer. It is intended for the reader who has some knowledge of computer techniques but wishes to know just how the LGP-30 operates.

The success of the desk-size digital computer is attributed to its wide range of applications. It makes it possible for small business operation to use automatic data processing techniques economically; to operate as larger computing installations with less "waiting time" and consequently quicker evaluation. It can be used in conjunction with large scale installations or in place of large scale installations where the latter are not economically justified.

When used with large scale computers, it serves to eliminate the bottleneck by decentralizing operation. The LGP-30 makes it possible to quickly evaluate trial ideas associated with more complex engineering designs, before putting the over-all problem on the larger computer.

When used alone, it permits the smaller company to obtain realistic answers to problems quickly and reduces the lengthy manual calculations from man-weeks to a few man-hours.

For the first time small business can justify the cost of the computer since it may be operated with no additional electrical service, ventilation, or cooling and requires a minimum of floor space.

HEXADECIMAL EQUIVALENTS OF TRACK AND SECTOR LOCATIONS:

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