A Laboratory Model Magnetic Drum Translator for Toll Switching Offices

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A laboratory model magnetic drum translator, capable of serving as a one-to-one alternative to the card translator, has been built to study the problems arising from the prospective use of microsecond pulse apparatus in a telephone office environment. Electron tube amplifiers and germanium diode logic circuits supplement the drum information storage unit to provide the functional operations required. Results of preliminary laboratory tests indicate the feasibility of equipment of this kind for telephone switching control.

INTRODUCTION

The magnetic drum is one of the most widely used of the modern large-capacity digital-data storage devices. It is used as a memory unit in many of the present-day large-scale digital computers and in other applications such as inventory control of airline ticket reservations and traffic control of airplanes in flight. Two of the properties of drums as storage media have been considered particularly advantageous. One is the capacity to store up to several hundred thousand bits of information in a compact space at a low cost per bit; the other is the ability to keep the information in an easily alterable but nonvolatile form unaffected by power failure or other interruptions of operation. In terms of the speed with which information may be stored or recovered, drum memories fall near the middle of the present-day spectrum; they are very much faster than punched paper tape or groups of telephone relays but are considerably slower than cathode-ray tube or ferromagnetic-core storage devices. All of the information stored on a drum may be read out during the course of one complete revolution and, similarly, new information may be entered anywhere in the storage space within the time of one revolution; thus the access time is ordinarily of the order of a few tens of milliseconds.

It has already been pointed out[1] that automatic telephone switching offices bear a generic resemblance to digital computers and it is therefore not surprising that the magnetic drum has engaged the attention of telephone engineers, since the speed and flexibility of such a device offers much promise in connection with forward-looking telephone office design. One system has already been described[2, 3] involving the use of magnetic drums for telephone switching control applications in an entirely new form of telephone office; it is the purpose of this article to describe another application of less complexity which could function in cooperation with equipment in existing telephone offices.

The standards of reliability and ruggedness which must be met by any equipment proposed for Bell System use are in some respects a good deal higher than those imposed on other commercial sytems such as digital computers. Thus when a new type of apparatus such as a magnetic drum and its associated electronic components is considered for a telephone job, it is necessary to determine whether the apparatus is capable of being designed to meet these stringent requirements. This was judged to be the most important objective of the undertaking about to be described, and it strongly influenced the choice of experimental application for the drum.

The program which the designers set for themselves to determine the possible suitability of the magnetic drum type of equipment might be summarized as follows:

(1) Choose an existing telephone application in which a magnetic drum system can receive a satisfactory work-out without disordering the system.

(2) Design a magnetic drum system to work cooperatively with existing office equipment, using existing power facilities. Assume that the design is aimed at practical application so that due regard is given to operating economies, and protection against power failures.

(3) Construct a full-scale model following the design, and test the model in the chosen environment long enough to determine the failure rate and the reasons for each failure.

(4) Evaluate the results in order to determine the sphere of usefulness, and the proper design philosophy for applying magnetic drum systems of any kind in existing telephone offices.

One telephone switching application which meets the qualifications of (1) above exists in the new No. 4A toll switching offices. Here, due to the demands of nationwide dialing, a large-scale translation function is required to convert destination codes into information which will properly route each call. The volume of information which must be stored for translation purposes, and the relatively rapid access desired, fall close to the optimum parameter values of magnetic drum systems. The action takes place in cooperation with crossbar and other relay-type switching equipment typical of the present-day telephone office, thus providing an environment suitable for observing the behavior of fast pulse circuits in the presence of electrical disturbances. Finally, there exists a relatively new piece of apparatus which now performs the translation function, namely the card translator. Thus, if an exact one-to-one alternative for the card translator were constructed employing a magnetic drum, full advantage could be taken of the testing procedures already developed and a comparison could be made against a norm of performance; furthermore, a field trial would be possible, if desired, with a minimum of interference with normal operation of the telephone plant.

It was decided, therefore, to build a full-scale magnetic drum translator which could substitute for a card translator in order to obtain laboratory experience with apparatus of this type and to determine its adaptability to telephone standards and practices. The completed equipment is shown in Fig. 1. The equipment on the one frame illustrated is the equivalent in function and capacity of one card translator with its associated table. This magnetic drum apparatus is not aimed at replacing the card translator, which is a well-engineered device known to give satisfactory service in day-to-day operation. For evaluation purposes in this article, however, it is assumed to be competing with the card translator.

The following sections describe the design features and operating details of the translator which was constructed. A brief description of the card translator and that portion of the 4A office in which the drum translator must function has been included to provide the necessary background for the description. It will become evident that the requirement of interchangeability which necessitates a one-to-one equivalence with the card translator has imposed on the drum translator a number of restrictions which are not inherent in it. These tend to prevent full exploitation of the speed and code advantages which might be realized with the drum. Furthermore, the rapidity with which all of the information on the drum is presented on a continuous read-out basis would permit a type of centralized operation which will be touched on briefly and which would seem to offer apparatus economies not attained in the test model. None of these factors, however, impairs the usefulness of conclusions which may be drawn from test results concerning reliability.

SURVEY OF MAGNETIC RECORDING PRINCIPLES EMPLOYED IN THE TRANSLATOR

All magnetic drums have certain features in common: they consist of a means of moving a thin shell of magnetically-hard material rapidly

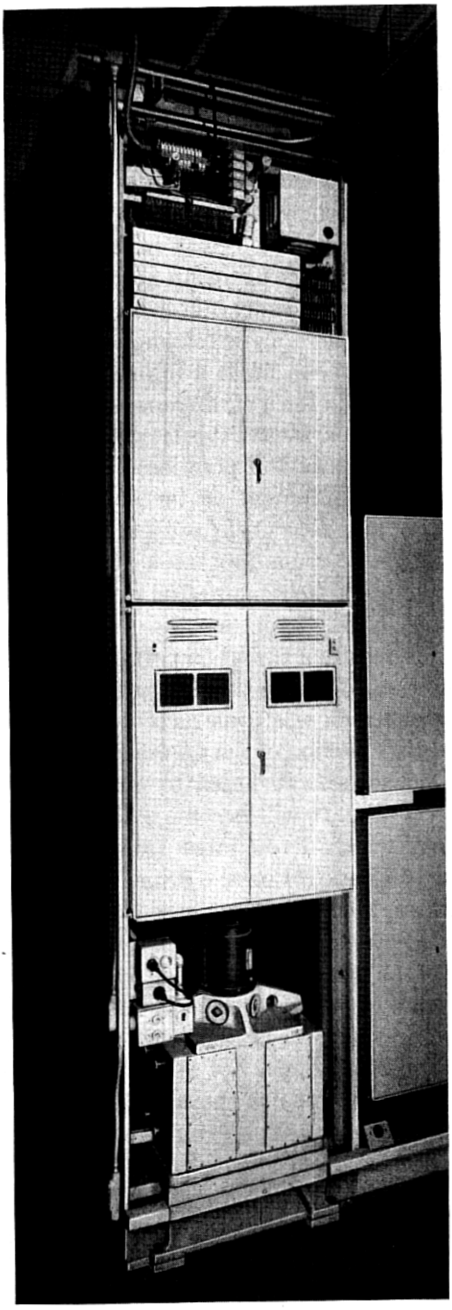


Fig. 1 — Magnetic drum translator, laboratory installation.

past one or more heads used for writing or reading digital data. Usually, as in the translator, the same head is used for both functions. In most drum-system designs the pole-tips of the heads are close to the recording surface but do not touch it, and the heads themselves bear a resemblance to those used in conventional magnetic sound recording, giving therefore, a "longitudinal" polarization to the medium as sketched diagrammatically in Fig. 2. There is very little further resemblance to sound recording, since digital information is stored in a binary or two-valued code which, on the translator drum, is represented by the two possible polarities of saturation of the magnetic medium. To one of these polarities is assigned the code value "*0*," and this condition prevails except where the opposite polarity is inserted to represent the code value "*1*."

It should be mentioned that several other systems have been devised which employ the two directions of saturation, sometimes accompanied by a general background of magnetic neutrality, to effect a greater concentration of digital information than that used in the translator. Systems other than the one chosen for this application were, for the most part, considered to be less reliable.

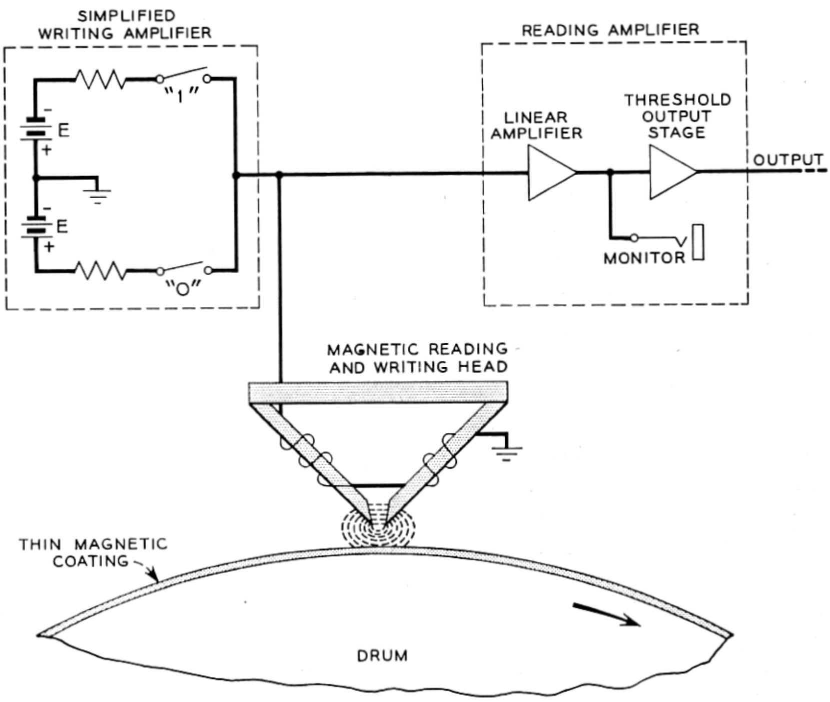


Fig. 2 — Simplified diagram of magnetic drum digital data storage system.

In order to facilitate an understanding of the action of the translator as a whole, a simplified account of the magnetic recording and reproducing process will now be given.

Magnetic Drum Geography

The circumferential strip of the drum surface which moves under the pole-tips of any magnetic head is commonly known as a *track*. On each track will be written magnetic perturbations or spots symbolizing "*1's*." It is essential that these spots be precisely located so that they may be readily removed or "altered." For this purpose a synchronizing track or some equivalent distribution of equally spaced identifying marks associated with the drum is provided. With the aid of the electronic circuits, the magnetic spots are restricted to a modular spacing defined by the synchronizing marks, and this module is spoken of as a "*slot*." On the drum surface, each intersection of track and slot is known as a "*cell*" and a cell may contain only one magnetic mark and therefore only one bit of information. As a matter of economics, the cell density should be as great as possible. The density which may be attained is determined by the degree of interference which can be tolerated among neighboring cells.

Writing Operations

The first step in preparing the drum to receive a recording is to uniformly magnetize the tracks to saturation in the polarity arbitrarily chosen to represent the code-value "*0*." This is a preconditioning operation required only when a drum is newly placed in service. Referring to Fig. 2, this may be done, for the typical head and track shown, by closing the switch marked "*0*" for the duration of at least one complete revolution of the drum. Enough current must flow through the windings of the head to establish the magnitude of fringing flux, from the pole-tips, required to saturate the thin magnetic coating. In the case of the translator drum, the coating is about ⅓ milli-inch thick; the clearance between pole-tips and recording surface is about 2 milli-inches; the interpole gap is also about 2 milli-inches at the tips, and about 20 ampere-turns of energization are required.

With the track thus preconditioned, there is virtually no output voltage from the head since the magnetization is essentially uniform and there is no changing flux threading the head to induce a voltage in the windings.

Whenever a "*1*" is to be written, a pulse of current from an electronic writing amplifier (indicated, for convenience, on Fig. 2 as a switch) is caused to flow through the windings of the head in a direction opposite to that taken by the preconditioning current. This pulse lasts for only two or three microseconds, and movement of the drum surface is negligibly small while the current persists. The peak value of the current pulse is sufficient to magnetize to saturation in the opposite direction that portion of the track which lies directly under the pole-tips at that instant. Areas of the track far-removed in each direction from the pole-tips of the head are, of course, unaffected by this operation, and remain at saturation in the original polarity. A region of transition in magnetization therefore extends in each direction along the track from the area directly under the pole-tips.

Fig. 3 illustrates some of the wave forms resulting from writing into and reading from four adjacent cells on one track of the drum. Line A shows the pulses of writing current which were applied to the windings on the head. These were caused to appear at precisely spaced distances along the track by the combined operation of the synchronizing system and an "administration" circuit. In cells 1 and 3 the writing current polarity is chosen so as to write "*1's*." Cell 2 remains in its original preconditioned state. In cell 4 a "*1*" was previously written but is now altered to a "*0*" by a writing current pulse of the same polarity as that chosen for the preconditioning operation.

Line B in Fig. 3 illustrates the resultant magnetic state of the drum surface as viewed by the reading head. The polarization portrayed as resulting from writing a "*1*" is a bell-shaped curve. When a "*1*" is selectively altered to a "*0*" the area of track directly under the pole-tips will be carried to saturation in the original preconditioned polarity. The whole cell area, however, cannot be affected so strongly, owing to the hysteresis properties of the coating material, and there will remain traces of the "*1*" type of magnetization near the cell edges, as indicated by the solid line in cell 4.

There is no difficulty in rewriting a "*1*" in a cell which has been subjected to the above described treatment. The procedure is that outlined for the original writing of a "*1*" and the results are practically indistinguishable from those obtained by writing in a virgin cell.

Reading Operations

On subsequent revolutions of the drum, the passage, under the pole-tips, of the magnetic irregularities created by writing "*1's*" will induce a change of flux through the windings of the head. The change is, of course, a function of distance along the drum surface but since the drum is rotating continuously at a substantially uniform speed the change

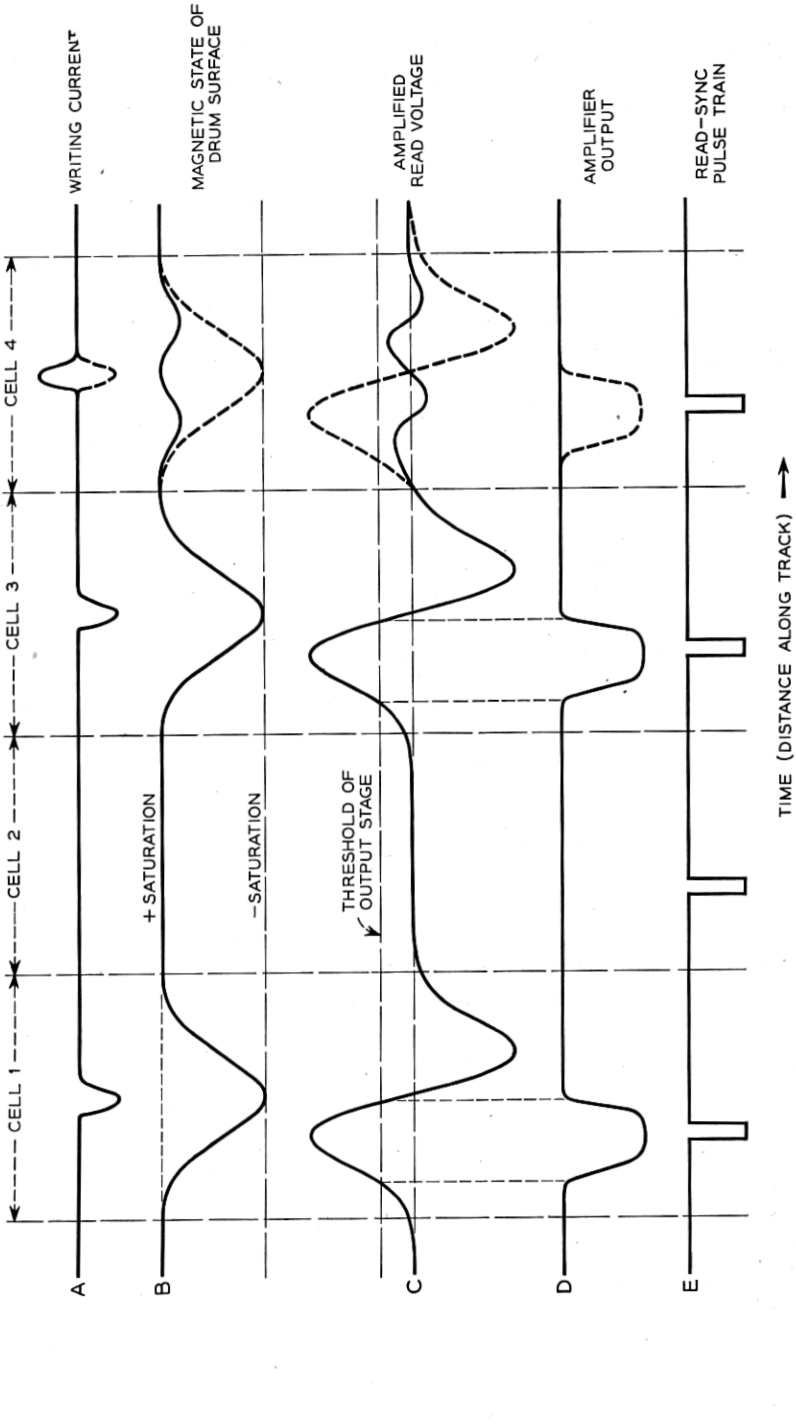


Fig. 3 — Magnetic writing and reading waveforms.

may also be represented as a function of time. This time-rate-of-change of flux within the coils of the head generates a voltage which is of the order of 50 millivolts peak-to-peak in the case of the translator. This voltage, after amplification, appears as shown in line C of Fig. 3. The trace shown is that which appears at the "linear output" monitor jack of a translator reading amplifier, and includes a phase inversion, characteristic of a three stage amplifier. Such a curve is readily recognized as being quite similar in shape to the first derivative of the normal error-function and hence we may infer that the magnetic condition of the drum surface, at least as interpreted by the head, may be portrayed by a bell-shaped curve, previously mentioned, similar to the error-function itself.

The residual magnetic irregularity pictured in cell 4 resulting from writing a "*0*" over a "*1*" will induce a voltage in the winding of the head having a different amplitude and wave shape from that occasioned by reading a "*1*." It is sketched out approximately to scale in Fig. 3 and is seen to be a smaller twinned-version of the "*1*" signal. Its amplitude ordinarily lies in the range of $\frac{1}{10}$ to $\frac{1}{3}$ of that of the "*1*" signal, and for about the middle third of the cell its instantaneous polarity is opposite to that which a "*1*" signal would have. These facts suggest at least two means of discriminating between the voltage signals obtained for the two code values: (a) on the basis of amplitude difference, and (b) on the basis of instantaneous polarity difference determined or sampled within a particular epoch in each cell.

The method adopted for the translator is that of simple amplitude threshold. The threshold value indicated by the dotted line in Fig. 3, is set so that the strongest of the residual signal outputs never exceeds it while, at the same time, the greatest possible proportion of the positive-going lobe of a "*1*" signal is allowed to produce an output. The threshold output stage of the amplifier is also arranged for limiting and this has the effect of blunting the peaks of the applied signals. The over-all result of these actions is shown by the shape of the signals in line D of Fig. 3.

Cell packing may be of major economic importance in a large installation. The general effect of making recordings closer and closer together is that the presence or absence of one of the recordings in a series has an increasing influence on the size and shape of the signals reproduced from its neighbors on either side. In the translator, the cells are spaced 20 milli-inches center-to-center along the track and the influence of action in one cell on the amplitude of reproduction from neighboring cells is never more than about 10 per cent. The trace of line C, Fig. 3, is drawn for this cell spacing and shows a slight inflection at the transition between the output voltage occasioned by reading cell 3, and the voltage obtained from the "*1*" which was originally written in cell 4. In many applications a much larger "influence factor" may be tolerable, but this usually requires greater elaboration of the signal detecting devices. The cell size is also influenced by physical constants such as design of the head, properties of the medium, and dimensional clearances. A discussion of such factors is outside the scope of this paper but it is not unreasonable to hope for an improvement of two-to-one in packing factor in future designs.

Reading Synchronization

The magnetic drum used for the translator provides 80 tracks. About sixteen microseconds is required for each cell in a track to pass under its head. Information occupying the same slot on the drum (so-called because of its obvious relationship to the term "time-slot" commonly used in the digital computer field) is presented at the various heads essentially, but not exactly, simultaneously. Departure from exact simultaneity is occasioned by small variations in the shapes and amplitudes of the output waves shown typically as line C in Fig. 3, and by small time-variations occurring in the writing process, as applied to the various tracks.

To achieve exact simultaneity, as required for certain subsequent operations of the translator circuitry, narrow "Read Synchronizing" pulses are produced by the synchronizing circuit previously mentioned. These pulses are located, within the time boundaries of the cells, so that they fall approximately at the center of the broad output pulses from the reading amplifiers and thus permit the latter to be sampled. This relationship is indicated in lines D and E of Fig. 3. Similar pulses, slightly displaced in time, are used to control the writing operations, and are designated "Write Synchronizing" pulses. The necessity for the time-shift is apparent from an examination of lines A and E of Fig. 3.

This condensed explanation of the technology of magnetic drum digital data storage devices, particularly as applied to the translator drum, should serve as sufficient background for the description of the translator wherein the drum is but one part of a large ensemble of apparatus.

THE JOB WHICH THE CARD TRANSLATOR NOW DOES

It will be advantageous to examine very briefly the card translator and its functions in the No. 4A toll switching system so that the analogous operation of the magnetic drum equivalent may be more readily explained. A more detailed description is given in Reference 4.

The demands of nationwide toll dialing require a very extensive repertoire of translations between destination codes and routing instructions, and it must be possible to change the routing instructions with ease. The card translator fulfills these requirements. Each individual translation item is contained on a metallic card; the output code of routing instructions is in the form of selectively enlarged perforations in the perforated field of the card, arranged so as to be read by photoelectric means, and the input code, which identifies the card for purposes of selection, appears in the form of tabs projecting downward from the bottom edge. Each card is capable of holding a total of 154 bits of information, input and output, and somewhat over 1,000 cards are stacked in a bin in each card translator mechanism.

It is possible to classify the elements of any translator into three broad categories: the memory unit, the translation selecting unit, and the translation delivery unit. In the card translator the memory unit is, of course, the group of cards; the translation selecting unit consists of code bars, electro-mechanically actuated, for displacing a selected card sufficiently so that it may be "read." It also contains a network of relays which perform the function of checking the authenticity of the input codes applied to the code bars. The translation delivery unit consists, in the main, of a number of output channels, each originating with a light beam for probing one of the code elements (a bit of output information) on the card. Each output channel contains a photo-transistor, a transistor amplifier, a cold cathode gas tube circuit which has been designated a "channel output detector" and a register relay. The register relays perform work functions and therefore are located separately from the translator; some are in the decoders, others in the markers.

In the 4A office, the card translator is one of several items of common control equipment which cooperate to establish the talking connections. Other items are the sender, the decoder, and the marker. The sender receives and registers and subsequently transmits the decimal digits of the called designation; the decoder receives the code digits (from 3 to 6 in number) from the sender and submits them to the translator for conversion into information needed for the proper routing of the call; and the marker selects an outgoing trunk and establishes a transmission path by operating the crossbar switches. Since this common control equipment is associated with any one call for only the short interval necessary to establish the talking-circuit connection, its speed of operation is a matter of considerable importance.

It is obvious that the decoder is the intermediary between the translator and the remainder of the office. Each decoder, of which there are a maximum of 18 in a large office, has exclusively associated with itself a card translator mechanism; each of these mechanisms contains an identical repertory of translations. Each decoder also has available, through connectors, a common pool of translators containing a large quantity of less-often used information. In order to better understand the duties that a magnetic drum translator must be expected to perform it will now be convenient to follow, in a highly abbreviated manner, a typical operation of the decoder and its associated card translator.

The first translation on an incoming call is performed using the first three decimal digits accumulated by a sender. As soon as three digits are available the sender connects to a decoder which immediately signals its individual translator to perform certain mechanical chores in preparation for selecting a card. There are several sequencing signals between the decoder and translator during the complete cycle of a translation (several of these signals must be synthesized by the drum translator); acting on one of these signals from the translator, the decoder passes the input code from the sender, adding certain supplemental information of its own.

The three decimal digits of the input code are in checkable combinations of two leads energized in each of three groups of five leads connected to the translator. The supplementary information supplied by the decoder is in a similar checkable combination on six leads. None of the remaining leads in the total of 38 is energized, since the translation being described involves only three code digits.

In the translator, the input code actuates the card selecting mechanism and also operates relays whose contacts are wired with a checking network which confirms that the input code, and the responsive operation of the code bars, is an authentic combination. This is done by establishing a path to operate a "code bar check" relay, CBK. (This relay retains the same identity in the magnetic drum translator.)

Acting upon the authenticity check, the card translator proceeds to select a card, and signals the decoder to begin timing for a possible nonappearance. When the card is in a position to be read, the decoder is signaled on two "index" channels, IND. The decoder now "reads" the card by applying 130 volt battery to the coils of its register relays; the required relays operate through the ionized cold-cathode gas tubes in the translator, and lock up, extinguishing the gas tubes.

The first card dropped may provide information sufficient for completing the connection; in this circumstance the decoder will then call in a marker. The first card, however, may specify that more digits are required and the decoder will so instruct the sender. The sender, unless it already has the necessary digits, is then dismissed by the decoder which also instructs the translator to restore itself to normal.

Six-digit translations are obtained in a manner similar to that described above except that the checking network on the relays is switched to check for six rather than three digits. In some instances the decoder must refer to one of the translators in the common pool of "foreign area translators" in order to obtain the required information. Frequently, several different cards must be dropped successively before a route is finally established for the outgoing call.

With the above description as a background, we may proceed to discuss the magnetic drum translator.

THE ANALOGOUS FUNCTIONS OF THE MAGNETIC DRUM TRANSLATOR

The magnetic drum translator is essentially a device which performs a translation by making a selection from a recurrent pattern of electrical pulses generated by a magnetic drum unit. A schematic diagram of the magnetic drum translator, as arranged for direct substitution for a card translator, is shown in Fig. 4. In this diagram, the system is divided into three principal functional components: (a) the drum memory assembly which produces (from the outputs of 80 reading amplifiers and a timing unit) a repetitive pattern of electrical pulses representing all the translations on the drum, both input codes and corresponding output codes; (b) the translation selecting unit which reads that portion of the pulse pattern representing input codes and acts to identify the unique code group which matches the incoming information from the decoder; (c) the translation delivery unit which, under control of the translation selecting unit, gates-out the particular pulses of the corresponding output code from the continuous stream of microsecond pulses, and converts them into signals capable of operating the register relays in the decoder.

To maintain direct interchangeability, two items of apparatus were adopted virtually without change from the card translator. These are the CODE CHECK RELAYS which accept and check input information, and the CHANNEL OUTPUT DETECTORS comprising cold-cathode gas tubes and associated transformers. This allows input and output terminal facilities to the decoder to be the same for both translators.

It should be noted that the magnetic drum memory assembly differs significantly in one functional respect from the binful of cards in the card translator. When a selected card is being read by the photo-electric cells in the output channels, no other cards are available. In the drum translator, all translations are continuously available and if a number of translation selecting and translation delivery circuits are employed, all may obtain translations from a common drum memory assembly at the same time without interference. This feature could not be demonstrated in the test set-up as planned, but it would have been incorporated in any test which included more than one decoder in an office. In such an arrangement, the various units illustrated in Fig. 2, except the drum memory assembly, would be furnished to each decoder. One drum memory assembly (and an emergency standby) would supply the pattern of electrical

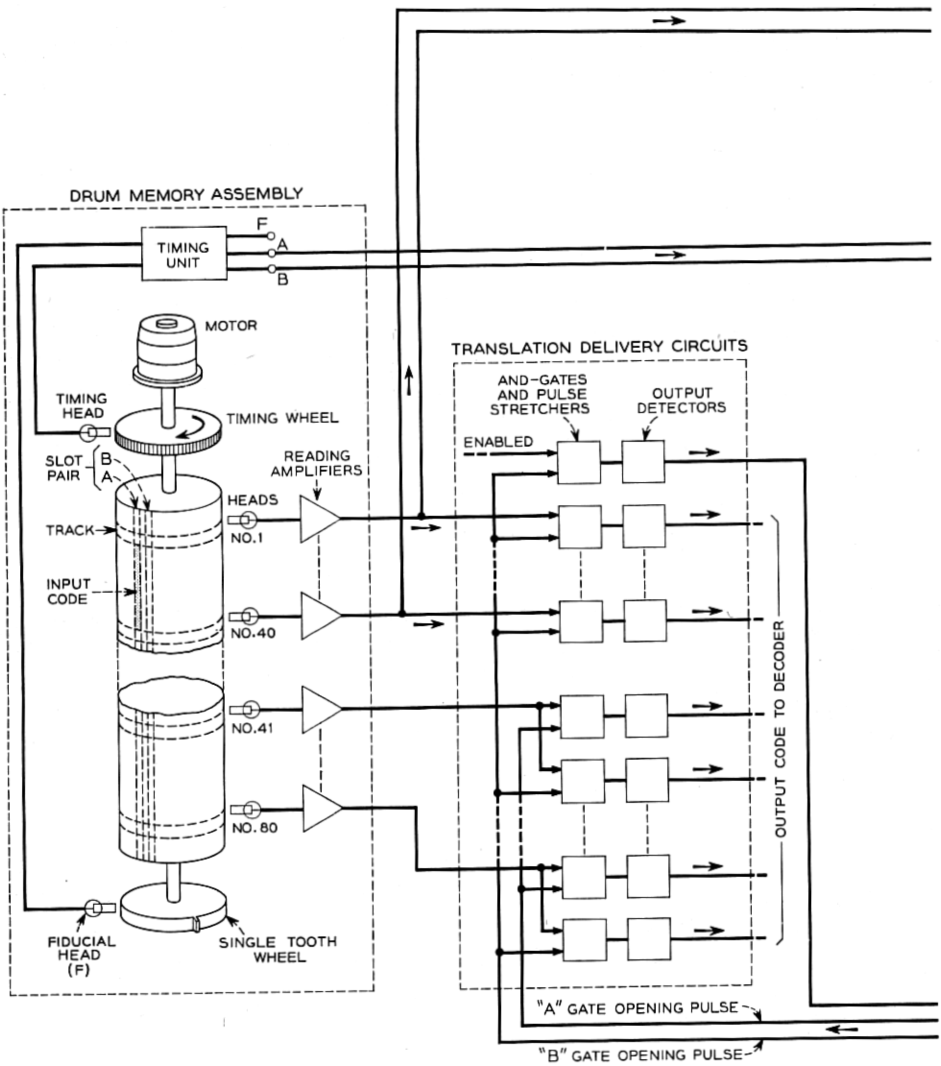
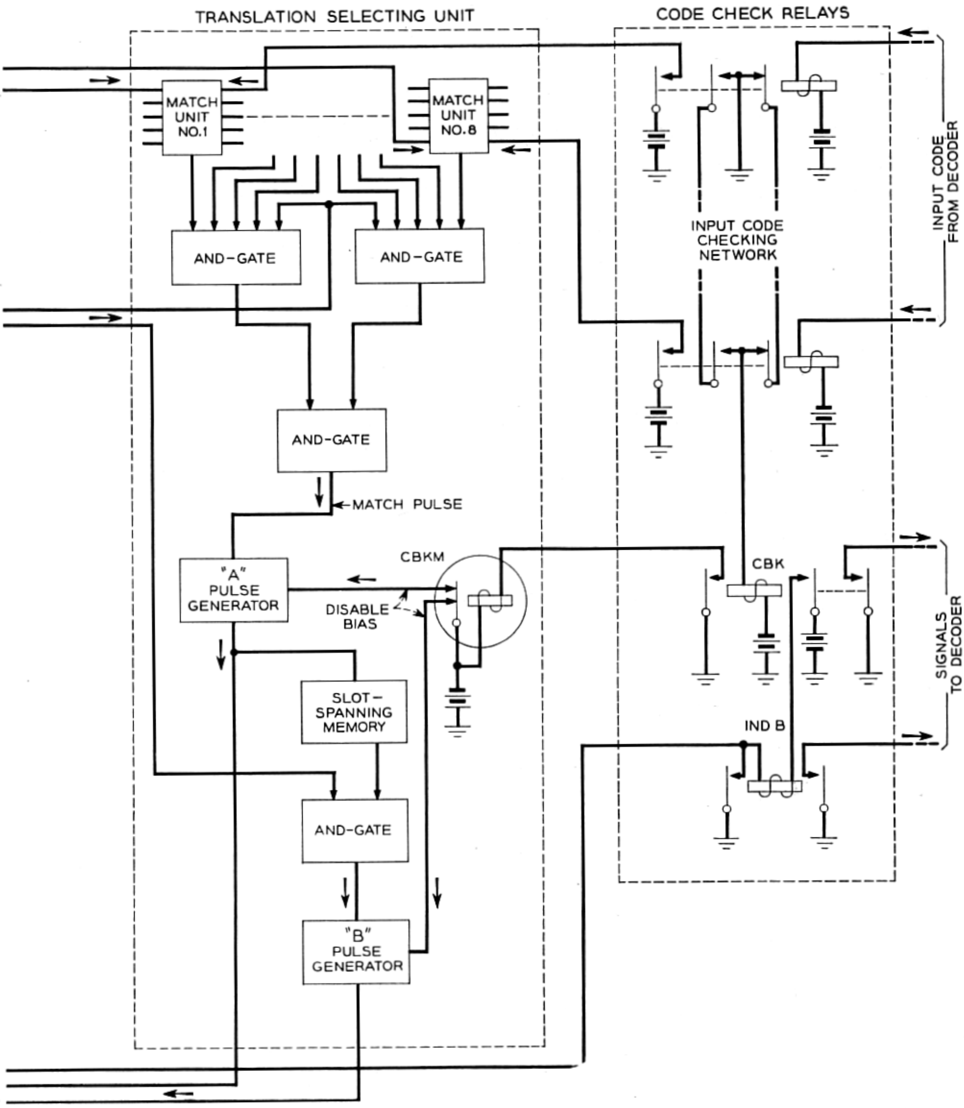


Fig. 4 — Magnetic drum

pulses to all translation selecting and translation delivery circuits in multiple. The object of such an arrangement, naturally, is to employ the magnetic drum system in the most economical manner. A further extension along the same lines would involve relay switching of the pulse circuits



translator block diagram.

to give access to the emergency drum memory, or to a "foreign area" memory where such extra memory capacity is necessary.

Let us now return to the discussion of Fig. 4 and consider the assignment of the translation information to the drum surface where it is stored. Recall that the drum surface is effectively divided into a grid by the coordinates of tracks, each passing under an individual write-read magnetic head, and "slots," each defined by the appearance of a timing pulse in a rhythmic train synchronized from the drum itself, and that the "cells," at the coordinate intersections, each accommodate one bit of code information.

Since each card in the card translator accommodates 38 bits of input code and 116 bits of output, about 160 cells, divided in the ratio of one cell for input to every three cells for output, must be assigned to each translation item. One simple and direct assignment would be to place the entire translation item in a single slot composed of 160 cells. With this layout the slot containing the desired translation would be identified by reading, or "matching" the input code, and during this same interval the output information in the same slot would be gated-out to the translation delivery circuits. A 1,000-translation drum would then be long and narrow, and far too many reading amplifiers would be required. Another evident arrangement would be to assign the entire input code to the first of each group of four slots proceeding under the heads, with the output code following in the next three slots. Such an allocation would require only 40 reading amplifiers but the drum necessary for the desired capacity, with the cell-spacing chosen, would have been larger in diameter than the mechanical designers cared to undertake in their first trial. A logical choice, therefore, was to place each translation item in a pair of adjacent slots, and this was done, although it was later recognized that other, more sophisticated, arrangements might offer certain advantages.

In Fig. 4, the apparent location of one translation item is sketched in relation to the drum surface. This sketch is not drawn to scale, since the slot width is actually only 0.020 inch, and the track width is comparable. It is also geographically inaccurate; actually the cells of any one slot are positioned in four quadrants on the drum, the associated heads being positioned in four stacks for mechanical reasons. However, all of the cells in a time slot pass under all of the heads at the same instant and the presentation of Fig. 4 was adopted for the sake of clarity.

Note, then, that the input code and one-third of the output code are recorded in the first or A slot of a slot-pair passing under the reading heads, and that the remaining two-thirds of the output code occupies the B slot which immediately follows. The parallel (simultaneous) presentation of the entire input code to the translation selecting unit permits that unit to indicate, by a pulse, that the translation item is the one desired and to gate-out the output code in the same slot while it is still passing under the heads. Having thus identified the first slot of a translation item, it is a simple matter to provide the facility for gating-out the remaining information recorded in the next succeeding slot.

It will be seen, from the circuit arrangement shown, that the translation selecting unit also receives a portion of the output code recorded in the second slot of each pair. It is therefore necessary to distinguish between the A and B slots of a pair. This is most conveniently done by the Timing Unit, which is provided with two outputs, the pulses defining the slots appearing alternately at these outputs. One output lead is chosen to define all the A slots and it is routed to the translation selecting unit to provide a portion of the pulse-pattern required for complete and proper identification of an input code.

The action of the magnetic drum translator in making a translation may now be traced by following the block diagram of Fig. 4. The decoder, of course, gives the same preliminary signals as for the card translator, but these are ignored by the drum translator, because it is continuously presenting all 1024 translations at the rate of 30,000 per second and need not take any preparatory steps, provided its relays have returned to normal after the last translation. The normal state of the relays is checked by means of a circuit through their contacts; if this circuit is complete, the decoder receives the signal to apply the input code as soon as it seizes the translator. A more elaborate checking arrangement could have made this signal conditional upon other tests, such as a "standard translation," to determine that the electronic circuitry (in bulk) was functioning properly, but it was not considered worthwhile to do so in the system described here.

The decoder, then, furnishes the input code of the desired translation item, causing certain of the relays labeled CODE CHECK RELAYS in Fig. 4 to operate. Contacts on these relays are interwired to provide the same checking network as in the card translator, and a check on the authenticity of the input code will be evidenced by operation of the relay labeled CBK. This event is signaled to the decoder so that it may start its "no-card" timer action. When CBK closes, it also operates a chatter-free mercury-contact relay, CBKM, in the translation selecting unit, permitting that unit to produce an output at the appropriate time. Each code-check relay which operates applies a positive voltage to one of the input terminals of a "match" unit in the translation selecting unit. For each of these input terminal there is a complementary terminal to which are applied negative-going pulses from one of the drum memory reading amplifiers. As will be explained later, advantage is taken of this complementary arrangement to obtain a signal indicating a match between either, (1) an operated code relay and a pulse from the reading amplifier, or (2) a nonoperated relay and no pulse from the reading amplifier. All of these signals, from 40 sections of the match units, are combined in a cascade of "AND" gates; when all indicate a match, the translation selecting unit delivers an output "match" pulse.

Since this match pulse is not strong enough to enable 40 gates in the output channels, it is passed to a "pulse generator" (a regenerative pulse repeater) which produces, virtually coincident in time, a powerful "A" gate-opening pulse. Note that both the "A" and the similar "B" pulse generators are enabled to operate only when the input code is authentic, as evidenced by the operated code check relay CBKM.

In an unrestricted magnetic drum translator design this identifying pulse would cause immediate registry of part of the desired information. Here, however, is evidenced one of the penalties for having a direct one-for-one substitution for a card translator. The decoder and card translator function in a definite sequence; one of the steps in this sequence is initiated by the IND signal from the translator which informs the decoder that the selected card is properly "indexed" so that it may be "read." Therefore, in the case of the drum translator, to preserve this sequence, the selected translation is permitted to pass unheeded, except that the IND signal is synthesized from the identifying B gate-opening pulse. This operation closes one relay, INDB, through a special output channel (topmost one in Fig. 4) provided for the purpose. The decoder, thus notified that the desired translation is available, applies battery to its register relays, and the output channels are completely enabled for a subsequent registry of the desired information.

The output information is usually registered during its next passage, one drum-revolution after initial identification of the item. The action of identifying the translation is again as described above, and there remains only to follow the operation in the output channels. Even before the translation selecting unit has initiated the identifying gate-opening pulse, reading amplifiers which are required to deliver an output code have each commenced delivery of a pulse to their corresponding gate terminals in the AND gate and pulse stretcher units. (See Fig. 4). When these pulse signals have reached a stable maximum, the gate-opening pulse (A or B depending on the slot which is being read at the moment) is free to pass through the gates and to trigger the pulse stretchers. The latter devices, each containing a single transistor in a monostable circuit arrangement, deliver 12-volt pulses lasting about a millisecond. The pulse stretchers from which an output code is not required are not triggered, owing to the absence of pulses from the corresponding reading amplifiers.

The remainder of the output channel, as previously stated, is borrowed directly from the card translator, and the action is similar. In the output detector, a transformer steps-up the 12-volt pulse signal to a voltage more than sufficient to establish a discharge in the control gap of a cold-cathode gas tube. Since the decoder has applied voltage through a relay coil to the main gap, the discharge transfers, and the resultant current flow operates the relay. The operated relay, which may be in the decoder, registers the code and locks to ground through an auxiliary contact. This action also extinguishes the gas tube, thereby extending its life.

Except for relay operation, all of the activity described here for two drum revolutions repeats itself for every subsequent drum revolution for as long as the code check relay CBKM remains operated. However, once the code is registered, no further use is made of the pulses in the output channels.

When the decoder has made use of the translation, it transmits a signal which is used in the code-check relay system to indicate when all relays are properly restored. In the card translator this signal is also used to restore the selected card, but in the drum translator this operation, of course, is not required.

Administration Equipment

To utilize the magnetic drum translator as described above, it is obvious that some means for writing-in the translations is as necessary to the drum as a card punch is to the card translator. Although a selective writing, or "Administration Unit" was required, a highly efficient design was not essential to the experiment. Consequently there was constructed a separate, portable aggregation of essential basic electronic circuits, arranged for manual control, but designed with a view to possible extension to fully automatic operation. This equipment will be described in a later section.

EQUIPMENT AND CIRCUIT DESIGN DETAILS OF THE TRANSLATOR

General Description

The entire translator is mounted on an 11-foot by 32-inch bay and has been made to conform to telephone central office practices as far as pos-

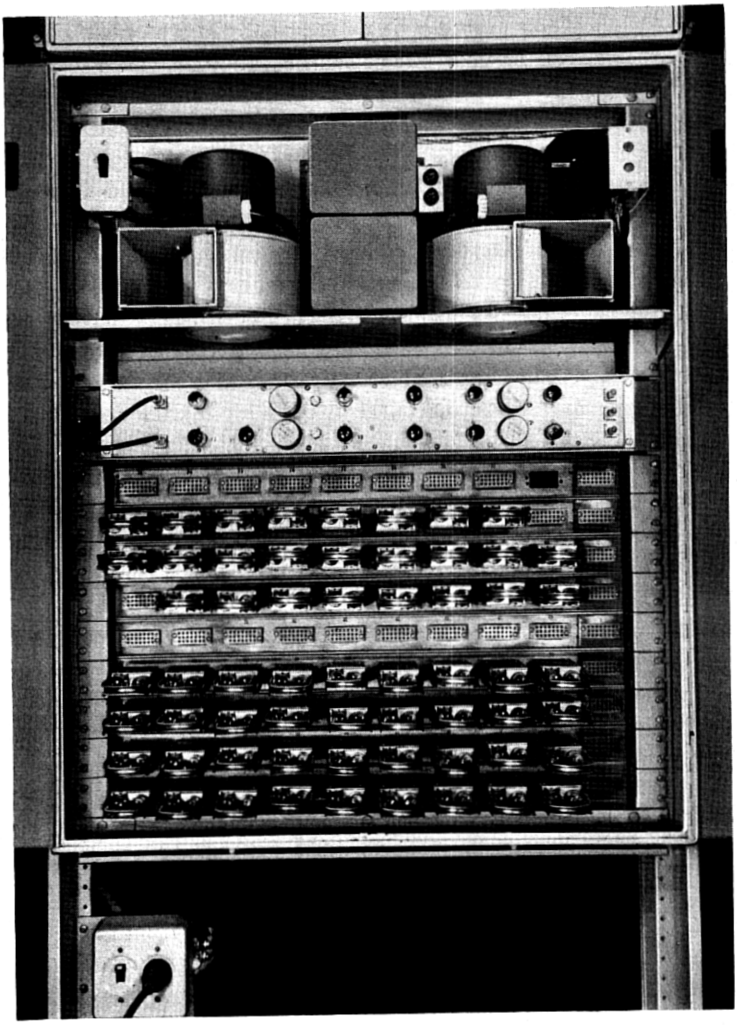


Fig. 5 — Lower casing containing partial complement of reading amplifiers, timing unit, filament transformers and blowers. Receptacle at right end of each amplifier mounting strip allows Administration unit to connect directly to magnetic heads associated with those amplifiers.

sible; except for the presence of the drum unit at the base of the rack, its appearance is not unlike that of other racks found in central offices.

Mounted directly above the drum unit is a casing of conventional design (shown open in Fig. 5) which houses the reading amplifiers, timing unit, filament transformers, and a self-contained forced-air ventilating

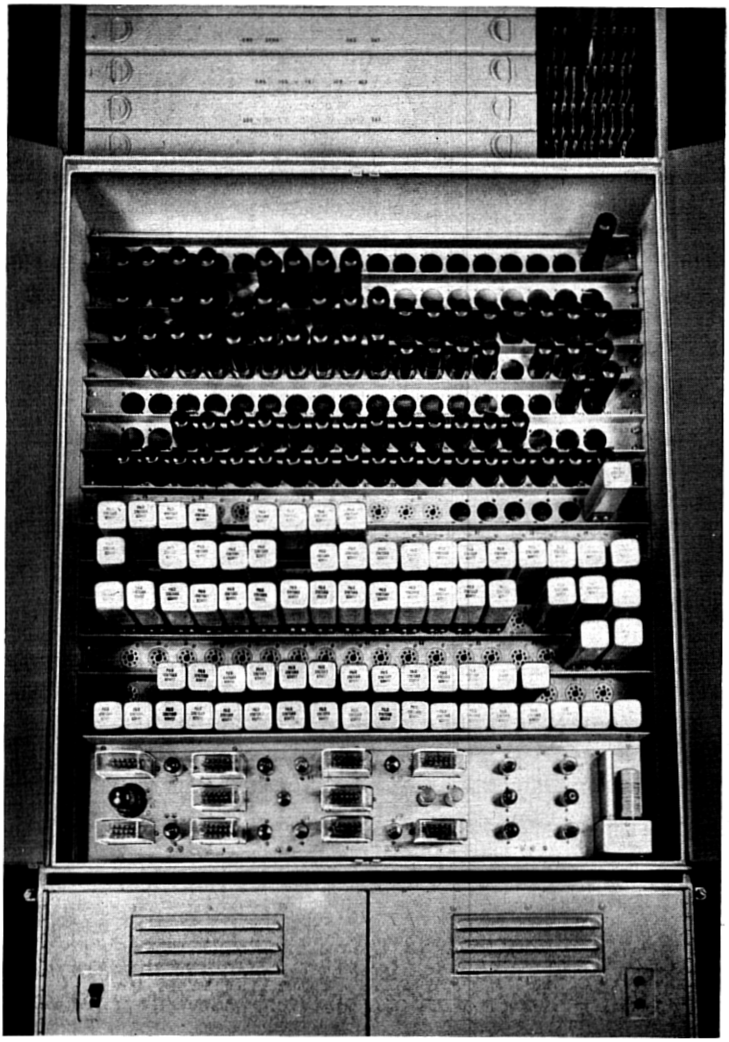


Fig. 6 — Upper casing containing translation selecting unit, and partial complement of pulse stretchers and channel detectors.

system. A second casing, (Fig. 6), located directly above the first, houses the translation selecting unit, pulse stretchers, and channel output detectors. The various plug-in components used in these sections are shown in Fig. 7. At the top of the rack are located the code-check input relays, fuses and terminal blocks.

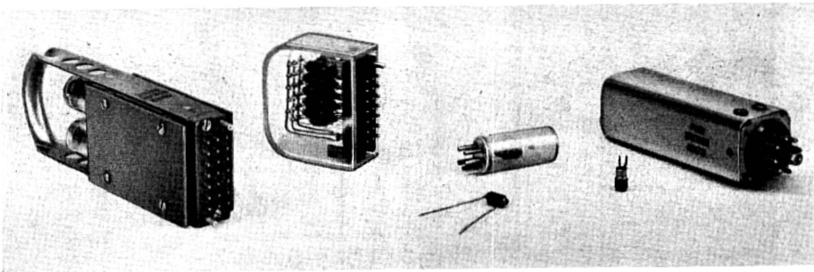


Fig. 7 — Plug-in units. Left to right, reading amplifier, match unit varistor cluster, individual varistor, match and-gate, transistor, and pulse stretcher.

In wiring the rack, use of individually-shielded conductors was held to a minimum. The cable between the drum unit and the reading amplifiers was composed of standard switchboard wire, shielded as a unit by removable sheet-metal enclosures, thus greatly reducing the bulk as compared to the usual bundle of coaxial cables.

The remainder of the wiring, which carries relatively high-level signals from unit to unit within the frame was also in the form of cables of switchboard wire; this type of wiring was tried as an experiment for microsecond pulse work, and was found to be successful in this instance.

Under normal conditions the entire translator, with the exception of the tube filaments and drum drive motor, operates from the standard plant batteries of +130 and −48 volts. Commercial 60-cycle power is normally used for filaments and motor; the motor is duplex and is designed to transfer automatically to the 48-volt plant battery in case of power failure, and the same provision would have to be made for the filaments in the event of a telephone plant installation.

Magnetic Drum Unit

The magnetic drum unit is located at the bottom of the rack, as shown in Fig. 1; a close-up view with one of the covers removed is shown in Fig. 8. A mounting casting supports the machine directly on the floor, straddling the lower member of the rack so that no load is imposed on the rack structure. The drum rotates about a vertical axis and is housed in two cast-iron end-bells spaced by a cast-iron shell. The end-bells carry the bearings for the drum, and serve to mount the motor, while the shell-casting rigidly locates the magnetic heads, each very close to the drum surface. This design requires a minimum of floor space, insures accurate bearing alignment, provides a convenient location for the magnetic heads, and permits the use of tightly-fitting gasketed covers to exclude

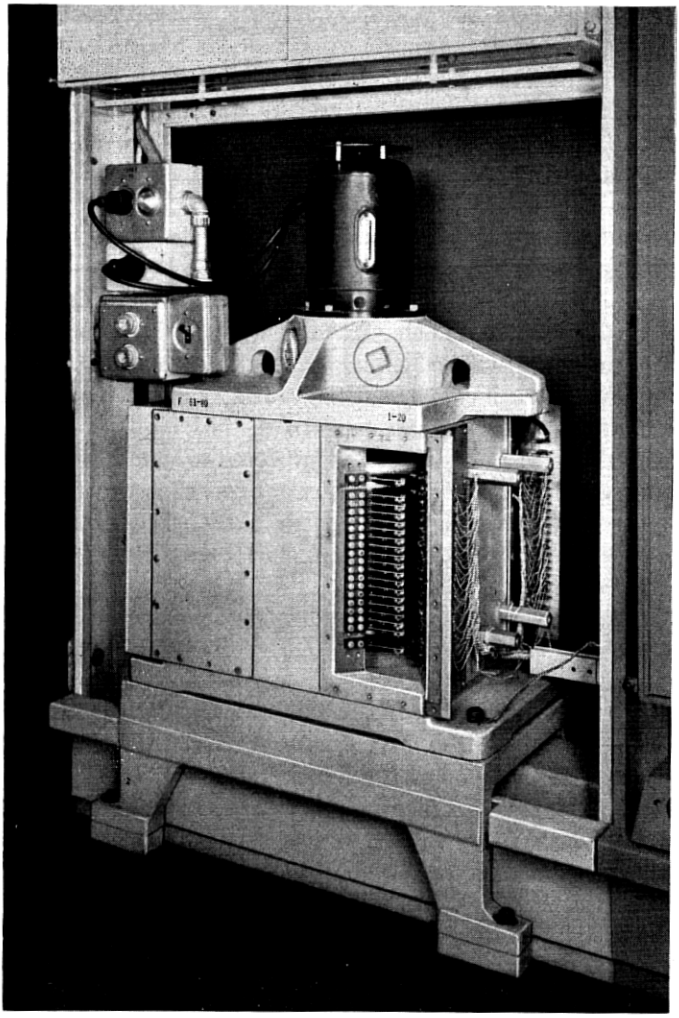


Fig. 8 — Magnetic drum unit partly uncovered to show magnetic heads and wiring terminals.

dirt and foreign material from the magnetic drum surface and the bearings. The $\frac{1}{16}$-hp motor drives the drum through a spring-diaphragm coupling.

The drum is comprised of a stress-relieved iron casting of high dimensional stability, a press-fitted steel shaft, and a $\frac{1}{16}''$ thick brass outer shell which carries the magnetic recording medium. Since both drum and housing are of similar materials, and have almost identical temperature-expansion coefficients, it is expected that pole-tip-to-drum clearance will remain unchanged under normal conditions of service. The drum, which is 12.8″ in diameter, 10″ long, and weighs 150 pounds, is dynamically balanced and runs without sensible vibration.

Commercial super-precision angular-contact ball bearings, two at each end, are used to mount the drum in its housing. The lower bearings are arranged to share the thrust load imposed by the weight of the drum, and the upper bearings are mounted opposing each other, and are pre-loaded one against the other. The upper bearings serve only as radial constraints, the outer races being free to move axially. This type of construction results in a finished unit having a total runout of only a few ten-thousandths of an inch without the necessity of machining the drum on its own bearings. For the experimental installation, the bearings were grease-packed at assembly and can be expected to function satisfactorily during any reasonable test period. If, however, such a drum unit were made a permanent part of the telephone plant, other provisions have been considered which would insure adequate lubrication over a much more extended period.

The magnetic coating used on the drum is an electro-deposited alloy of cobalt and nickel (90 per cent Co–10 per cent Ni) approximately 0.0003″ thick. This coating was selected because of its hardness, strength, uniformity, and desirable magnetic characteristics. The thickness of the coating is such as to result in a satisfactory cell-size without undue sacrifice in output. The purpose of the brass sleeve mentioned previously is to form a nonmagnetic surface between the magnetic coating and the cast-iron core since, if the coating were applied directly to a ferro-magnetic material, its effectiveness would be greatly reduced by the shunting effect of the base material. The brass sleeve also serves to facilitate plating the drum, since brass, unlike cast-iron, is amenable to the electroplating process.

Read-Write Heads

One of the read-write heads is shown in Fig. 9. The magnetic structure consists of three rectangular bars of laminated material, arranged in the form of a triangle (as schematically represented in Fig. 2). Two legs of this triangle carry single-layer coils which are series-connected. These two legs also serve as pole-tips, being pointed at the end and separated by an air gap. The third leg serves to complete the magnetic circuit and, in assembly, is butted tightly against the other members by means of a leafspring.

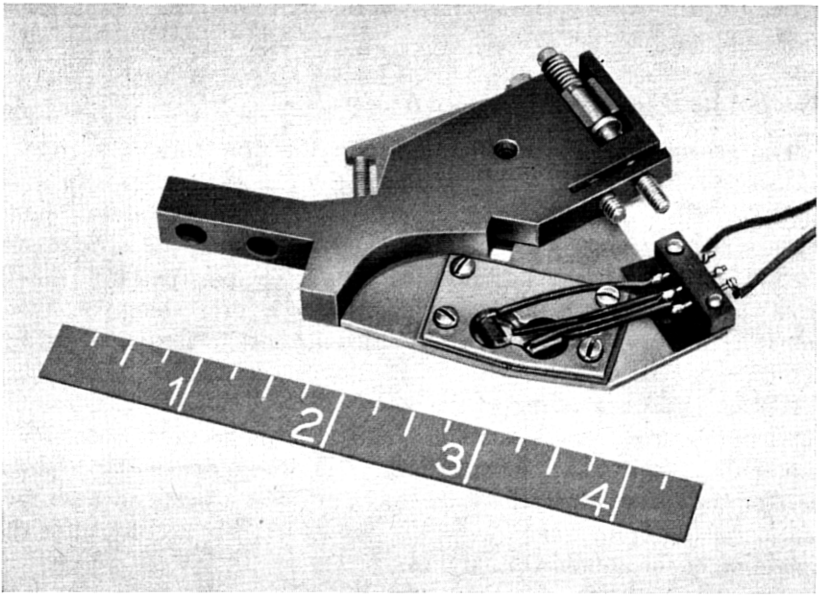


Fig. 9 — Magnetic head and mounting bracket showing means of adjustment.

The magnetic structure is assembled on a nickel-silver plate to which have been soldered two copper shoes which serve to locate the pole pieces and shield the pole-tips, thereby focusing the recording flux to some degree. After adjustment of the pole-tips, the assembly is clamped in a sandwich by means of a second, smaller nickel-silver plate. As is evident from the illustration, this magnetic assembly is in turn assembled to a mounting bracket which contains facilities for precisely adjusting the clearance between pole-tips and drum surface.

The pole-tips of the head are 0.050″ wide and the tracks are on 0.10″ centers, leaving a nominal value of 0.050″ between tracks to allow for misalignment of heads and for flux-spreading. Heads which are physically adjacent in each of the four corner stacks are mounted on 0.40″ centers, but the stacks are offset with respect to one another, thereby interlacing the tracks on the drum.

The read-write heads have been designed expressly for use in high-speed digital recording. Very thin laminations are used and this, coupled with carefully prescribed manufacturing techniques, results in a head having a satisfactory frequency response for the very short pulses employed. When used as a transducer to convert electrical pulses to magnetic flux, it is capable of responding faithfully to frequencies approaching ten megacycles per second.

The Timing Wheels and Associated Heads

The synchronizing pulses derived from the drum originate from a 512-tooth soft-steel gear mounted at the top end of the drum. In combination with a polarized reproducing head, the gear generates a timing signal which provides means for permanently locating the various cells used to store information on the drum surface. The polarized head differs from those used on the drum proper, being of a form which is conventional in tone-generators where, as in this instance, a sinusoidal output is desired.

A second gear is mounted at the bottom of the drum, carrying a single tooth of the same proportions as the teeth on the upper gear. In combination with a polarized reproducing head, otherwise quite similar to those used on the drum proper, this single tooth provides a signal once per revolution of the drum which (as will be shown later) is necessary for the operation of the administration unit.

The Reading Amplifier

One of the 80 plug-in reading amplifiers is pictured at the far left in Fig. 7. It employs two twin-triode vacuum tubes, and consists of a three-stage ac-coupled linear broad-band feedback amplifier, followed by a threshold output stage.

As shown in the circuit schematic of Fig. 10, the two halves of V1 and the left-hand half of V2 constitute the linear broad-band amplifier. A suitable choice of coupling elements insures that the amplification will diminish, with decreasing frequency, at a controlled rate for frequencies below a few hundred cycles per second. It is unnecessary to provide amplification at low frequencies, since the signals to be handled have no low-frequency components, and it is undesirable to do so from the standpoint of hum pickup. There is about 20db of feedback in the important part of the frequency range and the amplifier is thus substantially stabilized against variations of gain due to change in operating voltages and aging of tubes. The over-all operating voltage gain of the linear stages, with feedback, is about 56 db; the 3 db points are approximately 300 c/sec and 700 kc/sec.

The grid of the fourth stage of the reading amplifier is coupled to the output of the linear amplifier and is biased to about twice the plate-current cut-off value. The output signal from the plate of this stage, occasioned by reading a "*1*", will be a negative-going pulse of approximately 40-volt amplitude from a standing potential equal to the plate supply, +130 volts. As a precaution against false signals, an externally-mounted plate-feed resistor is provided to establish at the output a condition corresponding to that of no signal present when the amplifier is removed from its receptacle.

Timing Unit

The timing unit accepts an approximately sinusoidal timing-wave signal from the upper timing head, and converts this signal into two pulse-trains, each having 1,024 narrow pulses per drum revolution, designated as A sync and B sync, alternating in time and available on separate outputs for controlling all the rest of the circuit action of the translator. A block-schematic indicating how the pulse trains are produced is shown in Fig. 11.

The general procedure for converting from a sine-wave to a synchronous train of short pulses, two per cycle of input, may be traced through the upper channel of the drawing. The signal, as represented by voltage trace 1, is amplified and clipped until a steep-sided square wave is obtained; this wave, trace 2, is applied to a push-pull phase inverter from which a pair of oppositely-phased outputs is obtained. Each of the two outputs is then differentiated by means of an R-C network, and the nega-

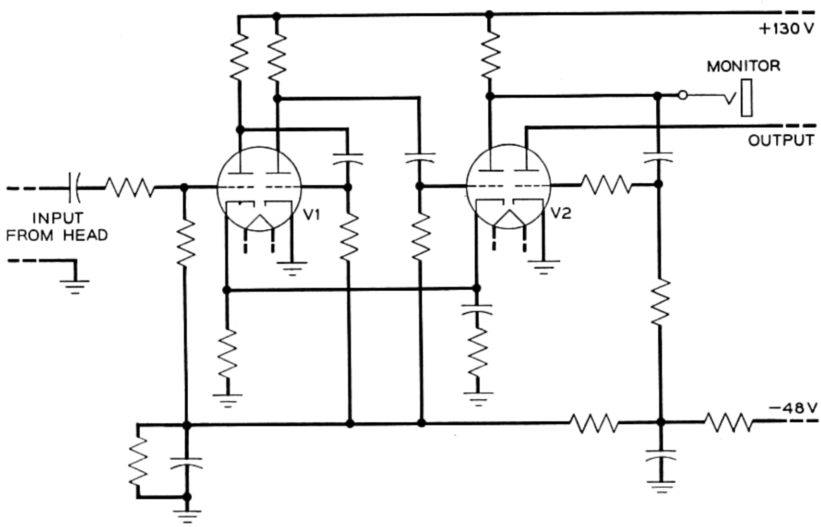


Fig. 10 — Reading amplifier circuit.

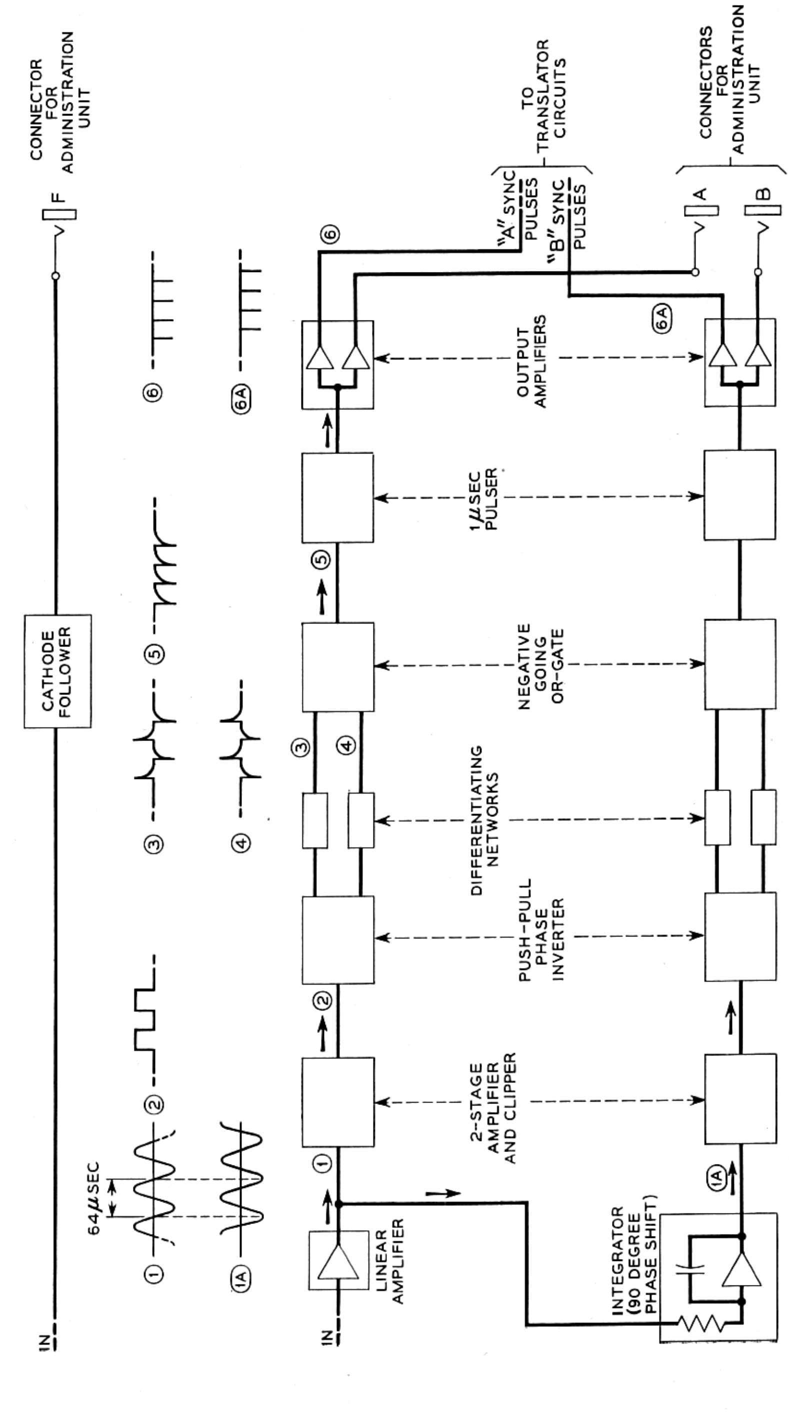


Fig. 11 — Timing unit block diagram.

tive-going spikes, traces 3 and 4, are combined in a negative-going OR gate of crystal diodes.

These spikes, trace 5, are used to trigger a cathode-coupled single-shot multivibrator, designed to give a rectangular pulse of about one micro-second duration. The multivibrator drives a pair of identical output stages: one furnishes the required A sync pulses to other equipment in the translator bay, and the other delivers its output to a coaxial connector so that, when required, the pulses may be furnished to the administration unit.

The B sync pulse-train is produced in the lower channel shown in Fig. 11. After some linear amplification, a part of the original input sine-wave is applied to a vacuum tube integrator circuit. The constants of the integrator are such that it provides very nearly a quarter-period of phase shift even if the drum varies from its nominal speed. The output of the integrator is then treated in the same manner as that described for the direct input, with the result that the required B sync pulses are produced.

The timing unit also contains a third channel which accepts the once-per-revolution signal from the special head adjacent to the single-tooth wheel. The output of this channel provides the fiducial signal, on a low-impedance basis, for administrative operations.

The Translation Selecting Unit

This unit, which appears as the bottom panel in the photograph, Fig. 6, performs a number of successive steps in making its selection. These are: (1) recognition of a match between input information from a decoder seeking a translation, and the unique corresponding information from the drum, selected from the flow of continuously-presented information; (2) production of a gate-opening pulse whose leading edge is substantially coincident in time with the leading edge of the particular A sync pulse corresponding to the entry for which the match occurred; (3) activation of a slot-spanning pulse circuit to bridge the time interval until the next-following B slot; (4) production, at a separate output, of another gate-opening pulse whose leading edge is substantially coincident in time with the leading edge of the identified B sync pulse. These actions will now be considered individually.

(1) *Recognition of Match*

Responsibility for this function is divided among a group of eight match-units operating with their associated differential amplifiers. Each match-unit is capable of comparing the inputs from five code-relays with the potentially-matching outputs of five reading amplifiers.

A circuit schematic of one of the units, with its associated differential amplifier and some of the connected apparatus, is shown in Fig. 12. The uppermost channel on this diagram is typical of all five channels. Resistors R1 to R5 are proportioned so that the potential at point C assumes a value of +115 volts for either of the two acceptable conditions of match: (1) code-relay unoperated and reading amplifier not drawing plate current, or (2) code relay operated and reading amplifier drawing a pulse of plate current. Whenever either of the two possible conditions of mismatch exists, the potential at point C assumes a value about 15 volts higher or lower, depending on the nature of the mismatch. Resistor R6 is introduced for protective purposes only. Varistor VR1 limits the nega-

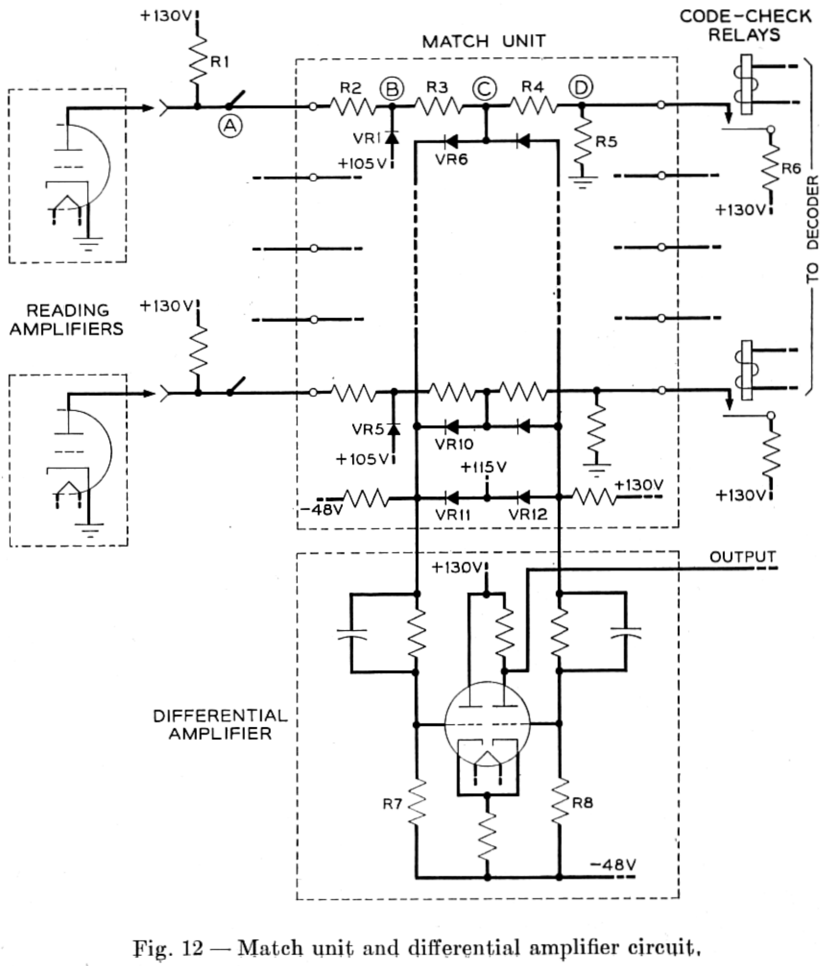


Fig. 12 — Match unit and differential amplifier circuit.

tive voltage excursion at point B, during a pulse, so that it never goes below +105 volts. This establishes the uniform pulse amplitude among the forty match channels which is necessary for proper functioning of the unit.

To detect and recognize the voltage conditions at the five junction points, two varistor gates and a differential amplifier are employed. One gate, comprising six varistors including VR6 and VR11, will transmit the type of mismatch signal which is more positive than +115 volts. This signal is dc-coupled to the left-hand grid of the differential amplifier as illustrated in Fig. 12. The type of mismatch signal which is less positive than +115 volts is blocked by this gate but is transmitted through the other gate to the right-hand grid. The threshold for this discriminating action is established by application of a fixed nominal potential of +115 volts to varistors VR11 and VR12.

At match, the output of each of the two gates presents a potential of +115 volts to the differential amplifier. The differential amplifier is biased (by inequality of R7 and R8) so that for this condition the right-hand triode is conducting, and the output potential is lower than the plate supply voltage. Positive-going mismatch signals on the left-hand grid, or negative-going signals on the right-hand grid are then equally effective in cutting off the right-hand triode, causing the output voltage to rise to plate supply potential signifying a mismatch.

The outputs from the differential amplifiers of the eight match units are combined with the A sync pulses in a system of AND gates, as illustrated in Fig. 4. A match-pulse output from this system thus signifies that conditions for match have been uniquely determined for 40 pairs of items. Thus the match unit, in total, is capable of distinguishing between all binary combinations of 40 bits or approximately 10^{12} items although when a self-checking code is employed, as in the translator application, many of these combinations are inadmissible.

(2) *The A Gate-Opening Pulse*

Occurrence of the match-pulse, as just described, indicates that the 40 items constituting one-half the contents of one of the A slots match the incoming input code; it is then desired to spill out from the other half of this same A slot the information which is also appearing at amplifier outputs at that instant. This is done by means of gates opened by the action of a gate-opening pulse, triggered by the match pulse.

The A gate-opening pulse is only a few microseconds in duration and normally is produced only once per revolution of the drum; a quiescent blocking-oscillator was chosen as the type of circuit best suited for this purpose. Whenever the code-check relays are operated in an authentic code combination, relay CBKM is operated, removing a disabling bias from the driver stage of the blocking oscillator. When in this condition, each occurrence of the match pulse will trigger the blocking oscillator, thereby producing the A gate-opening pulse once per drum revolution.

(3) *Slot-Spanning Pulser*

Whenever an A gate-opening pulse has acted to permit read-out of information from half of the proper A slot, it is also desired to read out all the information from the next-following B slot. The first step toward doing this is to cause the A gate-opening pulse to trigger a single-shot multivibrator whose characteristic period is long enough to just bridge the time until the next slot appears. The output of this pulser is combined with the B sync pulses in an AND gate so that the selected B pulse, corresponding to the wanted B slot, can be used to trigger another gate-opening blocking-oscillator just as the match pulse was used to trigger the A gate-opening blocking-oscillator.

(4) *The B Gate-Opening Pulse*

The outputs of all the reading amplifiers must be gated for the B slot. Hence the B gate-opening pulse must operate twice as many gates as the A gate-opening pulse and must be correspondingly more powerful. This requirement is met by using the same circuit design with parallel output tubes.

Pulse Stretchers and Channel Detectors

Fig. 13 presents a simplified schematic of one of the translator output channels, together with certain of the relays in the decoder. Package-wise, the pulse stretchers combine two functions: that of an AND gate with two inputs and a threshold feature, and that of a single-shot multivibrator for amplifying and lengthening the short input pulse from the gate. A single point-contact transistor provides the necessary gain for the monostable action. The inputs to the AND gate come from sources which supply negative-going pulses from a standing potential of +130 volts. When one or the other, but not both, of these sources supplies a pulse, a larger portion of the current being supplied to resistor R1 must be drawn from the non-active source; this extra demand causes a small voltage drop which becomes evident at the gate output. The resultant weak false signal is prevented from affecting the transistor pulser by the action of threshold diode VR1 which is normally back-biased a few volts by the potential divider R2, R3. Small negative-going signals from the gate will not overcome the bias and will therefore be greatly attenuated; normal gate-output pulses, occasioned by coincidence of pulses at both inputs will, however, overcome the bias and will be transmitted to the transistor monostable circuit.

When triggered at the base, the transistor delivers a pulse of about one millisecond duration to the load represented by the input transformer and the channel detector gas tube and thus provides the drive required to initiate ionization in the control gap of the gas tube. When brought into action, the transistor serves as a switch to connect capacitor C to collector supply resistor R6. The voltage change, occasioned by the resultant flow of current in R6, is communicated to the transformer primary through a blocking capacitor and a current limiting resistor. As capacitor C charges, the voltage at the transistor emitter will approach the collector supply potential at an approximately exponential rate. When the diminishing flow of emitter current can no longer maintain the transistor in its low-impedance mode, it reverts to its pre-triggered condition, and the timing capacitor C is then discharged, primarily through forward-conducting varistor VR2 and resistors R5 and R4.

Owing to the necessity of using early-production samples of the type of point-contact transistor chosen for this application, the associated circuitry for biasing the emitter into the normal non-conducting state is somewhat more elaborate than that which might have sufficed with later samples whose characteristics were more closely controlled.

The principal components of the channel detector are a step-up trans-

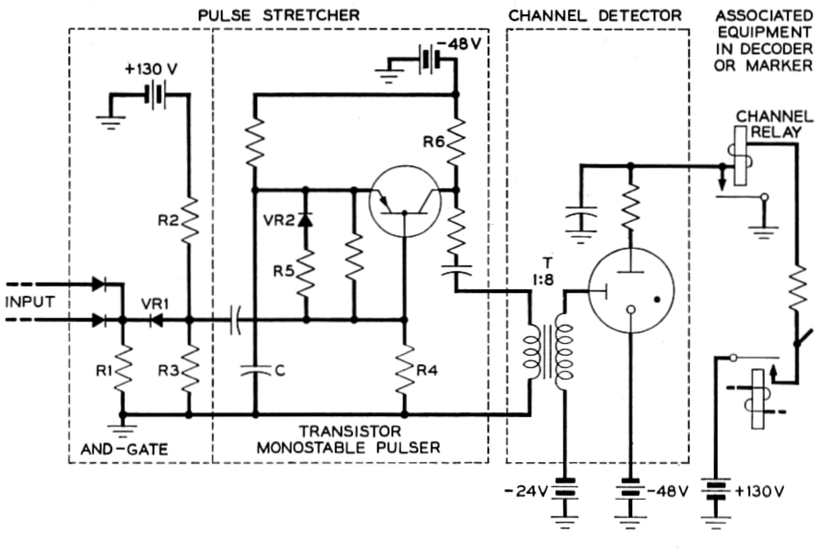


Fig. 13 — Pulse stretcher and channel detector circuit.

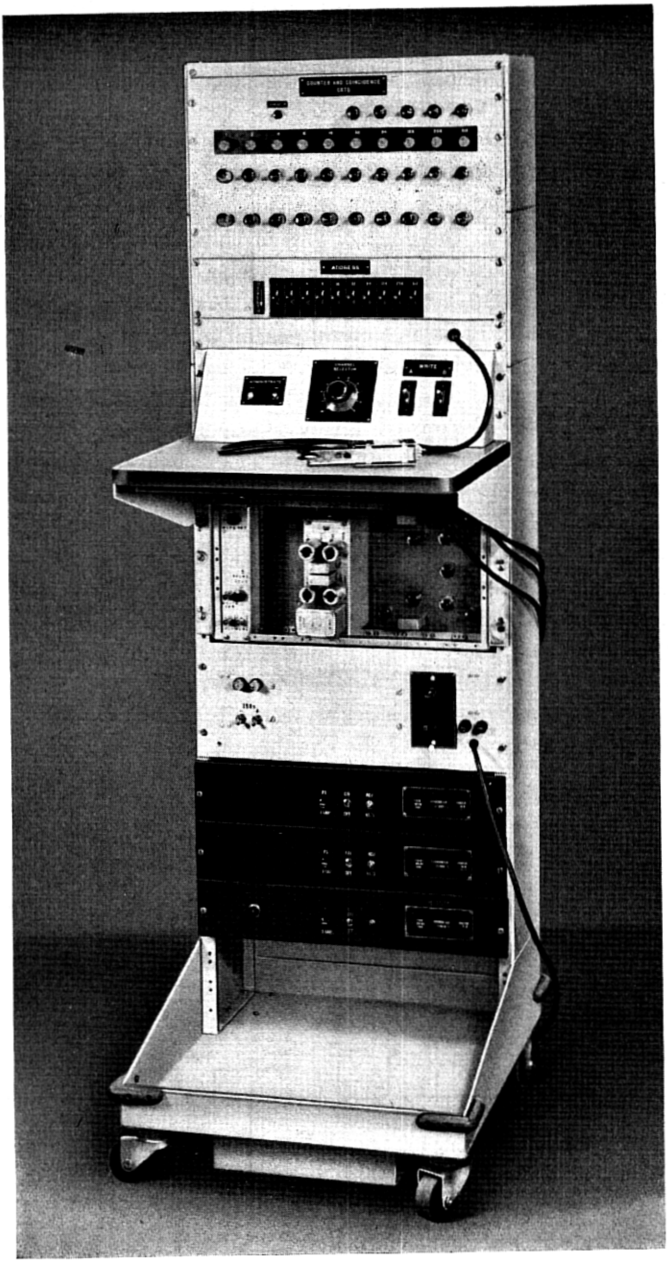


Fig. 14 — Administration unit. Three co-ax leads entering under shelf bring A, B and F pulses from translator. Cable leading to plug with bail-handle resting on shelf serves to connect writing amplifier output to magnetic heads in translator. Bottom cable connects to 60-cycle source which supplies all power.

former designed for the audio frequency range, and a cold-cathode gas tube. The starter-anode of the gas tube has a dc bias of about +24 volts with respect to its cathode to reduce the value of pulse voltage required to ionize it. When +130 volt battery is applied via the winding of the channel relay to the main anode of the gas tube, ionization established in the starter gap by the pulse stretcher signal will transfer to the main gap and cause the relay to operate. Closure of one of the relay make-contacts serves to divert the winding current from the gas tube directly to ground, thereby extinguishing the tube and prolonging its life. Other contacts, not shown, make the registered information available.

Components

A full complement of the electronic apparatus described in the last few sections utilizes plug-in components in the following quantities:

Twin-triode electron tubes	186
Cold-cathode gas tubes	121
Germanium varistors	552
Point-contact transistors	120

Only one type of each of these components is used in the translator; this uniformity greatly simplifies the maintenance problem and imposed little if any handicap on the circuit designs.

ADMINISTRATION EQUIPMENT

Whenever it is desired to add, or to change, a translation item on the drum, the auxiliary administration unit pictured in Fig. 14 is connected to the translator by three shielded cables, shown leaving the rack just under the shelf, and a ten-conductor cable, shown with its plug resting on the shelf. The shielded cables convey the A and B sync pulses and the once-per-drum-revolution fiducial F pulse to the administrator. The ten-conductor cable, with plug, is used to establish paths extending directly to magnetic heads on the drum. During the recording of any one complete translation item on the drum, this plug is successively shifted to each of nine multi-connector jacks located in the amplifier compartment of the translator.

The manual controls are located just above the shelf. At the right are the two keys for ordering a writing operation, one for the A slot and another for the B slot of the chosen pair. If either key is lifted, it will order the entry of a magnetic mark (write "*1*"). If depressed, the key will order the removal of a mark (write "*0*"). It is obvious that the translation is

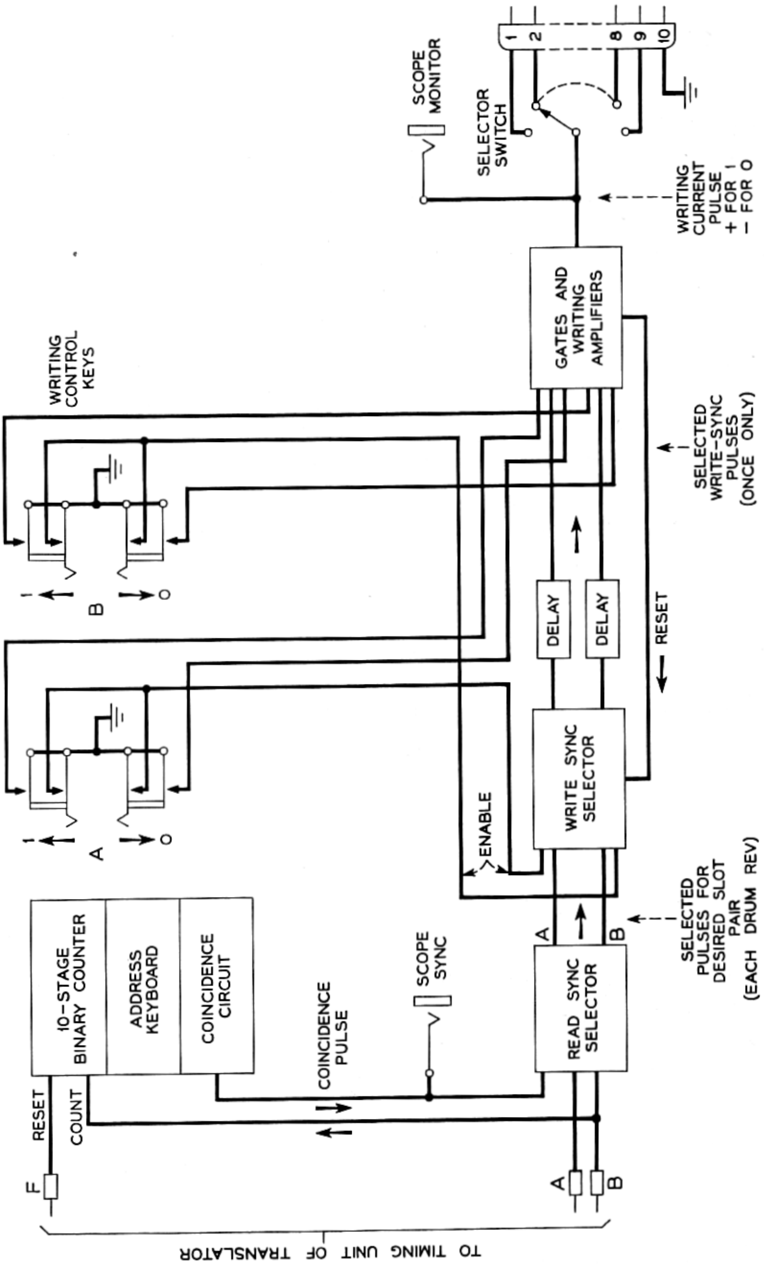


Fig. 15 — Administration unit block diagram.

inserted piecemeal by working in each track successively. The manual switching operation of connecting a single pair of writing amplifiers to each of eighty magnetic heads, in turn, is accomplished partly by setting the nine-position switch shown at the center of the panel, and partly by shifting the plug of the ten-conductor cable. At the left are two signal lights which serve as alarms to warn the operator of possible incorrect functioning of the equipment.

The operation of the administration unit can best be traced with the aid of the schematic block-diagram of Fig. 15. A ten-stage binary counter is supplied with B sync pulses from the translator; the 1,024 possible states of the counter are traversed in the course of exactly one revolution of the translator drum. The F pulse from the translator will, midway between two B pulses, set all counter stages to zero, once per revolution. After the first such reset, however, if the counter is working properly, it will always have returned to the zero condition just before the occurrence of the F pulse, by having counted 1,024 B pulses; under these conditions the F pulse, though still initiating reset action, does not change the state of the counter. The basis for the alarm signals mentioned above is a circuit arranged to detect if a change of state is occasioned by the F pulse.

Associated with the counter is a coincidence circuit with a keyboard on which may be set up any "address" between 0 and 1,023. When the count of B pulses equals the address set up on the keyboard, the coincidence circuit delivers a pulse which persists until the next B pulse alters the count; this coincidence pulse spans the time of occurrence of an A pulse, and is used in the read sync selector to gate-out a "selected" A pulse uniquely assigned to the address set up on the keyboard. A slot-spanning pulser, triggered by the selcted A pulse, gates-out the associated "selected" B pulse.

These selected pulses, which occur once per revolution of the drum, are passed through gates under control of bistable electron-tube pairs which can be set by the manual writing keys and are re-set by the writing action itself. This insures that the desired action takes place only once per key operation, instead of repeating, once per drum-revolution, as long as the keys are held operated. The manually-gated unique selected A or selected B sync pulse is then slightly delayed in time to become a selected write-sync pulse. It is passed on through further gates under direct control of the writing keys, and is employed as an input to a writing amplifier.

A pair of writing amplifiers is provided, one to write "*1*" and the other to write "*0*"; the circuits are identical quiescent blocking-oscillators sharing a common output transformer, and one or the other is triggered into action by the write-sync pulses. The output transformer supplies the writing current pulses, under control of the selector switch, to the chosen magnetic head. Arrangements are provided for synchronizing an oscilloscope to display the writing current pulses or the voltage outputs from the head at the selected address, as required.

When a new translation item is to be entered, or an existing one altered, the address corresponding to the desired slot-pair is determined from a card-index, or ledger, listing all items on the drum. The address keyboard is then set to the assigned number, thereby singling-out the desired slot pair so that the writing operation can proceed as described above. During this procedure, the monitoring oscilloscope may be used for verifying the new entry, two cells at a time. Over-all verification is accomplished by exercising the translator through facilities already available in the toll switching office. There is nothing about this procedure which precludes the use of automatic facilities for performing the administration. There is also no fundamental need to take the translator out of routine service during the administration operation, since each writing operation disables the equipment for only a few microseconds and would rarely delay a translation by as much as one drum revolution.

CONCLUSION

After short preliminary tests, the equipment described and pictured was installed in the switching systems laboratory at Bell Laboratories. A rapid-transfer arrangement permitted direct interchangeability with a card translator in a skeletonized model of a toll switching office.

A testing program was then begun entailing continuous 24-hours-per-day operation of the magnetic drum translator for approximately one year. After an initial shakedown period during which wiring faults and other minor troubles were recognized and cleared, many millions of translations were handled with only a small proportion of failures. The accumulated data on failure rate and cause was significant, being one of the primary objectives of the experiment. An analysis of the data indicated the desirability of certain simple design changes in the existing circuitry and established a basis for the selection of future designs.

If, in the future, consideration is given to the design of equipment of this type for some specific application, new electronic developments must also be taken into account. Many more types of transistors are now available than when the present design was undertaken, and some of the newer types have capabilities which make them obvious candidates for many of the jobs now done in the translator with electron tubes. Such a substitution would not only increase reliability and decrease power consumption, but since transistors are essentially current-operated devices they would seem to be particularly suitable for working with microsecond pulses in the environment of existing relay-equipped offices where the majority of interference transients are capacitively-propagated voltage-disturbances.

Evaluation of the magnetic drum reveals it to be a safe and very reliable means of storing several hundred thousand bits of information. During the course of these tests, the drum functioned perfectly, and the translations that were recorded at the beginning of the test were retained until near the end, when they were deliberately altered. During this interval of nearly continuous operation there was no detectable deterioration, or change in the signals obtained from the drum.

The results obtained from the tests of this particular drum translator indicate that the associated circuitry, working with microsecond pulses, can be designed to measure up to the exacting standards demanded for telephone office apparatus, whether the application be that of a magnetic drum translator or some other type of equipment.

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