APPLICATIONS OF ELECTRONIC TECHNIQUES TO TRAFFIC INSTRUMENTATION

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SYNOPSIS

The application of electronic techniques to traffic measurements is not new, but certain new electronic techniques developed in connection with the design of electronic digital computers can be applied advantageously to traffic instrumentation. The application of these techniques to measurements of speed, lane placement, and volume is discussed.

Requirements for traffic measuring instruments are given. These include ability to measure and record speed and spacing of each vehicle and to record the data on each vehicle separately. The equipment should automatically record the measurements and reduce the data. Field equipment should be portable.

To permit recording of data for each vehicle and, at the same time, to permit the automatic reduction of the data, it is planned that data from each vehicle will be recorded on IBM cards. In order to achieve portability, measurements in the field will be recorded on magnetic tape for later transcription onto IBM cards in the office. Recording on the tape will be in a code which represents the speed in miles per hour, the time of day in hours, minutes, seconds, and fractions of a second, and the lane occupied by the vehicle. All measurements will be by elements which are fully electronic in operation and which operate in a digital (as opposed to a continuous) manner.

Progress to date has consisted of building an electronic vehicle speed distribution recorder. Speed is measured by measuring the time required for the vehicle to traverse the distance between two roadway pickups placed three feet apart. Electro-mechanical counters record the numbers of vehicles having speeds within twelve predetermined speed ranges. These ranges are variable by means of switches on the panel of the instrument.

The need for traffic data on volume, speed, lane placement, turning movements and many other parameters (in a form which is easily reducible for analyses) is discussed.

For a number of years there have been applications of electronic techniques to the measurement of traffic data. As early as 1930 there are records of the use of photo-electric cells in the counting of traffic volume (*1*)[1]. As early as 1935 electronic timers were used in the measurement of vehicle speeds (*2*). Later electronic traffic instruments consisted largely of refinements of these first two applications. It is the purpose of this paper to discuss electronic techniques which, it is believed, have not been previously applied to traffic instrumentation. The techniques referred to are those developed in connection with the various general-purpose electronic digital computers which are now under construction by various groups throughout the country.

[1] Italicized figures in parentheses refer to list of references at the end of the paper.

In the program of the Institute of Transportation and Traffic Engineering on the Los Angeles campus of the University of California, one of the largest current projects is that of instrumentation. The project is divided into two phases—instrumentation for measuring the behavior of the driver, and instrumentation for measuring the movement of vehicles. Although the long range program will include the measurement of several other variables during this year and next the vehicle-movement instrumentation program has been limited to the measurement of speed, volume, and lane placement. Preparation of instrument specifications has been guided by the requirements of the Public Roads Administration, as set forth by Holmes and Reymer(*3*). These are:

1. The speeds of all vehicles must be measured.

2. Each measurement must be recorded.
3. Time spacings between vehicles must be determined and recorded.
4. The process of determining and recording these items for each vehicle must be completed in less than 1 second.
5. The records must permit segregation of data by traffic lanes, and the direction of travel of each vehicle must be indicated.
6. All measurements and recordings must be entirely automatic, because of anticipated widespread application of the method.
7. Speeds must be measured with an error of less than 5 percent within the normal range of vehicle speeds.

To these requirements have been added the following:

8. Data must be reducible without the intervention of an operator (except for the purposes of set-up and supervision).
9. Field equipment must possess the properties usually required in portable instruments.

These specifications have led to the following overall details of instruments of this type.

The need for automatic reduction of data from individual vehicles leads naturally to the decision to use punched-card equipment (such as manufactured by IBM, Remington Rand, etc.) with each vehicle represented by a single card. The use of punched-card equipment in connection with traffic surveys is not new. See for instance either the ASCE paper by James (*4*) or the Public Roads paper by Normann (*5*). Certain of the electronic digital computers now being developed might be used for this purpose. It is felt, however, that such equipment will not be generally available for a period of several years. By contrast, punched-card equipment is readily available and is capable of performing any of the operations which might be called for in the reduction of traffic measurement data.

Punched-card equipment has, however, two features which render it undesirable for use in the field. The automatic punching equipment is too bulky to be portable, and its speed of operation is relatively slow in comparison with the rates which might be necessary to record speed of vehicles passing simultaneously in each of six lanes. In order to be able to record automatically data in the field and at the same time to be able to have it (later) transcribed automatically and at a slower speed onto punched cards, some intermediate medium of recording is necessary. (In the parlance of computer engineers, this would be termed a "memory.") For reasons which will be discussed later, magnetic tape has been selected as this intermediate recording medium.

In most of the electronic speedmeters previously described, time was measured by measuring the charge acquired by a condenser during the period in question. Such a measurement is a continuous measurement as opposed to a discrete or digital measurement. When punched-card equipment is used, data must be presented to the punch in digital form. It is, therefore, desirable for speeds to be measured and recorded in a digital form. This leads to consideration of measuring time (and, therefore, speed) by counting cycles of a fixed-frequency oscillator during the period to be timed. Even this technique is not new to traffic instrumentation, having been used by Lawshe as early as 1940 (*6*). In the design of electronic digital computers and certain instrumentation for industrial control (as well as for nuclear research) electronic counters have been developed to the point where the most accurate method of timing now available makes use of a high frequency oscillator and an electronic counter (*7*). Such a method is, therefore, entirely feasible as a method for speed measurement. In applying this technique to the measurement of speed the counter may be so constructed that it indicates directly in miles per hour.

When the data concerning each vehicle are to be recorded on a separate card, it becomes important that the time of day at which the vehicle passes be recorded to a high degree of accuracy. This also can be accomplished by means of a special counter, operating from a suitable oscillator, and so designed that it counts in terms of hours, minutes, seconds, and fractions of a second.

In order to store the data from each car on some "memory" medium, it is necessary to use some form of coded signal which may be placed on a suitable medium and retained there until transcription has been completed. The medium used must be durable but easily portable. The more obvious techniques for making such recordings include:

Punched holes in paper or some similar medium,

Code marks on paper, the marking being such that it may be deciphered by means of photo-electric cell readers,

Exposed spots on photographic film,

Magnetized spots on magnetic medium.

Of the above techniques, the first two, punching or marking of paper, may be immediately eliminated because of the slow operating speed of such equipment. The use of photographic film is undesirable because of the extra operation of developing which it entails. Magnetic tape, on the other hand, may operate at either fast or slow speeds, and has the added feature that it may be easily erased and used over and over again.

At this point the developmental work accomplished to date will be described. During the early months of the instrumentation program, in order to begin development of digital speed-measuring equipment but at the same time to build an instrument which would be complete within itself, a vehicle speed distribution recorder was built. In the end result, this instrument is very similar to one described by Holmes and Reymer (*3*) in which mechanical counters record the numbers of cars having speeds within certain predetermined ranges. In the method of accomplishing the measurement of test data, this instrument has some interesting features.

Figure 1 shows a block diagram illustrating the operation of the vehicle speed distribution recorder. The motion of the vehicle is detected by two pickup elements placed 3 ft. apart on the roadway. As the front wheel strikes the first of these pickups, a signal passes through the rearwheel inhibitor, and turns on the electronic switch. While the electronic switch is turned on, pulses generated by the one-kilocycle oscillator are permitted to enter the electronic counter. When the front wheel strikes the second pickup, a signal passes through the rear-wheel inhibitor, and turns off the electronic switch, thereby stopping the flow of pulses to the counter. The rear-wheel inhibitor contains circuits which stop any signals initiated by the rear (or second set of) wheels of the vehicle. This inhibitor is adjustable to any desired maximum wheel base.

After the electronic switch is turned off, the scanning circuits operate, comparing the contents of the counter with the counts which would lie in the various predetermined speed ranges (or groups). As this comparison is made, the mechanical counter corresponding to the appropriate speed range is actuated. Because of the slowness with which the electro-mechanical counters operate, this scanning and recording operation requires $\frac{1}{10}$ of a second. As the speed-group counter is being tripped, the total counter is also actuated, keeping a record of the total traffic volume.

After the record has been made on the electro-mechanical counters, the electronic counter is automatically cleared so that it will be ready for the next vehicle.

Figure 2 shows the relative sequence of events in the various parts of the instrument. With the receipt of a signal from the first pickup the electronic switch is turned on,

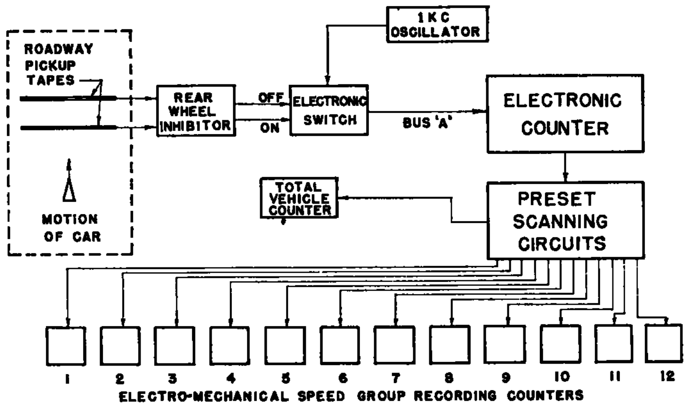

Figure 1. Block Diagram of Speed Distribution Recorder

and pulses appear on bus A (the bus between the electronic switch and the counter). With the receipt of a signal from the second pickup, the electronic switch is turned off, and the scanning and recording circuits operate. The rear wheel inhibitor operates from the time of the first signal of the second pickup until some time after the receipt of the second signal on the second pickup.

scale. As pulses enter the electronic counter, the count progresses along the speed scale from left to right. The final count will lie between two of the connection points on the speed scale. The electro-mechanical counter connected to these two points then registers.

As shown in Figure 3, electro-mechanical counter 1 counts the number of cars having speeds 10 miles per hour or less. Counter 2

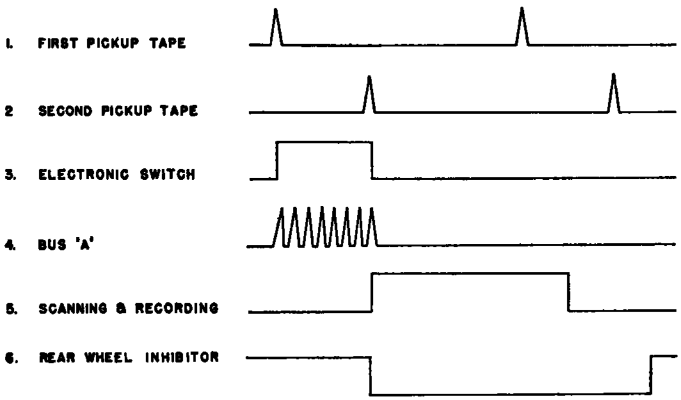

Figure 2. Signal Sequence in Speed Distribution Recorder

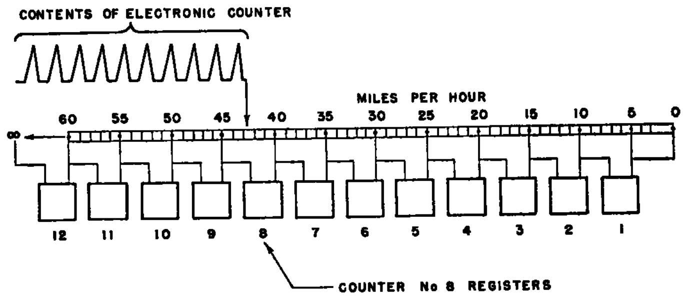

Figure 3. Typical Electro-Mechanical Counter Connections

The degree to which the electronic counter fills depends upon the speed of the vehicle. For fast vehicles the time of passage will be short, and the counter will fill to only a small part of its capacity. For slow speeds, however, the time of passage will be long, and the electronic counter may receive a large number of pulses. The preset scanning circuits determine the degree to which the counter has filled in relation to twelve predetermined values. Figure 3 shows a block diagram of these circuits. Each electro-mechanical counter is connected between two points on the speed

counts the number of cars having speeds greater than 10 but not greater than 15 miles per hour. The other counters are spaced at 5 mile per hour intervals up to counter number 12, which counts all cars having speeds greater than 60 miles per hour. It should be noted that, although Figure 3 shows the electro-mechanical counters connected at 5-mile-per-hour intervals, the connections may be easily changed by means of groups of toggle switches on the front panel of the instrument.

Figure 4 shows a photograph of the front panel of the vehicle speed distribution recorder.

The upper section of the panel contains the twelve speed-group counters and the total counter. The central section contains the toggle switches for presetting the speed groups. Also located in the central section are indicator lamps which are used in checking the operation of the instrument. In the lower section of the panel are located several control switches, along with meters which indicate the important voltages within the instrument.

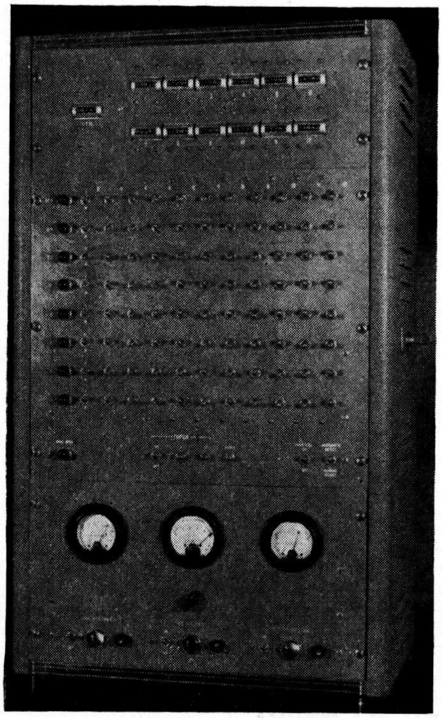

Figure 4. Front Panel of Vehicle Speed Distribution Recorder

Figure 5 shows a rear view of the instrument. In this view it may be seen that most of the tubes used are of miniature type.

As was previously implied, this instrument was not meant to be the ultimate in instrumentation, but rather as an interim instrument which would be immediately usable, and at the same time serve as a step in the developmental program. It has been described here because it contains some features which are interesting in themselves, and because it illustrates several of the specifications laid down. It measures and records the speeds of all vehicles, accomplishing the operation in considerably less than one second. All measurements and recordings are performed automatically, and no reduction of the data is necessary. The error is much less than 5 percent. The instrument is reasonably portable.

Work is underway on the development of equipment for recording the data from individual cars on magnetic tape. Provision will be made for simultaneously timing vehicles in

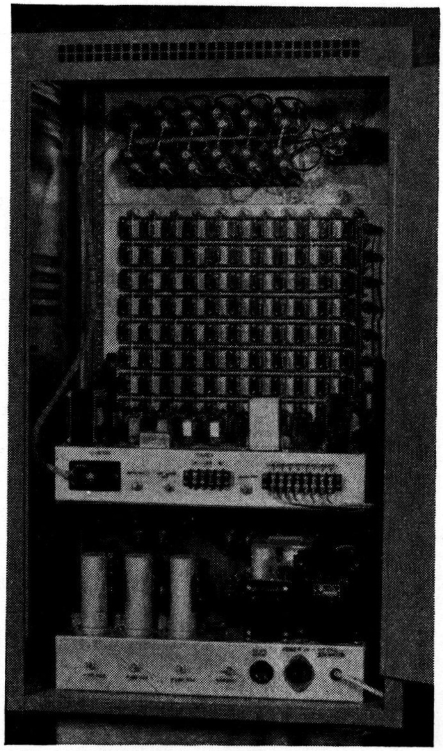

Figure 5. Rear View of Vehicle Speed Distribution Recorder

six different lanes. The measurements for the individual vehicles will be placed one behind the other on the magnetic tape. This will be accomplished by high speed circuits which scan the measuring circuits and record the results, in coded form, on the tapes at speeds which are much greater than the transit time of a vehicle. Each vehicle speed measurement will be accompanied by a code number designating the lane, and a coded representation of the time of day. Provision will be made for later addition of facilities for recording vehicle type.

As work progresses on the magnetic recording equipment, the design of the transcription equipment which will transfer the data from magnetic tape onto punched cards will be started. Once the data are recorded on punched cards, it is possible by means of standard punched-card equipment, to sort the data in terms of lane, speed, or other desired parameter which has been measured and recorded. This makes the instrumentation very flexible, and makes possible later reanalysis of data for purposes other than those of the original study.

In a discussion, such as that just presented, of equipment for use in recording traffic data, there are several important points requiring further elaboration. The following comments are more in the nature of a summary than a full discussion, but should serve in clearing up some questions.

It may be asked, "Why use digital type equipment?" Digital equipment has been chosen because it utilizes techniques already developed in other fields; also it is probably more flexible than other methods. For example, in the types of equipment referred to, the recording apparatus, the equipment for automatically transcribing to punched cards and the punched-card equipment itself is the same no matter what the information being obtained. For each new type of measurement, new roadway pickup elements and new field computing apparatus, which can almost always be quite small physically, are needed. The magnetic recorder must be taken into the field, but the transcribing equipment need not be reproduced for each case. As a matter of fact, it is quite likely that one general purpose transcriber could service all of the equipment measuring a variety of variables, in a region. Thus, data on speeds, lane placement, turning movements at intersections, roadway illumination, and glare from headlamps could all be recorded automatically in the field using different pickup units and then all transcribed in a common machine.

An important feature of digital type equipment is that the achievable accuracy is limited almost entirely by the field pickup elements used. In addition, difficulties due to variations in supply voltage, temperature, humidity, and so on can be reduced most effectively in digital apparatus. It appears quite feasible to construct portable apparatus having these features.

Cost of development of such apparatus is not small; but costs of reproduction, once developed, are quite reasonable. When the reduced costs of data analysis are considered it is felt that the development costs can be justified.

It is not intended that the need for data of the type referred to be discussed here; this subject has received considerable attention in the literature and elsewhere.

As has been stated earlier, the proposals mentioned here are only extensions of work already performed by others; it is hoped that this presentation will add to the development of traffic instrumentation by bringing together the ideas of several related fields and that electronic techniques will prove to be helpful in solving some of the problems in building better and safer streets and highways.

The authors wish to express their appreciation to Mr. H. R. Kaiser, who developed the vehicle speed distribution recorder and has contributed considerably to the ideas presented here.

REFERENCES

(1) B. Cooper, "Photo Cells Control Detroit Bridge Traffic," *Electronics*, June, 1930, pp. 114–116.
(2) "Phototubes Used for Catching Speeders," *Electronics*, Feb., 1935, p. 59.
(3) E. H. Holmes, and S. E. Reymer, "New Techniques in Traffic Behavior Studies," *Public Roads*, Vol. 21, pp. 29–45 (1940).
(4) E. W. James, "Determination of Losses in Travel Time," *Civil Engineering*, Vol. 3, pp. 463–5 (1933).
(5) O. K. Normann, "Preliminary Results of Highway Capacity Studies," *Public Roads*, Vol. 19, pp. 225–232, 240 (1939).
(6) C. H. Lawshe, Jr., "Two Devices for Measuring Driving Speed on the Highway," *American Journal of Psychology*, Vol. 53, pp. 435–441, (1940).
(7) W. H. Bliss, "Recorder and Timer for Short Intervals," *Electronics*, Nov., 1947, pp. 126–127.