Data Collection as a By-Product of Normal Business Machine Operation

J. C. TAYLOR†

Introduction

THE PURPOSE of this paper is to explain an automatic system of collecting data on a punched paper tape as a by-product of normal business machine operation.

In order to provide a concrete example of such an automatic data collection system, we will describe a system used in a department store to record the data pertaining to the sale of merchandise. Everyone is familiar with the usual role played by the cash register in recording the data pertaining to the sale of merchandise. The price of the article, clerk data, type of sale, etc., are set up on the keyboard and entered into the machine. This gives much information concerning the sale, but with present-day high-volume merchandising, much more information concerning the articles sold is necessary in order to obtain inventory controls, daily sales reports, etc.

First, let us consider for a moment why there is a need for such a data collection system. Before automation it was necessary to perform numerous manual operations in order to prepare various records required by the department store. The necessary reports were prepared by collecting duplicate sales slips, price ticket stubs, cash register receipt stubs, or other media during the day as the sales occurred, and later these media were picked up by clerical personnel who in turn sorted the media by hand and recorded the sales on tally sheets, spread sheets, or punched cards. These records were then processed by hand or through the use of punched card tabulating equipment to produce the reports mentioned earlier. However, during the collection of the information and preparation of these reports, many man-hours were consumed and many opportunities provided for human error and lost sales slips, price tickets or other media. The accuracy of such systems might average 80 to 90 per cent due to the lost media and manual errors. Therefore, the automatic by-product data collection system to be described will illustrate how all these manual methods, with their possibilities of lost media and costly man-hours, will be eliminated by capturing the desired data as a by-product of the normal business machine operation.

One solution to this problem is that of attaching a device to the cash register on the department store selling floor which will capture data pertaining to the sale of merchandise as the transaction is being handled in the normal manner. The cash register used in department stores is a very familiar item; with its classified accumulating features, printed receipt, and indication. Suppose each cash register in our typical department store were equipped with a National Punched Tape Recorder, which will not only capture data describing the sale but also capture data identifying every item sold through each cash register. Such a system will provide all the sales data and identification data necessary to produce the desired reports earlier mentioned. However, some additional information would be desired in order to make the inventory control records more complete. It is obvious that attaching Punched Tape Recorders to other machines used to write buyers' orders, or used in the receiving department for checking merchandise as it is received, will provide additional data which may be processed along with the data recorded at the point of sale and make complete inventory control records. In addition, the tapes from the various machines could also be processed to prepare additional reports and provide statistical data.

As the cash registers or other machines are operated, they prepare their normal hard copy original entry media such as cash register receipts, orders, listing tapes, invoices, etc., in the conventional manner. In no way will the Punched Tape Recorder slow down the operator, although the system is of itself completely sequential in operation, making the system 100 per cent accurate.

Thus one system has been described very briefly by which selected data entered through business machines has been captured as a by-product of the machine's normal operation, while in no way changing the operator's procedure.

The tapes created in this manner may now be applied as input to electronic computers or other data-processing equipment which will prepare the desired reports for the department store management, buyer, etc.

The System in Operation

With the preceding general outline as a background, we will consider in more detail the application of recording the data pertaining to the sale of merchandise. In order to explain the system more clearly, it will be explained in connection with the step-by-step sequential punching of merchandise identification and sales data on a paper tape under control of the cash register. Fig. 1 shows a cash register, recognized as that widely used in department stores, equipped with a Punched Tape Recorder.

The cash register being used in this explanation con-

† The National Cash Register Co., Main and K Streets, Dayton, Ohio.

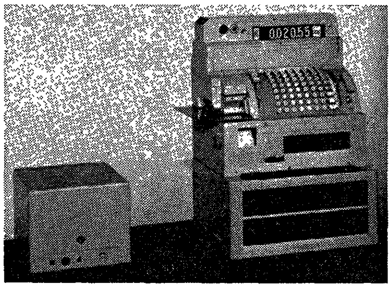
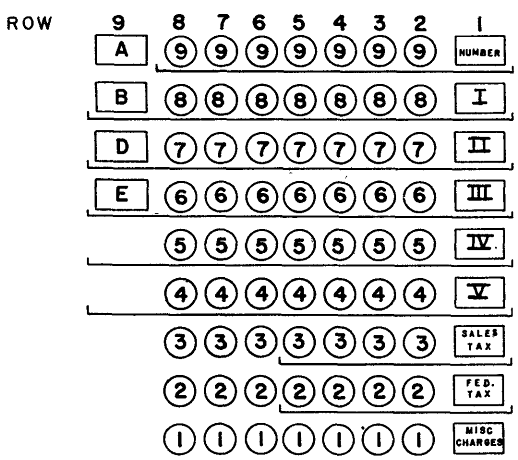


Fig. 1—Cash register equipped with punched tape recorder.

tains a plurality of rows of keys, as shown in Fig. 2, which are used on different operations of the cash register according to the data to be recorded. These data may have different significance in different operations of the cash register. Fig. 2 depicts a cash register keyboard having a total of nine rows of keys. Row 1 is the transaction row, rows 2 through 8 are amount rows which may or may not add into the machine accumulating totals, depending upon the transaction key used, and row 9 is a row of clerk print and totalizer selection keys. The transaction row of keys is used according to the significance of the data being entered on the amount keyboard, and controls the Punched Tape Recorder on each cash register operation. That is, the data set on the keyboard when used with the Number key may represent merchandise-identifying data, whereas when these same rows of keys are used to set data with a Department key in the transaction row the data may represent the amount of the sale or other sales data.



RECORDING SEQUENCE

TRANSACTION KEY ROW 1	FIXED	KEYBOARD
NUMBER	END OF FRAME	ROW1,8,7,6,5,4,3,2
I, II, III, IV, V	REGISTER # DIGITS 1,2,3	ROW-1,9,8,7,6,5,4,3,2
SALES TAX FED. TAX	END OF FRAME	ROW-1,5,4,3,2
MISC.	NO RECORDING	

Fig. 2—Cash register keyboard and recording sequences.

The keys in the various rows of the cash register control the differential positioning of switches according to the data set on the keyboard. The data switches which are differentially controlled are shown in Fig. 3. This figure shows the back of the cash register equipped with the necessary mechanisms and components to control the Punched Tape Recorder. The data switches are positioned by the indicating mechanism in order that the data set on the keyboard be still available after the cash register completes its operation. The indicator, at the top of the cash register, signifies to the customer what was entered through the keyboard.

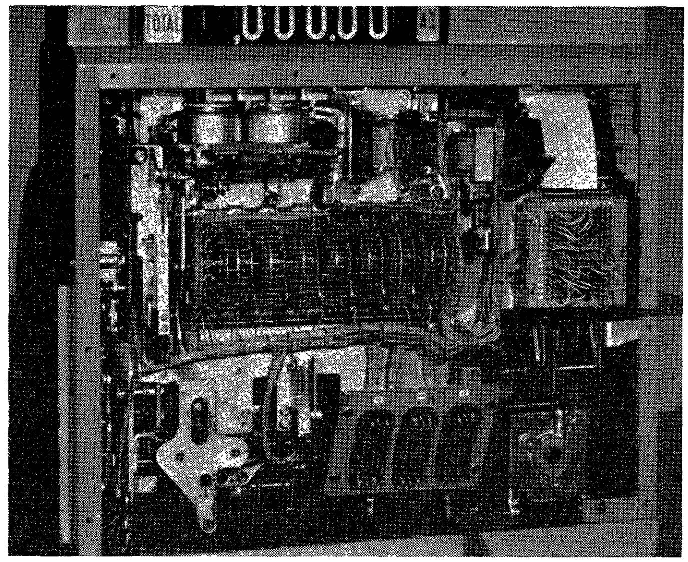


Fig. 3—Back view of cash register.

A means of program control controls the order and number of cash register switches which will enable and control the punching apparatus to produce various punching sequences according to the significance of the data. The keyboard and chart of recording sequences shown on Fig. 2 may be used to explain the program control. Certain representative sequences have been shown for the purpose of explanation. It is possible to program four different sequences for the system, each entirely different, the only limitations being that the word length of each cannot exceed 18 characters, including variable keyboard data, fixed data, and functional codes. The chart of recording sequences illustrates three sequences which are utilized in this particular example.

The brackets on the keyboard chart, which embrace a transaction key and certain other rows of the keyboard, indicate which rows will control the punching apparatus when the particular transaction key is depressed. For example, when the Number key in row 1 is depressed, rows 1 through 8 will control the punching apparatus, whereas when any one of the Department keys I, II, III, IV, or V is depressed, rows 1 through 9 will control the punching. On the other hand, when either of the tax keys, Sales Tax or Federal Tax, is depressed, only rows 1 through 5 will control punching and depression of the Miscellaneous Charge key and will not cause any punching sequence to be followed.

Referring to the recording sequence chart of Fig. 2, it will be noted that when the Number key is depressed the sequence of recording will be first an End of Frame symbol followed by the data set on the keyboard in the following order: rows 1, 8, 7, 6, 5, 4, 3, and 2. If no key is depressed in a row, a zero will automatically be punched into the tape when this row controls the punching apparatus. The End of Frame symbol is a functional code indicating that a new group of data is beginning. All data between two End of Frame symbols will be related to the sale of a particular item of merchandise. This symbol could complete a punched card, return a carriage of a tape-reading typewriter, or control an electronic computer, indicating that a group of information has now been read into the machine and processing may begin.

A second sequence of punching is called for when any one of the five Department keys has been depressed. This second sequence contains a fixed three-digit number (123), representing the cash register number from which the tape was punched. This number is obtained directly from the Punched Tape Recorder each time this program is called for. Next in this sequence is data punched according to the setting of rows 1, 9, 8, 7, 6, 5, 4, 3, and 2, in that order. Therefore, upon alternate use of the Number key and a Department key, a "frame" or group of related data is completed in the form of punched paper tape. The data punched under control of the Number key may describe the item being sold, including the class and style of the article, for example. The data punched under control of one of the Department keys will pertain to details of the sale and will identify the cash register at which the article was sold, what department it was sold in (one of five Department keys), identify the clerk making the sale, and the price at which the article sold.

The sequence of punching data in an operation when one of the tax keys is operated is in the order of an End of Frame symbol followed by rows 1, 5, 4, 3, and 2. The data set up on the keyboard with one of the tax keys is set apart from other data by the End of Frame symbol, as this application does not require that these data be associated with descriptive data, clerk, department, price, etc.

It may be noted that all five Department keys select the same sequence, yet each department transaction is identified by a different digit which is punched under control of row 1 to represent the Department key depressed. In like manner, the two tax keys select a second sequence and are identified by a digit punched under control of the row-1 differentially set switches.

These punching sequences serve only to illustrate the possibilities of punching sequences. One sequence (Number) punches a functional code and variable data controlled from data set on the keyboard. A second sequence controls punching of fixed numerical data and variable data from the keyboard. The third sequence punches only variable data (fewer rows than the first sequence) and a functional code, while another transaction key does not call for any punching sequence.

The program control means, therefore, is controlled from the cash register according to the significance of the data as determined by the particular key which is depressed in the transaction row, row 1, and will control the punching apparatus from only the required number of the differentially positioned switches in the cash register in the proper sequence.

The various components of the program control means and related controls are contained in the Punched Tape Recorder, which is separated from the cash register by a multiconductor cable. Fig. 4 is a view of the interior of the Punched Tape Recorder showing the supply of paper tape which may be seen at the left, the tape then passing across the punching unit, through the punching station, and to the right side of the recorder. Fig. 5 shows the punched paper tape passing from the punching station and being wound on a take-up reel. To the right rear of the unit can be seen the program board on which the sequences are programmed through the use of jumper wires. To the lower left of the recorder may be seen a "run-in" button which may be depressed to cause tape to be passed through the punching station, providing sufficient length of tape to start on the take-up reel (which also serves as leader to be started through tape reading equipment). As a by-product of advancing tape by means of this button, coded holes may be punched as required by the particular tape-reading equipment which will read the tape being prepared.

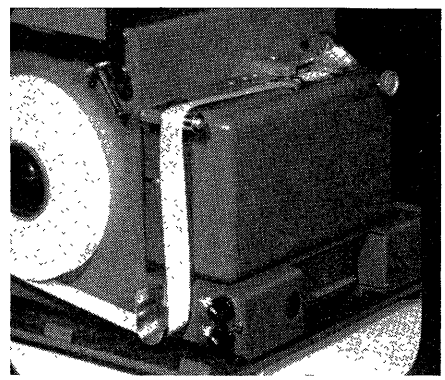


Fig. 4—View of recorder interior (left side).

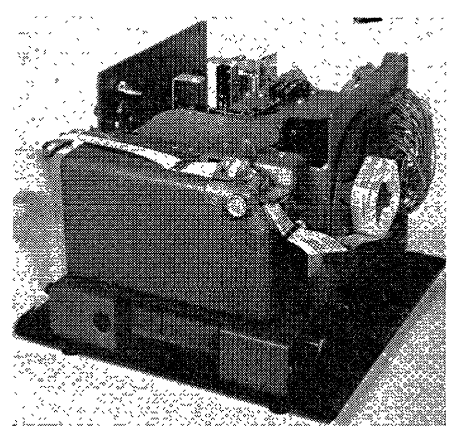


Fig. 5—View of recorder interior (right side).

The recorder contains control circuits, punch drive motor, paper punch, and a program control means including a scanning switch which is the "heart" of the system.

Inasmuch as when the cash register is operated, all data set on the keyboard are available at the same time, it is necessary to serialize the data when punching the paper tape which will contain data in the form of parallel code and serial digits. The scanning switch operates sequentially, each position selecting one character of data to be punched, and, after punching takes place, moving to the next position to read another digit and so on until the sequence is completed.

The system uses switch encoding techniques, which are a well-known art and therefore will not be discussed in this paper. However, the encoding is done, not directly on the differentially-settable switches but on an auxiliary program board which can be seen to the right back of the cash register in Fig. 3. This board actually represents the termination of the differentially-settable data-encoding switches and is provided for the purpose of encoding by means of jumper wires. One section of the board may be used for encoding the amount and clerk rows while another section may be used to encode the transaction rows. Each of the nine rows of the cash register is equipped with differentially-settable data-encoding switches; the transaction row is equipped with additional switches for the purpose of selecting the proper sequence of punching for the transaction key depressed.

System Block Diagram

The Cash Register–Punched Tape Recorder data collection system is completely sequential as to punching and consecutive entries and therefore is absolutely reliable in its operation. The operation of the system may be reviewed in connection with the block diagram of the system shown in Fig. 6.

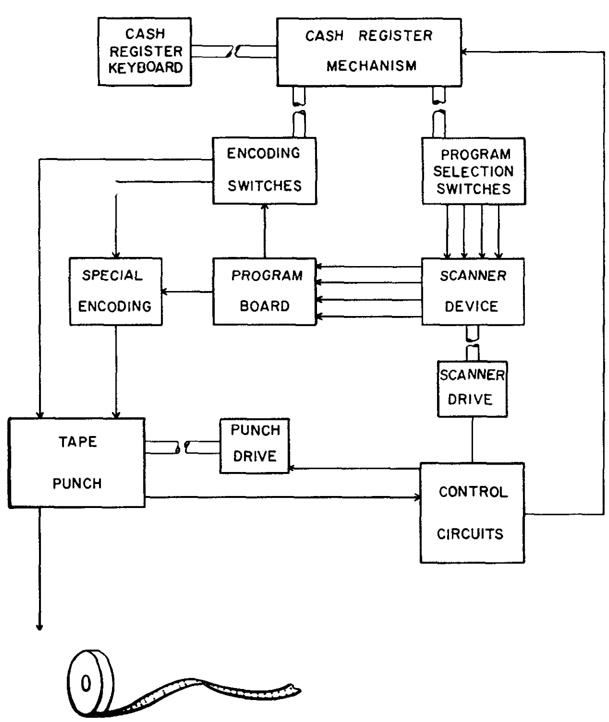


Fig. 6—Block diagram of Cash Register, punched Tape Recorder data collection system.

Setting of data on the cash register keyboard initiates operation of the cash register mechanism. The cash register mechanism, in addition to its normal functions of adding into machine totals, positioning the indication, and printing on the familiar receipt and sales journal, controls numerous components of the system. Among these components are two groups of switches differentially settable and controlled by data set on the keyboard. After these switches are properly positioned, a signal is applied to the group of switches used for the purpose of selecting a recording sequence and known as "program selection switches." If the transaction key used in row 1 on this cash register operation has been programmed on the program board to select a program sequence, that sequence is begun by bringing one section of the scanning switch into use. At this time, if a sequence is selected, the cash register mechanism is locked up under control of the control circuits. This lockup prevents the cash register from cycling again until the sequence of punching is completed. However, the keyboard is left free for setting up data of the next operation.

The program selection switches, having called for a program sequence to be followed, now cause the scanning switch, step-by-step in a sequential manner, to follow through the sequence programmed on the program board. The first position of the sequence applies potential through the program board to either the encoding switches, which have been differentially set by data entered on the keyboard, or to the special encoding network, which provides encoding for all fixed data and functional codes, depending on the programming of the sequence. Through either the encoding switches or the special encoding network, potential is applied to the appropriate electromagnets in the tape punch.

The tape punch being used is a motor-driven unit cycled under control of a single-revolution clutch. As electromagnets are energized, the single-revolution clutch is tripped. The electromagnets, having been energized, also set up conditions to punch the appropriate tape channels as the punch cam line revolves. The punching of the tape feed sprocket holes is automatic with each cycle of the tape punch. As the punch unit cycles and punching takes place, a cam switch applies a signal to the control circuits which in turn controls the scanning switch drive mechanism, advancing the scanning switch to the second position of the sequence involved. At this position the same pattern is repeated, with potential applied either to the encoding switches or special encoding circuits through programming to the tape punch electromagnets, causing coded data to be punched and once again signalling the control circuits to advance the scanning switch to the next position of the active sequence.

When the last position of a sequence programmed to control the punching apparatus controls the tape punch, the signal from the punch once again causes the scanner switch, through the control circuits, to advance one position. This next position (that following the last punching position) controls the control circuit in such a manner as to return the scanner switch to home position preparatory to the next recording sequence, and unlocks the cash register to allow the next cash register operation to take place. Although the cash register has been locked up during a recording sequence, it must again be emphasized that the keyboard has not been locked against operation. The operator may set up data on the keyboard ready for the next operation and the next operation will begin immediately when a transaction key is depressed and the register mechanism is unlocked.

The punching sequences may be selected in any order, repeating the same sequence if desired. Programming of the system is entirely dependent upon the application and the tape-reading equipment. Although there are but four sequences available, this is in no way a limitation of any magnitude. As was seen when the keyboard and recording sequence chart of Fig. 2 were examined, the same sequence may be selected by several transaction keys but differ in significance of data by a digit which identifies the transaction key used. It may also be pointed out that if all four sequences are used and still another is needed it may be possible to make two similar sequences identical. For example, suppose one sequence controls punching in the order of rows 1, 9, 8, 7, 6, 5, 4, 3, and 2 while a second sequence is controlled by data set on rows 1, 6, 5, 4, 3, and 2. It is obvious that these two sequences can be made identical, freeing one sequence, by controlling the second sequence as was done in the first. This of course will punch the tape with data set on rows 9, 8, and 7 which is insignificant for the second type of transaction.

With such a system as just described, a department store sale will be processed in the following manner. The salesperson will first set up merchandise-identifying data by indexing her key in row 9 of our typical cash register, indexing the class of the article in rows 8 and 7, and the style in rows 6, 5, 4, 3, and 2 and depressing the Number key. Depression of the Number key will cause the punching apparatus to be controlled as shown in Fig. 2, punching the class and style into the paper tape. The use of the Number key causes the keyboard entry to non-add. The sales person next indexes the quantity of items in rows 8 and 7, and the gross price in rows 6, 5, 4, 3, and 2, and depresses the proper department key in the transaction row. Thus the second sequence is selected, punching the register number, department, clerk (the clerk key stays down from the previous operation), quantity, and price in the tape. If several different articles are to be sold, each article is handled in a like manner and appropriate taxes and miscellaneous charges are recorded and the machine totalized. The total operation issues the printed receipt for the customer. These operations in handling a sale eliminate the need for accumulating and collecting sales slips, price ticket stubs, or cash register receipt stubs, and also eliminate many manual operations which would normally be necessary later since the tapes may now be fed into computers or tape-to-card converting equipment.

Further Step in Automation

It has no doubt been noted that in the foregoing example it was necessary to enter descriptive data through the keyboard for each item sold. This descriptive data may be of a very few digits, as in our example, and the extra keyboard operation for entering the descriptive data may not be objectionable. However, in high volume merchandising many items may require as many as 25 or 30 digits in order to identify completely the item being sold. Descriptive data of this magnitude might include data identifying class, style, manufacturer, size, fabric, season, color, base price, etc. Since the cash register has a limited number of rows of keys available to enter this data, several operations using the Number key to select a punching sequence would be necessary under the preceding system. The additional keyboard entries necessary in order to record data of this magnitude would be prohibitive in most cases because they would occupy the clerk's time as well as the cash register.

Accordingly, a further step was taken in automation to enable these identifying data to be punched automatically while the clerk operates the cash register in the usual manner to record the data pertaining to the sale of merchandise. This was accomplished by adding a third unit to the Cash Register—Punched Tape Recorder system.

This third unit, known as the National Media Reader, is a device which will read and transfer data from a prepunched price ticket or other media to the paper tape. It is shown in Fig. 7. The reading station of the Media

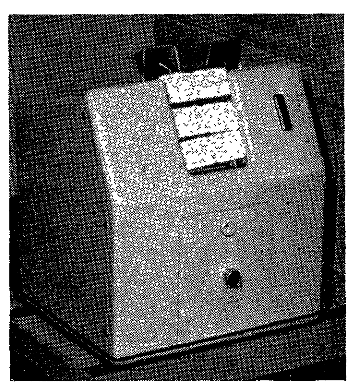


Fig. 7—Media reader.

Reader is seen at the top center of the reader. Fig. 8 shows the three pieces of equipment: Cash Register, Punched Tape Recorder, and Media Reader, all connected by flexible multiconductor cables which allow the equipment to be placed as required by the installation.

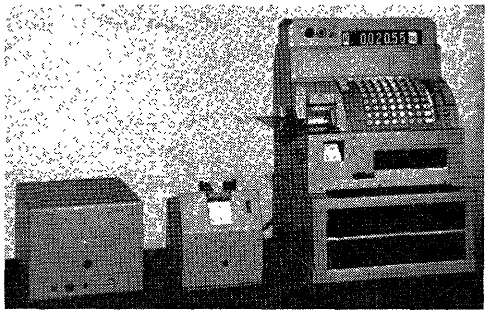


Fig. 8—Cash register equipped with punched tape recorder and media reader.

Fig. 9 shows a prepunched and printed price ticket stub which is being used for this application. These price tickets are usually punched and printed, when articles are ticketed in the marking room, with the descriptive data previously outlined in addition to the original price.

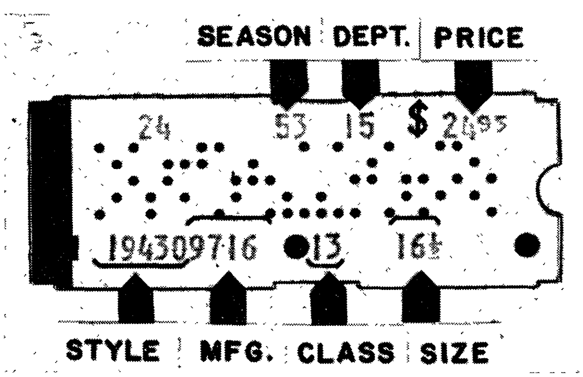


Fig. 9—Typical punched price ticket stub.

The use of the Media Reader simplifies the manner in which a salesperson handles a transaction. Upon selection of merchandise by the customer, the salesperson merely removes a stub of the price ticket and inserts it into the reading station of the Media Reader, which automatically reads the ticket and transfers the merchandise-identifying data to the punched paper tape in the recorder. Along with the reading of the price ticket, certain fixed functional codes such as End of Frame may be punched into the paper tape. While the price ticket is being read, the clerk indexes her clerk key in row 9, the quantity of identical items sold and described by the price ticket in rows 8 and 7, the gross amount of the items in rows 6, 5, 4, 3, and 2, and depresses the proper Department key in the transaction row. The depression of the Department key conditions the cash register so that it can cycle when reading of the price ticket is complete, causing the department sequence, including punching of the register number (provided by the recorder sequence itself), clerk, quantity, price, and department to punch into the tape as well as perform the normal cash register operations of entering amounts into totalizers, indicating the transaction, and printing on the receipt and sales journal. The handling of multiple-item sales is similar to that previously described: the ticket for each different item is read and each ticket reading is followed by indexing of the quantity, price, and department on the cash register. Taxes and miscellaneous charges are entered following the entry of merchandise information. The totaling operation is then performed and a receipt is issued as the transaction is completed.

Suitable interlocks in the system prevent the entering of sales data with the Department keys unless a price ticket has just been read to enter identifying data. The reverse interlock is also true; that is, a second price ticket may not be read until the cash register has been operated to enter the sales data with one of the Department keys. This system of automatically transferring descriptive data to the paper tape under control of the Media Reader and Cash Register does away with the necessity of entering descriptive data through the cash register keyboard.

The Media Reader consists of a motor-driven sensing mechanism, which mechanically senses with pins each character column of the price ticket. The sensing pins are controlled by a single-revolution clutch in sequence, a character column at a time. The five sensing-pins for each price ticket column sense for punched holes. Those pins, finding a hole, pass through the ticket and in turn operate switches associated with each pin. Those switches which were operated by pins passing through the punched holes apply potential to the tape punch electromagnets. Depending upon the configuration of punched holes in the price ticket column being sensed, appropriate tape channels are punched by the tape punch.

Block Diagram of System Using Media Reader

The operation of the Media Reader may be better explained by referring to Fig. 10, which is a block diagram of the Cash Register–Punched Tape Recorder–Media Reader data collection system. The block diagram for this system is similar to that of Fig. 6 except that two blocks have been added to represent the Media Reader. One block represents the Media Reader drive mechanism while the second represents the reading or sensing mechanism. As a prepunched price ticket is inserted in the reading station, the control circuits' sensing the presence of a media renders the reader motor bar effective. When the motor bar is operated, the drive mechanism causes the sensing pins to operate, sensing the first price ticket column. The sensing pins for the first column sense this column for punched holes and operate switches for those code positions in which holes are found. The switches which are operated represent in coded form the digit punched in this digit position or column of the price ticket. They then complete circuits to the proper electromagnets of the tape punch which trip the punch's single-revolution clutch, causing the coded form of the digit to be punched in the paper tape. The revolution of the punch cam line applies a control signal to the reader drive mechanism through the control circuits, causing a further cycle of the reader drive to render operable the sensing pins for the second column, whereupon the sensing means for this second column are operated. Again those sensing-pins, finding holes punched, operate switches, energize electromagnets, and punch the coded digit. Through the control circuits the reader drive mechanism is cycled to cause the next column to be sensed, and transferring of data again takes place. This operation is repeated, reading digit by digit the data prepunched in the price ticket until all desired data have been transferred to the paper tape. At any point during reading it is possible to program the reader to stop transferring data and reset the reader to its home position ready for the next price ticket reading. This is accomplished through an adjustable control which may be positioned to begin reset operation at any point after reading one or more columns from the price ticket. This "reset" control operates a switch which prevents all sensing pins from sensing for coded holes and allows the reader to return to its home position without causing the punch to punch any more data, although the ticket may contain additional data.

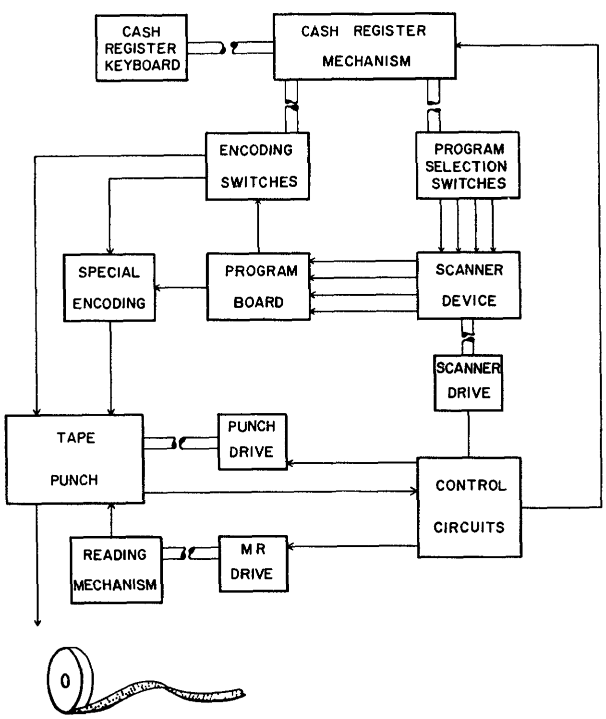


Fig. 10—Block diagram of cash register, punched tape recorder, and media reader data collection system.

Although the reader is returned to its home position, another price ticket cannot be read until a department or price operation is entered through the cash register keyboard. This insures that descriptive data will always be accompanied by the related sales data such as clerk, register number, quantity, price and department information. If the ticket contains a punched price, it might be used only as a base price because the actual selling price, whether marked up or down from the original price, will always be entered on the cash register keyboard. For this reason it is not necessary to repunch price changes in the price ticket.

Although this explanation dealt only with a price ticket application in a department store type application, it is obvious that as the requirement arises, the system can be expanded to include other prepunched media.

There are additional interlocks in the system which add to its accuracy. It has been mentioned earlier that the system is completely sequential in operation. For example, in the event of an open circuit in a data takeout circuit a digit would not be omitted. However, when the sequence calls for punching controlled from the circuit which is open, the punching will stop and the cash register and recorder will remain locked up until the condition is examined and corrective measures are taken.

Another series of interlocks is built around the supply of paper tape. As the supply of paper tape is nearly exhausted, a red warning light is turned on, leaving approximately 15 feet of tape. However, if this warning is ignored the punch will continue until approximately 18 inches of tape is left, at which time the punching stops immediately and the cash register remains locked up. At this time it is necessary to open the Punched Tape Recorder and tear the end of the tape from its pasteboard core. Thus, releasing the tape allows the punching to continue from the point at which it stopped, without loss of any data. The tape left at this point is sufficient to complete a normal transaction. However, if the operator again fails to replenish the supply of tape after completing the transaction, the punch and cash register lock up with $1\frac{1}{2}$ inches of tape remaining, sufficient to complete a normal cash register operation. At this point it is necessary to place a new supply of tape in the recorder. The new roll usually contains about 1,000 feet, which will last for the punching of 120,000 characters.

The paper tape, which is available in 5-, 6-, 7-, or 8-channel widths for various tape codes, is wound on a take-up reel of approximately 400 feet capacity (48,000 characters or about 1,500 transactions). A sample of a five-channel punched tape is shown in Fig. 11. A section of this tape is indicated as representing a price of $12.95.

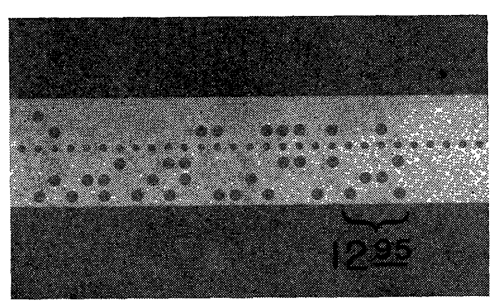


Fig. 11—Sample punched tape.

Although this description has centered about a system using a cash register equipped with automatic by-product data collection equipment, it must be realized that any business machine or mechanism with data settable switches might be equipped with tape recording devices such as have been described. Such machines as accounting machines, adding machines, time clocks, and many others could be equipped with the Punched Tape Recorder. The foregoing description also covered only a very limited application of the system to department store uses. It is obvious that the number of instances in which this automatic by-product data collection system is applicable is almost unlimited.

In conclusion, let us summarize the National Cash Register Company's automatic by-product data collection system. The system captures on punched paper tape, as a direct by-product of the normal business machine's operation, selective data pertaining to the entries through the keyboard of the business machine. As a still further step in automation, a means has been devised by which fixed descriptive data in the form of prepunched media such as price tickets may be transferred automatically to the punched paper tape being prepared by the operation of a business machine equipped with a Punched Tape Recorder. Through the use of this Media Reader it is now possible to automatically transfer data from the prepunched media to the paper tape, while operating the business machine in the normal manner without additional machine operations.

Computers Challenge Engineering Education

F. C. LINDVALL†

WHEN QUANTUM theory was newly stirring the world of physics, an older professor was reported to have said to his graduate students studying this subject, "I don't believe you young fellows understand this stuff any better than I do, but you all stick together and say the same thing." You computer enthusiasts say a great deal, some of which I understand. Your computers differ in detail and complexity, yet have much in common in concept and capabilities and in the fantastic rate with which new models appear. They have their limitations, but nobody underestimates their potentialities. Nor are the glamorous, rosy dreams of coming applications as far beyond the horizon as we might think. You know better than I the magnitude and momentum of the development effort and the tremendous interest which has been generated in all areas of technology and business.

In science and engineering education as well, computers have stimulated much excitement, critical thought, and even some concern. In fact, the computer is one of the more spectacular new developments which are a challenge to education. As a result, we in the colleges of science and engineering are being forced to examine the implications of this challenge. We are also being urged to offer courses in computer fundamentals, logic, design, components, applications, and use, not to speak of complete curricula leading to degrees in computer engineering. Some schools have strong research interests in modern computing and may be justified in offering such instruction. At the same time, other customers for our graduates give equally convincing arguments for more or less specialized instruction in, for example, control systems, instrumentation, automation, systems engineering, operations research, nuclear engineering, and information theory. Needless to say, we are somewhat confused and bothered beyond mere professorial petulance over these challenges to comfortable academic routines.

We cannot, and, I believe, should not, attempt in the colleges to meet these challenges by detailed specialization in all of these new and emerging areas of current interest and importance. We must, instead, do the more difficult job of examining each new development for those features that are truly basic, extracting the concepts that are new and fundamental, and synthesizing the important generalizations that have lasting value. This exercise of self-discipline, sticking to fundamentals, is not easy. The other course, that of following avidly in the classroom the exciting new developments, the intriguing applications, and the fascinating new details, is more fun, has high entertainment value for the student, and is an easy, pleasant way to teach. But, it has the elements of a gold brick, the superficial appeal—the form, but little substance. The values are apt to be transient.

Thus, in appraising new developments, engineering colleges must evaluate critically the fundamental character of these new advances—what is now involved and what is anticipated—so that curricula and course content of the basic sciences and engineering sciences may be improved as fundamental education for future professional application. We must always be critical of that instruction which is specialized training rather than comprehensive education.

To sharpen focus on this problem, we can examine three major areas of computer work which may occur on a college campus: research, computational service, and teaching. These areas, of course, have considerable

† California Institute of Technology, Pasadena, Calif.