# A Multistation, Centralized Digital Traffic-Counting System

ARA M. BALTAYAN and LUDWIG PALLAT, respectively, Manager, Development Laboratory, and Development Engineer, Automatic Signal Division, Laboratory for Electronics

A highly accurate, fast, economical, and convenient system for the collection, processing, and recording of traffic-count data has been devised using a digital computer as the central processing element. This paper is a description of this system, which eliminates the need for human intervention between the traffic detectors and the processed data and fills a need in the traffic engineering field. Some of the important advantages of the system are continuous data availability, reduced data-processing time, high vehicle resolution, reduced field maintenance, low telephone line costs, low power consumption, and fully transistorized modular construction. That a series of traffic counts for all the stations can be fed into a general purpose computer with no waiting period between each report is a major advantage of this system, because the processing time on the high-speed general computer is reduced to a point where the investment for the digital computer described is easily justifiable.

• A HIGHLY accurate, fast, economical, and convenient system for the collection, processing and recording of traffic-count data has been devised using a digital computer as the central processing element. This paper describes the system, which is completely automated and eliminates the need for human intervention between the traffic detectors and the processed data, thereby filling a long-felt need in the traffic engineering field.

Figure 1 is an artist's conception of the use of the centralized digital traffic-counting system for covering an entire State. Figure 2 shows the actual routing of the telephone network for an experimental setup in the State of Connecticut. The computer in question has a capacity of 60 traffic-counting stations. As shown in Figure 1, a multitude of detector types may be used as sources of information for this computer; to name a few, pressure detectors, magnetic detectors, radar detectors, and induction loop detectors. Each dot on the map of Figure 1 represents a traffic-counting station, at which one or more traffic-counting detectors may be used. The information from the traffic-counting detectors is fed through a network of telephone circuits to a central location which houses the computer.

There are various methods of data transmission from the traffic-counting stations to the centralized computer. Among the most economical methods, the party line method of multiplexing proves to be the most desirable one. By the use of proper tone-coding equipment at the transmitting end and decoding equipment at the receiving end, as many as 20 detector stations may be connected to a circuit using the party line principle. This reduces the number of individual lines that must be run to the central office where the computer is located, resulting in economy of line rental. A "voice-grade" type of telephone line is required for this service. If individual direct lines are privately owned by the State or the municipality using the equipment, the information can

Paper sponsored by Committee on Electronic Research in the Highway Field.

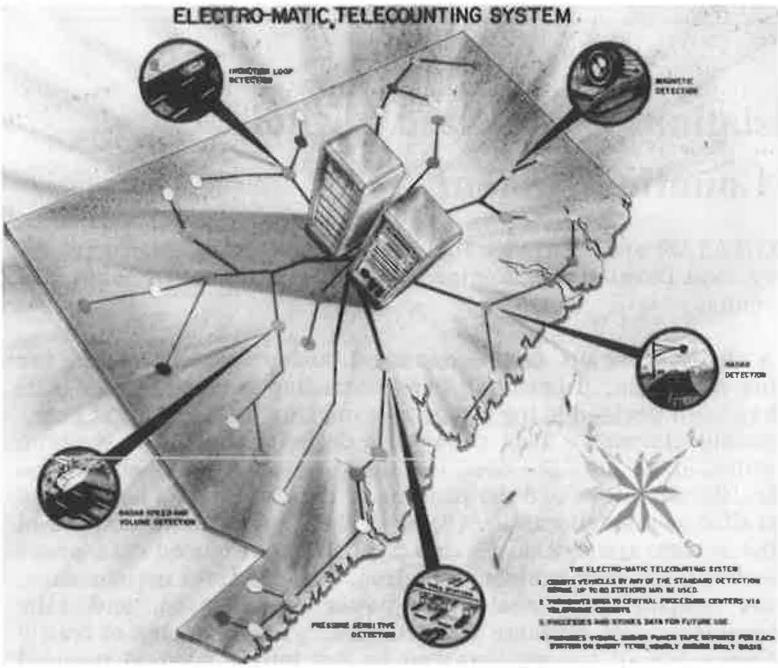



Figure 1. Artist's conception of telecount system.

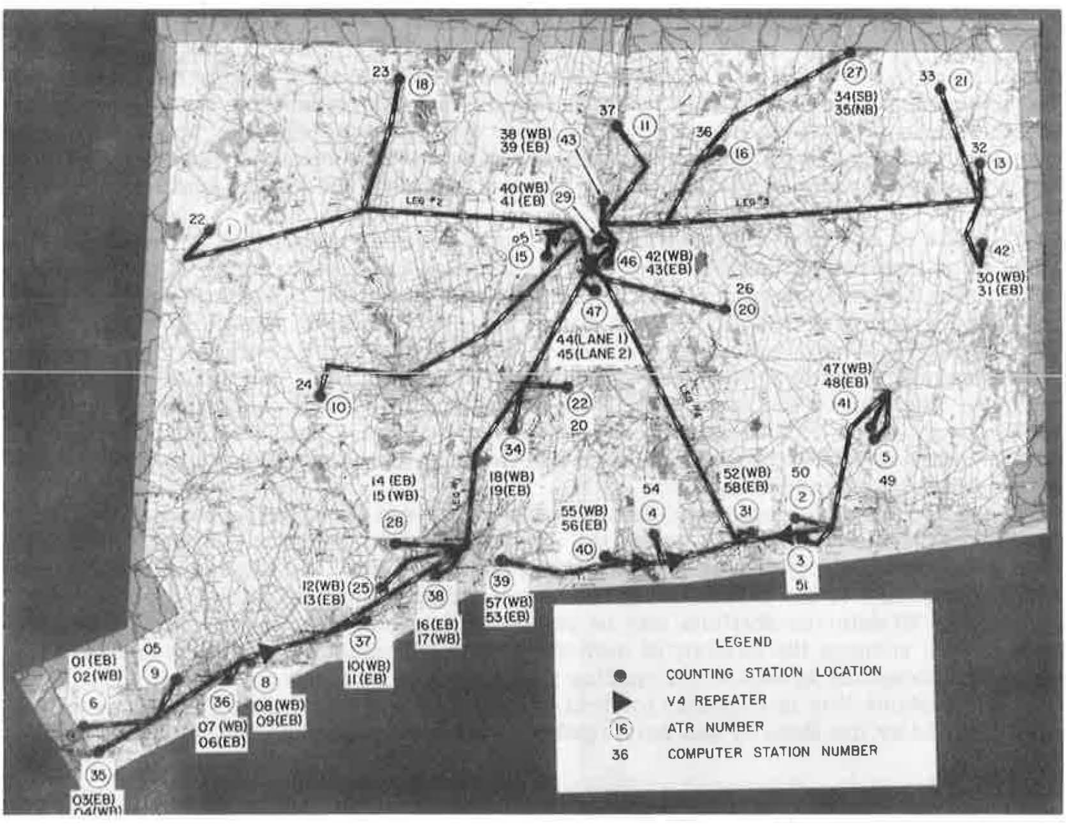



Figure 2. Map of experimental telecount system in Connecticut.

be transmitted over a pair of these lines without reverting to the use of telephone lines.

A third method of data transmission might be the use of teletype-grade telephone circuits to feed the information from the traffic-counting station to an intermediate point and code the information at this location for transmission over a voice-grade circuit. In some cases, this combination will reduce the cost of rental of transmission lines. In applications where the agency has a microwave link facility, this latter could be used, at least in part, for long-distance transmission of the data. From the terminus of the link individual circuits may be used between the decoder at the end of the microwave link and the central station. The party line method may also be used to transmit the information from the link terminal to the computer.

Figure 3 is a close-up of the three racks that house all of the necessary components or equipment that make up the traffic-counting system. The decoding equipment is in the left-hand rack. The latter may be categorized as auxiliary equipment.

Before detailing the operation of the system, the auxiliary equipment used in the transmission of data by the party line method is discussed. Figure 4 shows the scaler unit. It is normally located at the detector station. This unit has three basic functions. The first is to scale down to one any number of actuations that may be obtained from different types of detectors, or scale down to one the number of actuations produced by a number of detectors for the same location connected to the same line, providing a traffic count on a per-lane basis. To illustrate the use of the scaler unit with a few examples, it is assumed that there is a pressure detector at one location. If vehicles are being counted, the pressure detector will normally give two counts or two pulses per vehicle. This will result in double the number of actual vehicles passing the traffic-counting station unless an intermediate piece of equipment is used to count it down by a ratio of 2:1.

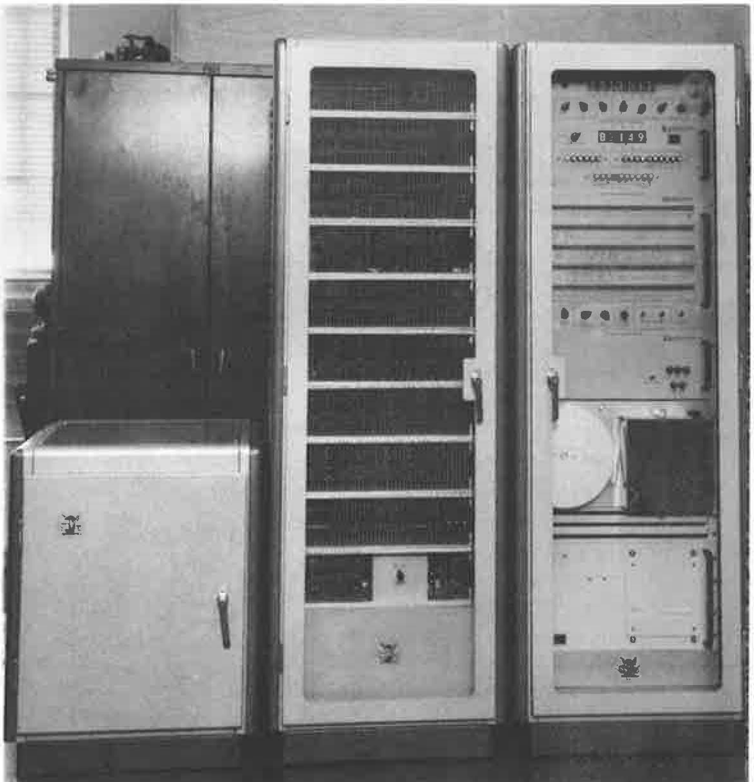


Figure 3. Central office equipment racks.


Figure 4. Scaler unit.

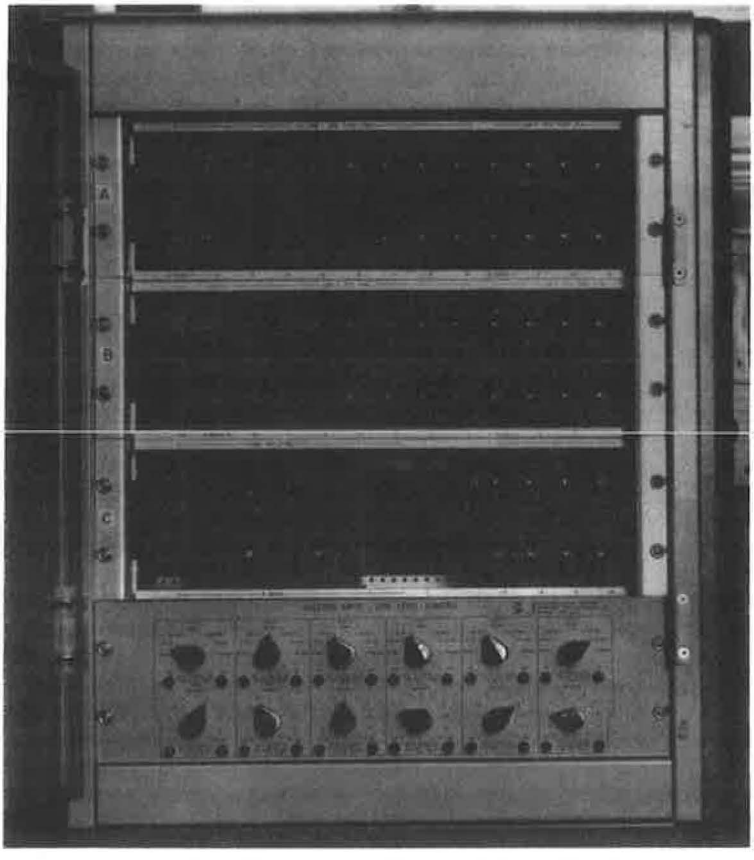



Figure 5. Line compensators and tone decoders.

In another instance, it is assumed that there is a multilane roadway with a vehicle detector in each lane. In this case, if there is no interest in the individual lane traffic count, the output of all four detectors could be fed into the scaler which would be preset for a ratio of 4:1, thus providing an average value for traffic per lane at that particular station. On the other hand, setting the ratio to 1:1 will give the total volume in both directions.

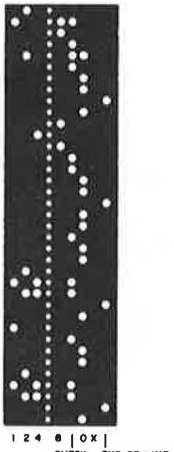
The second function of the scaler unit is to provide an output suitable for the type and method of transmission between the detector station and the "Telecount" system. By changing one of the printed circuit modules in the unit any one of three types of output may be obtained: (a) a pulse output that may be used for transmission over a teletype-grade circuit; (b) an output that will provide a relay contact closure for each traffic actuation; and (c) a tone-coded output for multiplexing on party lines. Thus, the versatility of the scaler unit makes the centralized traffic-counting system universally adaptable for operation from any type of detector as shown in Figure 1.

A third function of the scaler unit is to provide a clean output for each vehicle actuation, thereby nullifying any possible contact bounce which may be generated by the detector. Figure 5 is a close-up of the decoding equipment that may be used when the party line method is utilized. The top section of this figure shows the filter units which decode the information applied to the party line. The tone-coding equipment is designed with a response of 300 to 3,000 cycles thus allowing up to 20 stations to be connected to a multiplexed circuit. This range is within the bandwidth of a voice-grade telephone circuit.

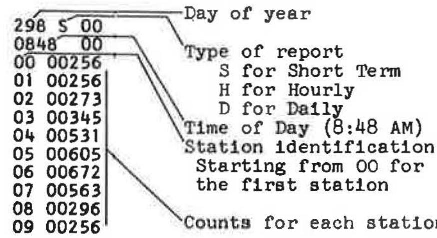
The panel in the lower portion of Figure 5 shows the controls for a set of six compensators. These are amplifiers that compensate for the loss of signal between the transmitting and receiving points. The amplified composite signal on each multiplex circuit is fed to the tone filters whose outputs are fed to their respective input circuits in the centralized computer.

The output of the centralized traffic-counting system is in the form of a punched tape, shown in Figure 6a. This is a standard 1-in. paper tape which may be used as an input to the majority of general purpose computers. In the case of computers that do not accept a punched tape form of input, translators are available to translate the information from the punched tape to a punched card or magnetic tape. The code used for recording the traffic data is the IBM 8-channel punch tape code which is a universal code. If the computer available to the agency uses some other code, the information may be translated from one code to another without difficulty.

The output of this computer provides three basic types of reports for each station. Each station has a short-term, an hourly, and a daily report. As described in more detail later, the short-term report is the traffic count for a period of less than 1 hr, adjustable or settable from 5 to 30 min by means of a dial on the panel of the computer. At the end of each hour, the computer will also punch out automatically an hourly report for all stations connected to it. At the end of each day, a daily report, giving the daily total traffic count for each station will also be




(a)




(b)

Figure 6. Output tape (a) and print-out format (b).

punched out, followed by an hourly report, as well as the last short-term report.

If the data punched on the tape are adequate for the purposes of the agency, the output tape can be run through a Flexowriter type of electric typewriter and the data printed in alphanumeric form. The format presently used in this computer is such that the report, if run through a Flexowriter, will produce a calculating machine type of report; that is, the traffic count for each station will be recorded vertically in a column. Figure 6b shows a section of the typewritten report. Every report will contain the following information: the day of the year followed by a letter such as S, H, or D depending on whether the report is a short-term, an hourly, or a daily report. The next line will be the time of the day for which the report is being printed. The first two digits indicate the hour of the day (on the basis of 24 hours), and the last two digits indicate the minutes. The third line starts with the station identification. Each station is assigned a number, the first one being designated as 00 followed by a five-digit actual traffic count for the counting period specified. There are sixty of these data lines.

Aside from the printed report, visual indication of the actual count is also displayed on numeric indicators on the display panel of the computer.

To acquaint the reader with the different components of the system, they are discussed separately. Referring to Figure 3 again, the center rack contains all of the plug-in modules. These are printed wiring board assemblies.

The rack on the right contains the larger units; i. e., the Bernoulli disk, the tape punch, as well as all of the indicating and "read-out" panels associated with the circuitry located in the rack on the left. From top to bottom, the units in the right-hand rack are the digital clock, the display and control panel, and the check-out unit. Beneath the check-out unit is the power supply. The punch used in this particular installation is the tally punch which operates only during the punch-out period. For this purpose, the punch motor is started about ½ min ahead of the actual punching period and stops right after the last data of any report have been punched out.

The heart of the system is the memory disk which is located at the bottom of the rack. The memory disk is known to the industry as the Bernoulli disk. This is an extremely reliable device due to its unique construction and special design for use in missiles. Its advantages are discussed later. This memory disk has a capacity of forty recording tracks of which only seven are presently used in this particular system. This gives some idea of the reserve capacity which is available for connecting additional input lines to the system by increasing the number of input circuits and associated hardware, and modifying a few counters.

The close-up of the individual panels in the right-hand rack provides information as to the settings of the controls. As mentioned previously, the first unit on top is the digital clock (Fig. 7). The clock produces a binary-coded decimal output for the day of the year and the time of the day. It also produces pulses at the beginning of every minute, hour, and day. The latter are used for controlling paper tape read-outs. The dial at the upper left corner of the panel enables the clock to be turned "off." In its center position, it allows the digital clock to be set manually by setting the dial for each


Figure 7. Digital clock panel.

individual digit represented and displayed in the numeric display shown in the center of the panel. The first three digits show the day of the year, the following two digits the hour of the day, and the last two digits the minutes. The third position of the dial at the left top corner of the panel is the "run" position of the clock. This is the normal operating position of this dial. The numeric display on the digital clock gives the chronological information just described at all times.

The second unit in the rack is the display and control unit (Fig. 8). Its function is to display the actual count at every station when a print-out operation is performed. In addition, a manual read-out is also possible by selection and actuation of the proper station selection button. The "read" button must then be depressed in conjunction with the type of report selector button to read either one of the three different types of report for each station. By the same token a manual print-out can also be obtained in between the scheduled print-out periods for the short-term, hourly, or daily report. To avoid accidental printing of the hourly or daily report manually, a safety feature has been included so that a manual print-out for the latter two reports requires the depression of both the selected report button as well as the short-term button. The dial at the left-hand top corner of the panel is for the selection of the short-term print-outs. By setting this dial at one of the positions of the switch, a short-term print out may be obtained for 5-, 6-, 10-, 12-, 15-, 20-, or 30-min intervals. The setting of this dial at the manual position eliminates the print-out of a short-term report. In this position of the dial, only daily and hourly reports will be printed out automatically on the output tape for all the stations. Selective print-out of data for any particular station is not possible.

The four individual pushbuttons in the center of the lower row of controls on the panel are used for the preparation and starting of the telecounting system. The start button will place the computer in action. The button on its right will allow the general reset of all the stations and addresses on the memory disk. Selective reset of any particular count for any station is accomplished by momentarily pushing the station reset button. A normally nonilluminated indicator on the top right-hand side of the panel lights up to indicate a power failure or the reduction of the AC supply voltage below an acceptable limit. In this latter case, a fail-safe circuit is actuated which inhibits the application of information to the disk. This eliminates the possibility of entering the wrong traffic count due to the malfunction of any part of the circuitry in the computer. To supplement the power failure indicator, an audible signal is also produced in the rack which can be repeated at any other remote location.

The unit below the display and control panel is the manual check-out panel (Fig. 9). The manual check-out panel contains 325 indicator lamps connected to the outputs of the different functional circuits to indicate their operational status. The indicators, by continuously showing the operating status of the circuits to which they are connected, provide for ease in servicing the computer equipment. In addition to indicating the

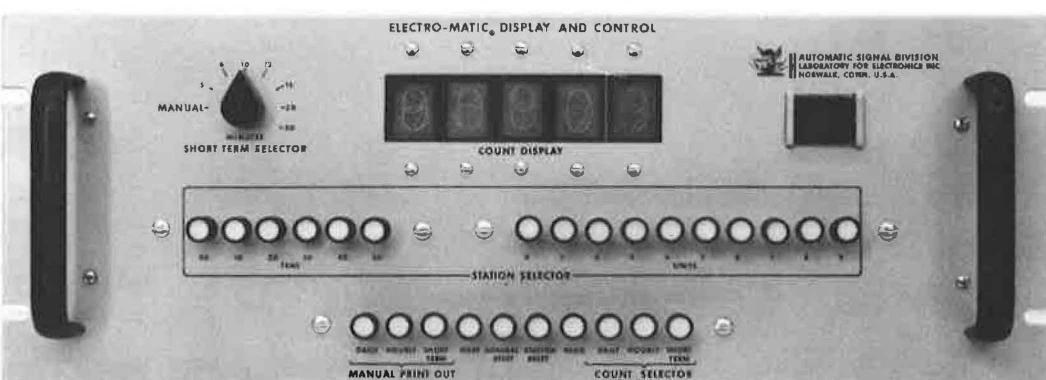



Figure 8. Display and control panel.

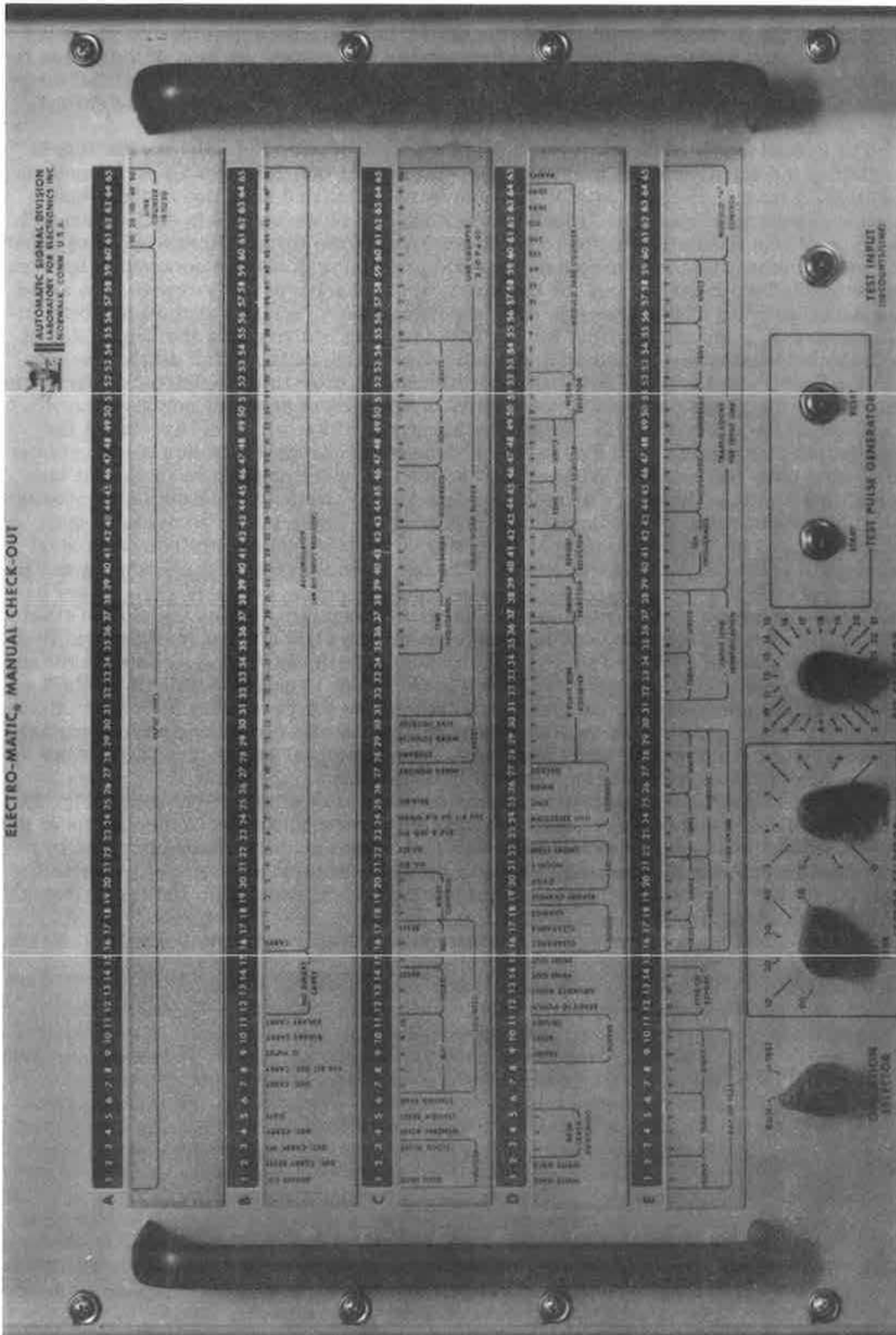



Figure 9. Manual check-out panel.

operative condition of the different cirucits of the computer, the indicator lamps also enable the entire system to be checked out by the injection of artificial signals into the computer. Checking of individual address locations on the memory disk may be effected by means of the controls located on the lower portion of the panel marked "sector selector" and "bit selector" as well as the "test pulse generator." These controls are inoperative unless the selector at the bottom of the left-hand rack is set to the test position.

The change of function of this panel from run to test is accomplished by the knob on the lower left side of the panel. In the test position, pressing the test input button on the right-hand side of the panel puts in ten counts on each input line. Thus, a check-out of the output tape will indicate whether the circuitry is performing properly with reference to entering the information on the data track, processing it, and writing it back on the memory track. A simulation pulse generator has been incorporated in the manual check-out portion of the computer which makes the computer go through its functions at a slow pace enabling the servicemen to observe any abnormal indication if present.

Figure 10 shows the tally paper tape punch which prepares the tape. The output tape, as mentioned earlier, will be used as the input to the majority of general purpose computers for processing of the data, or as the input to an electric typewriter for a numeric print-out of the reports. The output tape operates automatically at the end of the day and by the hour, on the hour, as well as at preselected short-term periods.

The last but most important part of the system is the Bernoulli disk (Figs. 11 and 12). The top portion of Figure 11 shows the rack of printed circuit boards related to the disk, and the lower portion has a switch on the left-hand side to start or stop the Bernoulli disk manually.

Figure 13 is a simplified flow diagram of the system. The detector pulses from the

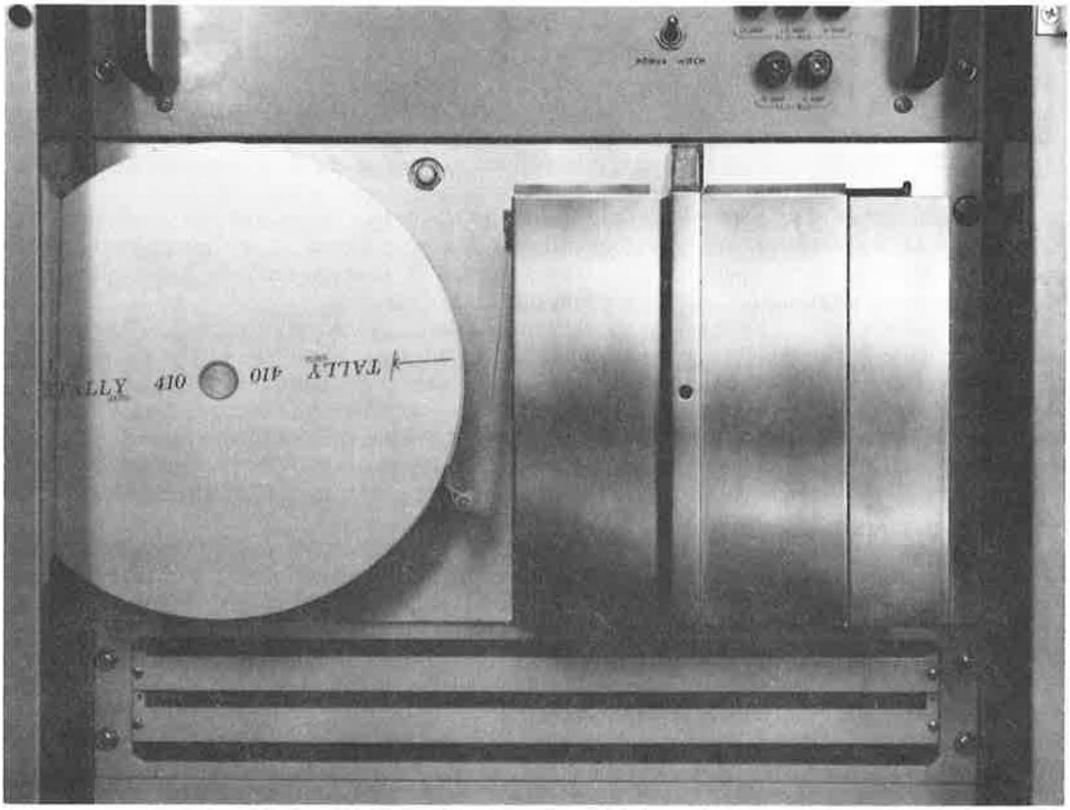


Figure 10. Tally paper tape punch.

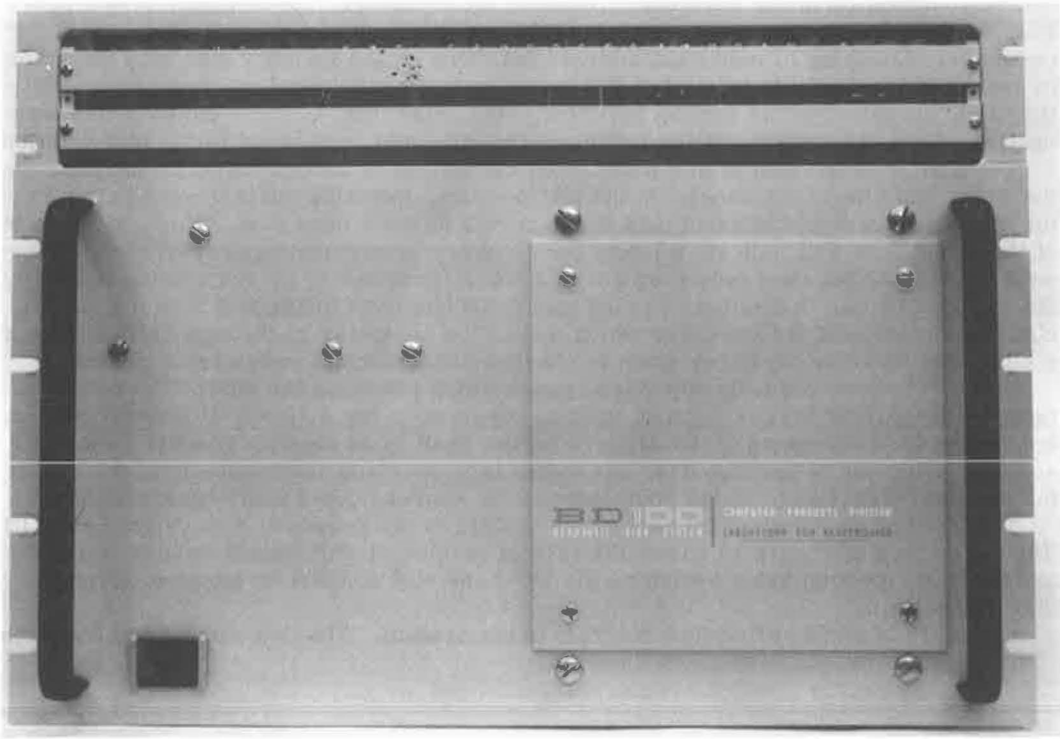


Figure 11. Memory disk panel and associated electronic circuitry.

different stations are fed into their respective temporary storage circuits. A line selector interrogates these storage circuits in succession to check if a traffic count has been registered in the temporary storage circuit.

The memory storage represented by the large block has three distinct storage cells for each input line—180 in all, corresponding to 60 input lines. The memory device could be compared to an endless chain with a series of storage buckets passing through a loading station designated as "Adder" on the diagram.

The memory device and the line selector operate in synchronism to allow the detector information from any line to be transferred to the buffer storage at the proper time so that it can be dumped in the corresponding memory cells (short-term storage cell, hourly storage cell, and daily storage cell) for that particular detector station. This transfer from buffer storage to memory storage is accomplished in the adder. The number of traffic counts stored in the temporary storage as well as the buffer storage can not possibly be more than one because the interrogation cycle lasts for only 50 millisec.

The memory storage loop goes through a control unit that, through commands received from the manual control at any time, or from the digital clock at preset intervals, extracts the information from the memory device and transfers it to the tape punch for a permanent record of the traffic count for each station on the paper tape. Following the transfer of the stored information from the memory to punched tape, a new counting cycle is started on the memory storage for that particular type of traffic report; i.e., short-term, hourly, or daily. On the other hand, if the read-out control unit receives a manual command for a visual read-out only, the updated traffic count for any selected detector station will appear as a numeric indication on the count display without resetting or destroying the updated count information on the memory storage device. As mentioned earlier in the text, a digital clock furnishes the print-out commands to the control unit for print-out at regular intervals and at the same time supplies the correct

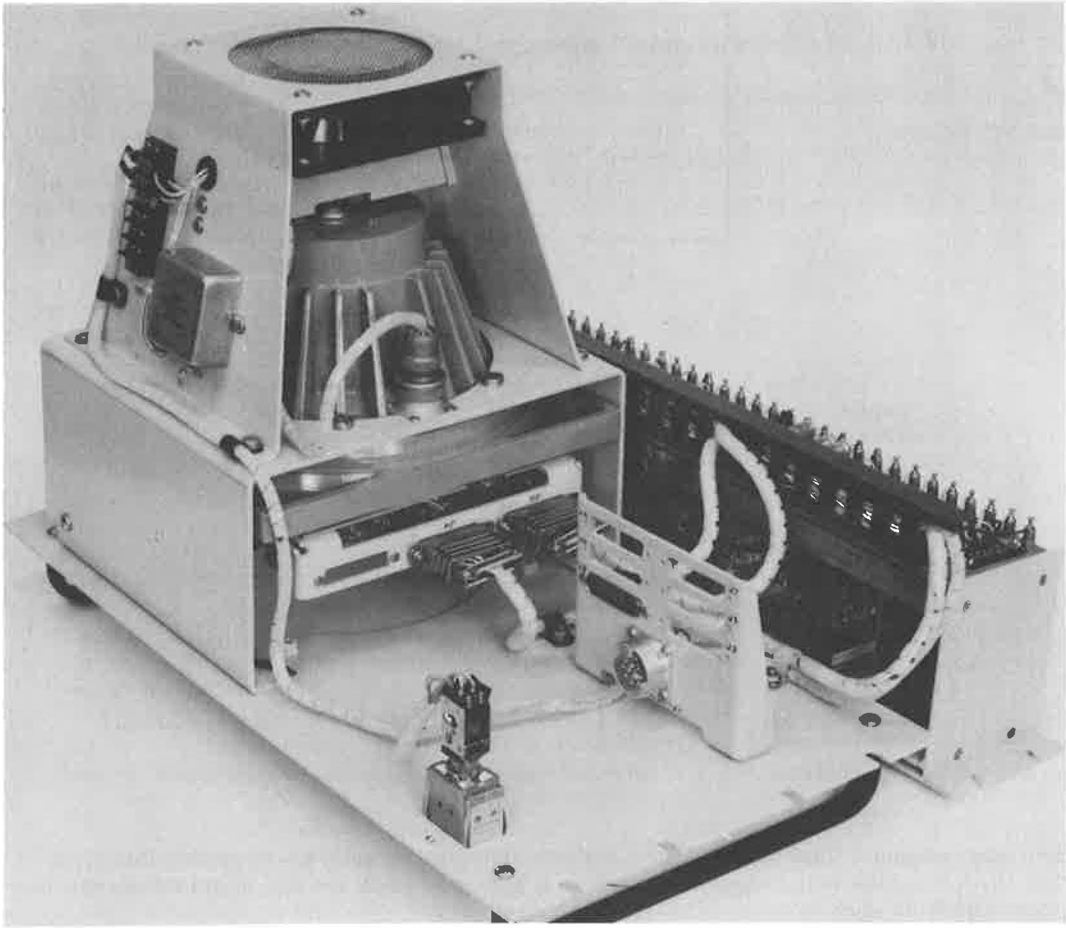


Figure 12. Rear view of memory disk panel and associated electronic circuitry.

date and time information to the paper punch for chronological identification of the report.

The preceding description summarizes the functional characteristics of the computer. The following are some of the advantages of the centralized traffic count system:

1. High-density resolution. The high-speed scanning and checking of information on the 60 input lines insures high resolution even in the heaviest traffic with a minimum possible headway. The sensing cycle being only 50 millisec, it is ten times faster than any possible rate of arrival of vehicles at the detection point.

2. Continuous data availability. Due to the fast read-out and printing of the transmitted data, there is no loss in count as received by the computer. Traffic counting is accomplished without any break in the processing, even during the printing operation.

3. Manual read-out. By selecting the station and pushing the appropriate read-out pushbutton the display of the updated traffic count for the short-term, hourly, or daily accumulated traffic count for that particular station can be displayed in numeric form on the display panel. This is a useful feature which insures the remote checking of any detector location at any time without affecting the print-out of the collected data on the tape.

4. Traffic counts on per-lane basis. The traffic counts in this telecount system are accumulated on a per-lane basis and automatically provide the traffic volume in vehicles per hour per lane. When a detector covers one lane only, the information is transmitted

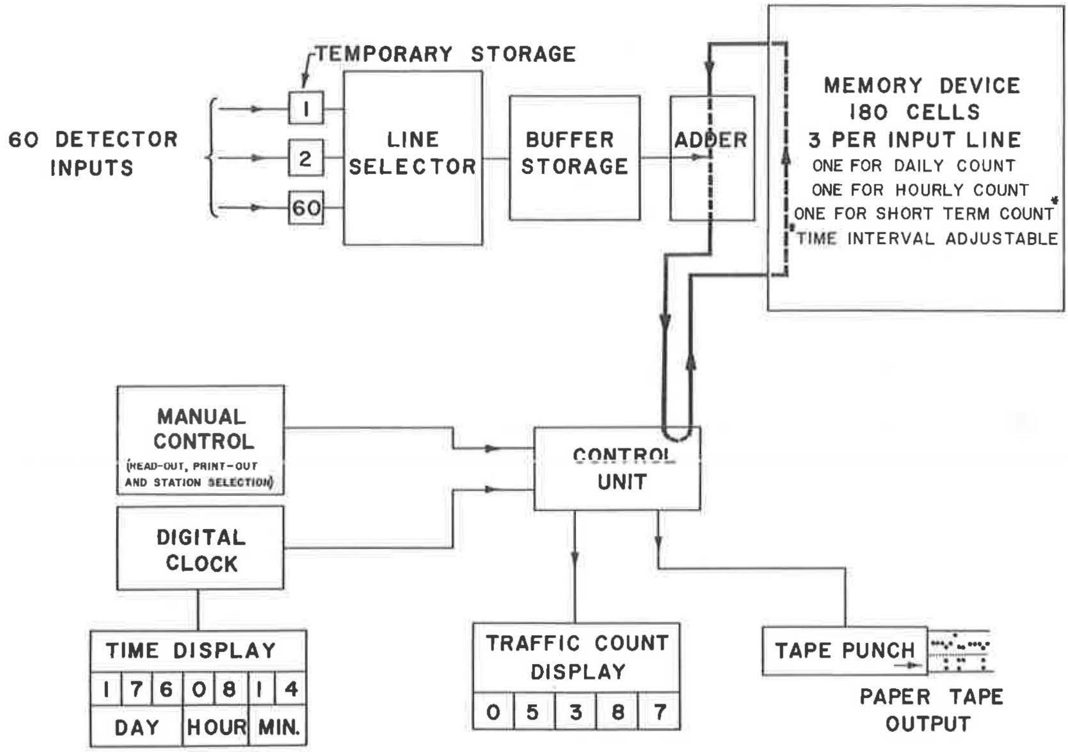



Figure 13. Functional block diagram of telecount system with 60 detector inputs.

over the telephone line as is. When a single detector is used to cover two lanes, a two-to-one scaler will reduce the count to a per-lane base and the information will be transmitted as such to the traffic-counting computer.

5. Ease of detection of detector failures. The detectors being used as sensors for the traffic counts are normally spread over a wide area. A visual check at the computer will clearly indicate if data are being received from any one of the 60 sensing stations. As a result, the presence of any traffic actuation at any counting station may be determined at a glance.

6. Manual start and reset. The digital clock, which is part of the system, can be set and started at the push of a button at any time. Also, at the push of a reset button, the traffic counts previously recorded in the memory storage can be erased and a new traffic counting cycle started.

7. No cards. The use of a punch tape output eliminates the need for individual cards for each report. In the majority of applications, the tape is directly fed into the general purpose computer, thus eliminating the possibility of mislaying or losing the cards.

8. Reduced high-speed computer time. It is common knowledge that high-speed general computers are quite expensive in hourly operational costs. If it were necessary continuously to feed the traffic-count data into a general purpose computer, an expensive piece of equipment which could have been used beneficially for some other purpose during this time, would be occupied. The purpose of this traffic-counting system is to gather the information on tape while the general purpose computer is free for use for other purposes. Thus, the latter computer is used only for a very short period of time for the complete processing of the collected data.

9. Reduced data processing. As compared with manual data processing, the tape output obtained by the paper punch reduces tremendously the manpower and time required to process the basic counts furnished by the detectors, by feeding the totalized

information into a general purpose computer. The general purpose computer will, with the data applied from the paper tape, perform any additional computation.

10. Computation errors eliminated. Because the traffic count is received and recorded without the intervention of any human element, including the processing of the punch tape, the final results are free from any possible human error.

11. Low communication costs. With the use of tone coding, the party line method of transmission can be used effectively and economically. This will decrease the cost of rental of telephone lines because up to 20 stations can be put on one party line. This is accomplished with the use of tone generators at the detector station, and decoding circuitry at the receiving end.

12. Modular design. The whole system is built on a modular design which gives it great flexibility. All of the basic circuits (i.e., the flip-flops, gates, multivibrators, etc.) are on plug-in types of printed circuit modules which are easily removable from the racks.

13. Transistorized circuitry. The computer is transistorized in its entirety except for the tally punch and the memory disk proper. This insures low power consumption and reduces the size of the computer. In addition, heat generation in the equipment is reduced tremendously.

14. Military design. Military design is a term quite loosely used and synonymous with the word reliability. The techniques used in the design and assembly methods, as well as the quality and grade of the components used, classify this unit as a highly reliable piece of commercial equipment.

15. Wide temperature range. The use of silicon transistors throughout the computer insures the reliable operation of the computer in the temperature ranges of from -20 to +170 F, without the use of forced air cooling.

16. Long life. Judicious selection of computer-grade components insures long operating life with a minimum of down time.

17. Low power consumption. The entire computer system has a current drain of only 6 amps at a nominal AC line voltage of 115v.

18. Reduced field maintenance. Because all the equipment is centrally located field maintenance is reduced to the detection and transmitting equipment only.

19. Low mechanical wear. Because the digital computer, with the exception of the printed tape punch and the Bernoulli disk, is an all-electronic piece of equipment, there is practically no mechanical wear involved. The construction of the tally punch is such that millions of operations are required before the changing of any of the punches. A more detailed description of the Bernoulli disk follows at the end of this paper.

20. System check-out circuitry. The incorporation of a system check-out in the computer will be found invaluable in helping the serviceman to check the entire system.

21. System test circuits. This feature enables the operator to watch the operation of electronic circuitry. Unlike a mechanical system which would give an audible or visual indication of its operation, electronic solid-state circuitry operates without any outward indication of its status; therefore, indicator lamps are connected to the circuitry to provide a visual indication of its operation.

The Bernoulli disk used in this computer is a type of memory disk that, compared to other comparable memory equipment, has numerous advantages. It is a rotating, magnetic storage device using the Bernoulli principle to stabilize the flexible recording medium. The rotating disk pumps air between the disk and head plate. This flow is controlled so that the aerodynamic forces of air and the dynamic and elastic forces on the disk resolve in a stable equilibrium. The flow of air assures a close and controlled separation between the disk and the head plate and prevents contact between them. The following are some of the considerations in the design of the disk.

1. Simplicity of design which yields inherent reliability and long life.
2. Closely controlled separation permits reliable, high density recording at a low cost per bit.
3. High storage capacity with small physical dimensions.
4. No head adjustment required during installation. It has separate read and write heads.

5. Preloaded, sealed bearings require no maintenance.
6. Units are lightweight and compact.
7. The unit is hermetically sealed.
8. Proper selection and matching of materials provide wide operating temperature range.
9. Stabilizing forces are large in comparison with the mass forces acting on the light, thin flexible disk, providing a rotating device insensitive to external shock and vibration.
10. Magnetic drive coupling, operating through a stainless steel diaphragm, isolates the disk from the mass of the motor.
11. Low disk mass minimizes gyroscopic effect.
12. Low mass results in negligible disk bearing loads.

Efforts have been made to describe the telecount system as simply as possible without going into any technical details as far as the electronic or logic circuitry is concerned. Furthermore, coverage has been limited to a description of the computer as shown in Figure 3.

As mentioned previously, application of the system in study areas of various sizes will possibly require expansion of the computer to accommodate more input lines. Other types of output, as well as other output formats (such as incremental magnetic tape), are also obtainable.

A preliminary analysis of the economies associated with the use of this system vs the present manual method of data collection and processing indicates a definite saving in manpower and time with the additional benefit of having the data available for immediate processing.

The built-in capability of the computer to give short-term traffic counts down to 5-min intervals is a great asset for spot studies of troubled locations.

Even though the telecount system has been designed primarily for the purpose of traffic counting, the instantaneous information displayed by the computer could conceivably be used by agencies such as traffic departments of States, counties, or municipalities for surveillance purposes.

## ACKNOWLEDGMENTS

The authors express their appreciation to Howard S. Ives, Connecticut State Highway Commissioner, for permission to locate the computer in the State highway department building and make use of the present ATR stations as input sources to the computer for this field test. Special appreciation is due to David S. Johnson, Jr., Israel Resnikoff, and Israel Zevin of the Planning, Traffic and Design Division, Connecticut State Highway Department, for their cooperation during this field test in supplying traffic data previously collected for comparison purposes and help in the installation at the detector locations.

Appreciation is also expressed to the sales and technical staff of the Southern New England Telephone Company for their efforts and cooperation in supplying the network which proved the feasibility of the system as a whole.

A word of thanks is due to Mr. Mulvany of Friden for providing a Flexowriter for use during this test, and to the members of the Development Laboratory of Automatic Signal, sincere thanks for their participation in this project from the time of conception to date of complete installation for the long hours they had to put in to make this project a success.