between tape and box varied with the length of the loop.

In a free-loop system it is difficult to find a satisfactory way to keep the tape tight against the head. This requires that the tape be pulled across the head against a drag or pressure pad. Two center drive capstans are necessary, one to pull in either direction. Moreover, these capstans must be of the pressure-roller type. It was found that such capstans roll dirt particles into the tape and cause weak signals. In the prototype the tape was pressed against a flat head by a pressure pad. It was found that the pad required excessive pressure, wore the head unevenly, and got the tape dirty. In later designs, the whole tape was put under tension by spring-loading the loops and applying a small amount of opposing torque to the reel motors at all times. The head pressure problem was solved by bending the tensed tape around a curved head.

At first, the loops were put under tension by tying long rubber bands, used because of their low inertia, directly to the floating loop pulleys. It was found, however, that the rubber bands deteriorated when the Uniservo was left in the sun on hot summer days.

Figure 12 shows the essential mechanical features of the present tape panel. It was noticed that the equal and opposing motions of the loop pulleys could be tied together. An equalizer bar was made to tie the loops together, and tension was applied to the equalizer bar. With this device, a spring could be used rather than a rubber band, because it was out of the high acceleration system. The spring moves hardly at all, and does not load the center drive.

A block-and-tackle arrangement with a mechanical advantage of three connects each loop with its synchro arm. This reduces a long travel of the loop to a short travel of the synchro arm. It also buffs the inertia of the synchro arm out of the loop system, because the loop sees only one-ninth of that inertia. The motion of the two synchro arms, like that of the loops, is equal and opposing. Like the loops, the arms are connected through an equalizer system.

Some features have been designed into the machine to facilitate the changing of reels. The entire process now takes less than 20 seconds. A tape leader keeps the Uniservo threaded and under tension. The tape is connected to the leader by means of a simple clip joint. It is not possible to mount a reel backwards.

A master reel system has been designed as a safeguard against the erasure of valuable data. If a master reel ring has been placed in a reel, it contacts a microswitch on the Uniservo. The switch prohibits writing on (and therefore erasing) the tape, but permits reading from the tape.

There were many other interesting problems in the design of the Uniservo, but the limits of this paper prohibit their discussion. It should be pointed out, however, that not all of the circuits discussed are duplicated for each Uniservo. Our aim has been to use the minimum amount of circuitry consistent with reliable operation. The counters which count off 720 digits are in the common input and output synchronizers, not in the separate Uniservos. The bad-spot detector circuits are also associated with the synchronizers. Power supplies are common, head drivers and amplifiers are common, even part of the center drive control circuit is common. Each Uniservo in itself contains little more than a magnetic head, a bank of relays, and a servo-following tape transport system.

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**Input Devices**

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*There are three separate means for input to the Univac central computer. The first and most direct is a keyboard directly connected to the computer. With this keyboard small amounts of data are inserted into the computer, one word at a time. This direct input is used chiefly for computer operation, maintenance functions, and program alteration. The other two means for input make use of magnetic tape and the Uniservos. These are the card-to-tape converter described in another paper, and a keyboard-to-tape transcription known as a Unityper. This latter device, discussed in this paper, transfers data directly from source documents onto magnetic tape.*

A typist with little special training can operate the keyboard of a Unityper much as she would a typewriter. As she types, digit by digit, the Unityper records the corresponding Univac pulse code combinations on tape. Data on tape are then ready for Univac use as soon as the reel is transferred to a Uniservo.

These principal requirements of the keyboard-to-tape transcription function dictate the basic units shown in the diagram in Figure 1. First, the device must be able to accept random inputs from the keyboard and encode them in Univac code. Second, the digits must be recorded on tape as densely as possible, and uniformly spaced. Therefore, the tape must step discretely as each character is typed.

Furthermore, since typists sometimes make errors and therefore must erase, the necessity for erasure places the most stringent requirements on the tape transport system. Erasing on tape is accomplished by back-spacing while the recording head records zeros, but this backward step must erase only the incorrect character and must not overshoot into the next previous character. Also, the new character when entered must be positioned on tape exactly where the incorrect character was. Thus forward and backward steps must be equal in length.

The operating cycle starts with a signal from the keyboard. This signal is encoded in a 1-to-8 line encoder which drives the eight channels of the recording head. A secondary keyboard signal also pulses the tape transport system and the tape steps. As the tape moves, the pulse combination is recorded.

In the Unityper, shown in Figure 2,
each key operation discharges a capacitor into a resistor matrix encoder, which sets up the combination in eight unit memories. At the same time, a keyboard signal steps the tape 1/20 inch and sets a duty cycle delay flop. This delay flop, a monostable trigger pair, is used to delay the keyboard pulse while recording takes place. Before the tape stops moving, the delay flop recovers and clears the unit memories. As soon as the tape stops moving, the Unityper is ready for the next character.

The data being typed must be arranged in computer format, 60 12-digit words to a block with 2.4 inches of blank tape between blocks. While the typist is entering data it is essential that she know her position within this block. For this reason position-indicating devices, including digit and word counters, and block-beginning and block-ending detectors, are built into the Unityper. The counters are disks appropriately geared to the tape drive. These disks are calibrated to indicate to the typist the number of the word and digit just recorded. The block-ending and block-beginning detectors are cams driven by the tape drive. These cams operate switches at the beginning and ending of each block.

The block-ending switch lights an indicator lamp and prevents further typing until the space between blocks has been recorded. The block-beginning switch lights an indicator and prevents back-spacing into the space between blocks.

To nullify any attempt to record a second digit before the recording of the first has been completed, a typing rate limiter blocks the normal path of the keyboard pulse and completes a path to the error line for 65 milliseconds after each key stroke. If another keyboard pulse is generated during this period, the error circuit is energized.

This error circuit consists of a thyatron-driven relay. Contacts of the error relay disable the Unityper for anything except an erase operation. Operation of the erase key steps the tape backward to erase one character and clear the error circuit. Once the error circuit has been cleared, successive operation of either the erase or the back-space key erases the tape, digit by digit. However, it is imperative that erasing be limited to the 60-word block of information currently being typed. For this reason the block-beginning detector disables the back-space and erase circuits and lights a block-beginning indicator lamp after the first digit of the block has been erased.

Typing within a block takes place at normal typing rate. As a time-saving feature, an automatic operator which can execute repetitive operations at 20 characters per second is included in Unityper I. This automatic operator, controlled by the block-ending and block-beginning detectors, provides a recycling circuit for the keyboard pulse.

The first function of the automatic operator is to record on tape the 2.4-inch space between blocks required by the universo. Operation of a blanking key coin-
incident with a signal from the block-ending detector generates a keyboard pulse and inhibits the unit memories. The pulse steps the tape and recycles through the automatic operator to step the tape again. After 48 steps, the block beginning detector inhibits the blanking circuit at all times except at the end of the block. If the typist tries to enter a 721st digit or if she strikes the blanking key prior to the 720th digit, the keyboard pulse is channeled into the error circuit.

A second function of the automatic operator arises in connection with the Computer block length. In case data do not completely fill a block, some Univac symbol must be inserted to fill in the remaining space. Completion of such a block is done on the Unityper by a skip operation. Depressing the skip key starts a pulse circulating through the automatic operator, stepping the tape forward repeatedly as in the space between blocks. But during this operation the Unityper records a digit called 'ignore.' The block-ending detector terminates this operation. These two automatic features alone provide considerable speed gain over digit-by-digit operation since they can be performed at a speed of 20 digits per second. However, a study of computer routines and data indicated that more frequent check points similar to block ending would be desirable. Material of this type contains many items of different lengths called fields. The conclusion was that check points inserted within the block length as required by the data would greatly increase the speed and accuracy of the equipment. A check point at the end of a field could prevent further typing if the typist should attempt to type too many or too few characters in that field. Another type of check point similar to block beginning at the beginning of the field could limit erasure to that field.

This extension of the automatic functions was included. It is controlled by a punched paper tape stepped in synchronism with the magnetic tape. The paper tape is photoelectrically examined after each step. Each of the eight possible holes has a different meaning to the automatic operator. The paper tape is prepared according to the needs of each specific program on a special tape-punching machine. The two ends of a given tape are cemented together and the resulting loop is placed in a control-loop reader as shown in Figure 3. This loop reader is a plug-in assembly containing a motor which drives the tape by means of a sprocket wheel, and photoelectric cells and exciter lamps which search for holes in the paper tape. The loop controls the automatic operator by relays driven by the photoelectric cells.

For example, a typist frequently omits a character from a field or types an extra one. The loop system detects this type of error as follows: A particular hole punched in the paper loop at the end of a field energizes a forced-check relay. As its name implies, this relay forces the typist to check her position. It does this by blocking the normal circuit of the keyboard pulse and completing the path to the error circuit. To proceed, the typist must strike the control bar on the keyboard. In so doing she releases the forced-check relay. If the typist attempts to enter another character without first releasing the forced-check relay, an
error is registered; striking the control bar prior to a forced check point also registers an error.

As already stated, the error circuit can be cleared only by an erase operation. Under control of the loop, erasing is repetitive and continues back through the current field. A stop punch at the successive fields can be erased by successive registers an error.

The recording is terminated by a stop punch.

To make the loop program independent of computer block length the loop-stepping circuit is inhibited during the space between blocks. Thus a field of computer block length the loop-prepared specifically for a given type of input data. However, some copy requires more than one sequence of control punches. Therefore, the loop system was extended to include three separate control loops. The typist can either type in the no-loop condition, that is, free of loop control, or she can call in any one of three loops as required by the data.

Change from one loop to another or to no-loop must be programmed on the loops to ensure completion of the current field before leaving the loop. Therefore, even loop changeover points are governed by the loop.

So far, this discussion has dealt with the problems inherent in the keyboard-to-tape transcription function itself. But, as is usually the case, each such problem when solved generated several more of a new breed. The new generation of problems were specific ones of circuit, mechanical design, and construction. Among these there are a few that warrant description because they represent successful working solutions to problems that face all designers of this type of equipment.

The resistor matrix encoder is of interest chiefly because its construction is ingenious and admirably adapted to sub-assembly production (see Figures 4 and 5). Fifty-one separate input lines are required between the keyboard and the encoder, while only eight output lines go from the encoder to the unit memories. The encoder should be placed physically close to the keyboard. In fact, it is housed on the back of the keyboard unit in a space 1 3/4 by 12 by 7 1/2 inches. The eight output lines connect to the rest of the equipment via plug-in cables.

The basic construction is simple. Two predrilled bakelite sheets are mounted on 1 3/4-inch spacers. Across the long dimension run 51 input lines from the keyboard. Holes drilled below a given line represent binary ones in the code for the character represented by that line. Both sheets are drilled with the same pattern.

Across the short dimension of the output side of the encoder run the eight output lines. The matrix is wired up simply by placing resistors between corresponding holes, soldering one end to an input line, and the other to an output line. The entire array is folded back on itself to conserve space.

The resulting array is pulsed from the keyboard by discharging a condenser into one of the input lines. A pulse on an output line fires its corresponding unit memory thyratron, as shown in Figure 6. The thyratron anode circuit consists of a voltage-dividing network between 150 and 75 volts. Circuit values are adjusted so that 33 milliamperes normally flow from the 75-volt source through the head to the 150-volt source maintaining the mid-point of the divider at 76.2 volts. This current generates sufficient flux in the head to saturate tape to binary zero, that is, to erase polarity. Firing of the thyratron upsets the voltage divider and drops the mid-point voltage 2.3 volts to 73.9 volts. Under these conditions, current through the head coil reverses to 33 milliamperes in the opposite direction. Resulting flux saturates the tape to the binary 1 polarity. The
thyratron is cleared when the duty cycle delay flop recovers and opens the clear relay contact in the cathode circuit.

The logical and the physical conditions imposed on the tape transport system made this unit an interesting design problem. As pointed out previously, the tape must move in discrete measured steps forward or backward in response to random input pulses. Furthermore, in the case of automatic operations, high-speed stepping on the order of 20 steps per second is required.

Obviously, the solution to this problem was not simple. It was necessary to devise a means to accelerate a mass of tape to recording speed, record on tape, and then stop the tape, all in 50 milliseconds, to achieve the 20-digit-per-second rate.

The first step in the design was to minimize the mass of tape to be accelerated by using floating loops of tape to control the reel motors as shown in Figure 7. As in the Uniservo, the center drive empties or fills a floating loop of tape. The reel motors are both energized during operation. Reel motor brakes are controlled by this loop. A cord runs from each loop pulley through the panel to operate the reel brakes. As the supply loop shortens, it releases its reel motor brake and the reel takes up tape. Thus the loops are kept at optimum size and the center drive sees only a few inches of tape as its load.

The center drive capstan can be seen projecting through the tape panel just below the digit counter disk, as shown in Figure 7. Mechanical means for stepping this capstan were first considered. Among the ideas in this connection were the use of Geneva gears and a solenoid-operated ratchet system. But the precision required, the 2-direction stepping, and the random response features made such systems impractical. Wearing of parts in most such systems would have quickly changed the length of the step.

While this problem was under consideration, the General Electric Company brought out a 96-pole permanent magnetic synchronous induction motor for use as a remotely controlled slave motor. It was recognized that this motor, if pulsed correctly, would step from one stable position, with respect to the field, to the next. A circuit was designed to do this in response to a keyboard pulse as shown in Figure 8.

To hold the motor in a fixed position, one of the two fields is supplied with +90 volts via a relay contact. In the meantime, a capacitor connected to the other field charges to +90 via a second relay contact. Both relays are energized simultaneously when a keyboard pulse sets the first of two delay flops. Unlike the trigger pair used to control duty cycle these delay flops are not used to delay the pulse. Instead, they provide a static output to energize the relays for their delay period. In changing position the d-c relay reverses current through the d-c field, while the capacitor discharge pulses the other field and the armature turns. The relative positions of armature segments and field poles, and the direction of currents, determine the direction of rotation. See Figure 9.

In the static condition, half of the d-c field poles are aligned with armature segments and the other half are aligned with the armature spacers. Since the two halves of the field are excited 180 degrees out of phase, this is a stable position. The capacitor fields are also 180 degrees out of phase, each 90 degrees out with respect to a d-c phase. Furthermore, one set of capacitor field poles leads its corresponding armature segment faces by one-half of a segment, and the other set lags by one-half of a segment. This offsetting of the poles biases the motor to fix direction of rotation. When the relays are energized, there is a reversal of current through the d-c field, a pulse is applied to the capacitor field, and the motor steps clockwise. The capacitor field is disconnected after 8 microseconds and the d-c field is reversed after 12 microseconds. The extra 4 microseconds on the d-c field prevents overshoot.

The reverse stepping problem is solved simply by switching the fields of the motor by means of the reverse relays. In this case, the original d-c field becomes the capacitor field and conversely. This is done by operating the erase or backup key, either of which energizes the reverse relay and generates a keyboard pulse. However, before the pulse arrives at the stepping circuits, the reverse relay contacts reverse the field potentials, and the motor steps backward one-fourth of a step. Some time later, the keyboard pulse operates the stepping circuits as in forward operation and the motor steps backward one full step. Still later, the reverse relay drops out to restore the original conditions and the motor then steps forward one-fourth of a step to the lock-in position it held before the error was made. This controlled one-fourth step overshoot ensures complete erasure of the incorrect character. Effectively, this system is a high-precision 2-way escapement. Physical wearing of parts is no problem, and the speed of operation can be controlled by delay flop timing.

To avoid superposition of recorded digits caused by failure of the tape motor to step, a tape movement checker (Figure 10) is employed. This checker includes a relay binary counter which changes state every time the motor-stepping circuits are energized, and a relay which changes position every time the motor actually steps.

This latter relay is energized by a photoelectric cell. On the shaft of the center-drive motor is mounted a disk with 24 equally spaced holes. A photoelectric cell searches for holes in the disk. Since the motor steps 1/48 of a revolution per digit the photoelectric cell will find a hole on alternate steps. A change of photoelectric cell output is positive proof that the center drive has advanced. When illuminated, the photoelectric cell output energizes the tape relay. This arrangement is half of the checker. The relay binary counter forms the other half.

The relay binary counter is shown in Figure 11 with all relays de-energized, a condition defined as zero. When the binary counter relay is energized by the motor-stepping circuits, its contact energizes relay 1 in the binary counter circuit. Contacts 1-1 and 2-1 close the holding circuits for their relays. Contact 1-2 prepares an energizing circuit for relay 2. When the binary counter relay drops out, it energizes relay 2. Contact 2-2, when energized, prepares a clearing circuit for relay 1. With both relays ener-
The output demands placed upon an electronic computer vary considerably with the type of problem being performed. In order to achieve the widest possible latitude in this respect, the Univac System incorporates three different output devices, each of which serves its purpose when required. Such a design may at first seem merely a matter of convenience, yet the more important consideration is to avoid the use of higher powered equipment for small-sized tasks. The output typewriter directly associated with the supervisory control desk is used for writing out the smallest amounts of output data. Its principal use is for computer testing, straightening out program routines, for program-to-operator functions where certain directives to the operator are put into the routines for 'on-the-spot' action by the operator, and, in the case of certain special problems, for very limited amounts of actual problem data output.

Next to the control printer stands the Uniprinter, which is the principal output means at the present time. The Uniprinter is a magnetic-tape-operated typewriter and achieves speeds of 10-12 characters per second. This device was intended to be an intermediate device but has, so far, satisfied many situations. If large output is demanded, parallel operation of the necessary number of Uniprinters can always be undertaken.

The high-speed printer represents the third and highest speed output device and, although still in development, is the logical fulfillment of the demands arising in problems where extremely large volumes of output data are encountered. A complete array of output equipment will shortly be available to the Univac user.

When the plans for the Univac output devices were made, it became obvious that certain unit assemblies would be desirable. The first unit was the printer assembly shown in Figure 1 at the right. This unit contains the typewriter, with electrically operated actuators and a relay-type decoder. This unit can be operated from the tape-reading unit, shown at the left in Figure 1, so as to make a Uniprinter or it can be connected to the supervisory control desk where it then serves as the directly connected typewriter-printer.

Finally, it is basically the same unit which, with the addition of two chassis, can be connected to a Uniprinter to obtain a printed copy of what has been recorded.

A simplified block diagram of the Uniprinter is shown in Figure 2. The basic operating pattern is cyclic. Operation is started by an initiating pulse from the start switch. This pulse supplies the 'go' signal to the tape drive motor. The tape moves across the 8-channel head at about 2 inches per second. As soon as any combination is detected in the eight unit memories, a signal is generated which passes to the 'stop' input for the tape motor drive system and into the decoding delay. Whatever signals have been set up in the eight unit memories are decoded in a relay-type decoding function table. This function table is a folded whiffletree arrangement which has permitted the decoding of the 6-channel remainder of the equipment is housed in a 6-foot cabinet. At the top of this cabinet is the tape transport equipment and the recording head. Below this is the control panel which contains switches and indicator lamps for the error, block-ending and block-beginning circuits. Below this panel are the electronic equipment chassis and power supplies. A printer, which is described in the paper on output devices, can be connected to the Uniprinter if printed copy is desired. Through the three windows in the control panel, the control loops are visible to the typist. Thus, from her position at the keyboard, the typist has complete control of the transcription process.