Automatic Number Identification

and Its Application to No. 1 Crossbar, Panel and Step-by-Step Offices

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Automatic number identification provides facilities for automatically obtaining calling customers' directory numbers in No. 1 crossbar, panel and step-by-step central offices and transmitting these numbers to a tandem or toll office for recording on centralized automatic message accounting equipment for billing purposes. Present centralized automatic message accounting systems require operators to request the calling customers' numbers and to key these numbers into recording equipment. The new facilities feature a simplified procedure for customers, improvement in speed of service and greater accuracy of billing records. Offices with local automatic message accounting facilities already have these features and are not candidates for automatic number identification.

I. INTRODUCTION

As the range of customer dialing has been extended, it has become increasingly important to provide arrangements for automatically recording and processing the data required for billing these calls. To accomplish this, a system using punched tape recording and known as automatic message accounting (AMA) has been developed. This system has been arranged for local office application in No. 1 crossbar, No. 5 crossbar and step-by-step offices. Here, automatic number identification is an integral part of the system. This application is economical only when calling rates for customer-dialed multiunit traffic and toll traffic are relatively high; in places where the calling rate is low, AMA features may be located more economically at a tandem or toll-switching location. This is known as centralized automatic message accounting (CAMA). In its earlier arrangement, an operator has been bridged on the connection momentarily to obtain the calling number and to key it into the system. Automatic means of performing this action have been developed and it is the purpose of this article to describe automatic number identification (ANI) as it applies to No. 1 crossbar, panel and step-by-step types of local offices. As it is to be applied to No. 5 crossbar offices without local AMA, automatic number identification is of a different type and is beyond the scope of this article.

Automatic number identification as presently developed is for use with one- and two-party lines. Multiparty lines are recognized as such and their calls will be referred to a CAMA operator for identification.

II. METHOD OF OPERATION

Fig. 1 is a block diagram of the major equipment items required for automatic number identification, exclusive of maintenance facilities. These are:

1. an ANI outgoing trunk circuit

2. a link circuit to connect the trunk to an outpulser

3. an outpulser and identifier-connector circuit to seize and prime an identifier

4. an identifier circuit to determine the calling customer's number and forward it to the outpulser, which in turn transmits the number to the CAMA office

5. a number network and bus system to connect each customer's directory-number sleeve wire to a grid of bus panels and to connect the output of these panels via an identifier connector to an identifier.

Fundamentally, the operation is quite simple. A call proceeds in the normal fashion until the called number has been transmitted to the

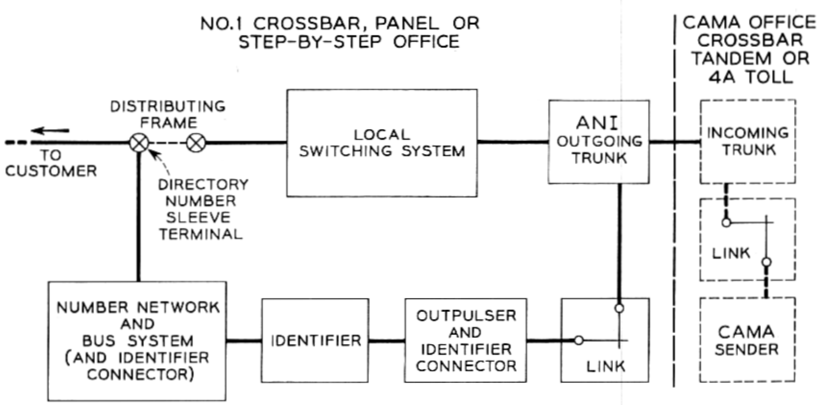

Fig. 1 — Block diagram of automatic number identification system.

CAMA sender, whereupon the identification equipment comes into play. This action is initiated by the outgoing trunk, which establishes a connection through the link to an outpulser. This circuit, by means of connecting facilities within itself, seizes an identifier. The identifier connects itself to the number network and bus system and signals the trunk to apply an identification signal to the sleeve wire toward the local switch train. This identification signal is a 5,800-cycle frequency at approximately two volts, and it finds its way over the sleeve of the switch train and back to the customer's line equipment. Here the path continues through the distributing-frame cross connections that attach directory-number significance to the line circuit, and the identification signal reaches the directory-number sleeve terminal. All of these sleeve terminals are cabled individually to networks connected to a bus system. These buses are arranged in a grid pattern in such a manner that the identifier can quickly scan the groups of output leads and identify the central office and the four digits of the calling number. This information is transferred to the outpulser, which forwards it to the CAMA point by multifrequency pulsing. Then the outpulser releases its connection through the link and the trunk connects the transmission circuit through for talking.

At the CAMA office the calling number is recorded on AMA tape along with the other information required for billing purposes. After switching of the call is completed, the called customer's line is rung, and when answer and disconnect take place, the corresponding timing entries are recorded under control of the supervisory equipment at the CAMA office.

III. NUMBER NETWORK AND BUS SYSTEM

A unique and fundamental part of the identification arrangement is the network and bus system, for which the electrical equivalent is shown in Fig. 2. The customers' directory number sleeve wires are cabled from the distributing frame to terminals on the number networks at panels in the primary bus system. The sleeve terminations are arranged in a square pattern of 100 rows and 100 columns. Each sleeve wire is connected through a 0.05-microfarad capacitor and 510-ohm resistor to ground; the junction of these components is connected through 20,000-ohm resistors to one vertical and one horizontal bus in the grid. Thus, each sleeve is associated with one of the 10,000 coordinate points in the grid and may be identified in terms of the vertical and horizontal buses to which it is attached.

If it were practical for the identifier to examine 200 buses to determine the calling number, no additional bus system would be needed. This, however, would require an excessive number of detectors. Therefore, an arrangement is provided using two secondary systems, each arranged in a square pattern of ten rows and ten columns. The primary buses are concentrated in the secondaries as shown in Fig. 2, with the vertical buses connected to one secondary grid and the horizontal buses to the other secondary grid. With this arrangement, an identifier equipped with ten detectors may be switched from one group of ten secondary buses to another. With an input signal at one of the number networks, an output signal will appear on one bus in each of the four secondary groups of ten, and the buses so marked correspond to the numerical digits of the customer's number. Thus, the identifier makes four successive tests to identify completely a number in a 10,000-line unit.

In the primary bus arrangement, the vertical buses are designated thousands and units and the horizontal buses hundreds and tens, as shown in Fig. 2. This particular numbering arrangement of the buses is

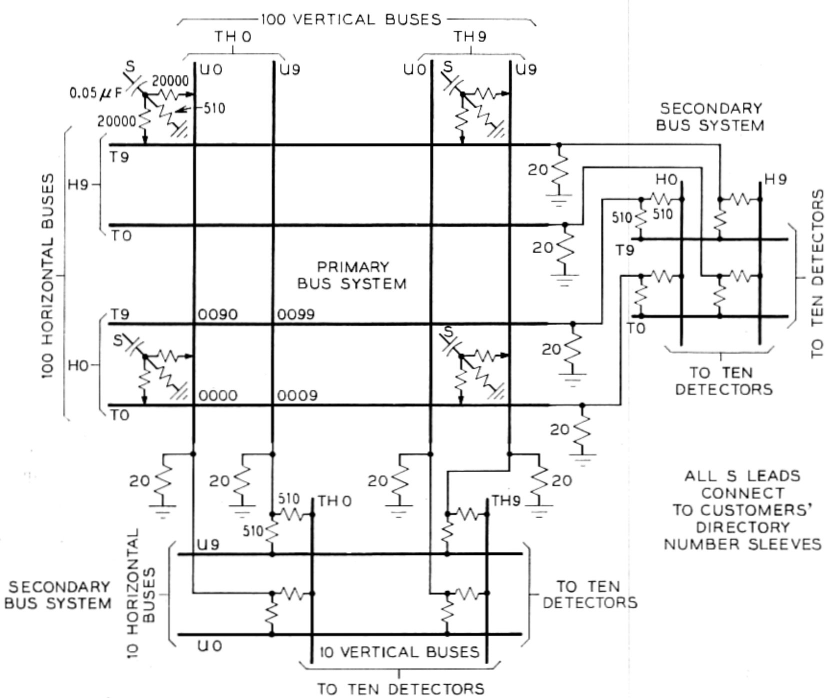

Fig. 2 — Number network and bus system.

used to provide the most convenient grouping of networks on the number network panels, as illustrated for the 00-hundred group in Fig. 2.

In multioffice buildings, a single group of ANI equipment may serve as many as six central offices, each having a maximum of 10,000 numbers. In buildings containing more than six central offices, a second group of identification equipment is required and simultaneous identifications may be made in the two groups. Successive groups of thousands buses are tested until a signal is found, then the hundreds, tens and units are examined to complete the identification. Office identification is accomplished by recognizing the particular thousands group in which the signal is found.

In offices with two-party lines, the tip parties are connected to a second set of primary buses. Before the identifier connects to the secondary buses, it is provided with information as to whether the calling customer is a tip party and, if so, it transfers the two secondary grids from the primary that contains the ring party numbers to the one that contains the tip parties. In this way, it differentiates between the two parties on a line in spite of the fact that the signal is present in the number networks for both parties.

Many primary buses will have less than 100 number networks connected to them. This will occur in offices with two-party lines where the networks are divided between tip and ring bus fields; it will also occur in offices with four-party, multiparty or PBX lines, for reasons that will be described later. Actually, the handling of PBX lines is such as to result in connecting more than 100 networks to some buses. This means that the number of networks connected to a particular bus may vary from none connected to a full complement of 100 or more. In order to minimize the resultant variation in primary bus voltage, a 20-ohm termination to ground is provided on each primary bus. This makes it easier for the detectors to discriminate between the wanted signal and the unwanted signals which result from backup paths through other networks.

A number network consists of the capacitor and three resistors associated with a single customer's directory number. These networks are mounted in groups of ten on a card approximately nine inches by three inches, photographs of which are shown in Fig. 3. The components are connected to brass details staked to the card in an unique pattern that facilitates joining them together and to terminals for external connections. The terminals for the capacitors appear at one edge of the card for cabling to the distributing frames. The terminals for the 20,000-

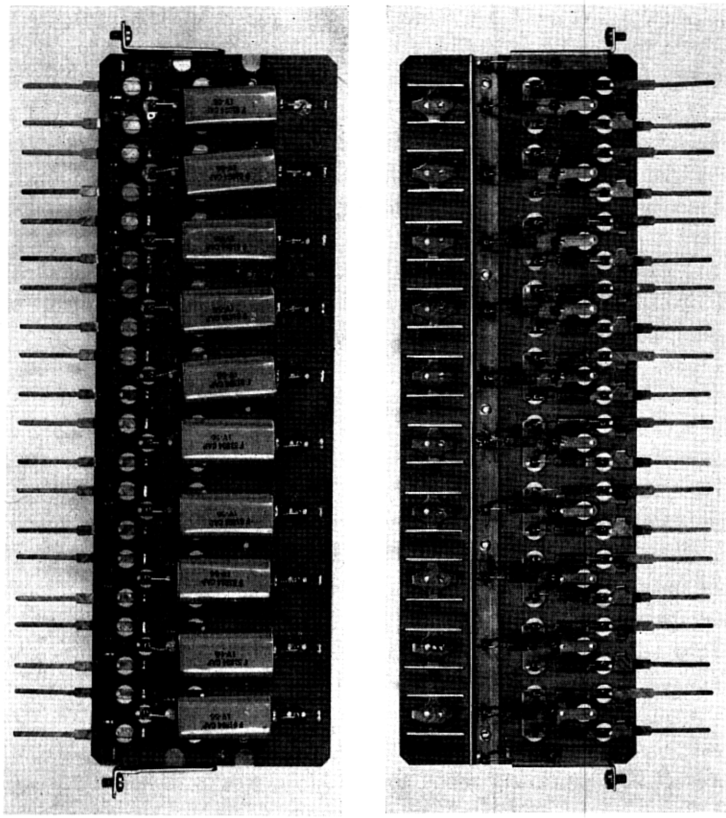

Fig. 3 — Opposing sides of card on which number networks are mounted in groups of ten.

ohm resistors project from the opposite edge of the card in positions that facilitate strapping to either tip or ring party buses.

The primary bus system is made up of panels, each of which accomodates twenty cards or two hundred number networks. A photograph of one of these bus units, partially equipped, is shown in Fig. 4. The panel itself is made of phenol fabric and, on the rear side, a grid of small buses is attached. These buses are arranged in vertical and horizontal groups. One bus of each group belongs to the tip party system and the other to the ring party system. At each position on the panel where buses cross, projections of these buses are carried through the panel to the front, where they appear as terminals for connection to the networks. Also at each position are two holes suitably positioned so that a card of ten-number networks may be mounted vertically on the rear of the panel and have its 20,000-ohm resistor terminals project through the panel to the front. Ten bus panels are mounted vertically on a 23-inch frame, which thus serves 2,000 numbers. Five such frames are needed for a full 10,000-number unit. Corresponding vertical buses on the ten panels of one frame are multipled vertically. Similar connections for the horizontal buses of the five frames of a central office are provided by interframe wiring. In crossbar offices with coded or "X" numbers, one or two additional frames are required for these networks (the method of connecting them will be described below). These numbers are outside of the 10,000-number series, and are provided for PBX use.

In addition to the two vertical buses that provide for tip and ring party identification, a third vertical bus (not indicated in Fig. 2) is provided. To this are connected all four-party or multiparty numbers; one of the 20,000-ohm legs is used for this purpose and the other is left unused. The four-party and multiparty buses are grouped together through suitable networks so they can be examined by a single "party"

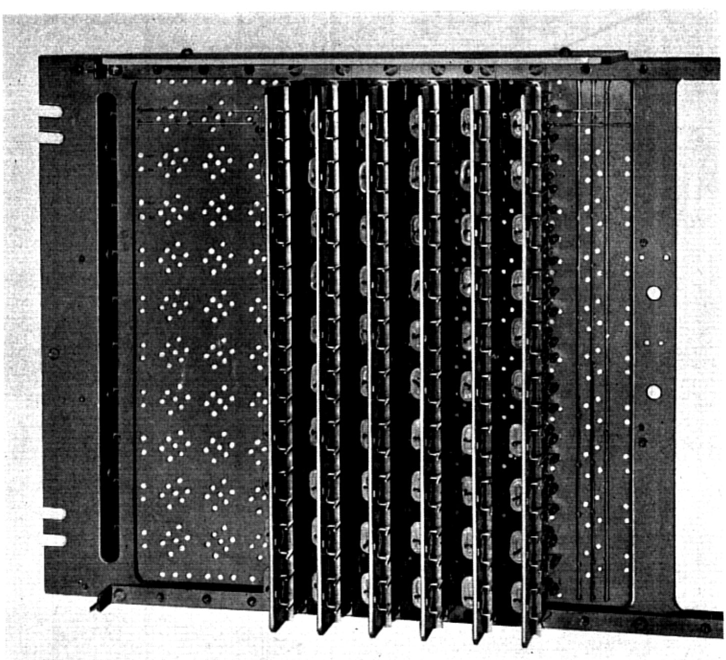

Fig. 4 — Primary bus system unit, partially equipped.

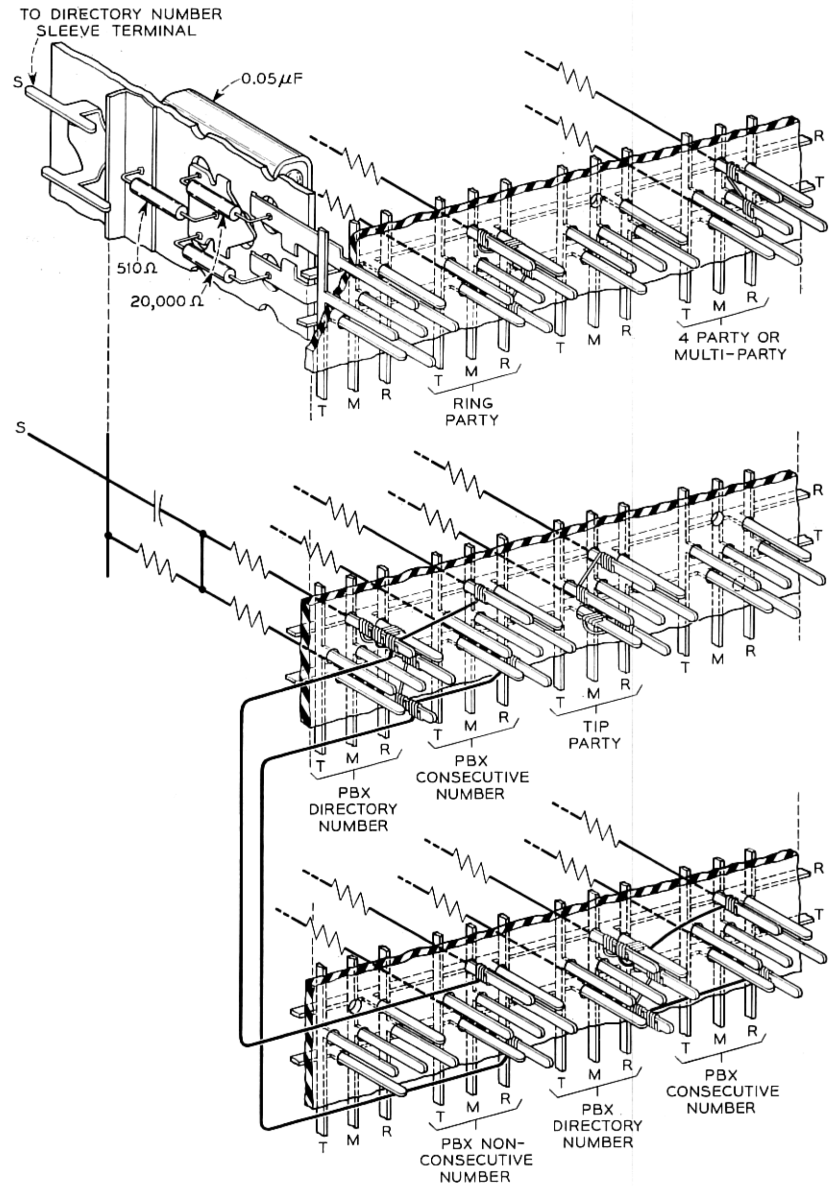

Fig. 5 — Section of primary bus panel, showing arrangement of buses and connections for typical networks.

detector in each identifier. The appearance of a signal results in the call being routed to an operator at the CAMA office, who will ask the calling customer for his number and key it into the CAMA equipment for recording on the AMA tape.

Fig. 5 is a sketch of a transparent section of a primary bus panel, facing the front. It shows the physical arrangement of the buses and typical network connections, including a ring party, a tip party and a four-party or multiparty number, as well as the connections for PBX

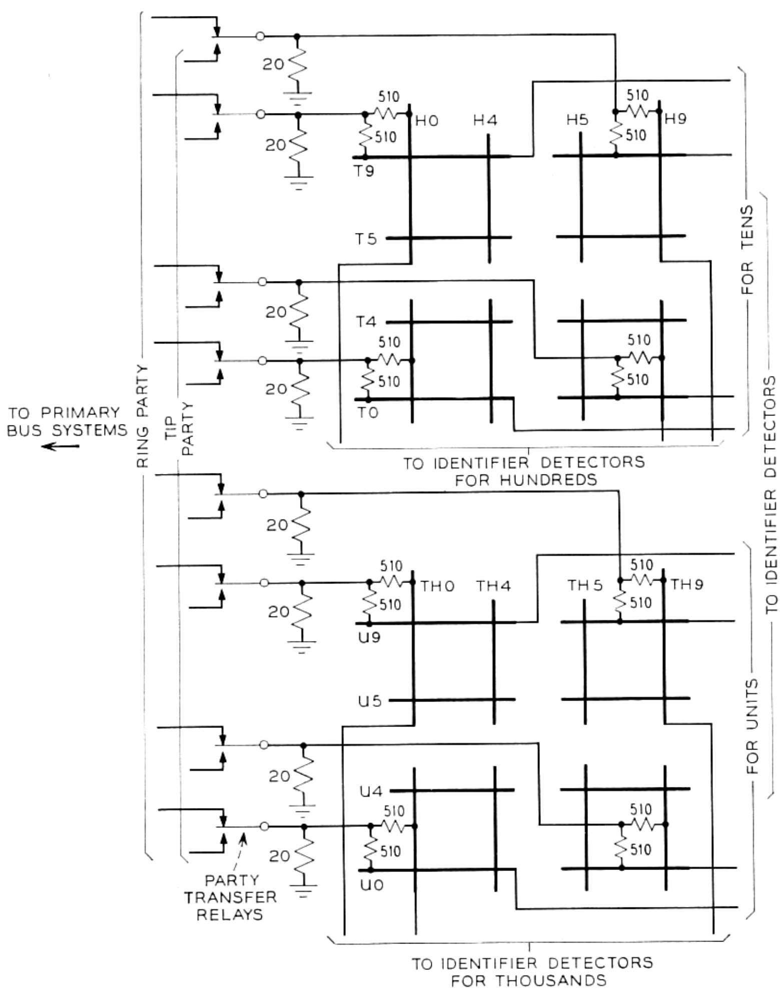

Fig. 6 — Secondary bus systems.

numbers which will be described later. The connections between network terminals and bus terminals are solderless-wrapped, with short bare-wire straps being used for adjacent terminals and insulated wire for the others. Changes in party line assignments are easily effected by unwrapping the two straps (one if multiparty) and wrapping two new ones.

The secondary bus system has been so named because the term is useful in understanding its circuit function in conjunction with the primary system. Actually, it does not use buses like those in the primary system. The resistors that make up the secondary grids are mounted on the identifier frames, together with the relays that serve to transfer these grids from the ring to the tip primary system when a tip calling party has been indicated. Fig. 6 shows the secondary bus systems in an array that is convenient for circuit understanding. Each bus is divided at the middle and its two halves are connected to separate primary windings of the input transformers in the amplifier detectors. These primary windings are connected opposing each other so that the noise and other unwanted signals on the secondary buses will be largely cancelled out.

IV. IDENTIFICATION ON PARTY LINES

On calls from two-party lines, party information must be obtained and forwarded to the identifier so that the proper one of the two primary bus systems may be switched in before number identification. In the No. 1 crossbar system, tip and ring party information is registered in the originating marker in the standard manner while the call is being switched. This information is forwarded to the ANI trunk while the marker is setting up the switch linkages. From the trunk, the information is passed on through the outpulser link to the outpulser and then to the identifier. In the panel system, the district selector makes the party test and records party information but it is not feasible to pass the information forward to the trunk. Therefore, the ANI equipment must make a party test of its own. This is done by the outpulser, which recognizes the conventional ringer ground through the switchhook as indicating a tip party. In the step-by-step system, a party test is made by the ANI trunk during the interdigital time between the first two digits dialed after the trunk is reached, and the result is forwarded to the outpulser, as in the case of the No. 1 crossbar trunk.

As indicated previously, calls for four-party and multiparty rural lines will not be individually identified but will be recognized as calls requiring operator identification. This recognition is made by connecting the networks for these lines to the third vertical bus in the primary bus system and providing a special multiparty detector in the identifier to examine the output of the multiparty buses, after attenuation to simulate losses in the secondary bus system. In the event that an economical method for identifying the parties on a four-party line is obtained, automatic identification of these numbers can be made by providing an additional primary grid system for the third and fourth party numbers. By confining these numbers to selected hundreds groups, the additional grid would need to be only a portion of a full primary bus system, and this would serve to minimize the cost.

V. PBX FEATURE

Since calls from all lines in a PBX are ordinarily billed to a single account number, it is desirable in any automatic message accounting system to be able to record all these calls by account number on the original tape. This avoids cumbersome translating procedures in the accounting center. With ANI, this feature is readily available. The network corresponding to the billing number, like any ring-party customer, is connected to the ring-field primary bus system. The networks representing the other lines in the PBX, however, are not connected to the bus system at the locations where they are mounted. These are multipled, as shown in Fig. 5, to the terminals of the directory or billing number network. Electrically, therefore, they act as if they were all connected to the primary bus grid at the same location as the directory number network. This arrangement can be used for nonconsecutively as well as consecutively numbered PBX lines, although the nonconsecutively numbered lines require longer jumper wires for multipling. Some PBX groups may extend beyond a single number network frame. To care for these cases, terminal blocks are provided at the top of all number network frames and interframe tie cables furnish the connections between frames.

As indicated earlier, in No. 1 crossbar there may exist a special category of numbers sometimes called "X numbers" and sometimes "coded numbers" which are outside the 10,000-number series comprising a central office unit and which serve as additional lines for PBX groups. It is desirable that calls from these lines, like those from other PBX lines, be billed to a common billing number in the 10,000 unit. This is accomplished electrically in the same manner as for the nonconsecutive PBX lines. Physically, since they have no position in the 10,000-number grid, they are connected to number networks mounted on a separate frame and cabled over to the base-number network.

VI. OFFICE IDENTIFICATION AND OUTPULSING THE CALLING NUMBER

During its search for the calling number, the identifier scans the groups of secondary buses by connecting its detectors to the thousands buses of each office secondary grid, one after another. Meanwhile, the identifier keeps tract of its progress and, when it finds the signal, it grounds a corresponding lead to the outpulser, thus enabling that circuit to register the office of the calling customer. During this action, the particular thousands digit registered in the identifier is being transferred to the outpulser. Thereafter the identifier scans the hundreds, tens and units buses and registers these digits in the outpulser. Although identification is made on a one-out-of-ten basis, a translation is introduced so that registration in the outpulser is on a two-out-of-five basis.

With the registers in the outpulser full and checked against missing or extra information, and the digit representing the office translated to the corresponding three-digit office code, the outpulser releases the identifier and starts outpulsing the calling number to the CAMA office. The information is sent in the following order: KP signal, information digit, three-digit office code, four numerical digits and ST signal. The KP and ST signals use the conventional frequencies that serve to actuate a receiver at the beginning and end of a sequence of information. The information digit serves to indicate one of four conditions:

1. Calling customer identified automatically.
2. Calling customer on a four-party or multiparty line, and therefore requires identification by the CAMA operator. No office or numerical digits are sent for these calls.
3. Calling customer is under service observation, and therefore the AMA record for his call requires a service-observing mark in addition to the usual information.
4. Calling customer could not be identified because of trouble in the automatic equipment. This condition requires identification by the CAMA operator. No office or numerical digits sent for these calls.

When all digits have been outpulsed, the outpulser is released and the trunk is closed through for the talking condition.

VII. AUTOMATIC NUMBER IDENTIFICATION IN COMBINATION WITH DIRECT DISTANCE DIALING

The introduction of direct distance dialing (DDD) eliminates the need for an operator to control the switching of a call, and automatic number identification will remove the need for an operator to obtain and record the calling number information. Hence it is natural that the two facilities would appear together in many areas. However, there are no design or operating conditions that make this imperative. Automatic number identification may be used in No. 1 crossbar and panel offices for seven- and ten-digit calls switched through tandem or toll CAMA offices. For the ten-digit calls, the called number is always outpulsed on a multifrequency (MF) pulsing basis and this requires an "MF-type" ANI outgoing trunk in the local offices. Seven-digit calls originating in these offices and switched through tandem may use the panel call indicator method of outpulsing the called number and for this a "PCI-type" ANI outgoing trunk is provided. Other seven-digit ANI calls use the "MF-type" pulsing.

Direct distance dialing calls in step-by-step offices with ANI may be switched through tandem, toll, No. 5 crossbar or step-by-step intertoll offices equipped with CAMA. These calls outpulse the called number on a dial pulse basis, and usually require a preliminary or directing code to switch the call through the originating step-by-step office. Offices with automatic ticketing, whether converted to AMA or not, are not candidates for ANI, since they already have their own arrangements for identifying the calling customer.

VIII. CIRCUITS

8.1 *Trunk Circuits*

The fundamental requirements for the ANI trunk circuits are similar in the three switching systems. These trunks must be able to recognize the correct time to perform the ANI function and then seize an outpulser through the outpulser link. They must participate in several ways in the party-test function before number identification, and they must provide a path between outpulser link and outgoing cable over which the outpulser can forward the calling number after it has been identified. Then, after release of the outpulser, they must provide a transmission path with talking battery and supervision toward the calling customer and trunk supervision toward the tandem end. Also, they must provide the necessary sleeve ground to hold the originating switch train.

Due to inherent differences in the three switching systems, it has been found best to design separate trunks for each. Furthermore, variations within each of the systems in methods of pulsing and signaling have resulted in two types of trunks for each system. In No. 1 crossbar and panel, one type is provided when the called number is to be transmitted by MF pulsing and the other type when PCI pulsing is used. In step-by-step, one type of trunk is provided for loop signaling and the other for the so-called "E and M lead" signaling which is required for the longer distances and when voice repeaters or carrier circuits are used.

Crossbar and panel trunks must receive a signal from CAMA indicating readiness to receive the called number. For MF circuits, this signal is a momentary reversal of battery and ground and is relayed through the ANI trunk and back to the DDD sender as a go-ahead signal. For PCI circuits, the corresponding signal is the removal of battery and ground at the CAMA end of the trunk. At the time this occurs, the ANI trunk is cut through and the signal is transmitted directly to the subscriber sender (in this case, there is no DDD sender connected).

All the ANI trunks need a "start identification" signal from CAMA to indicate when that equipment is ready to receive the calling number. Crossbar and panel trunks must also recognize when the district junctor or selector has reached the cut-through position. Only then is the sleeve continuous, as required for transmission of the identification signal. Receipt of the start identification signal, together with detection of district junctor or selector "cut-through," when required, causes the ANI trunk to initiate the identification function.

8.2 *Outpulser Link Circuit*

This circuit uses a six-wire, 100-point crossbar switch as the linkage medium for connecting trunks to outpulsers. One switch is required for each group of ten trunks. The control features are very simple and require one preference chain relay for each trunk and a group of three control relays per outpulser for each group of ten trunks.

8.3 *Outpulser Circuit*

The outpulser has a number of functions to perform. On some calls, as described earlier, it will receive party information from the trunk and on others it will be told to make party test by a signal from the trunk. Then the outpulser seizes an identifier, which, as it finds the signal, registers in the outpulser the office identity and numerical digits of the calling customer. If the calling customer's line is one on which service observations are being made, the connected service-observing equipment will operate a service-observing detector in the identifier. An indication to this effect is registered in the outpulser. As the digits are registered in the outpulser, they are checked and the digit representing the office is translated to the three digits representing the calling office code. Outpulsing to CAMA then takes place, with the calling number preceded, of course, by the information digit. This outpulsing is done on a multifrequency basis at the conventional rate of approximately seven digits per second.

The outpulser is provided with checking and timing features so that it can detect a trouble promptly. In this event, the outpulser calls in a trouble-recording medium known as the "trouble ticketer" and provides it with the significant information preparatory to printing the trouble record. The trouble ticketer is a new facility introduced with the ANI equipment and will be described later. After making the trouble record, the outpulser makes a second trial identifier seizure.

8.4 *Identifier Circuit*

Consider a building with several central office units and a common group of identification equipment. For each ANI call, the identifier must test the thousands secondary buses for each office, one after another, and, when the signal is found, test successively the hundreds, tens and units buses in that office. Fig. 7 shows how the identifier performs the steering and testing functions and registers the results of its search in the outpulser.

During the search from one office to another, the thousands steering relay THS in the digit steering circuit is held operated. Relays OF0, OF1, etc., in the office-steering circuit operate successive identifier connector thousands relays TH in the secondary network and bus connector circuit. These relays close, in succession, the detector inputs to the thousands secondary buses of the different offices. During this time the register-steering circuit holds the detector outputs closed to the thousands translation circuit relays THR0-9. When a signal is found, the operated detector energizes its associated THR- relay representing the digit received. The THR- relay operates two-out-of-five thousands relays TH- in the thousands register of the outpulser circuit, thus registering the thousands digit of the calling customer's number. At the same time, the identifier office-check relay OFK operates and, in conjunction with the energized office steering relay OF-, operates an office relay OF- in the office register of the outpulser circuit. This latter OF- relay registers the office containing the calling customer's number. Further advance of the office steering circuit is blocked by relays not shown.

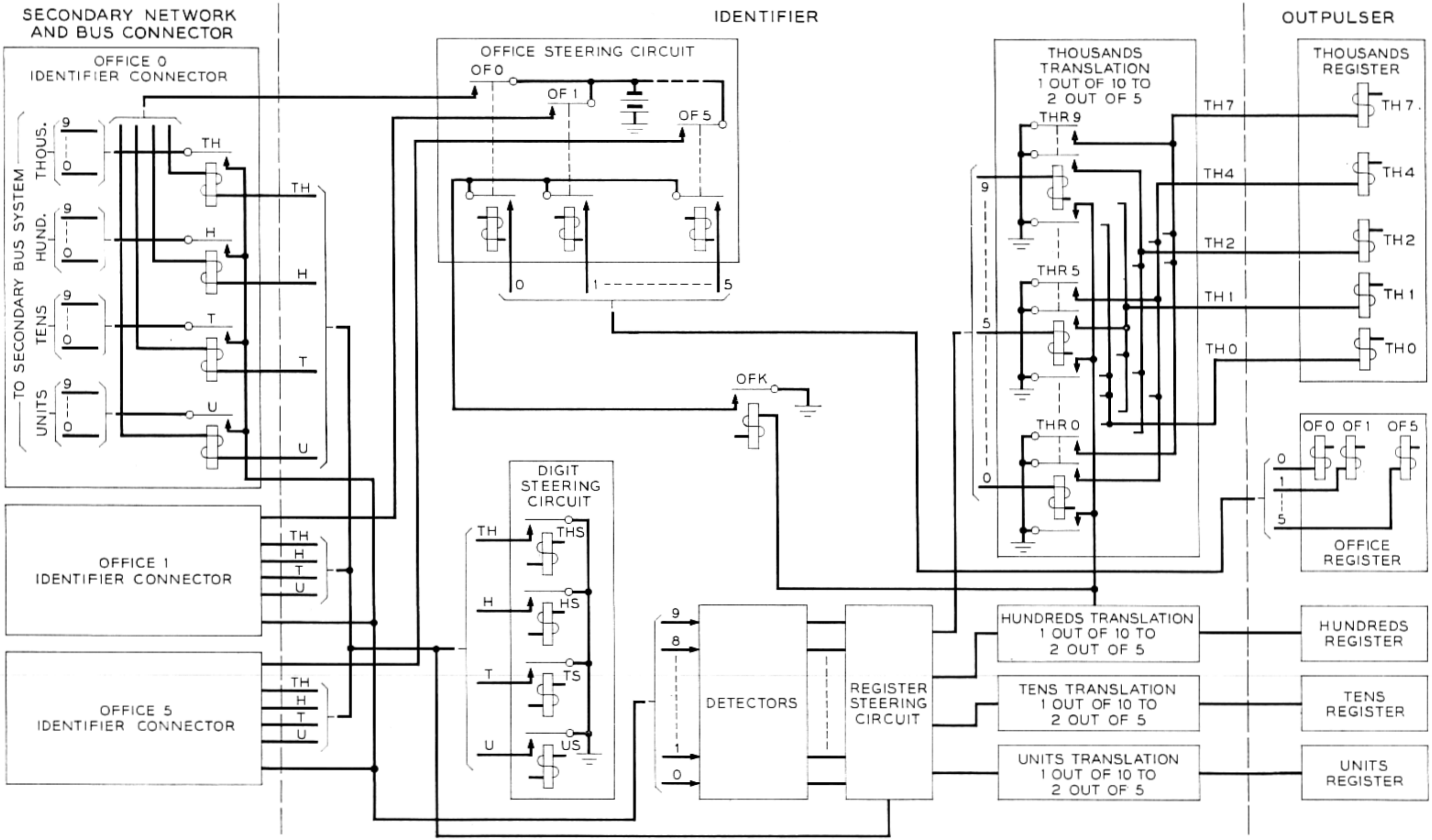

Fig. 7 — Identifier and outpulser steering and register functions.

Meanwhile, the operation of the OFK relay has brought the digit steering circuit into play, and it operates, successively, the hundreds, tens and units steering relays HS, TS, and US over paths not shown. These relays operate the corresponding secondary network and bus connector H, T and U relays, which serve to connect the detector inputs successively to the hundreds, tens and units secondary buses of the identified office. At the same time and in synchronism with this sequence, the detector outputs are connected to the hundreds, tens and units translation relays, which function to register the corresponding digits in the proper outpulser registers. During periods of light load, the identifier will not only scan successive office buses until the signal is found but will continue its search thoughout the remaining offices, in order to pick up troubles that cause wrong detector operation. The action of the circuit in case it encounters a trouble condition will be described later.

In one identifier group, which may serve as many as six central offices, only one identifier can be connected to the bus system at a time. Therefore, it is important that the search be completed quickly so as not to delay the traffic. The average identifier holding time is approximately 0.27 second for the largest groups and is less, of course, for others. With this speed of operation, the "one-at-a-time" identification method will care for traffic greatly exceeding the amount now foreseen for any group of six offices. In buildings having more than six offices, two or more independent identifier groups will be furnished and may operate simultaneously. Features in the detectors for discriminating between real and spurious signals require that the detectors be connected to the buses for 12 to 15 milliseconds for each test. Additional time for operating the register relays in the outpulser and for transferring detectors between tests, as well as for the initial circuit preparation, bring the over-all time up to the value quoted.

8.5 *Operation in Case of Identification Failure*

The identifying signal may be blocked temporarily in the panel system if the brushes of a hunting selector bridge a grounded terminal to a terminal carrying a signal. It may also be blocked temporarily in a step-by-step office as a selector wiper hunts across a terminal carrying a signal. These conditions can result in a failure to identify one or more digits of the calling number. To care for this situation, the identifier is arranged so that, if digits are missing, it will make a retest to fill in the missing digit or digits. If the retest is successful, no trouble record will be made.

If the identifier is unable to make an identification in two tests, a trouble is assumed and the outpulser is so notified. This circuit seizes the trouble ticketer (as previously described) and gives it information for a trouble record. The outpulser then releases the identifier and makes a second trial, using the other identifier, if available. In the event that the second trial should fail in two tests, the outpulser sends out the proper information digit to call in the CAMA operator for identification.

IX. TRANSMISSION AND DETECTION OF IDENTIFICATION SIGNAL

Considerable study and testing, both in the laboratory and in the field, was done to determine a suitable voltage and frequency for the identification signal and to develop a reliable amplifier-detector. The upper limit on the signal voltage was found to be controlled principally by induction into adjacent circuits on panel office selector banks and consequent disturbance to transmission. Field tests indicated that the voltage of the signal on the switch train sleeve must not greatly exceed two volts, assuming operation to be within the frequency range imposed by limitations to be described later. The signal undergoes considerable attenuation, particularly as it is transmitted through the translating resistors of the number networks and through the coupling resistors between primary and secondary bus systems. Fig. 8 is a simplified circuit showing the path of the signal from the directory number sleeve to the amplifier. This path is, in effect, a series of voltage dividers. Typical voltages are given at successive junctions along the path. The nominal value of the final voltage at the input to the amplifier-detector is 90 microvolts. This signal must be amplified to approximately 90 volts to operate the registering device, representing a voltage amplification of a million times, or 120 db.

The determination of a suitable frequency for the identification signal was made after experimentation with several lower values in the field. At 1,900 cycles, the induction crosstalk into the panel selector banks was sufficient to be audible to customers using other circuits in the office. Frequencies in the nighborhood of 200 cycles are clear of this objection, partly because of the reduced sensitivity of the ear and partly because of lower coupling. However, this frequency would be more difficult to distinguish from surges and would require a longer operate time in the detector, as will be evident later. When the frequency was raised from 1,900 to 5,800 cycles, the noise on disturbed circuits was reduced to an insignificant level. This was due in part to the effect of lessened receiver sensitivity and in part to masking by noise from other sources in this frequency range. Regarding the upper limit on the frequency, a major consideration is the avoidance of interference into program circuits and carrier facilities by secondary induction. Although these circuits would not be in the same cable with the signal carrying sleeve, they may be in the same outside cable with the identified customer's pair, which does pick up some signal because of electromagnetic coupling with the associated sleeve lead through the switch train.

As for the transmission path of the identification signal, large variations must be met in the conditions contributing to the load on the sleeve lead and in the elements causing momentary interference. As previously described, the selectors in the panel and crossbar switch trains are in the "operator talking" condition, and this requires a very low-resistance dc ground on the sleeve from the ANI trunk during identification. To meet this requirement without placing too heavy a load on the oscillator, an inductor is used which has approximately 0.5 ohm dc resistance and 450 ohms impedance to the 5,800-cycle signal. Panel offices, unlike crossbar and step-by-step offices, present a 2-microfarad capacitor in series

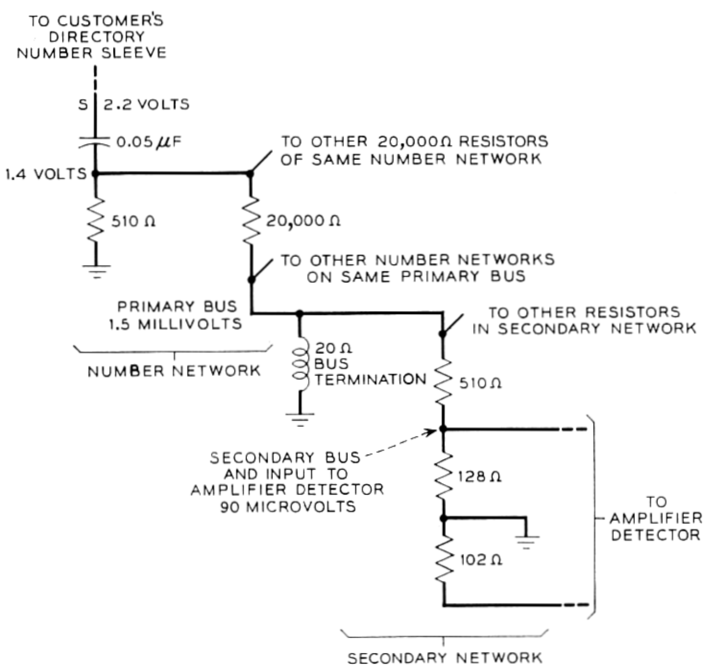

Fig. 8 — Path of identification signal through number network and bus systems. Voltages shown are nominal values.

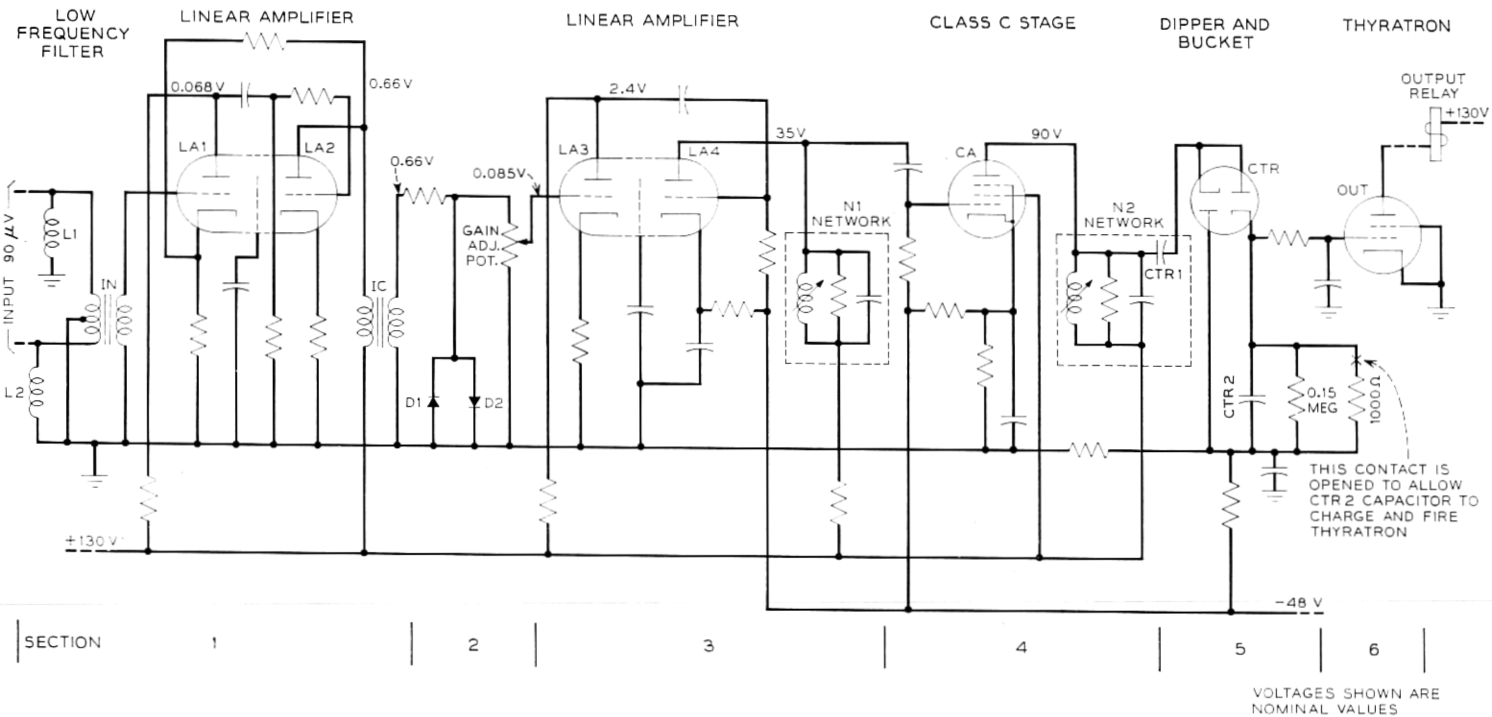

Fig. 9 — Amplifier-detector circuit. Voltages shown are nominal values.

with the switch train sleeve, and either 220 ohms to battery or 112 ohms to ground on the number network side of the capacitor. Additional resistance in the transmission path may be encountered at the sequence switch brushes and multiple bank brushes, or even at relay contacts. All systems have a great variety of relay or crossbar switch hold-magnet windings connected to the sleeve. On the identified sleeve, these constitute an additional load. On nonidentified sleeves, these magnets may be releasing and producing surges and voltage peaks which impose a nonoperate requirement on detectors that are examining the corresponding buses at the time. All of these conditions contribute to the operating requirements and margins of the amplifier-detectors and of the ANI system.

X. FEATURES OF THE AMPLIFIER-DETECTOR

In much of conventional amplifier-detector design, the margin between operate and nonoperate conditions is largely determined by the signal-to-noise ratio. Where both signal and noise are in the same frequency band, discrimination is made by amplitude. In ANI, however, there are times when the unwanted signal approaches or even exceeds the wanted signal in amplitude and is indistinguishable by frequency. Fortunately, these times of high unwanted signal are of short duration, because they are caused by various transient conditions in the switching systems.

Some of the features of the amplifier-detector that provide the needed amplification and yet retain adequate discrimination against the summation of unwanted signals are of interest. Fig. 9 is a simplified sketch of the amplifier, divided into sections for descriptive purposes and with representative voltages indicated at significant points. As previously described, the two input leads of the amplifier are connected to the two halves of the secondary bus and the primary windings of IN transformer are connected opposing. With this arrangement, much of the noise on the secondary buses is cancelled out. The L1 and L2 inductors, in conjunction with the reflected capacitative impedance looking into the primary winding of IN transformer, constitute a bandpass filter. As low-frequency components of noise enter the amplifier, this filter removes practically all of each surge except the spikes associated with the steep wave fronts. This is necessary in order to prevent surges and 60-cycle pickup from blocking the legitimate signals by overloading the amplifiers. The spikes are of such short duration that, in spite of their considerable amplitude, they do not cause blocking. The first section includes a twin-triode linear amplifier LA1-LA2 with the two halves in cascade and with transformer coupling to input and output. The voltage gain in this section, which includes the IN and IC transformers, is some 7,300 times, or 77 db.

The second section uses two oppositely poled silicon diode clippers D1 and D2 which limit both peaks of the spikes before they can reach the tuned circuit in the next section. Since the tuned circuit would oscillate, it is necessary to limit the sudden voltages which it receives. This application of the silicon diodes utilizes a characteristic that makes them, in effect, reverse-biased up to 0.6 volt in the forward direction. The identification signal is too low in this stage to be affected by the clippers. The adjusting potentiometer GN is just beyond the clippers. With normal settings, a loss of about 18 db exists in the second section.

The third section is another twin-triode amplifier LA3-LA4 working into a 5,800-cycle tuned network designated N1. The resistance in this network is provided to reduce any tendency to oscillate. The voltage gain in this section is about 410 times, or 52 db.

The fourth section, using tube CA, is a class C stage designed to eliminate signals below the expected minimum operating signal. Since this stage is biased beyond cutoff, it ignores signals below the desired level. Otherwise, these signals would help build up the grid voltage at the output tube and impose a more severe nonoperate condition on the detector. This stage has a voltage amplification of about 2.6 times, or 9 db. It has a tuned plate circuit designated N2 in Fig. 9.

The fifth section is a "dipper and bucket counter" comprising a double-diode CTR and two capacitors. On each negative half-cycle of a signal the small capacitor (CTR1) is charged, and on each positive half-cycle it spills its charge into a larger bucket capacitor (CTR2) which therefore gradually increases its voltage in steps until it operates a thyratron tube in the sixth section. A resistance is bridged around the bucket capacitor to enable the detector to forget comparatively small numbers of pulses resulting from random surges. When the detector is not testing for a signal, a low-resistance 1,000-ohm circuit is maintained across the bucket capacitor. The testing time is controlled by the identifier, which opens the 1,000-ohm circuit for an interval of 12 to 15 milliseconds.

From this description, it can be seen that the amplifier-detector not only has the amplification necessary to raise a 90-microvolt signal to a usable value but also discriminates by filtering, by blocking out signals known to be spurious because they are too big or too small, and by counting an appropriate number of cycles of legitimate signal before being satisfied.

XI. MAINTENANCE FACILITIES

In the event of an identification failure or certain other irregularities, a trouble record is made. This shows the identity of the various ANI circuits involved and the stage to which each had progressed at the time the trouble appeared. This record will be recorded by a ticket printer of the type used in step-by-step automatic ticketing. After the trouble record, a second attempt is made using the other identifier when provided. If this attempt should also fail, due to the trouble being in the network or somewhere else outside the identifier, no second trial trouble record is normally made. This is because the trouble ticketer will be busy printing a record of the first failure. If it is desired to take a trouble record after second trial instead of first trial failures, a key must be operated that is provided for this purpose. Trouble records cannot be taken after both first and second trial failures because the functioning time of the trouble ticketer is about six seconds, and to wait for it to become free would seriously extend the second trial identifier-holding time. In the event of a second trial failure, the appropriate information digit is sent to cause the CAMA operator to make the identification. A special trouble record will be made at tandem and will include the calling customer's number as obtained by the operator; this record will be returned or reported to the originating office for maintenance use.

Testing equipment is provided for the ANI trunks, outpulsers, identifiers and networks, with means for selecting any combination of these circuits. Tests are made by selecting the trunks directly rather than through the switch train. Normally, the identification signal, instead of following the switch train path back to the number networks, is diverted to an artificial test network. This facilitates applying marginal tests to the detectors to anticipate approaching troubles. It also permits holding the test connection while service calls are allowed to use the regular number network and bus system. If it is desired to include the regular number network system in the test path, a patching connection must be made on one of the number network frames to a particular number network. In either case, the identified number, instead of being pulsed out to tandem, is steered back to the test equipment and displayed on a set of lamps.

When new customers are given service or when line numbers are changed, it is important that the corresponding service order work be checked to verify correct identification on calls from these lines. This identification is made by the ANI equipment. In No. 1 crossbar and step-by-step offices, existing test train facilities are used to direct a test call to the line to be verified. In panel offices, this connection is established by patching at a distributing frame. In all cases, the test connecting facilities will have access to the ANI outpulsers through the outpulser link. After the line to be verified is reached, the ANI equipment is actuated and the outpulser obtains an identification by the normal process. Instead of forwarding this number to a distant CAMA office, the outpulser will display it on lamps convenient to the observer.

A new facility will be available in No. 1 crossbar and panel offices for identifying lines that have been routed to permanent-signal holding trunks because of receiver off-hook or line trouble conditions. Here an auxiliary circuit will be provided with access to the outpulsers through the outpulser link. To determine the number of a line that has become connected to a permanent-signal trunk, the test man will patch the new auxiliary circuit to the jack of the permanent-signal trunk. Upon receipt of a start signal, the ANI equipment will function and the identified number will be displayed on a special ticket produced by the trouble ticketer. Since line troubles might or might not give a tip party indication if party test were made, the identifier will always test first in the ring field on permanent-signal calls. If no identification is made, it will then test in the tip field, since the trouble may be on a party line with only a tip station connected to the identification buses. It is not planned to provide this facility in step-by-step offices because, in the absence of any common control equipment, routing of these calls to permanent signal holding trunks is not feasible.

XII. CONCLUSION

The development of automatic number identification is a major advance toward full automation of all customer-dialed calls in the Bell System. It provides a simplified procedure for the customers, faster service in completing calls and greater accuracy for billing records.