# A Method of Coupling a Small Computer to Input-Output Devices without Extensive Buffers

JAMES H. RANDALL†

## General Description of Computer

THE computer referred to in this paper is contained in a package about desk size. It is intended to sell at a relatively low cost as compared to other general purpose type computers and accordingly would be considered in the "small" class. The basic components used are transistors and diodes. Although the design was aimed specifically at business applications, the computer is nevertheless a general purpose machine with internally stored program. Typical of the applications intended are the problems of small businesses such as payroll, stock inventory, production control, interest calculations, etc. The computer can be considered as an extension of the accounting machine system rather than an integrated data processor.

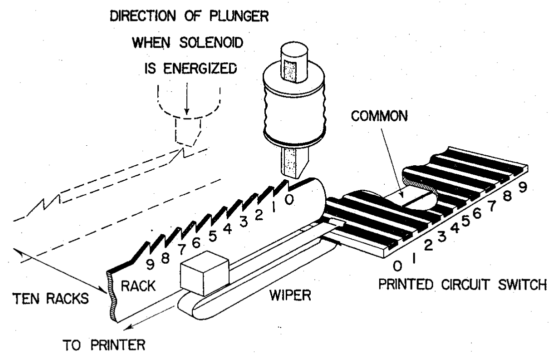


Fig. 1—Illustration of a rack with accompanying solenoid and position detector switch.

## Mechanical Accounting Machine

In business applications, one must use all shapes and sizes of business forms. Therefore, a standard mechanical accounting machine with a large carriage suited to these forms was utilized for printing data from the computer and as a source of keyboard entry into the computer. The use of the accounting machine provides the additional advantage that format control of printing on the forms is taken care of on the accounting machine itself and does not have to be stored in internal memory.

This accounting machine is essentially a parallel digit device. The maximum word size has been chosen as ten digits (numeric only). As is conventional in accounting machines the keyboard has ten columns of nine keys each, one column for each digit position in the word. Depressing a key in any particular column determines the value, zero through nine, of the digit printed in that digit position. (Depressing no key causes a zero to be printed.) After all the desired keys have been depressed, the machine cycle is initiated and all the digits of the word are printed simultaneously.

Associated with each column of the keyboard is the conventional rack as shown in Fig. 1. During the machine cycle all ten of the racks are simultaneously driven in a setting direction parallel to their long axes, successively passing through positions representing digital values, zero through nine. Each rack may be stopped at any one of the ten positions, depending upon which key is depressed in that corresponding column of the keyboard. The racks are connected to the printing mechanism so that the value of each digit printed is determined exactly by the position of its corresponding rack at the time of printing. After all of the racks have assumed their proper positions they are held stationary for a period of time sufficient to complete the printing operation and then restored to their original positions.

For keyboard entry of data, the computer must detect the positions of all racks after they have been stopped by the keys, and transfer this parallel information into the memory. In order to print words from the memory, the computer must stop each rack at the proper digital position. This is actually done by a process that pulls in a solenoid for each rack, stopping it at the proper position as it is moving in the setting direction.

## Magnetic Ledger Card

In a large percentage of businesses, the data continually being used in calculations are stored in printed form on ledger cards. In general, the problem is to take data from a ledger card, combine it with new data to get the desired result, and bring the information on the ledger card up to date. If the ledger card system is to be retained, it is advantageous if the data on the card is also in machine-readable language. To accomplish this, a strip of magnetic material was added along one edge of the ledger card. On this strip are recorded magnetically certain controls and all of the current information printed on the card. The computer must both record data and read data from this magnetic strip.

To make the magnetic ledger card really practical for the applications intended, it is necessary to store 50 to 100 digits of information on the magnetic strip. The choice of scanning speed and recording density resulted in a read and record rate of about 400 pulses per second.

† The National Cash Register Co., Dayton, Ohio.

There is a data track and a clock track on the strip and the data are recorded serial digit and serial code (four bits per digit). To get the maximum amount of data on the card, a variable word length system is used which requires that an end-of-word symbol follow each word.

Recording on the card is under control of the computer and must be done at the rate of 400 pulses per second, which is also the reading rate.

### Reading Punched Cards

In certain applications it is necessary to do some types of distribution for writing reports, etc. The computer was accordingly designed to read punched cards which are sorted on available commercial equipment.

A modified IBM 026 card punch was used for reading the cards. This punch has a duplicate feature which reads one card and simultaneously punches the information read into the following card. By temporarily disabling the punches and operating in the duplicate mode, the cards can be read one after the other at the normal reading station. This data appears as parallel-code serial-digit at a rate of about eighteen digits per second. The computer must take the data at this rate and store it in internal memory.

### Internal Construction

Both a core and drum memory were considered for this computer. Since the capacity of the memory is relatively small (100 words), it seemed more economical to use a drum. However, with a drum, communication with each of the aforementioned input-output devices would require extensive buffering and add substantially to the cost of the computer. Therefore, a core memory was considered. The core memory has three major advantages. First, any address can be selected in a very short time. Second, the read-write operation can be stopped and started almost instantaneously and at any point in a word. Third, it is possible to read out a word starting from either the high or low-order end. By exploiting these characteristics it was possible to synchronize, rather than buffer, the memory to the communications devices.

The basic clock frequency of the computer is 25 kc, making a bit time and the read-write cycle for a core 40 μsec. The word length is ten digits of four bits each, or 40 bits. Reading out of the memory is always done in a completely serial fashion. There are two basic modes for this process, "word cycles" and "digit cycles." Initiating a word cycle causes an entire word of the memory to be read (or written into) without interruption. With two extra bit times for control, this cycle takes a total of 1680 μsec. A digit cycle reads only one decimal digit, or four bits, from the memory. The length of this cycle is 200 μsec including an extra bit time for control. These digit cycles may follow one after the other in sequence to read out an entire word. However, any amount of time may elapse between the completion of one digit cycle and the beginning of the next.

In the computer are two single-digit registers of four bits storage capacity each. They are used for certain arithmetic and control operations and also are used as buffers, as will be shown.

### Reading Data from Accounting Machine

Entering data into the computer from the accounting machine is comparatively simple. As previously discussed, the value of each digit of the word entered into the keyboard is represented by the differentially set position of a corresponding rack. As shown in Fig. 1, a switch was added to the machine which has ten parallel conductors on one surface, extending in a direction perpendicular to the racks and spaced the same distance apart as the digital positions of the racks. A wiper on each rack then makes contact with one of these ten conductors, dependent upon the position at which the rack is stopped. The wiper also makes continuous contact with a single common conductor for each rack, extending in the direction of movement of the rack. Consequently, if voltage is applied to any one of these common conductors, the same voltage appears, via the wiper, on the conductor corresponding to the position of the rack.

When the computer receives a signal that the racks are in position, it initiates a word cycle that scans the switch and copies the information into memory at the same time. That is, the digit selector selects the digit position in memory in which to write and at the same time selects the corresponding rack to be examined for its digit position. Effectively, the computer is taking the parallel digit one-of-ten coded data from the switch, properly encoding and serializing it and copying it into memory.

Since the computer is operating at the 25-kc rate during scanning of the switch and the racks remain stationary for a sufficient length of time to allow the scanning to be completed, no buffering is necessary.

### Printing with the Accounting Machine

Printing a word from internal memory presents a more complex problem. Each rack must be stopped at the proper digital position by a solenoid, shown in Fig. 1.

A means was provided for generating a pulse each time the racks are moved from one digital position to the next. These pulses are fed into a counter which operates to produce in coded form a number representing each of the digital positions of the racks as they move from positions zero through nine.

When a signal is received to start the print operation and before the racks move, a word cycle occurs which successively loads the digits of the word to be printed into one of the digit registers. Each digit is compared to the number in the counter, and if any digit in the word is a zero, a solenoid is energized which prevents movement of the rack corresponding to that particular digit. For example, if the five high-order digits of the word were each zero, the five corresponding racks that cause the printing of those digits would be prevented from moving.

The remaining racks then begin to move in the setting direction. When they reach the "one" position, the counter would then be storing the number representing that position. At this time the same word cycle is repeated, but now in all positions of the word where the stored digits are equal to "one," solenoids will be energized to stop all the corresponding racks at the "one" position. This entire sequence is repeated each time the racks reach a new digital position.

The racks move at a constant velocity with 8 msec time elapsing between digit positions. However, the word cycle at each position requires only 1.68 msec, which, with the aid of high-speed solenoids, is adequate time to catch the racks. Thus, a timing system and a series of word cycles operating at the internal 25-kc rate eliminate the need of a word-length buffer.

### Recording on Ledger Cards

The synchronizing technique is applied in the following manner to recording on the ledger card. A card clock is generated internally at the 400 pulse-per-second rate. This clock records the clock track on the magnetic strip and also synchronizes the computer. The card is scanned in opposite directions for read and record; accordingly, the data are recorded on a card from high-order to low-order digit so that it may be read from low-order to high-order digit.

Upon receiving a signal to record, the computer initiates a digit cycle which loads the high-order digit of the first word to be recorded into one of the single-digit registers. In the following bit time the content of the register is examined to determine if the digit is a significant one—that is, a number other than zero. If not, another digit cycle follows immediately, loading the next lower order digit into the same register and the check of the content is repeated. This process continues until the first significant digit is detected. At this time the word scanning operation halts and the next card clock pulse that occurs starts the recording of an end-of-word symbol. When this is completed, the bits making up the digit stored in the register are transferred to a single bit storage one at a time in sequence, each time a card clock pulse occurs. The output of this single bit storage as the bits are stored one after another determines precisely what is recorded on the data track of the magnetic strip. When the last bit of the digit has been transferred to the single bit storage, another digit cycle occurs which loads the next lower order digit into the digit register. The following card clock pulse then begins the serial recording of that digit. This sequence of events continues until all of the digits have been recorded. If another word is to be recorded, the new address is selected in one bit time and the scanning process begins again.

If the word is found to be all zeros only an end-of-word symbol is recorded. In this case the ten-digit cycles required to examine the word can easily occur while the next end-of-word symbol is being recorded. It is not necessary, therefore, to have any unused space between words on the card.

By synchronizing the memory to a slow card clock only five bits of buffer storage are needed for recording any number of digits.

### Reading Ledger Cards

Reading ledger cards is essentially the reverse of recording, but with the 400 pulse-per-second clock output from the card being in control. Upon receiving a signal to start reading a card, the computer first initiates a word cycle that clears out (writes all zeros into) the address in which the first word is to be stored. As the data come from the cards serially, each bit is loaded into the digit register having the four bit capacity. A check is made to see if this digit is an end-of-word symbol. If it is not, a digit cycle is initiated and the contents of the digit register are loaded into the low-order digit position of the word. In similar fashion the succeeding digits are first loaded into the register and then into the next higher order digit position in memory. When an end-of-word symbol is detected, no digit cycle occurs and the digit selector of the memory is reset to the low order digit position. The next address in the memory to be loaded is then cleared. This takes place before the next bit of data is received from the card. The process then is repeated for each word to be entered from the card.

By synchronizing the memory to clock pulses received from the card, only one digit of buffer storage is needed in the reading of magnetic ledger cards.

### Reading Punched Cards

The punched cards are read in a serial digit fashion from high to low-order digit. A clock pulse is received from the reader which signals the computer that the card is in a position for reading a digit. At this time a word cycle clears out the address to be loaded, and the output of the card reader is loaded by a digit cycle into the low order digit position in memory. When the next clock pulse is received, the previous digit is shifted into the next higher order position of the word in memory and the new digit is loaded into the low order position. All of this can easily take place between card reader clock pulses which occur about every 55 msec. When the last digit of a word is loaded, the word is stored in the proper position. Again, synchronizing the memory to the card reader clock eliminates the need for any buffering at all.

### Conclusion

By synchronizing the core memory in a small computer to input-output devices, the buffering required is greatly reduced. Additional savings are realized because small existing registers which are already a necessary part of the computer can be used as the buffers.