another question as to whether the 1,000,000 passes were over one tape area or if different areas of the tape were used each time.

Mr. Nordyke: The tape was read over the same area of tape which was of the order of 20 inches. Again I want to emphasize that this is a high figure even though we have obtained it. The total number of passes on a longer length of tape, or a tape in which there are weak spots, is much lower, although you will still get reliable tape operation.

L. C. Hobbs (Radio Corporation of America, RCA Victor Division): You mentioned tape stretch during the rapid start-stop. Could you elaborate on this as to the magnitude of the velocity overshoot, and any steps taken to overcome it, aside from not using the tape during that time?

Mr. Buslik: At the present speed of about 75 inches per second, I do not think the overshoot in speed is as serious as we have shown in the slides. The overshoot is approximately 10 per cent, but that can be modified by the distance between the reading station and the point where the tape is actually being driven. When I said that we have accomplished a 5-millisecond start time, it does not mean that we are starting to read or record at that time; we have also incorporated a safety factor in the start and stop time. Also, we feel that by the use of other backing materials that are somewhat stiffer than the present acetate tape, this stretching can be reduced.

J. L. Hill (Engineering Research Associates, Inc.): It is apparent that there is some slippage between the capstan and the tape, both in acceleration and deceleration. To what extend does it damage the tape? Have you observed any accumulative effects of stopping in the same place?

Mr. Buslik: We have no accurate records because, as the tape is rewritten, the start and stop processes may not occur at the same place, but we have run tape, started, and stopped it, for many hours without being able to notice abrasion on the tape surface. I might point out that the rubber surface of the capstan is located so as to accelerate the tape from the backing, rather than from the oxide side. We have run tests at several times the speed that we are now using, and at those speeds we could notice some abrasion of the tape during starting and stopping.

High-Speed Printing Equipment

L. ROSEN

The Synchroprinter was developed to provide a rapid means of printing out data from electronic computers. Although the development was motivated by a very specific application in the United States Government Department of Defense, after attainment of the original objective it became clear that a much broader field of application was available.

The Synchroprinter is shown in front view in Figure 1. The essential elements of the printing mechanism visible are the type wheels, or type roll; the sync pulse generators; and the drive motor.

The principle of operation can also be described by reference to Figure 2, although generally in electronically controlled operation another system, to be explained later, is actually used. As an example, let us assume that we want to print a 3 in column 1. The type roll and sync pulse generator are rotating continuously and a voltage pulse is generated in each sync pulse generator coil as the pulse generator rotor passes it. When we close switch 3, the pulse from coil 3 of the sync pulse generator reaches the thyratron grid and, firing it, allows it to unload the capacitor C1 through the print hammer coil, thus actuating the print hammer, at the correct instant to print a 3 in column 1. Of course, inked ribbon and paper are placed so that an impression is transferred to the paper when a type hammer strikes the print wheel character. Separate selection circuits and thyratrons serve the other print hammers; however, a common sync pulse generator triggers all the thyratrons.

Figure 3 illustrates a more common method of controlling the printer. Here each print hammer has an electronic counter as well as a thyratron associated with it. These counters are usually of the binary type but may take almost any form. The only requirement placed on them is the ability to count and produce a carry pulse after receiving 10 counts when operating with a numeric printer. Now to print a 3, the counter is preset to 3 either by counting or other means, such as a simultaneous set pulse to the appropriate sides of the binary units. After the counter has been set, the printer is signalled to print out by closing switch B. When the rotor of the start pulse generator passes the zero coil a pulse unblocks the gate and allows pulses from the sync pulse generator to reach the counter. After seven pulses in our example, the counter carries and its output pulse triggers the print hammer thyratron

Figure 1. Front view of the Synchroprinter

Rosen—High-Speed Printing Equipment
which actuates the print hammer. The print roll is engraved in such a way as to have the 3 appear on it seven sync pulses after the zero.

During this printing cycle, the print roll rotated continuously, while the paper was not moved. The print cycle occurs during one revolution of the print roll, or 1/30 of a second. When printing of a line is completed, an independent signal is sent to the paper advance mechanism, which causes the paper to be advanced one line during the next revolution of the print roll. Thus the printer is capable of printing and line feeding in 1/15 of a second or a line rate of 15 per second. This means 600 characters per second for a 40-character line, or 1,200 per second for an 80-character line, or 1,800 per second for a 120-character line.

Figure 4 illustrates a satisfactory circuit for the thyratron driver for the print hammer.

Figure 5 illustrates an arrangement which allows the same electronic counter to be used both for controlling the printer and for counting data. During the counting cycle, the carry gates are unblocked and the sync pulse gate is blocked. The counter now operates as a decade scaler. When the count cycle is completed, the carry gates are blocked and the sync pulse gates are unblocked. Pulses now flow to the counter from the sync pulse generator as described previously.

If the counters are not reset before each count, the printer of course prints subtotals, while resetting the counters after the print-out gives the total. The counter here described might be the counter of an analogue-to-digital converter of the type where the number of pulses produced corresponds to an incoming voltage amplitude or time length.

In addition to the features already described, the Synchroprinter can be equipped with column markers. These are small metal arms which can be flipped into active or inactive position. When the column marker solenoid is actuated, the active column marker arms draw a vertical line between characters, thus separating columns or indicating decimal points.

The printer specifications are given in Table I for a 40-column, 10-character unit known as the N-I. The A-I, or alphanumeric unit, has about the same per-

Rosen—High-Speed Printing Equipment
performance characteristics, except that 36-character type wheels are used.

One of the interesting features of the printer is its construction in building-block form. Assemblies are removable as integral units for repair or replacement, while the whole unit can be removed from its dust case and operated out in the open for purposes of inspection or adjustment.

An interesting adaptation of the printer mechanism to plotting data which is in digital form has been proposed. For purposes of explanation let us assume we wish to plot points ranging from 0 to 10^6 = 100. In this case, 10 of the type wheels of the printer would be engraved as shown in Figure 6, which is a developed view of the periphery of the type roll. Now, if we select the print hammer by means of one digit and the position of the character to be printed by means of the other digit as shown in Figure 3, the printer is capable of selectively printing any one of the 100+ marks. Thus we can plot one point of a curve in 1/15 second. The remaining 30 type wheels can also be converted to plotters or can be retained as character printers. By converting 32 type wheels and using 2 or 32-character type wheels we will be able to plot 2^32 or 1,024 points. An interesting feature of the plotting arrangement is that the accuracy of the ordinate of the point printed is determined entirely by the accuracy of the engraving on the type roll. One advantage of this plotting mechanism is that its full-scale transit time is only 1/15 second.

Various alternative paper movement mechanisms of course suggest themselves for operations requiring either accurate abscissa displacement or paper movement in both directions.

**Summary**

We now have a tested and dependable printing mechanism capable of printing 15 lines per second. This mechanism can be paralleled to any reasonable number permitting the printing of large quantities of data at high speed. A simple modification of the mechanism permits plotting digital data. The printing mechanism is designed for control by electronic means and therefore can be applied wherever the data to be printed can be reduced to digit form.

---

**Discussion**

W. P. Byrnes (Teletype Corporation): Have you determined how many carbon copies you can produce on the Synchroprinter?

Mr. Rosen: We have produced up to three copies that I would consider legible. I must admit that I dislike carbon, because it makes a mess, but we have produced four carbons. The unit shown does not have a paper guide mechanism capable of handling unjointed carbons. We have used the Teletype roll, paper and carbon held together loosely in a roll, in our experimental work, but the present paper drive will not pull these carbons. With a relatively simple modification we can pull the kind of carbon that is glued on the edge, or on the top and bottom.

D. Haagens (Control Instrument Company): Can you tell us something about the speed and the price of the alphabet printer?

Mr. Rosen: The alphameric unit is capable of operating at the same speed; nominally, at 50 revolutions per minute. I say nominally because at present we do not have a synchronous motor. I will answer the second part of the question after the meeting (it is no secret, but I do not think this is the proper place for it).

C. T. Schaadel, Jr. (Consolidated Vultee, Fort Worth Division): Will you please state the number of characters available in one line?

Mr. Rosen: The present unit is 8/4 inches wide, or really 7 1/16-inch paper with 1/2-inch margin on each side. We have 40 characters in the unit. The printing control is substantially like salami, you can slice off what you want in building it. There is an ultimate limit where the shaft becomes so long that it is no longer practical.

J. J. Earshen (Cornell Aeronautical Laboratories): You showed the method in which the information is read out of the electronic counter, but do you have to use some sort of complement code because of the fact that you were using roll-out pulses there?

Mr. Rosen: It is rather difficult to answer the question in a simple way. The only thing that you must do is to make sure that the print hammer thyratron is energized at the right time. We will engrave whatever character you want at that position. The equipment does not have to be operating in the way shown in the slide.

Another possible setup is where there is a comparison of the code set up in the
A Survey of Analogue-to-Digital Converters

HARRY E. BURKE, JR.

A GOOD many years ago Aesop told a story about a grain miser whose horde was raided by ants that silently crept through cracks into his warehouse to extract his store, kernel by kernel. It is easy to picture the frustration of this wretched man, opening his granary doors one day to find his treasure gone. Today, engineers and scientists are frustrated by a reverse situation—they want to empty their storehouses of raw information, but succeed in doing it only “kernel by kernel,” or point by point. Raw data continue to pile up at such a rate that research laboratories and test facilities are overflowing with unreduced information. Manometer tube photographs, theodolite records, frequency-modulated carriers on magnetic tape, galvanometer deflections from recording oscillographs, strip-charted pen gyrations, and so forth, are gathering dust despite a frantic effort to reduce them to useful engineering conclusions.

There is now available a technique to help break this bottleneck, and to accelerate the tedious data reduction process to a point where it at least approaches the speed at which raw data can be generated by modern instrumentation. This technique is that of analogue-to-digital conversion, and it has already reached a point far beyond mere engineering curiosity. A variety of instruments has already been designed and used to prove the value of this approach.

The term ‘analogue’ is used here to describe a dependent parameter that varies by some ratio in the same manner as does some independent parameter.

For instance, the voltage generated by a thermocouple is analogous to the temperature differential experienced by the couple, and is hence an analogue voltage. In the same manner, the deflection of a galvanometer, the shift of a carrier frequency, or the rotation of a shaft can be continuously proportional to some other varying physical quantity, to become analogue functions. Figure 1(D) is a curve describing some such function, and is essentially an analogue plot. Analogue functions are characterized by being continuous in nature, with an infinite number of values.

The term ‘digit’ implies discontinuity, that is, the presence or absence of some finite symbol in describing the phenomenon. Figure 1 illustrates a typical function by means of an analogue plot and by certain digital presentations. Figure 1(A) describes the function of Figure 1(D) by means of familiar Arabic symbols, while Figures 1(B) and 1(C) are typical binary records of the same information. Roman numerals or Egyptian pictures could have been shown with equal significance. The term ‘binary’ (or 2-state) here means the presence or absence of one type of symbol in a geometric location coded to some special significance. For instance, a hole may be punched in a card. This hole is a binary mark, in that either there is a hole or there is not a hole. This hole can then be made to take on a decimal-binary form by its location on the card. If datum points are to be assimilated by the human brain with the minimum of effort the presentation should be in a tabular Arabic form, as this best matches the brain’s previous training. On the other hand, machines do not have the versatility of the brain, and they can best work on a binary signal. Machine assimilation of data is therefore usually carried out through some binary-coded data-handling system.