to be eight (or a multiple of eight) pulses gained or lost before the error would not be caught.

In case of an error, the operator can reverse the wire through the block in which the error was sensed by using the low-speed reverse position and trying again.

In 4-channel operation, the gap senser is also used to provide a fifth channel punch at the beginning of each block. This is used only as an aid to the operator to assist him in locating information visually on the punched tape.

One part which was rather blithely passed over, and which will now be described further, is the synchronizer. Figure 6 shows the logical diagram of this part as well as some idealized pulses. An AND gate or coincidence gate gives output when there are signals on all inputs. An OR gate gives output when any input has a signal on it. There is no output from an AND gate when an inhibitor input has a negative signal. The basic idea of the synchronizer is to use a narrow clock pulse to sample the signal coming in. If enough of a pulse is produced at the output of the transformer for the regeneration gate to catch and hold the output up as long as \( CP_2 \) lasts, a regular pulse is produced. If it does not, only a spike will be produced. However, the input pulse is long enough so that a full pulse will be produced at the next narrow clock pulse time. The second stage examines the output of the first stage. If only a spike comes through, it will be gone before \( CP_3 \) is up. The first regular pulse gets through the input gate and is lengthened by the regeneration gate. The length of \( I_a \) and \( I_b \) is such that there will always be at least two full pulses from the first stage. However, only one gets through the second stage because the negative of each pulse arrives 1 microsecond later to inhibit the next one, allowing only the first one to get through. This also means that a weak pulse toward the end causes no concern, since there is always a stronger pulse to inhibit it. The top group of signals shows a case where the first pulse that gets through the input gate is a full \( CP_0 \), and produces a normal pulse. The bottom group shows the other case where the first pulse is a spike and does not produce a normal pulse. The next pulse then produces it.

Figure 7 shows the logical description of the main part of the outscriber with the parts that are used in 4-channel operation. The logical parts that comprise the various blocks previously described are labeled. It will be noticed that the second stage of the synchronizer is combined with the binary counter. Attention is directed on the logical diagram to the method of recognizing a one on the wire. The binary counter is set by the first pulse from the pulse shapers. In case of a one, the first pulse is on \( I_a \). The pulse on \( I_b \) turns it off. Between times, it produces a train of regular half-microsecond pulses. The gate which generates \( S \) is continually inhibited as long as this train lasts. However, after the train, the 1-microsecond delay line lets one pulse get through, producing \( S \). \( I_b \) is still on at this time and the coincidence of \( I_b \) and \( S \) in the first stage of the shift register indicates a one.

The outscriber has been in operation for about a year and is usually in operation at least 16 hours a day. Figure 8 shows the outscriber and the Flexowriter printer. The unit on the left contains everything but the punch and some of the power supplies. Figure 9 shows the package part of the outscriber and Figure 10 shows the wiring side of the packages. The over-all performance is much nearer than the wiring. The switch panel is in the lower part of the picture. The switch with the knob missing is the 4-to-6-channel switch which is never changed, since we have operated only with four channels up to this time.

The punched tape produced by the outscriber is fed into the printer where the proper characters, including sign and space, are interpreted. The number of columns up to four can be selected by a switch. The method of determining when a character is to be interpreted as sign or space is to use a contact on the carriage to sense the position of the sign. The space or carriage return always follows the sign.

The paper tape can also be used to punch cards. This operation merely makes square holes out of round ones. Two different units are used. The first one is a card punch ordinarily used for manual punching from a keyboard. A Flexowriter reader and a system of relays for code conversion were added. The other tape-to-card unit required only very minor alterations for use with SEAC. The first one was modified only because this commercial equipment was not available at the time.

Operational Experience with SEAC

ERNEST F. AINSWORTH

The input-output to SEAC is principally accomplished with magnetic wire, and to the best of the author's knowledge no other computer in operation at this time uses this means. Of course, it is much faster than Teletype tape; it takes 17 minutes to load the high-speed memory from Teletype and this can be done in 10 seconds with the wire cartridge. But it also has many other factors in its favor when compared to other fast methods.

It is extremely convenient to carry to and from the machine. At present The Laboratory has 250 of these cartridges and each operator has several to contain his codes and results.

A cartridge can contain a fairly large amount of information, about 14,000 words. This is enough to load the high-speed memory many times and is the equivalent of over 7 hours of Teletype tape reading. Many programs may be put on the same cartridge, so the position indicator on the face of the cartridge makes it easy for the operator to select a given program. One other device which has been found to be useful is the loud speaker connected to the amplifier. This enables the operator to detect the location of the information exactly and also seems to give him a sense of satisfaction when he is able to hear something going on.
The wire units are comparatively inexpensive. They consist of commercially available parts with some modification.

This system has been in operation about a year and a half and we are fairly well pleased with its performance. No statistics have been recorded on the failure rate of these units, but it is low enough so that very little thought is given to them, and operators are mildly annoyed when they fail to work the first time. Since there is no checking of input-output in SEAC a summing technique is used to detect read-in errors. After the machine has taken in information, it is instructed to sum up all the information just read in and print out the sum. If the sum is correct, it is allowed to continue; if not, the information is read in again.

One of the objectionable features of the equipment as it is presently used is the long start-stop time. It takes over one second for the wire to attain full speed. When first installed, the start was much faster but this resulted in many broken wires. It did not appear possible to overcome this difficulty without considerable modification of the original equipment, so slower operation was employed. It was not the jerk of sudden starting that broke the wire, but the operation of the clutches threw out a slack loop when the wire stopped. When started again the wire developed a kink and broke. Plated wire breaks very easily when kinked.

Wire breakage is one of the troubles with a system of this kind. Sometimes it is due to operator error, sometimes to mechanical failure. Often it is impossible to say which. At any rate, it does not happen very often and we do not consider it a serious objection. In a 6-month period, about 10 to 20 wires break, out of the 250 cartridges in use. When the wire does break, the cartridge can be rewound with new wire or the old wire can be spliced and used, if the spliced area is avoided.

Experience with the type of tape units described by J. L. Pike shows that they possess many good qualities. One thing they definitely prove is that it is certainly possible to get fast and reliable start-stop times without complicated and high-power servo systems. These tape drives are also comparatively inexpensive and easy to construct. They require very little maintenance. The part that wears out most quickly is the ball bearing in the jam roller. They are held in place by one bolt and usually last 2 to 3 months. Sometimes the tire on the jam roller wears and develops flat spots. Since the use of nylon was introduced for these tires, it has been necessary to resurface one tire in about the last six months.

At present, the tapes are being run at 60 inches per second and printing at 110 pulses per inch. The tapes run quite well at 10 feet per second, but at present the computer cannot receive pulses as fast as this would present them. The amount of information that can be put on a tape depends on the manner in which it is recorded. When it is desired that the tape be able to stop between batches of information on it, enough blank space must be left for it to be able to do so. This space is left on in the printing operation by delaying the printing until the tape has had time to move sufficiently. SEAC can print or read, at most, eight words per instruction. If the program calls for more information than eight words at a time, there is no point in leaving this blank space every eight words since the tape is to keep on running. The computer is constructed so that the programmer may state in the instruction whether he wants this space left or not. We call printing without these spaces 'compressed' printing. Using compressed printing, a 600-foot tape takes 12,000 words; with uncompressed printing, it takes 8,000 words. The entire high-speed memory can be read in or printed out in less than five seconds.

Since SEAC does not check its input-output, it is necessary to put checks in the program. One way to do this is to reverse over the information immediately after printing on the tape, read it back in, and check with what is still in the memory. A shorter way is to have the last word printed be the sum of the previous words. Then each time the information is read in, it can be summed and checked. If the sum shows an error, the computer can back up and try it again with a very small loss of time. This will usually be successful as almost all of our errors are reading errors caused by missing a digit. We have had reported runs of five and six hours with no errors at all. This is with the use of commercially available tape and home-recorder quality heads. There has been a negligible amount of trouble due to flaws on the tape. This we believe is because a
1-to 8-inch channel width is used and because of our use of the tape scraping process previously described by J. L. Pike. After the tapes have been scraped, we print them from one end to another and examine them for any bad spots, but we reject very few.

When this type of tape unit was first used, there was trouble with the tape becoming electrostatically charged and sticking to the side of the tank. Radio-active material was inserted in the tank to help the charge leak off. This was an improvement, but was not very effective at speeds much over 3 feet per second. A tape with a conductive coating was tried and this eliminated the trouble completely. In fact, it eliminated it so completely that it now contributed to our present large difficulty involving creases in the tape.

The tape falls to the bottom of the tank so readily that the tape on the bottom is creased by the weight of that above it. These creases cause the tape to be held away from the head, resulting in smaller than normal pulses.

This is by far the worst trouble with the tape units. It has been found to be related to how much tape is in the tank and how long it is left there. At present we are putting only 600 feet of tape in a unit and we find we must replace it in 1 to 2 weeks. Neither of these requirements prevents profitable operation, but it is hoped to improve the situation. The problem is being attacked from two directions: (1) trying to keep the tape from being creased, and (2) improving the ability of the units to read through a crease.

To prevent creases, one of the methods tried was to tilt the unit to about 40 degrees from the horizontal, so that part of the weight of the tape was supported by the sides of the tank. This helped, but not very much. Another method being tried is to put projections in the tank as shown in Figure 1. As may be seen, part of the tape rests on each support and no part of the tape has to bear the weight of very much tape above it.

This helps quite a bit. It is found that tapes can be left in this unit for 3 or 4 weeks as compared to 1 or 2 weeks in the other units. We are also looking for tapes with different types of plastic bases, hoping that one may be found that is more crease-resistant.

To the problem of making the tape unit put up with more severe creases the approach has been to improve the way in which the tape is held against the head, putting more pressure on the tape right at the gap, where it will do the most good. Results on the test bench look quite promising, but it has not yet been put into operation on the computer.

Perhaps a clearer picture of the operational characteristics of the wire and tape units will be obtained from a description of how they are used in the solution of a particular problem. The problem chosen as typical is the finding of a minimum solution of a 50 by 72 matrix, subject to certain conditions. It is solved by the simplex technique, and the same code is used for a matrix of any size up to 50 by 72.

The first phase is a preparation phase. The instructions are read into the machine from wire in about 8 seconds. A cartridge containing the data for the problem is now placed in the wire unit. In a typical problem it contains about 500 nonzero elements. The computer now reads in the data 8 words at a time, transforms them from binary coded decimal to binary, arranges the data in suitable order, and inserts the zero elements. They are now printed out on one of the magnetic tape units and checked by reading back into the computer and comparing with what is still in the memory. Around 4,000 words are printed on the tape. The time consumed by this phase is:

Wire data read in .................. 2 minutes

Computation .................. 4 minutes

Print and check tape ........... 3 minutes

9 minutes

The actual solution of the problem is done in the second phase. This consists of processing the data a number of times until a solution is reached. Each data processing performs the following operations: 56 words of data are read in from one tape unit, are operated on by the machine, and then printed out on a second tape unit. The output data from this processing become the input data for the next one. One of these processing cycles takes the following time:

Tape running .................. 3 minutes

Computing ............................. 2.0 minutes

Teletype printing .......... 0.25 minute

4.75 minutes

The number of times it is necessary to go through the processing cycle to get a solution depends on the problem. The simplex method of solving approaches the answer progressively. The number of cycles required cannot be determined beforehand.

Assuming that the cycle is gone through 72 times, this phase of the problem takes 72 by 4.75/60, or 5.75 hours. About 52 per cent of the time is tape-running time.

The final phase of the problem is the checking and presentation. The answers are substituted back into each of the 50 original equations to see if they satisfy. Results are changed from binary to binary-coded decimal and printed out on Teletype:

Tape .......................... 1 minute

Wire .......................... 6 minutes

Computation ................. 3 minutes

Teletype ......................... 7 minutes

14 minutes

There have been quite a few problems of the type just described actually run on SEAC.

It is the belief of the author that the experience with SEAC described in this paper shows that it is possible to construct from commercially available components some comparatively inexpensive input-output devices which are of somewhat modest performance but reliable and certainly useful for computer applications.

Discussion

W. H. MacWilliams (Bell Telephone Company): I have heard speakers referring to a Dyseac. I assume that this is an automatic computer. Can you tell me what else it means?

S. Greenwald (National Bureau of Standards): The reason for the particular term has to do with the sponsoring agencies and the purpose of the computer. It is a new computer that is coming along well. It is built somewhat along the logical lines of SEAC, but uses the printed wiring described in Miss Haueter’s paper. It will be a good deal more powerful than SEAC, in that it will permit input, output, and computing functions to go on simultaneously. It will also be a good deal easier to maintain, we hope, because of the plug-in features.

H. F. May (Teleregister Corporation): What is the technique used to eliminate static charges on the lucite plate in the tape storage unit?

J. L. Pike (National Bureau of Standards): They are coated with a product, known as Photosweep, which can be purchased in photo equipment houses. The composition of it I know nothing about but when sprayed on lucite, it eliminates completely static charges and seems to wear forever. We have had no trouble with it.

Mr. MacWilliams: What work have you done on multichannel recording?

Mr. Greenwald: For some time, we have been experimenting with multichannel recording. For this purpose, we have used a Raytheon-type mechanism similar to the one described by Mr. Snyder. In this par-
ticular equipment, we use five channels of information, and one sync channel. We have not considered it a high-priority job, because we felt it was more important to get some of the other equipment working, and working well. However, we do intend to incorporate one of the multichannel units in SEAC in the very near future. We hope it will work out.

C. T. Schaede, Jr. (Consolidated Vultee, Fort Worth Division): Using the miniaturized printed circuit technique for your components and packages, have you ever had trouble with the component failing during actual computer operations? You described part of your developed circuit technique for your packages. Do you have trouble with reliability of the components for using the printed circuit?

Miss Haueter: I mentioned the fact that the printed circuit package would be used in Dyseac. We are not using it in any of the equipment we now have. The off-subscriber shown was a hand-wired unit. The situation should not change in printed circuits any more than in hand-wired circuits. We would expect the same failure that is obtained in anything that uses dials, tubes, and transformers.

Mr. Schaede: Did I understand you to say that you did not remember an error ever having occurred? That would indicate you have had no component failures during the computer operation.

Miss Haueter: I stated that I know of no error that got through our error-checking circuit.

Mr. MacWilliams: A nice distinction.

O. Whiteby (Stanford Research Institute): I wonder whether any of the speakers can tell me whether they can distinguish between misreads from the tape due to dust and those due to kinks?

Mr. Ainsworth: We have no way, at the moment, of telling if they are dust or not. When we first hooked up the equipment, we looked for kinks when we had errors; we almost always found them there. I do not think dust would cause as much trouble with the 1/8-inch channel width that we use on the present tape system.

R. C. Boe (Cook Electric Company): Will Miss Haueter elaborate on this method of synchronization?

Miss Haueter: Our basic repetition rate is 1 megacycle. We use the dynamic flip-flops, which means when a flip-flop is turned on, it continues to put out pulses at a 1-megacycle rate, until something turns it off. Therefore, there is no conflict. It continues to put out pulses until something occurs later on, even though what has happened is at a very low rate. The actual synchronizing process which I referred to consists of generating a single 0.5-microsecond pulse from a longer pulse which occurs asynchronously with the clock. This is a somewhat more difficult problem which I had hoped to discuss, but did not have time.

The UniServo—Tape Reader and Recorder

H. F. Welsh

H. Lukoff

A practicable method of obtaining adequate input-output speeds for digital computing devices is the high-speed tape recording method, but the designing of a good tape system has been, to say the least, extremely difficult. In this paper, the history of the development of UniServo, the Univac tape transport device, will be briefly sketched.

The need for higher speed input and output devices became apparent as soon as the idea of electronic computing was projected. Among the early objections to computers, the more farsighted pointed out that, even if a machine could be made, its use would be severely limited by inability to converse with it at appropriate speed. It was realized at the time that a great deal of development work on input and output devices was necessary before a satisfactory commercial computer could be built.

It was fortunate that the first Univac contract was with the Bureau of the Census. The Census problem demands large quantities of conversation and therefore the computer, to be useful, had to have extremely high speed input and output equipment. The final specifications for the future UniServo were decided upon with the Census problem in mind, yet without making the computer in any sense a single-purpose device.

The most important aim in speeding up input and output operations was to have them interrupt the computer as little as possible. With this established, certain decisions became immediately necessary.

First, it was decided that input and output operations should take place in two separate steps. For input, the preparation of tape takes place apart from the computer, in a Unityper or card-to-tape converter. Reading of data from tape into the computer takes place at higher speed on a UniServo. For output, the computer records on tape by way of a UniServo but the printing of the data takes place apart from the computer on a Uniprinter.

The second decision was to tolerate no speed less than that obtainable with high-density multichannel magnetic recording. Here was envisaged the UniServo, a tape transport device recording parallel channels on magnetic tape. The following performance characteristics were predicted:

- Speed: .120 inches per second
- Pulse density: .100 pulses per inch
- Instantaneous conversation rate: .12,000 decimal digits per second

The third decision was to make all input and output operations automatic, that is, to have all UniServo operations initiated by programmed instructions in the computer memory. In view of the fact that the speed of reading and writing on tape is slow compared with the speed of electronic operations, it was decided to include separate control circuits for input-output operations. Consequently, the computer circuits do not have to be tied up all the time the UniServo is in operation. In fact, there are only two functions which require the cooperation of the central computer control circuits:

1. Instructing a UniServo to read or write.
2. Transferring from an input register to the memory or from the memory to an output register.

For the input instructions, the logical sequence is to read from tape and then transfer from the input register to the memory, but this would require the com-