CREDIT TERMINAL DESIGN COMPETITION

A STUDENT DESIGN PROJECT

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A. J. Pennington September 1967

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CREDIT TERMINAL DESIGN COMPETITION

Background

Dominion Telephone and Telegraph Corporation is a rapidly growing company, which in the past six years has acquired 14 independent operating companies. Today it operates nearly 12 million telephones in Southern California, Montana, Michigan, Saskatchewan, and the Dominican Republic. DT & T actually serves as a holding company for 24 separate operating companies in its system, some of which are only partially owned by the parent corporation. In turn, 68% of DT & T stock is held by a vast international congiomerate known as General Universal, Ltd.

General Universal pursues a particularly aggressive policy of acquisitions and mergers, and this policy is reflected in DT & T. Mr. J. B. Ramjet, chairman of the board and chief executive officer of DT & T, desperately desires to achieve a modern and progressive image for the company so that it will be easier to acquire additional independent operating companies. At the same time, some of his existing operating companies have territories that overlap with those of the Bell System, and embarrasement and lost revenues have sometimes resulted from this competition.

Ramjet is also acutely aware that telephone company tariffs are tightly regulated by state commissions and by the FCC. Any sources of revenue that are subject to looser regulation--or no regulation at all--will help improve DT & T's modest return on investment and bolster Ramjet's position with the General Universal home office in the Netherlands.

One of Ramjet's staff conceives of the idea of a terminal device that will read credit cards and accept keyboard entered data for transmission to data processing equipment. Ramjet immediately seizes on this idea because:

1) This equipment could help promote the dynamic progressive image of DT & T (provided Bell doesn't offer such equipment sooner).
2) This terminal device might be exempt from some of the rate-setting constraints of the regulatory agencies.
3) At the same time, DT & T will probably be able to obtain a monopoly on the use of such equipment within its operating territories, because of the inviolate (according to telephone companies) law that the only electrical connections that can be made to the telephone system are those which are made through interfaces provided by the company.

Ramjet orders a marketing study, which proves satisfactorily optimistic, and then commands a full-scale development project. However, because of the rapid, crazy-quilt pattern of growth of DT & T, the company as yet possesses essentially no R & D capability. Also, the company possesses no manufacturing capability at all. Some operating companies buy most of their equipment from Northern Electric (General Tel's manufacturing arm) and others buy from a variety of suppliers, including Sieman of Germany.

The decision is made to contract out the R & D effort and the manufacture of the device or devices. A design competition between two engineering firms is arranged. The competition calls for the preliminary design of terminal devices, with the construction of prototypes, if practicable. The successful firm will win the right to manufacture the device for DT & T under an involved contract drawn up by corporation attorneys.

Specifications given to the contestants of the design competition are indicated on the next page.

Specifications

1. Modularity

The marketing survey indicated that there should be three basic types of terminals:

Model A

Credit card validation only. Reads 10-decimal digit account number from credit card. If valid, imprinting mechanism is unlocked, allowing embossed charge receipt to be issued. If invalid, credit card is locked in machine.

Model B

Credit card validation, plus price information. Performs all functions of Model A, and in addition, allows entry of 5 decimal digits of price data. This device is intended for use in service stations.

Model B-1

Performs all functions of Model B, and in addition automatically transmits a 4-digit address code identifying the terminal device.

Model C

Credit card validation, plus entry of numerical data from keyboard. Provision should be made so that this keyboard can be used flexibly, for the entry of all types of accounting and control information.

Model C-1

Modification of Model C similar to Model B-1.

These models should be built with similar parts, circuits and packaging because of marketing, installation and maintenance considerations. All units should allow the use of a conventional telephone handset on the same line, e.g. when it is desired to transmit audio information from the computer to the operator of the device.

2. Operational Function

The device is to cycle through the following steps:

1) credit card is inserted by operator
2) preset telephone number is automatically dialed.
3) when call is completed, account number on credit card is automatically transmitted over telephone line.
4) data signal is received by device from computer. If signal indicates credit card is valid, device allows the entry of numerical information.
5) Model B: Operator takes positive action (e.g. pushing a button) to enter numerical information. The possibility of entering numerical information set for the previous customer must be minimized.

   Model C: Operator enters each successive numerical field (e.g. price, tax, stock number) after a signal is received from computer.

   Operator must be able to abort the operation because of incorrect entry of data.
6) Operator completes cycle by pulling lever to imprint charge receipt.

Entry of address data for Models B-1 and C-1 may occur at any appropriate point in the cycle.

3. Human Factors

Device must embody the tenants of good human engineering. The device must be usable by untrained clerks. The opportunity for clerical error must be minimized.

4. Compatibility

(a) Device must be compatible with existing telephone equipment. Provision must be made for automatic dialing on lines connected to either Strowger step-by-step, crossbar, or ESS central exchanges.

(b) Data transmission should be by "touch-tone," so that the device can be used to communicate with any data processing equipment designed to receive data from touch-tone telephones.

5. Credit Cards

No restriction is made on the type of credit card. Account number may be sensed optically, magnetically, electrically, or mechanically. However, the card must be of a type likely to gain wide acceptance and if possible, it should be one of the types already in use.

6. Reliability

The device must provide for very high reliability of credit card reading and data transmission. Consideration should be given to the use of error detecting codes.

7. Cost

The manufacturing cost of the device must be quite low, perhaps not quite so low as that of a pay phone, but certainly not as high as that of a color television set.

REMOTE CREDIT TERMINAL

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CHAPTER 1

OVERVIEW

A. THE PROBLEM

Retail credit constitutes a multi-billion-dollar-a-year growth industry. For many firms, it has come to represent an investment larger than that in merchandise. Nearly every major retailer is now either initiating or expanding issuance of credit cards. Credit policies are being liberalized, charge accounts are being aggressively promoted, and the average balance per account is rising. In fact, credit has become a fundamental merchandising tool, forcing some companies to issue cards en masse and unsolicited. Seven thousand firms have issued an estimated 200-million credit cards in the United States. Mobil, for example, processes 95 million individual charge tickets a year and sends out 21 million statements. American Oil has doubled its credit transactions in the last five years.

This growth, however, has created an acute problem. Potentially, through loss, theft, or misuse, the credit industry has created 200-million opportunities for credit card fraud. Since option and similar accounts require more effort to bill and collect, and since their balances remain outstanding for longer periods of time, immediate detection of fraud is difficult. Furthermore, many companies now issue cards with no expiration data, thus increasing the possibility of accumulating incremental bad debts ("incremental" refers to the increase in bad-debt accounts that occurs after an account is beyond its cutoff point.)

Compounding the problem, in the effort to make their cards more desirable, many firms are expanding into high risk areas such as hotels, restaurants, airlines, and car-rental agencies. Although typical bad debt losses are something on the order of one half of 1% of total credit sales, one oil company recorded a 4% loss on hotel charges last year. Losses of 5% of credit sales have been experienced with bank-issued credit cards. One Chicago bank posted an incredible fraud loss of $46,000 during a single day.

The extent of the crisis is illustrated by the following facts:

--one and one half million credit cards are lost or stolen each year.

--in all, more than $20 million is lost annually through fraudulent card usage.

--Fraud and misuse are spreading. The Postal Inspection Service reports a 400% increase in credit card frauds in the last two years. Carte Blank announced double the number of losses in 1966 than two years before.

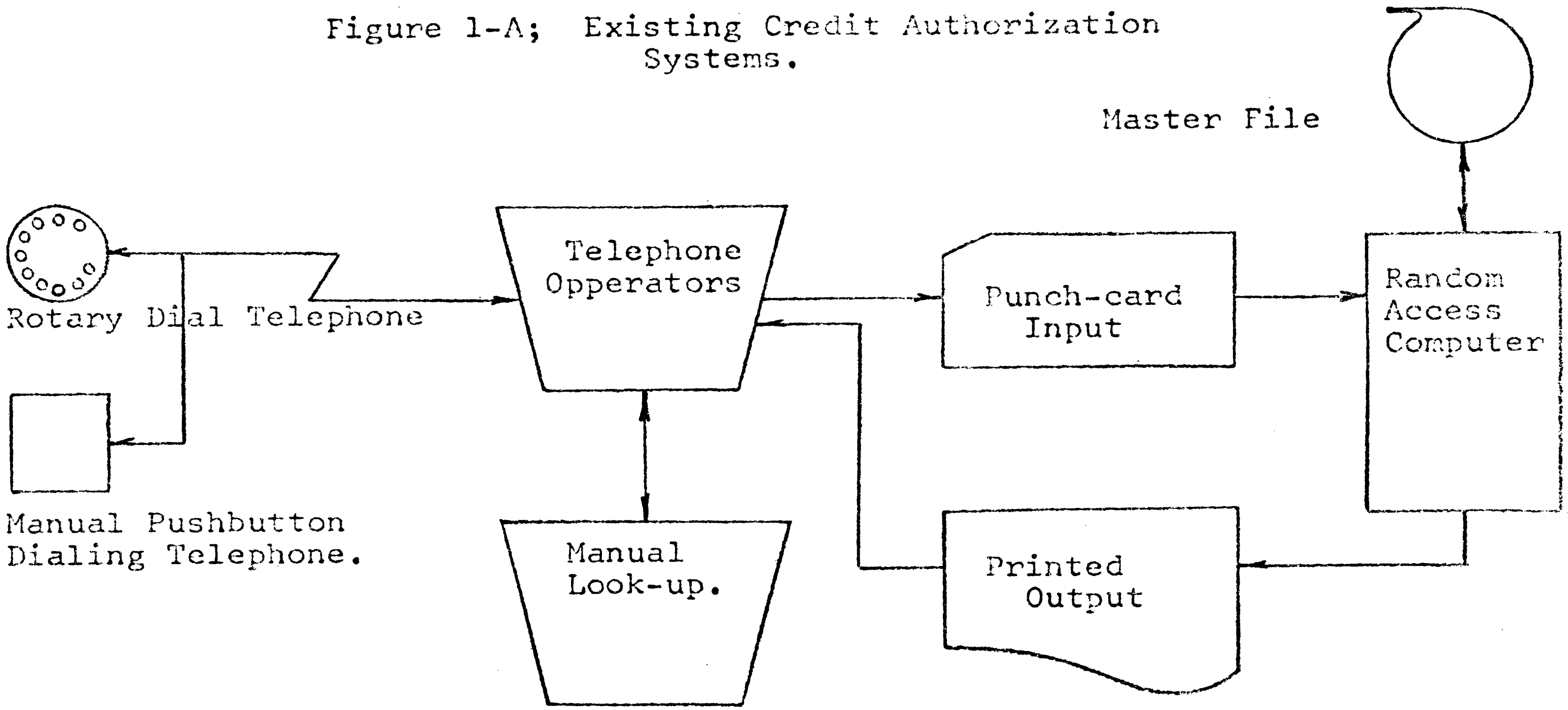
--There is evidence that credit card fraud is systematically committed by criminal organizations. A Chicago credit card ring is said to operate a thriving, well defined, national buy-sell market for stolen credit cards. Fraudulent sales average almost $1000 per card. (The record for a single individual bad credit card is reportedly $24,000.)

This discussion, then, clearly establishes the need for greater protection of the credit investment. Several existing protection systems will be considered next.

B. EXISTING SYSTEMS

Traditionally, the simplest form of control has been the publication of a cancellation or stop list. Theoretically, sales personnel are supposed to check the cancellation list on every credit card transaction--at least those above a specified amount, or "floor release limit"--to verify that the card is still to be honored. Publication of a cancellation list often gives a parent company the right to charge back retailers for worthless invoices written on expired or cancelled credit cards.

Figure 1-A; Existing Credit Authorization Systems.



The procedure, however, is inconvient, and without charge back for worthless invoices written on expired or cancelled cards, the dealers have little incentive to use the lists. Even with charge back on listed numbers, two problems remain--first, the difficulty of keeping the stop lists short enough to be both fair and practical, and second, the problem of keeping the lists current.

A more advanced method utilizing a random access computer minimizes these difficulties. Figure 1-A illustrates the procedure. On sales above an established floor release limit, sales personnel are required to telephone a local operator. The clerk informs the operator of her station number and the number of the suspicious credit card. The operator then types the suspected number--or in the case no card is presented, the customer name and address--into a random access computer. This initiates a negative search of a tape containing a record of all invalid cards. The operator relays the result.

If a manual, rather than computer system is used, the authorization time is on the average of 2 to 2 1/2 minutes, and often as much as 7 minutes. A computerized search requires from 45 seconds to several minutes.

Even greater speed is obtained utilizing IBM's Audio Response Unit, as shown in Figure 1-B. To initiate an authorization inquiry, the sales clerk dials the authorization extension. The clerk then dials the account number and dollar amount of the sale. These characters are received by the ARU & transfered to the System/360 where they are stored until an end-of-message is indicated. The 360 then gains access (by account number) to the authorization file where the account record is located, its status determined, and the appropriate authorization response selected and sent to the ARU. The ARU decodes the message into specific vocabulary addresses which are then used to select sequential vocabulary sounds from the audio output of the ARU. The completed audio message is finally transmitted to the sales clerk.

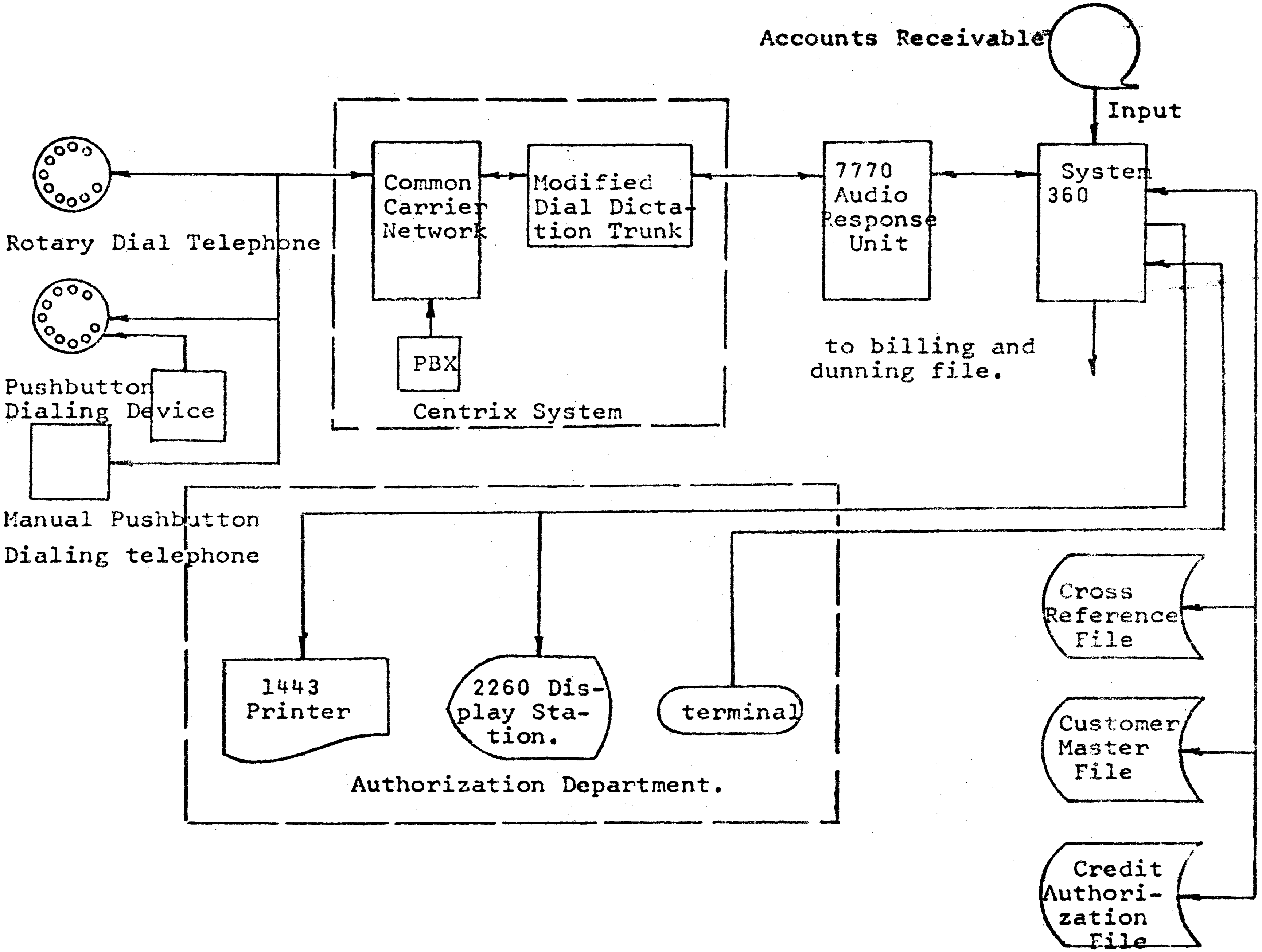
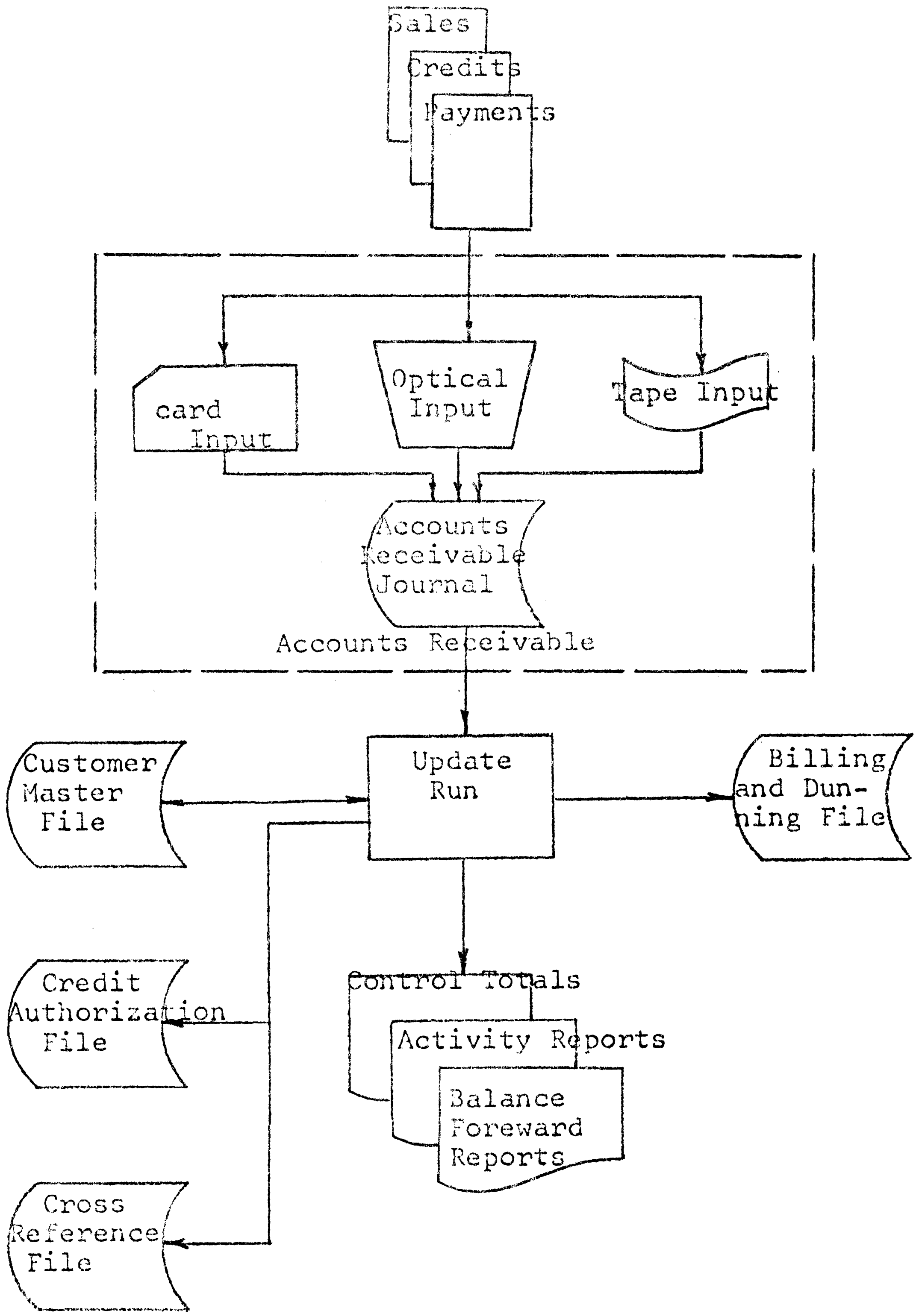


Figure 1-B; Complete IBM Authorization System Utilizing the 7770 Audio Response Unit.

Figure 1-C; Updating Procedure.



Access to the cross-reference file is by a randomizing process on the first four or five letters of the customers last name, and the first three or four digits of the customers address.

In the case of a negative response, the exception authorizer initiates a search for the customers record in the customer master file. A complete customer history, displayed visually on terminal screens, is then available for reference.

The updating process is indicated by Figure 1-C.

With proper specification of communications requirements using data such as Figure 1-D which relates peak traffic to the percentage of busy calls, once the number of trunk lines cc), authorization times of less than 30 seconds are possible.

C. THE OPTIMUM AUTHORIZATION SYSTEM

From the review of existing systems presented in the previous section, it is possible to determine the specifications of an optimum authorization system. They are:

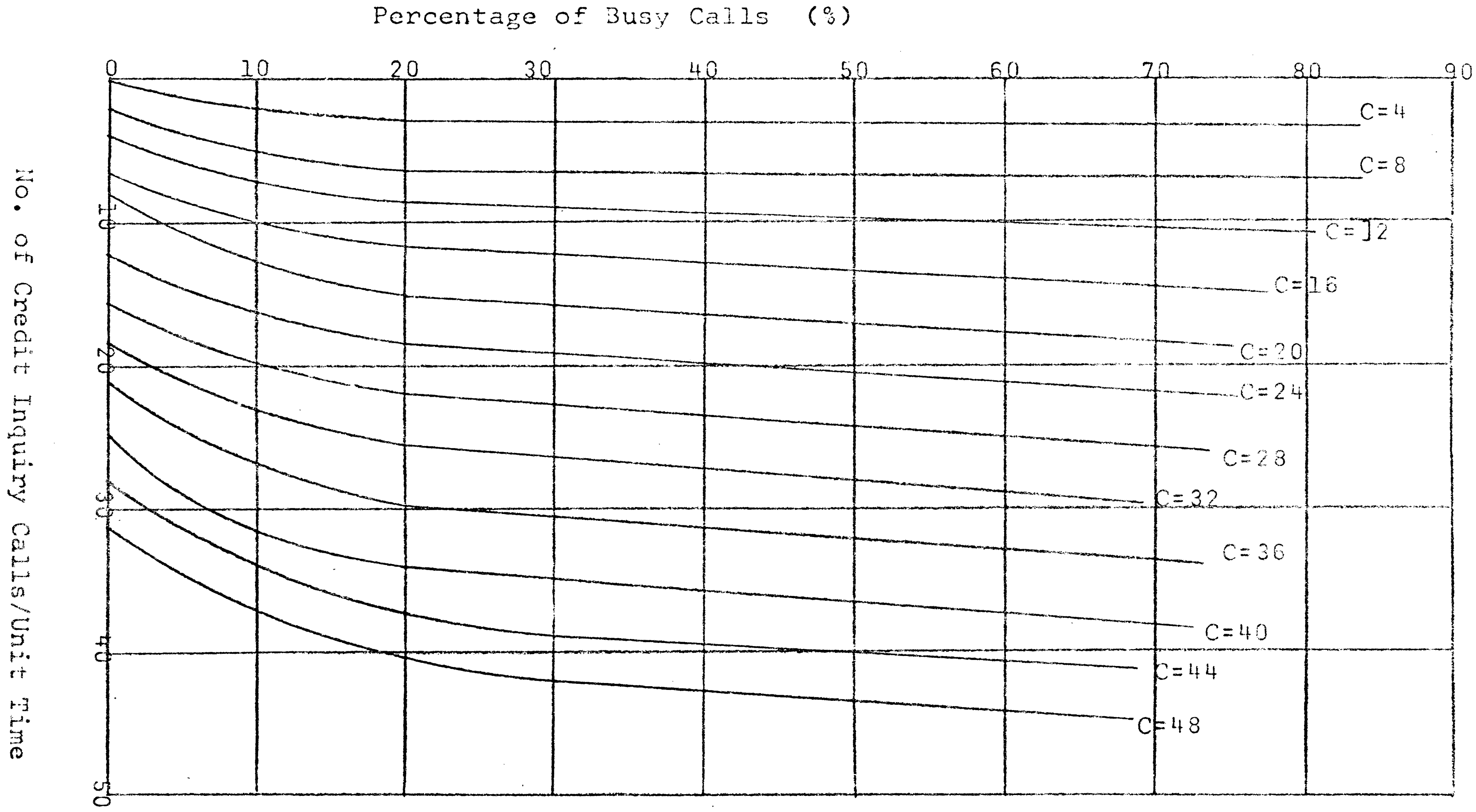
SPEED--The authorization procedure should consume a minimum of time, both to provide maximum customer service, and to minimize the loss of sales personnel time. Thus the optimum system must:

1. Be able to automatically detect and transmit the credit, price, station, inventory, and any other necessary information at speeds compatible with existing data transmission equipment.
2. Decode and process the transmitted data at computer speeds.

COMPATIBILITY--The existing communications and data processing systems within the retail organization must be used as much as possible.

In addition, credit authorization should not fully occupy computer processing time. Normal accounts receivable programs should be run concurrently with the credit authorization program. This "multiprogramming" capability necessitates a nondedicated computer system.

Figure 1-D; Communications Specifications



ACCURACY--It is necessary to prevent sales to undesirable customers and to minimize the possibility of erroneously denying a purchase to a credit-worthy customer.

TIMELINESS--The data for the credit check must be as current as possible, and thus must reflect all changes and transactions as of the previous days close of business.

ACCOUNTABILITY--The system must be designed to prevent fraudulent or inaccurate authorization by sales personnel. Thus, the authorization procedure should be a necessary part of any sales transaction.

In the case of improper authorization, the optimum system should possess auditability, that is, possess the capability of assigning responsibility for improper authorization to individual sales personnel.

FLEXIBILITY--The optimum system must:

1. Be able to handle any realizable degree of authorization activity without resulting breakdown.
2. Allow for varying authorization (floor) limits by branch or department as required.
3. Be able to expand or modify authorization operation without compromising standards.

SIMPLICITY OF OPERATION--

1. A minimum of technical training should be required of sales personnel.
2. Maintenance procedures should minimize down time.

These, then, are the criteria of an optimum credit authorization system. Any real system must attempt to approximate these specifications.

D. ADVANTAGES

The optimum authorization system described above would be, in effect, the basis for a completely automated retail credit system. Some of the more obvious advantages of such a system are:

--<u>Increased speed of authorization</u>--under an ideal authorization system, the only constraints upon the speed of credit approval would be the system's data transmission & computer capabilities. Credit decisions should be obtained in a matter of seconds. Increasing the speed of authorization reduces customer imitation and gives sales personnel more selling time.

--<u>Concise and accurate credit approval</u>--

--<u>Greater consistancy in authorization</u>--Since credit approval is made by computer application of company authorization policies, the variations possible when a number of authorization personnel apply the policies are eliminated.

In addition, due to the increased speed & accountability of the optimum authorization system, the credit authorization process can be applied to a greater number of sales transactions.

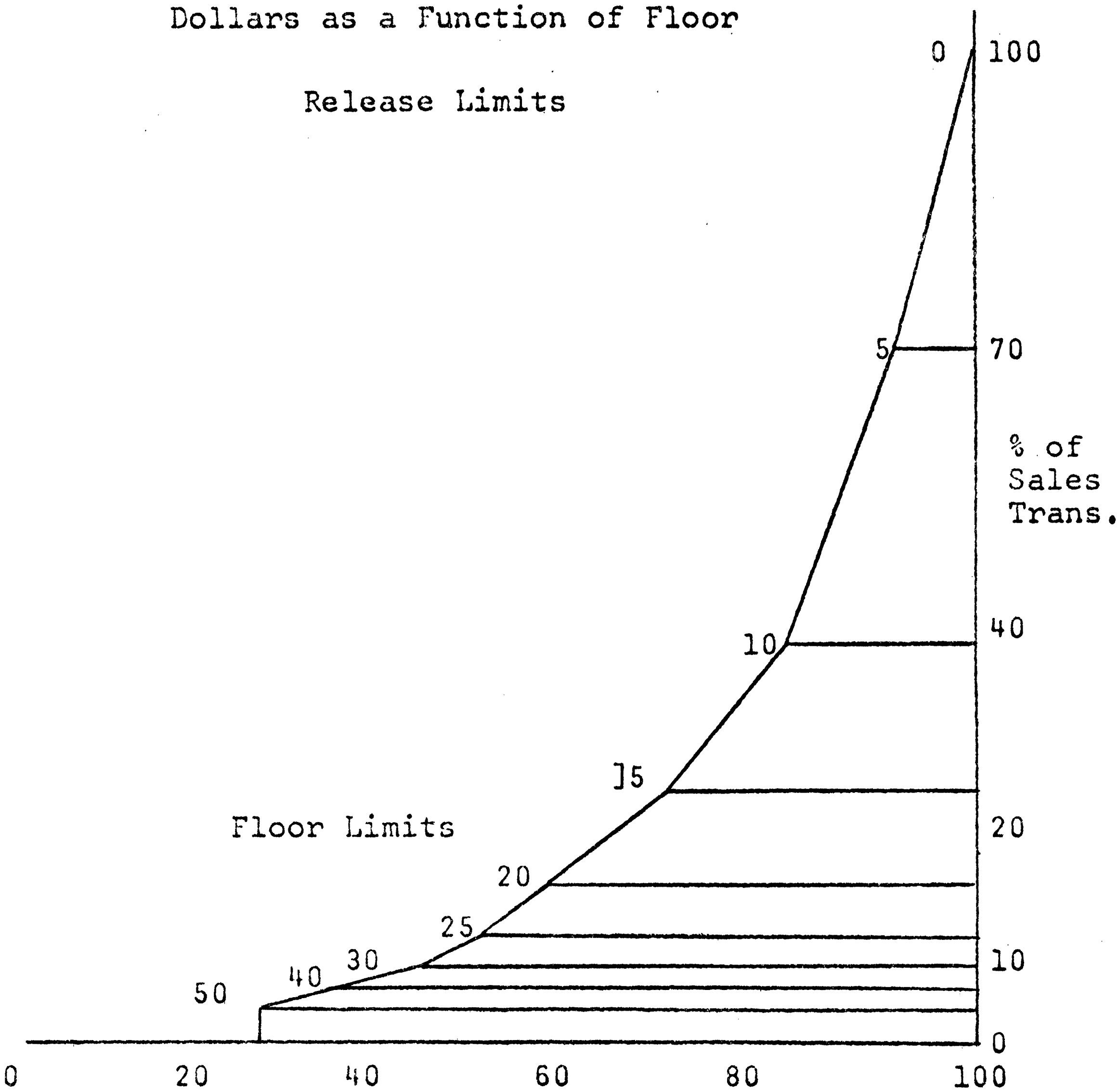
--<u>Reduction of routine, manual effort</u> in processing credit authorization inquires.

--<u>Greater protection of the credit investment</u>--The Chicago Stores Division of Carson, Pirie, Scott and Company, a large retail department store, tabulated sales checks over a period of time to determine 1. the percentage of transactions and 2. the dollar volume for any given sales check dollar value. From this data, the cumulative percentage of transactions and the dollar volumes for various floor limits could be displayed graphically. Fig. illustrated this relationship between sales transaction dollars and floor release limits. Note that a $25 limit, typical in the industry, covers about 40% of the transactions and 80% of the dollar volume. Limits under $10 would result in a greatly increased transaction volume without a corresponding increase in dollar coverage. Using an automated credit authorization system, a lower floor limit, and thus greater protection of the credit investment, is possible.

Figure 1-E; Sales Transaction

Dollars as a Function of Floor

Release Limits



% of Total Dollars Protected.

In addition, an automated authorization system can prevent loss of protection through compromise of floor limits in periods of greatest credit activity.

--Reduction in bad debt losses--

1. Immediate detection of the use of lost, stolen, or fraudulent plates.

2. Prevention of bad debt buildup through daily updating of accounts receivable.

3. Reduction of incremental bad debt losses. Stores are powerless to prevent below-floor-limit purchases made with a charge plate. However, lower of floor release limits would significantly reduce this incremental bad-debt write off.

--Minimumization of collection costs--The reduction of collection effort and its corresponding costs.

--Data Collection--The information detected by the optimum credit authorization system can be used for many functions, in addition to the credit authorization function. The data recorded in the accounts receivable master file can be a valuable management tool in such areas as:

1. Credit Promotion. Special mailings of promotional material can be made to customers with a common credit status, such as inactive accounts or those whose average balance has decreased significantly. The effectiveness of this kind of promotion can be measured by comparing the actual purchases made by customers who receive the mailing against a control group of customers who do not.

2. Sales promotion Selective promotional mailings can be made based upon an analysis of customer buying habits indicated by the data in the master record.

3. Bad debt analysis An analysis of bad debt accounts can be made to refine credit application approval practices.

4. If <u>inventory information</u> is included within optimum credit authorization system, this data can be evaluated to:

   a. Provide accurate inventory control.

   b. Detect purchasing trends, and thus help shape marketing strategy.

The desirability of an optimum authorization system is evident. Such a system would provide greater customer service, streamline and standardize credit approval, and provide valuable data. However, one question remains unanswered. Is the cost of an optimum authorization system justified?

E. COST CONSIDERATIONS

No simple answer can be given to the question of cost justification. The desirability of an authorization system utilizing remote terminals is, of course, dependent upon both the specific protection system and the nature of the particular firm. However, several areas of savings can be considered:

--Reduced bad debt losses through (1) elimination of buildup through daily up-dating. (2) lower incremental losses resulting from lower floor limits and (3) refined credit application approval practices.

--Lower collection costs.

--Decreased personnel costs. With routine authorization inquires computer controlled, authorization personnel will be freed for more important functions.

--Reduced accounting costs. Presently, invoice information must first be gathered, and then converted--often manually--into a form acceptable for computer use. Automatic transmission of invoice information from remote terminals would eliminate these indirect steps, and thus reducing costs while providing instantaneous accounting.

Data transmission and computing costs would be minimized since the firm's existing systems would be utilized. In addition, invoice imprinting devices for credit cards are now universally accepted. Thus the cost of remote terminals can be considered as only the cost of the additional credit authorization feature.

In conclusion, then, these considerations indicate that an optimum credit authorization system may be economically feasible.

F. SUMMARY

The cost of credit card misuse is substantial. Although a number of security systems have been marketed, all fail in some degree to fulfill the specifications of an optimum authorization system. The advantages and cost considerations of such a system justify its selection as an interesting and practical EE 473 design project.

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CHAPTER 2

GENERAL CONSIDERATIONS FOR A CREDIT TERMINAL SYSTEM

INTRODUCTION

The problem, as originally assigned to the EE 473 class, was to design a complete credit check system. This was to include the design of a computer terminal, a method of data transmission and storage, a method of interfacing the transmission line to both the computer and the terminal, and the design of an appropriate accounting system. A market analysis as to the saleability of the system was also to be considered. After the first three weeks of the semester it became obvious that some of these problems were of too wide a scope to be analyzed in eleven weeks, and that other problems had already been solved by companies prominent in the field.

The problem, therefore, was redefined, both as to its scope and its objectives. The purpose of this chapter is to introduce the problem, general considerations for its solution, and the reasons for the solution's development along particular lines.

A. REDEFINITION OF THE PROBLEM

During the first two weeks of the semester, an attempt was made to gather information on the type of accounting systems used in both large retail stores, such as the J. L. Hudson Co. in Detroit, and in large nationwide credit card firms, such as American Express. Several accounting instructors from the University of Michigan's Business School were interviewed. Although similarities existed between the accounting systems used, there were enough differences so that the design of a general system would be extremely difficult, if not impossible. Two lines of approach were thus open to the group.

1. A study could be made of an existing accounting system in a particular store (or particular credit card firm) and a complete credit checking system could then be designed to meet this company's particular needs.
2. A credit checking system could be developed independent of any existing system. In essance, the problem of integrating a computer into a company's accounting system would be ignored.

This latter approach was taken. As a result, the problem narrowed down to just performing a credit check on an individual, and immediately updating the firm's accounts receivables.

To keep the system general, it was also decided to make use of existing lines of communication. Although a large department store could install special communication lines from all its sales desks to a central computer located in the store, it would be impossible for a nationwide chain of stores, like S. S. Kresge Co., or a nationwide credit card system, like Diner's Club, to run special lines from all its sales locations to a central computer. Thus it was decided that all data would have to be transmitted over conventional telephone lines.

The next problem was to design a transmitter to translate the numerical information into electrical impulses, and then transmit these impulses from the terminal to the computer. A similar device would be needed on the computer end to transmit information back to the terminal. A touch tone transmitter was decided upon for the terminal, not only because it is compatible (or can be easily made compatible) with all existing telephone exchange equipment, but because the translater/transmitter, the oscillator pad from a touch tone telephone (see appendix C), is inexpensive ($22 from Graybar Electric). Another advantage in using touch tone data transmission is that the decoder, the device that demodulates the touch tone signals and feeds it into the computer, is currently manufactured by

Western Electric and IBM. By using their equipment all interfacing problems between the terminal and computer were solved, leaving the design of the credit terminal as the only problem remaining. The solution of this problem makes possible a completely automatic credit check system--a system that not only gives stores instant credit information on a customer at the time of purchase, but also provides immediate posting of the transaction to the customer's account.

Complete specifications for the terminal problem are in the introduction to this booklet.

B. INITIAL SYSTEM DEVELOPMENT

It is assumed that any firm large enough to require an automatic credit check system already has a computer in use. Most companies of any size employ computers for routine time consuming problems, such as the computation of payroll, and the printing of customer billings. To make use of these existing computers, the system was made universal enough so as to be compatible with any general purpose digital computer. A time sharing computer is not required. All queuing of incoming calls to the computer is taken care of by an IBM 2701 transmission control device. Besides queuing incoming calls, this device also routes output signals from the computer to the appropriate phone line. For details on computer utilization, see chapter 11.

Although it was originally considered desirable to have the terminal operate directly from an existing sales counter cash register, this idea was dropped when, as described above, it was decided to keep the system compatible with, but separate from, existing sales and accounting systems.

After this decision was made, the system's design centered around complete two way communication between the terminal and the computer. The customer's account number, pricing information, and, if desired, the inventory number of goods purchased, was to be read into the computer. The computer, after processing this information, would then send back a confirmation which would be checked for accuracy at the terminal. The printing of the price on the customer's receipt was to be controlled by the computer instead of the terminal. This would assure complete agreement between the price stored in the computer and the price on the customer's receipt, eliminating the possibility of undetected transmission error between the terminal and the computer. This design was eventually dropped, however, because the existing data sets manufactured by Western Electric do not allow for complete two way communication. Although they allow for complete transmission of numerical information from the terminal to the computer, transmission from the computer to the terminal is limited to three audio tones. (see appendix C).

After talking with Bell Telephone engineers it was decided that noise error on touch tone lines was so negligible, for our purposes, that even if a two way data set were to be designed, the added cost of providing the necessary numerical decoder to each terminal could not be justified. Therefore, unlike conventional computer terminals, a credit check terminal would not require complete two way transmission of data. This allows the use of an ordinary desk top touch tone telephone as the only interface needed between the computer terminal and the telephone lines, resulting in substantial cost reductions.

CHAPTER 3

SYSTEM DESIGN AND ANALYSIS

A. GROSS CHARACTERISTICS OF SYSTEM

In the last chapter we discussed the rational for several basic design constraints. They are listed here to aid our present discussion:

1. Centralized computer to handle data processing
2. Existing telephone lines to provide a communication link between terminal and computer
3. Touch-tone signals to transmit data.

On the next page (Figure 3-A) is a basic block diagram of our complete system. This overall configuration is a product of the essential system objectives as well as our initial constraints. Several interesting and rather significant consequences can be seen from this simple diagram.

First, note that there is no conceptual limit to the number or size of computers used. A pilot system could use a small, general purpose computer such as a PDP-8 or Honeywell 516 to provide service for 100 to 1,000 terminals. At the other end of the spectrum, a nationwide matrix of credit check terminals might require a system of regionally distributed IBM 360 computers. In a multi-computer set-up, phone lines would provide communication links between the computers as well as between computer and terminal. These inter-computer links would be essential if our system is to encompass accounting functions as well as credit checking. A more detailed discussion of the possibilities and scope of the computer side of this system is reserved for Chapter 11.

The decision to use telephone lines as an interface between the computer and the terminal resolved many of our problems. By using phone lines, our terminal design can be completely independent of the specific computer employed. We need only be sure our device is compatible with a standard telephone

GENERAL LAYOUT OF COMPLETE CREDIT CHECK SYSTEM

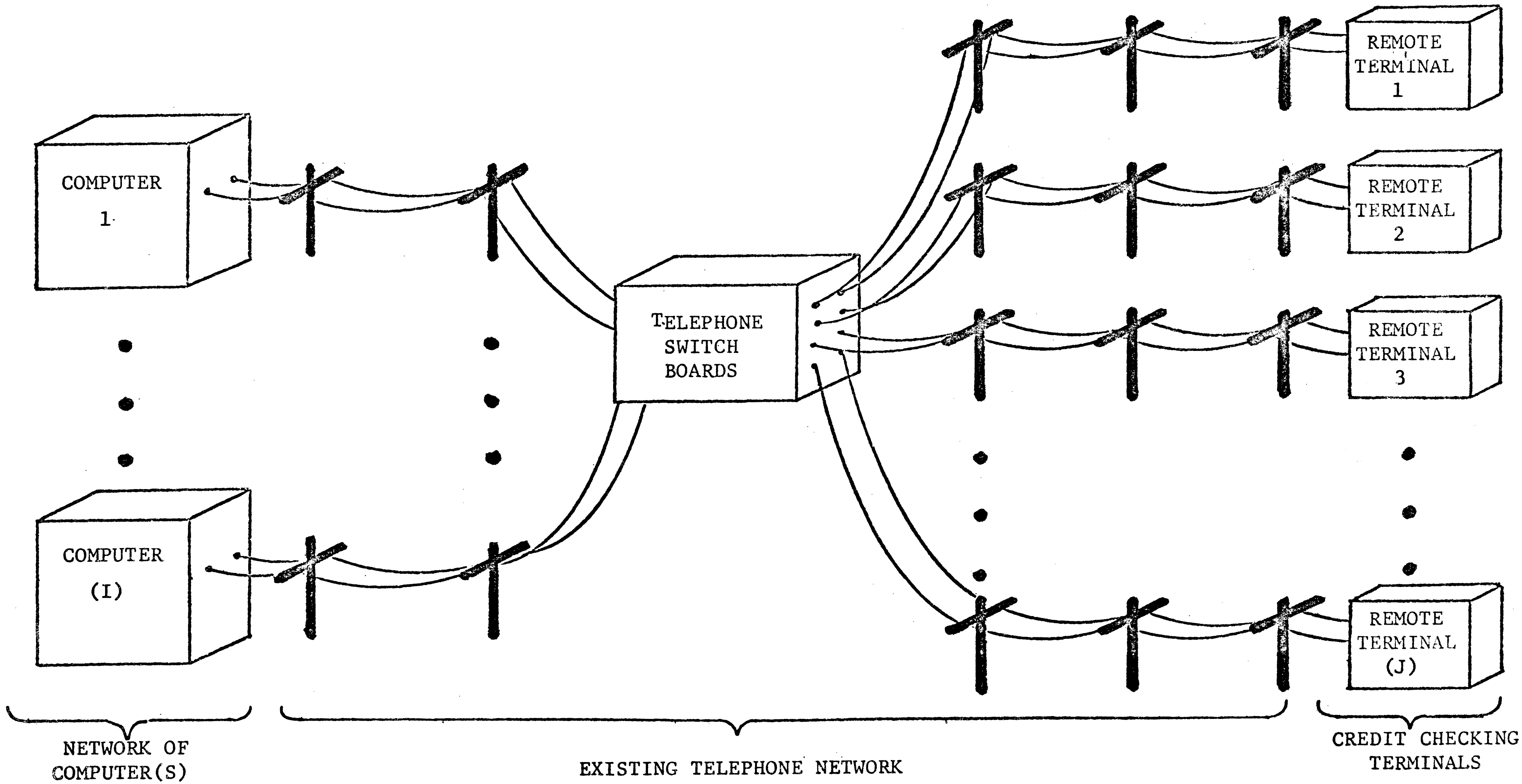


Figure 3-A

line. The details of the options and constraints we faced as a consequence of communicating on the telephone line are taken up in Appendix C.

Although it is not shown in the system diagram, the decision to use the touch-tone signals deserves discussion here. Fundamentally, a touch-tone signal is a composite of two audio frequencies. The coding of the decimal digit into touch-tone signals can be seen by the sketch below:

	X	Y	Z
A	1	2	3
B	4	5	6
C	7	8	9
D	*	0	#

TOUCH TONE MATRIX

The digit 5 is encoded as frequencies B and Y, 9 is encoded as frequencies C and Z, etc. Hence, touch-tone is a two-out-of-seven code. Any of the seven frequencies can be put out on the phone line by closing a relay contact associated with that particular frequency. This immediately suggests that we can use a standard touch-tone phone as our transmitter, and then send any digit by closing two of the seven contacts we have placed in parallel with the existing seven contacts in the touch-tone matrix pad. See Appendix C for the circuit diagram of the touch-tone pad and the location of our parallel contacts.

B. FLOWCHART OF TERMINAL OPERATION

In order to see exactly what hardware is going to be needed in our terminal, early in the term we drew out a flowchart of the terminal operation so that we would know what functions our device needed to perform. The flowchart is presented on the next page (Figure 3.B).

FLOWCHART OF TERMINAL TRANSACTIONS

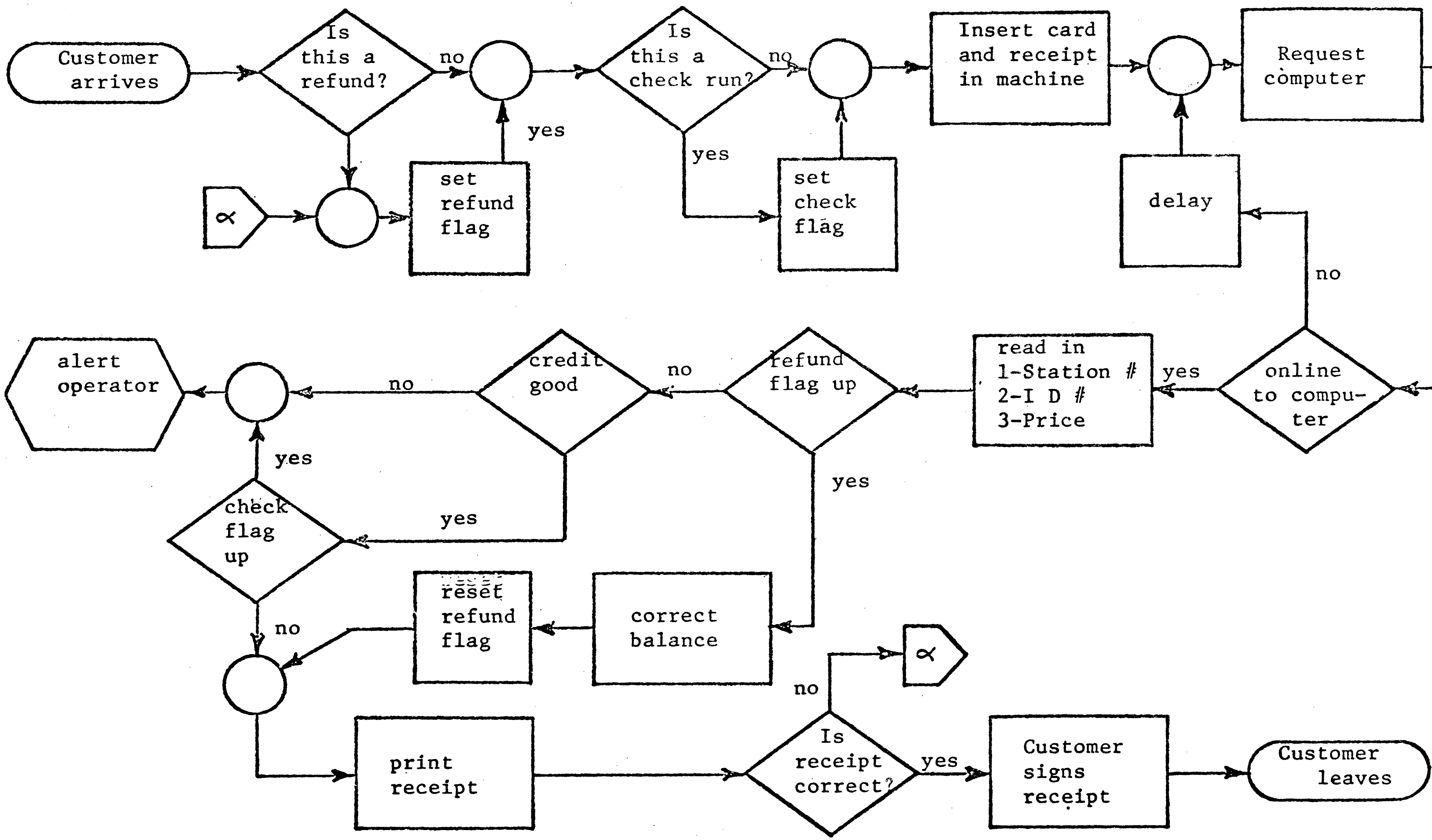


Figure 3.B

This chart points out that our device is more than just a credit checking terminal. We have also decided to include a price read-out feature which will allow the terminal to instantly update a company's central accounting files. Although this feature increases the technical complexity of the device as well as its cost, we found this option necessary if we hoped to attract a large market. Recall that in Chapter 1 we showed that regional and national chain stores lost most of their money to legitimate accounts which ran up large expenses far beyond the card holders willingness to pay. This problem could be minimized by an instant updating of central accounts. Losses due to stolen credit cards, while significant, were not as great a factor.

Another feature we felt essential to a well designed credit checking terminal was the ability to correct any mistake made while entering a purchase on the device. Hence, we have included the refund option. This is simply a switch which is normally off; but, when a mistake is made can be turned on. When the computer senses that the switch is on, it will add the price, rather than subtract the price, to the customer's account. A simple toggle switch would be prone to abuse; a key switch similar to a car's ignition switch seems to be a better solution.

Consider for a moment the branch in our flow network where we alert the operator when the credit is bad. It is likely this will be a seldom used (but essential!) route. Hence we are including a "check mode". When the operator wants to check his credit alarm system, he merely throws a switch to enter the check mode, then any card used when the check switch is set will trigger the alarm. Daily use of this option should insure the operator against continually accepting bad check cards because of a faulty terminal.

C. SUBSYSTEMS

With the flowchart of the terminal's operation to guide us, it is a rather simple matter to logically break the terminal into meaningful subsystems. The blocks of the flowchart that will require hardware implementation are:

1. Set credit flag
2. Set check flag
3. Call computer
4. Computer on line?
5. Delay
6. Read stations, ID number, and price
7. Is this refund? (i.e. sense refund flag)
8. Is this a check run? (i.e. sense check flag)
9. Credit good?
10. Print receipt
11. Signal operator (for bad credit)

Setting up and reading the refund flag, check flag, station number, ID number, and price are all input functions to the computer and could be grouped in one integrated "read-in" sub-device or subsystem. Reading the credit card poses such unique problems, however, it was decided to make it a sub-device itself. Thus, the input task will be performed by two devices: the card reader and the price reader.

Dialing the computer has been assigned to the automatic dialer sub-device.

Steps 4, 7, 8, and 9 above are decision blocks. The actual decisions are made in the computer and all the terminal needs to do is sense what the computer has decided. Hence, a subsystem evolved call the "signal receiver".

The functions of printing the receipt and signalling the operator were combined in the "read-out" subsystem.

Hence, we finally settled on the following break-down of the device:

1. Automatic dialer
2. Credit card reader
3. Price reader (includes other miscellaneous read-in functions)
4. Signal receiver
5. Printer (read-out)

D. SPECIFICATIONS FOR ELECTRONIC SUBSYSTEMS

AUTOMATIC DIALER: This is the first hardware device to perform when the terminal begins its sequence of operation. Basically, this subsystem has the task of linking our remote terminal to the correct computer via commercial telephone channels. Therefore, the automatic dialer must meet the following specifications:

1. Begin operation when the operator pushes the start button <u>and</u> when the dial tone is present on the telephone line.
2. Proceed, asynchronously of its environment, to close 2 out of 7 relay contacts that are parallel with similar contacts in the touch-tone matrix. These contacts were explained earlier in this chapter.
3. Contact closures should be for a minimum of 45 ms with 40 ms quiet time between closures.
4. The sequence of closures must represent the particular telephone number of the computer needed.
5. Provision should be made for easy altering of the phone number.
6. The devices task is complete when a 2025 HZ signal is sent over the phone lines to confirm that the terminal has in fact been linked to the computer.

The approaches to this problem and the design finally used are discussed in Chapter 4.

SIGNAL RECEIVER

This subsystem is intended to convert the audio answer-back signals from the computer into a sequence of contact closures to be used by other terminal devices as needed. The signal receiver must meet the following specifications:

1. Accept audio signals in the range of -6 dbm to -14 dbm.
2. Have an input impedance of 600 ohms.
3. Recognize 1785 HZ signals and close appropriate relay contacts when either or both of these frequencies are present.
4. Ignore the rather powerful touch-tone signals generated by the telephone.

Design details of this device are discussed at length in Chapter 9.

CARD READER

The card reader has two main design criterion: size and speed. The standard credit card allows a space of approximately one inch by three inches in which to place an identifying number. The card reader must be able to read two out of a possible seven characters in a space one inch wide for each number, and also be able to read ten numbers in a space of three inches. Some means of sequencing the reader is necessary to insure that the numbers will be read in the proper order.

The speed of response is governed by the ability of the telephone equipment to transmit signals. As discussed before, the pulse width must be 45 milliseconds with a quiet time of 40 milliseconds between pulses. This limits the speed of response of the reader to a maximum of ten numbers per second.

In addition, the card reader must be more reliable than an operator reading the card and manually punching the number out on the touch tone matrix. The card reader must also be stable in spite of changes in temperature and operating conditions.

PRICE READER

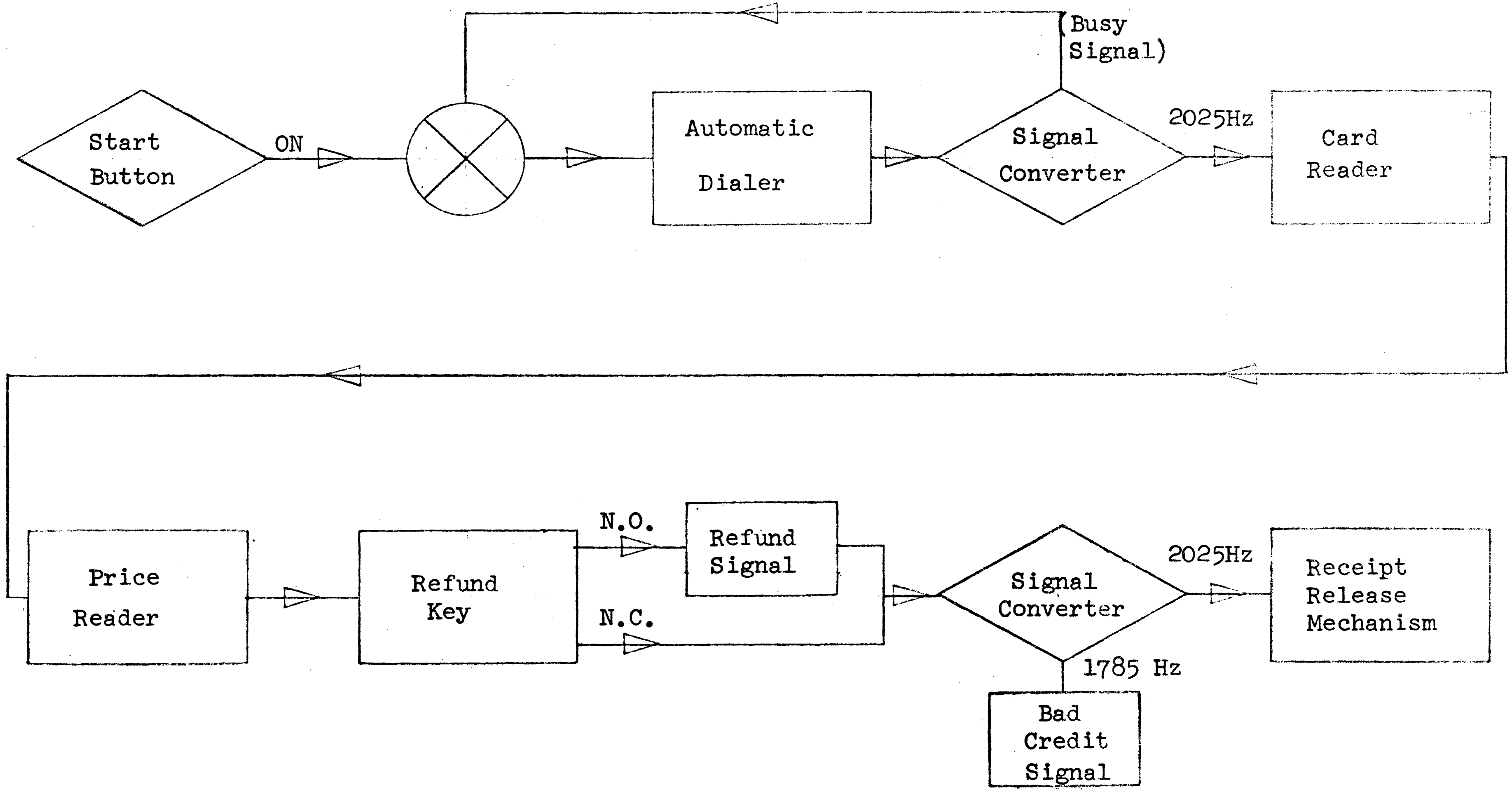
The price reader is subject to the same speed requirements as the card reader; that is, a maximum of ten numbers per second, as it must also be compatible with touch tone telephone equipment. The price reader is required to read only five numbers to give a readout corresponding to any sale up to $999.99. However, some means of sequencing the price reader is necessary to insure that the price is read into the computer in the required order.

PRINTER

Ideally the printer would embody the basic elements of the price reader to insure that the price read into the computer is the same as the price printed, and also to eliminate another separate subsystem. The reliability of having the two systems working together is an additional advantage.

The Addressograph (see Chapter 8) is a system which incorporates a printer with provisions for a price reader and a card reader. The modifications to the Addressograph are covered in Chapter 8 and will not be discussed here.

In addition to the above mentioned design criterion, in respect to all subsystems, it should be stressed that economy, ease of construction, ease of service and repair, and simplicity of construction are of the utmost importance in the design of any subsystem.



FLOWCHART OF THE HARDWARE INTEGRATION

CHAPTER 4

AUTOMATIC DIALING SYSTEM

A. Design Constraints

In addition to the specifications presented in the section "Credit Terminal Design Competition," the design of an automatic dialing device was constrined by (1) the requirement of compatibility with existing data transmission equipment and (2) the necessity of interfacing the device with the total remote terminal system. A partial list of design specifications was presented in Chapter 3, "System Design and Analysis." A complete list is outlined below:

1. The device must be compatible with existing telephone equipment, that is, compatible with either strowger step-by-step, crossbar, or ESS switching equipment.
2. Dialing is initiated only upon the fulfillment of two necessary conditions:
   a. Closure of an enabling "call computer" switch by the operator <u>and</u>
   b. The recognition of a dial tone on the telephone line.
3. The device must simultaneously close two out of seven relay contacts in parallel with similar contacts in the touch-tone matrix. This process must occur once for each digit in the computer link-up telephone number.
4. Contact closures should be for a minimum of 45 ms with a 40 ms minimum quiet time between closures. For a complete discussion of data transmission utilizing touch-tone frequencies, see Appendix B.
5. The dialing process must terminate upon recognition of a 2025 Hz signal confirming that the terminal has in fact been linked to the system computer.
6. Maintenance procedures, such as alteration of the link-up telephone number, must be accomplished with economy, convenience, and minimum down time.

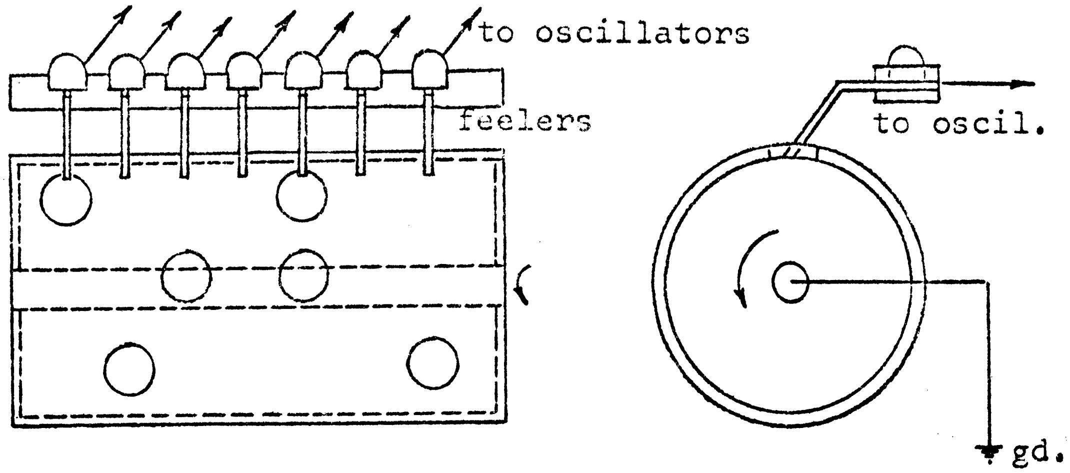


Figure 4-A-a; Mechanical
Touch-tone Dialer

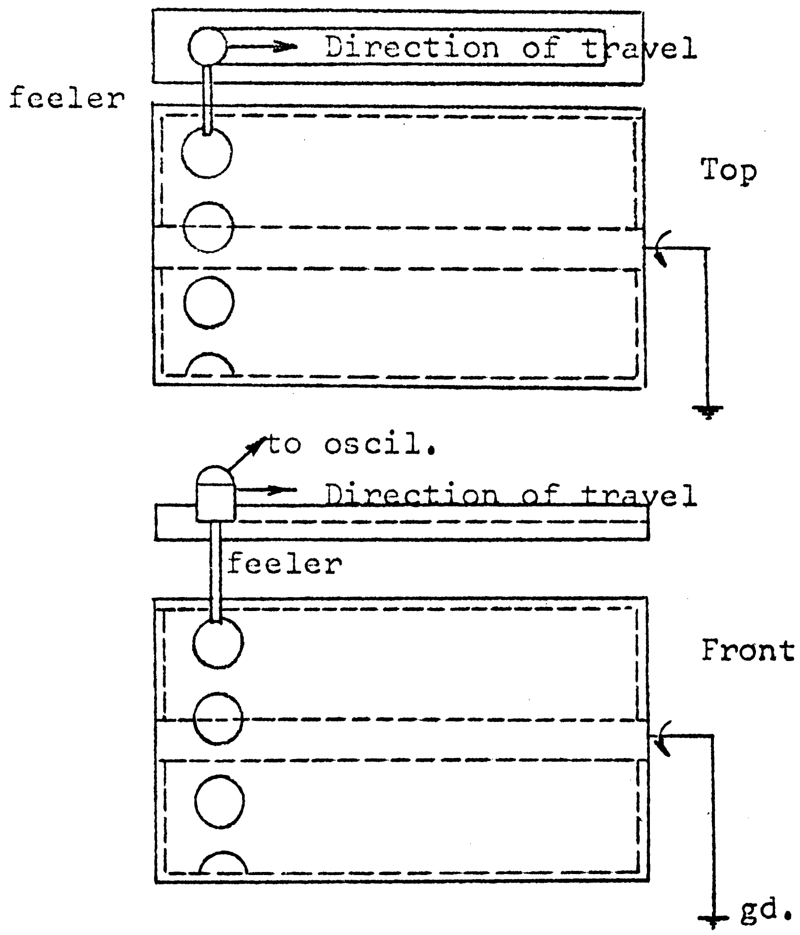


Figure 4-A-b; Mechanical Rotary
Dial Automatic Dialer.

7. Voltages available from the power supply are +24, +12, +6, and +4 volts ac or dc.

With these constraints in mind, an analysis of the automatic dialing function may be performed. This is done in the next section.

B. ANALYSIS

It is evident that the automatic dialing procedure is simply a sequencing or shift operation. Thus, any device which performs this sequencing function may be adapted for use as an automatic dialer. Stepping relays, shift registers, and binary counters are examples of such devices, the only requirement being that the mechanism successively activate the proper touch-tone oscillators for the proper time duration. The body of this report outlines the consideration, ultimate selection, and design of these alternate automatic dialing devices.

C. MECHANICAL AUTOMATIC DIALER

The first approach to the design problem was mechanical. Figure 4-A-a illustrates the mechanical touch-tone automatic dialer. Its operation is as follows: The body of the device is a conducting cylinder constrained with a removable, non-conducting jacket. Seven mechanical fingers are positioned above the cylinder such that, as the cylinder and its jacket revolve, the feelers pass over holes positioned in the plastic jacket, as shown. In this manner, as the cylinder revolved, contact closure is successively accomplished for two of the seven oscillators of the touch tone matrix. One complete revolution corresponds to sequencing the entire computer link-up telephone number.

An adaption of this device to the requirements of rotary dial--rather than touch tone-dialing is shown in Figure 4-A-b. Here, after the proper number of connect-disconnect operations for a single telephone number digit, the feeler is positioned to the right to read the next digit. Thus it is obvious that more than one revolution is required for rotary dial operation.

Figure 4-A; Multivibrater with
Diode Steering.

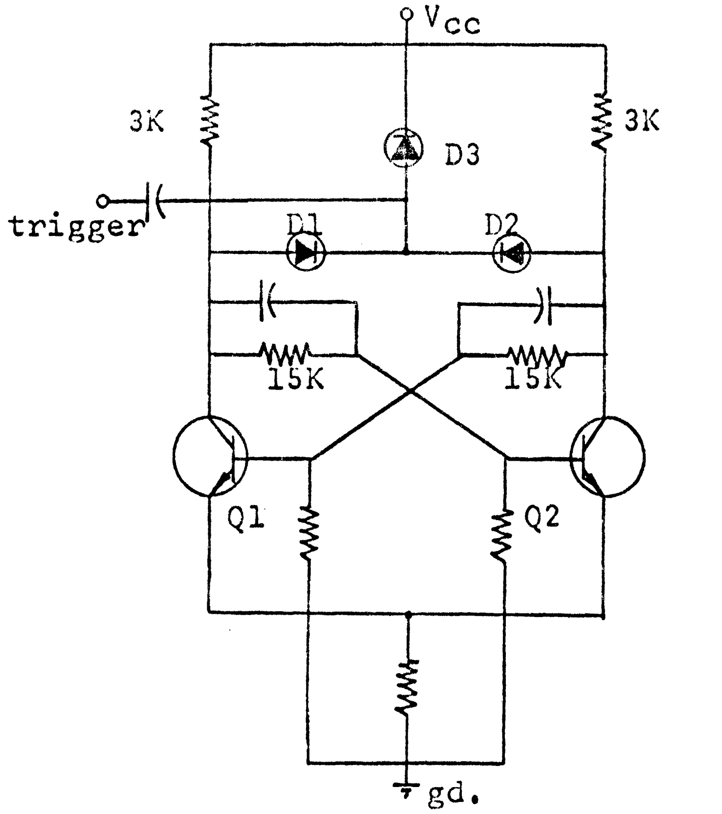


Figure 4-B-a; Collector Diode
Steering

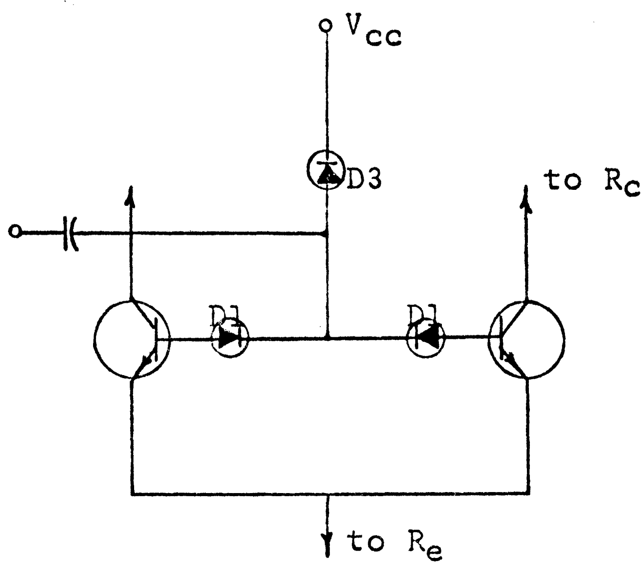
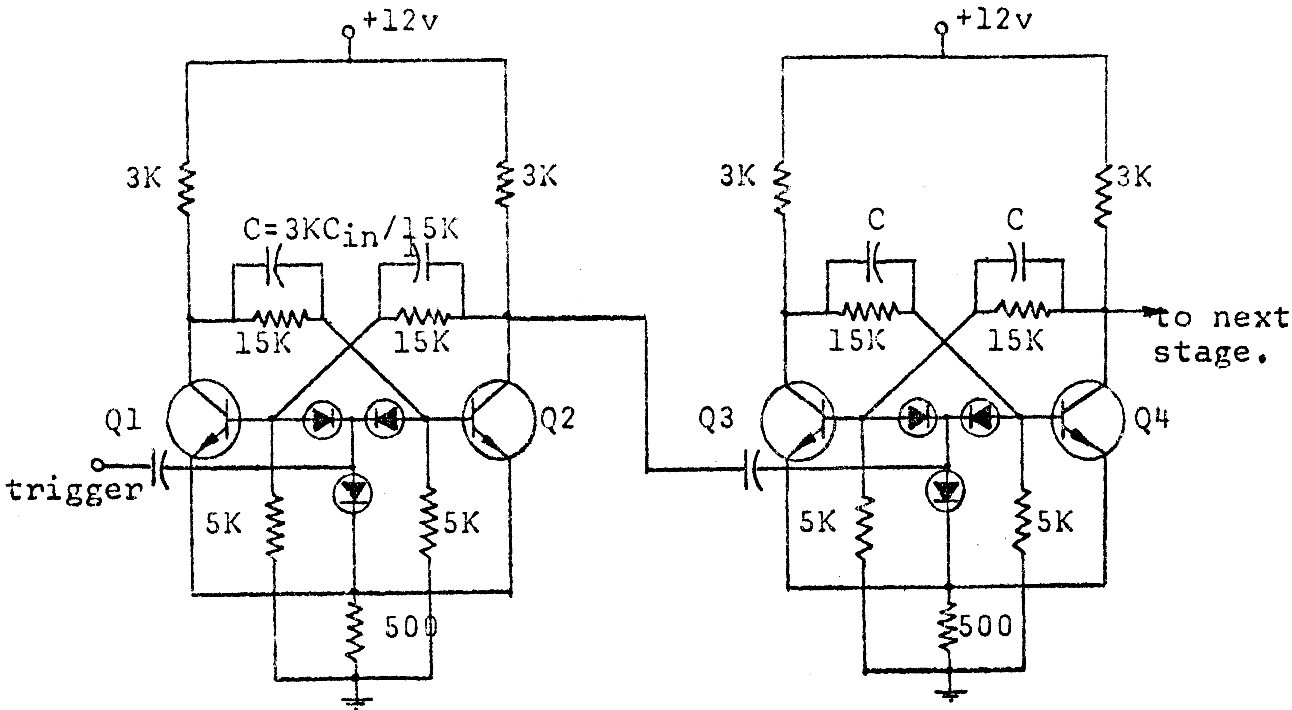
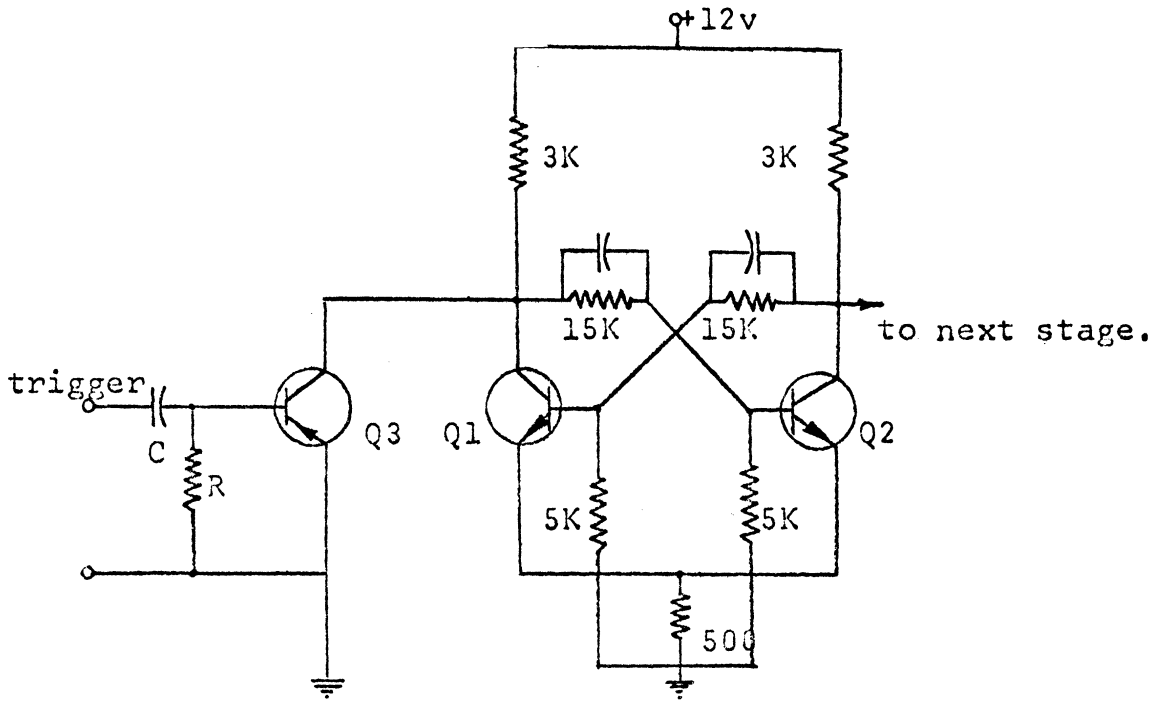


Figure 4-B-b; Base Diode
Steering

Figure 4-C; Discrete Component Binaries



a) Diode Steering



b) Trigger Amplifier

The removable jacket would permit easy servicing. However, although the cost of the mechanical automatic dialer would be moderate, the inherent lack of relibility of mechanical operations excluded this design from further consideration.

D. DISCRETE COMPONENT AUTOMATIC DIALER

A chain of bistable multivibrators or flip-flops will also provide the necessary sequencing operation. For a complete discussion of biasing multivibrators see Pulse, Digital, and Switching Waveforms by Millman and Taub. Since only a positive voltage supply was available, a self-biased transistory flip flop was required.

Difficult was encountered not in biasing but in symetrically triggering the flip flops. Figure 4-B illustrates the use of steering diode to obtain symmetrical triggering. Assume Q2 to be conducting. The voltage drop (V_{cc}) across the collector resistor of Q2 reverse-biases D2. Since there is no voltage drop across the collector resistor of Q1, D1 is at zero bias. Thus, a negative (relative) trigger signal will be transmitted to the collector of Q1, and thence (to the input of Q2) through the RC combination connecting the collector of Q1 to the base of Q2. A transition in Q2 from on to off results, reversing the diode biasing.

The sensitivity of the circuit to the input signal can be increased by a factor of beta through triggering at the input of the transistors, as in 4-B-b. Alternately, a trigger amplifier (as in Figure 4-C) may be used.

The final circuit configurations for the bistable-multivibrator portion of the discrete component automatic dialer is shown in Fig. 4-C. It was found that the choice of the commutating capacitors, C, was most important. In general,

$$C = \frac{(R_C)(C_{in})}{R_b}$$

where C_{in} is the input capacitance of the transistors.

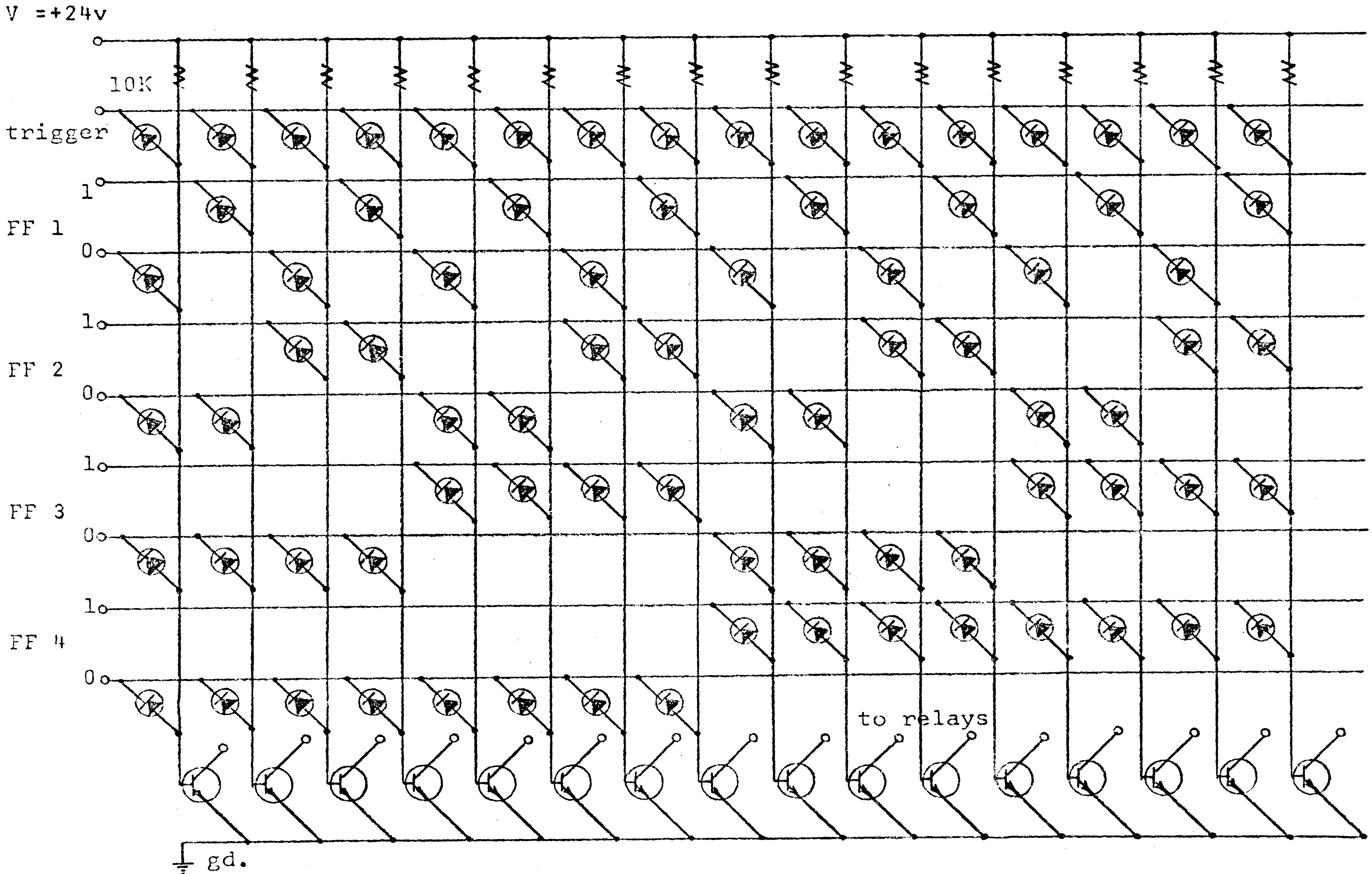
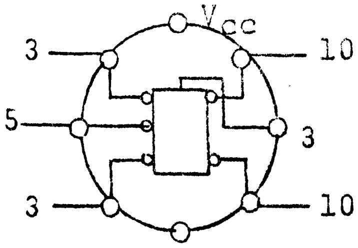


Figure 4-D; Diode-transistor matrix.

Figure 4-E; Fairchild Semiconductors



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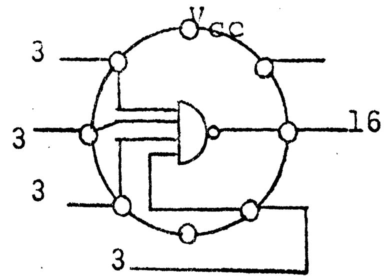

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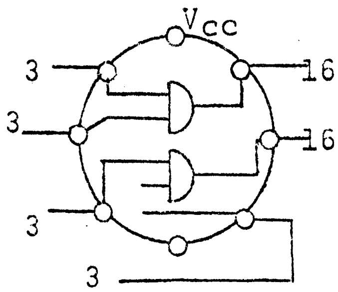

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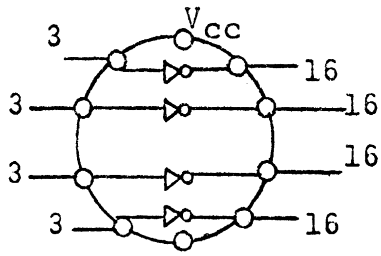

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Decoding of the multi-cascade into discrete sequential outputs is accomplished with the diode matrix or code-operated switch of Figure 4-D. If the inputs are controlled by four flip-flops with 0 and 1 levels of either 0 or +12v, the transistor inputs are triggered if and only if all the cathodes of the diodes are biased to +12v. Thus it is clear that the rectangular diode matrix is simply a diode and gate. The upper input, which follows the square wave trigger signal, ensures that the transistor outputs remain off for one half cycle. The outputs of the transistors touch tone cause contact closure in two oscillator relays each. Hence, the complete device operates as a discrete component dialing device with 16 possible outputs.

The materials cost for the bistable multivibrators is low. However, the code-operated switch requires 48 diodes at approximately 30¢ each. Numerous solder connections and large circuit boards are required. In addition, barameter or parameter variation is likely.

E. INTEGRATED CIRCUIT AUTOMATIC DIALER

The three disadvantages mentioned above, namely, (1) high materials and manufacturing cost, (2) space consumption, and (3) parameter variation can be minimized through the use of integrated circuits.

Figure 4-E represents a portion of the Fairchild medium power RT Micrologic integrated circuit family for a TO-5 pin configuration. All input load and output drive factors have been normalized using as a basis the current required to turn on a low-power gate transistor. Thus the number of elements that may be driven by an output terminal may consist of any number of parallel low and medium power elements as long as the sum of all the input factors does not exceed the output drive factor of the driving element. Hence, it is evident that one may obtain maximum integrate circuit utilization (and the fewest elements) through mixing compatible logic families.

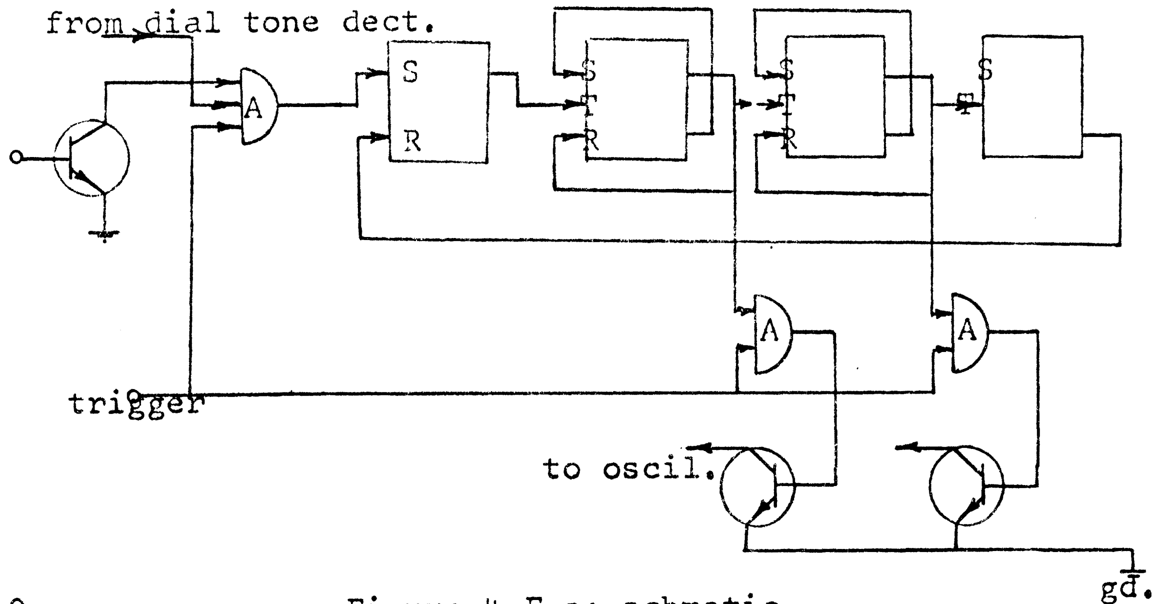


Figure 4-F-a; schmatic.

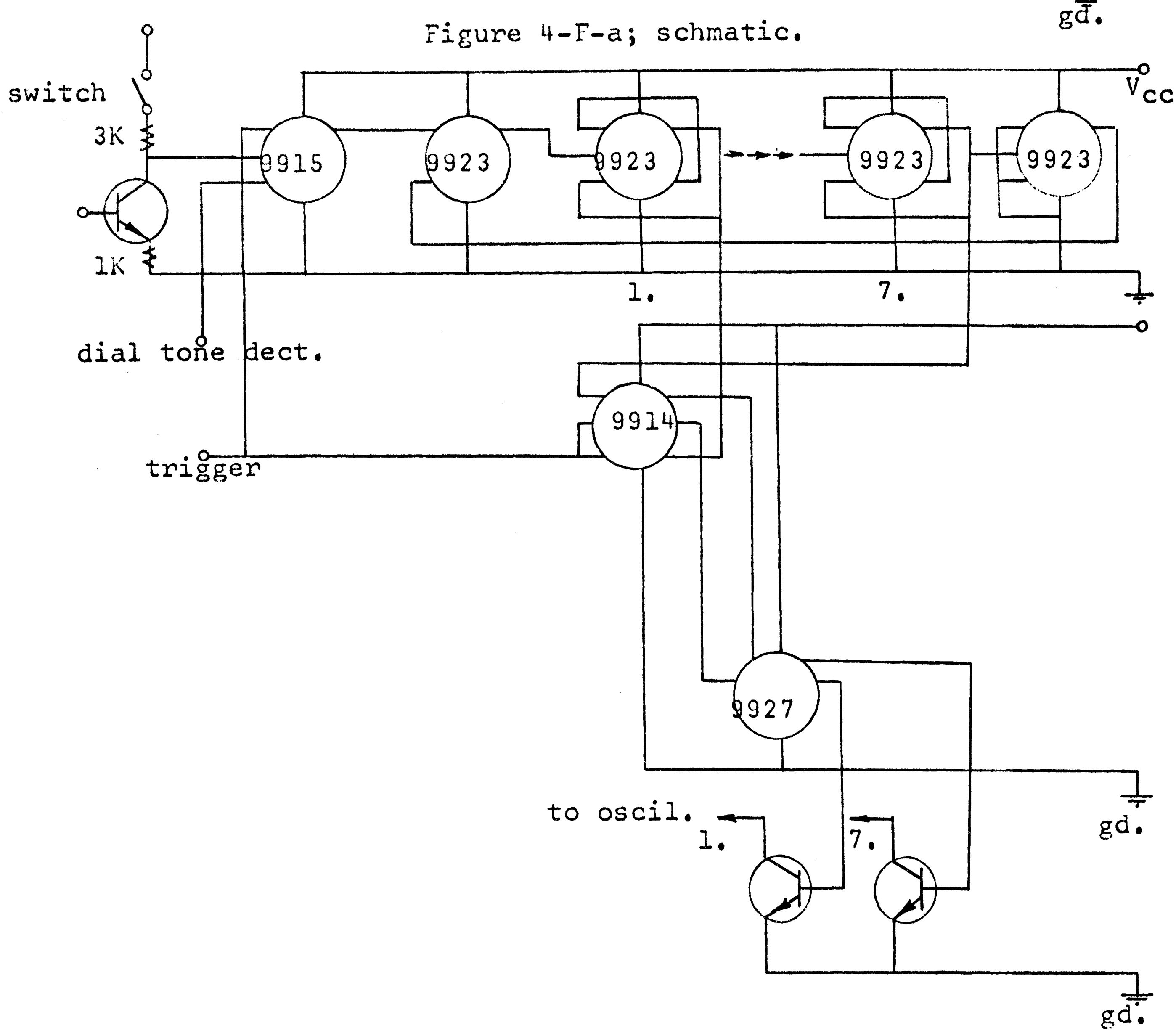
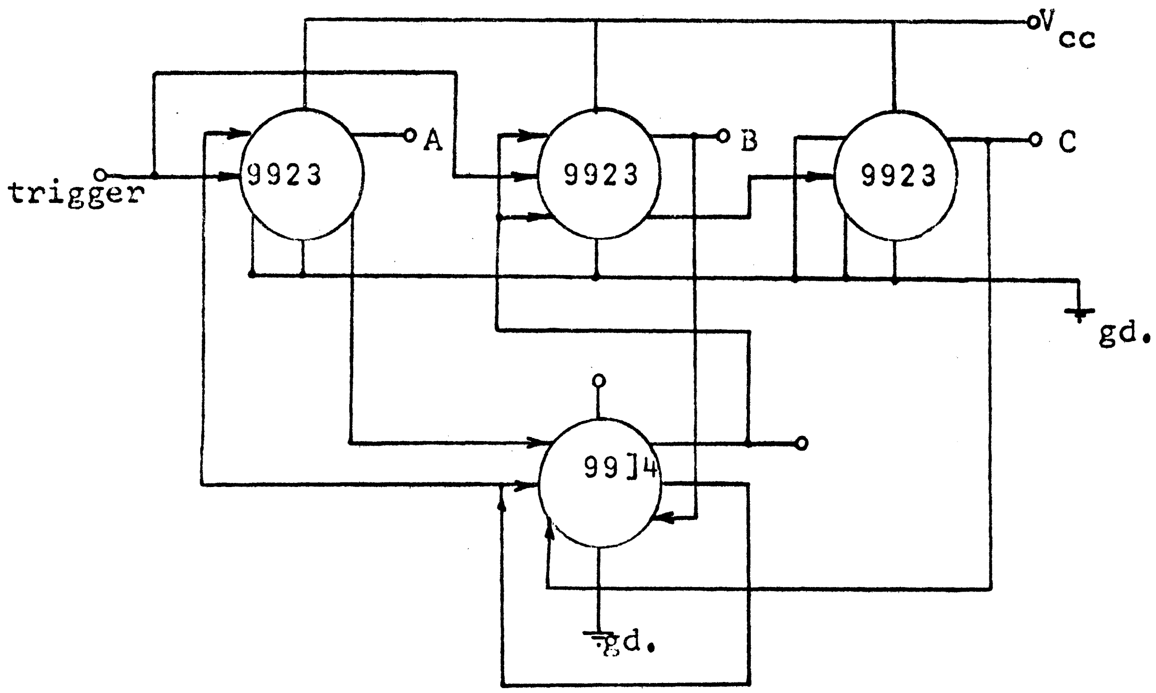


Figure 4-F-b; Integrated Circuit Automatic Dialer.

Figure 4-G; Mod 7 Counter.



	A	B	C
0	0	0	0
1	0	0	0
2	1	1	0
3	0	1	0
4	1	0	1
5	0	0	1
6	1	1	1

Figure 4-F-a and 4-F-b indicate the final automatic dialing device design. Figure 4-F-a illustrates the operation with standard logic elements. The sequencing portion is a ripple carrier counter. Each stage has its outputs cross-connected to its inputs. In the ripple-carrier, an input causes the least significant stage (in a 1 state) to change to 0, which in turn cause the next stage to change to 0, and so on until the "ripple" terminates at a stage which changes from 0 to 1. The count is initiated only when (1) the enabling switch, represented the transistor, is closed and (2) dial tone is recognized and (3) the triggering pulse is "up". The flip-flop outputs are ANDed with the trigger signal to ensure a quiet time. The outputs of the transistor switches activate the proper touch-tone oscillators.

The proper wiring diagram utilizing Farichild elements is shown as Figure 4-F-b.

G. POTENTIAL APPLICATIONS

Integrated circuit shift registers and binary counters are normally used when high counting rates are encountered. This design problem is unique in that the counting rate is very low (approximately 10 Hz) and the count total low (seven). Thus the advantages of the 1C approach can be more fully exploited if (1) rapid data transmission is required or (2) if it is desired to transmit additional information from the remote terminal. As previously mentioned, the automatic dialer operation is basically a sequencing operation, and thus, if necessary, a device could be adapted to transmit price, inventory, station, or any other information. With higher counting rates or increased total count, the ripple technique creates race problems and conventional BC counters with gating must be used. A mod seven counter with inhibiting is shown in Figure 4-G. For more complete information, see manufactures application notes.

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1. Angelo, Electronic Circuits, McGraw Hill, 1964

2. Fairchild Application Brief, RT Micrologic Family.

3. Military Standardization Handbook, Selected Semiconductor Circuits, Mil-HDBK-215, U. S. Government Printing Office, 1960.

4. Millman and Taub, Pulse, Digital, and Switching Waveforms, McGraw-Hill, 1965.

CHAPTER 5

MECHANICAL CARD READER

INTRODUCTION

The information on a credit card must be transferred by some device to the computer. Some of these devices are: a mechanical card reader, a capacitor card reader, a magnetic card reader, and a photo-cell card reader. This chapter will be concerned with the mechanical card reader.

The primary restriction on any card reader for this system is that the minimum signal duration and interdigital time cannot be less than 40 ms. The Touch-Tone signalling system accepts 50 ms signal duration and interdigital time which implys 10 digits per sec. maximum dialing rate.

A. APPROACH TO PROBLEM

There are various types of mechanical card readers that could be used for this system but the simplest and most economical one is one that has direct contacts in parallel with the push-button contacts in the telephone. Therefore this implys that the card reader will use a 2/7 coding scheme.

Since the card reader will use a 2/7 coding scheme the credit card will have a 7 by 10 (10 digits required for credit card number) matrix on it, with two holes per column. When two of the seven sensors drop in the two holes per column two contacts will be closed corresponding to one digit.

B. DESIGN OF THE CARD READER

One of the major drawbacks in building the mechanical card reader was that it had to be built to fit in the addressograph which was purchased for the system. Another important problem encountered in the design was that the sensor contacts had to remain in the open position when the reader head was ahead of the credit card or behind it. (The credit card would be stationary while a head with a roller for printing a receipt and with the mechanical reader in it would move across the card).

An International Business Machine program assembly unit was purchased as a part of the mechanical reader. This assembly unit consisted of seven partial sensors (extensions had to be added due to mounting difficulties), fourteen spring contacts (two per sensor), and seven screw contacts. All of the spring contacts will be electrically grounded and each screw will have a wire going to the corresponding switch of the Touch-Tone matrix.

The program assembly unit was mounted to the already existing roll across head of the addressograph. Because this unit had to be mounted approximately three inches above the plane in which the credit card layed, extensions were added to each of the seven sensors (see Figure 5-A). These extensions caused a large variation in the movement of the sensors perpendicular to the corresponding rows of the matrix of the credit card. Therefore a guide plate was added to the reader design so that the sensors would follow the correct rows (see Figure 5-B).

To determine the different operating planes, or levels, needed for the sensors a rectangular piece of metal was used along with a solenoid, a switch, and a rail. One of the lengths of this "plane operating section" was allowed to pivot about a fixed line of action while the other length moved all of the sensors into the same operating plane at the same time (see Figures 5-C, 5-E, 5-F). The motion of this "plane operating section" was controlled by a solenoid and a roller lever switch. The roller level rides on a rail. This rail has a section cut out of it the length of the credit card. The switch is operated in the normally open state, and therefore, will close when it moves across the rail where the section was cut out. This action will cause the solenoid to be activated thereby dropping all the sensors to the operating plane, or level, of the credit card and allowing the sensors to drop in the holes of the credit card.

The solenoid and switch are rigidly attached to the already existing moveable head of the addressograph and the rail is rigidly attached to the body of the addressograph (see Figures 5-D and 5-F.

C. OPERATION AND DESCRIPTION OF CARD READER SUBSYSTEM

By mechanically reading the credit card, tones are translated into multifrequency signals. The frequencies of these tones are determined by the closure of two switches in the three by four multifrequency signalling matrix. This corresponds to the two holes per column in the credit card where each column represents one digit.

The digit-frequency relationship on the manual dial can be considered in terms of horizontal rows and vertical columns: four frequencies are associated with the rows and three frequencies with the columns. The column frequencies are all in one group, while the row frequencies are in another (see figure 5-F). Operating a button, which is equivalent to each of two operating sensors in one column on the credit card making contact, transmits a signal made up of the frequencies corresponding to the row and the column which intersect.

The Touch-Tone multi-frequency signal generated is a one-transistor oscillator generating two frequencies any time a signal pushbutton is operated or a single digit is "read" from the credit card. Seven frequencies are provided, with each digit corresponding to two frequencies according to the table below:

TABLE 5-1

TOUCH - TONE

Frequencies cps	1209	1336	1477	
697	1	2	3	
770	4	5	6	Dial
851	7	8	9	Digits
941		0		

When the credit card is "read", mechanical sensors fall into the holes in each of the ten columns sequentially, and close coil tap contacts to select the proper signal frequencies for each digit.

Since the button-operated contacts are normally open, the contacts are normally open, the contacts operated by the card sensors can be connected in parallel with the corresponding button contacts. In addition to selecting frequencies, every contact closure operates a common switch which disconnects the handset transmitter to guard against voice simulated dialing errors and connects the Touch-Tone calling circuit into the telephone set network.

The credit card when placed on the addressograph will remain in one position. When given a signal the carriage containing the ink roller for printing the receipt, and the mechanical card reader, will move across the credit card. The credit card will have two holes per column and the mechanical sensors will sense these holes and thereby close two switches which is equivalent to pushing one button on the telephone. The signal will then be transmitted to the computer.

In this prototype the mechanical reader reads the information off just the credit card but it should be noted that by extending the longitudinal distance of the addressograph there would be additional room for the computer telephone number and the terminal identification number. This method would eliminate the need for the automatic dialer and, therefore, reduce the cost of the system.

The mechanical card reader of this prototype has undesirable mechanical variations that could make the reader unrealiable. The fault of these mechanical variations is due to the inaccuracy of the machined parts and could result in erroneous readings. However, these mechanical variations would be eliminated through accurate machining when the terminal is mass produced and thereby result in a much greater realiability.

D. COST ANALYSIS

The major parts of this mechanical reader are the program assembly unit, the solenoid, and the switch. The prices for one unit for these parts are:

program assembly unit $20.00

solenoid and switch $ 6.00

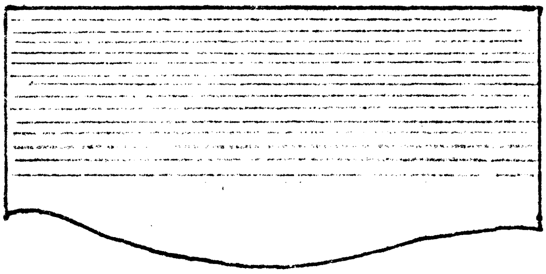
Buying these parts in quantities of one thousand, the prices would be:

program assembly unit $15.00

solenoid and switch $ 4.80

Therefore, the total cost of the mechanical reader is approximately $20.00

FREQ.	DIGITS
697	1 2 3
770	4 5 6
851	7 8 9
941	0
1209	1 4 7
1336	2 5 8 0
1477	3 6 9



CREDIT CARD

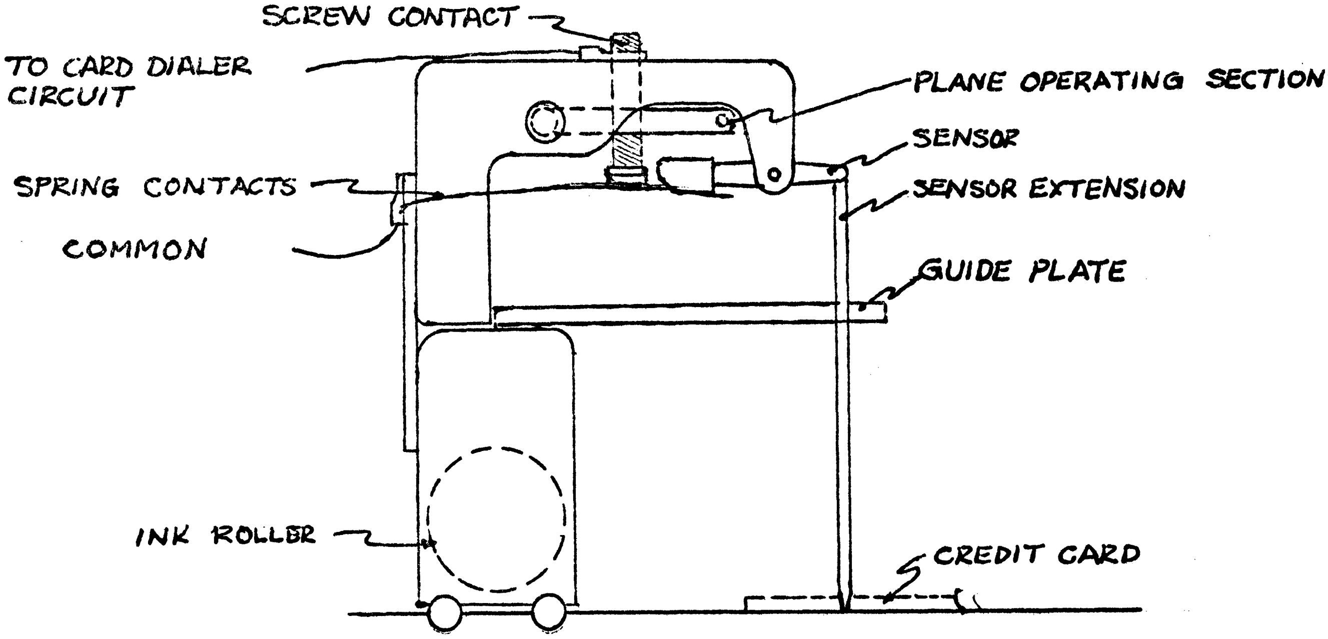


FIGURE 5.A - MECHANICAL CARD READER (SIDE VIEW)

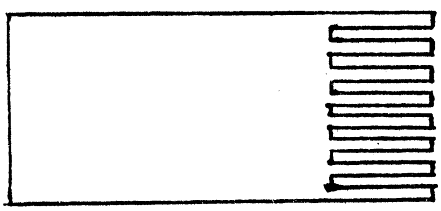


FIGURE 5.B - GUIDE PLATE (TOP VIEW)

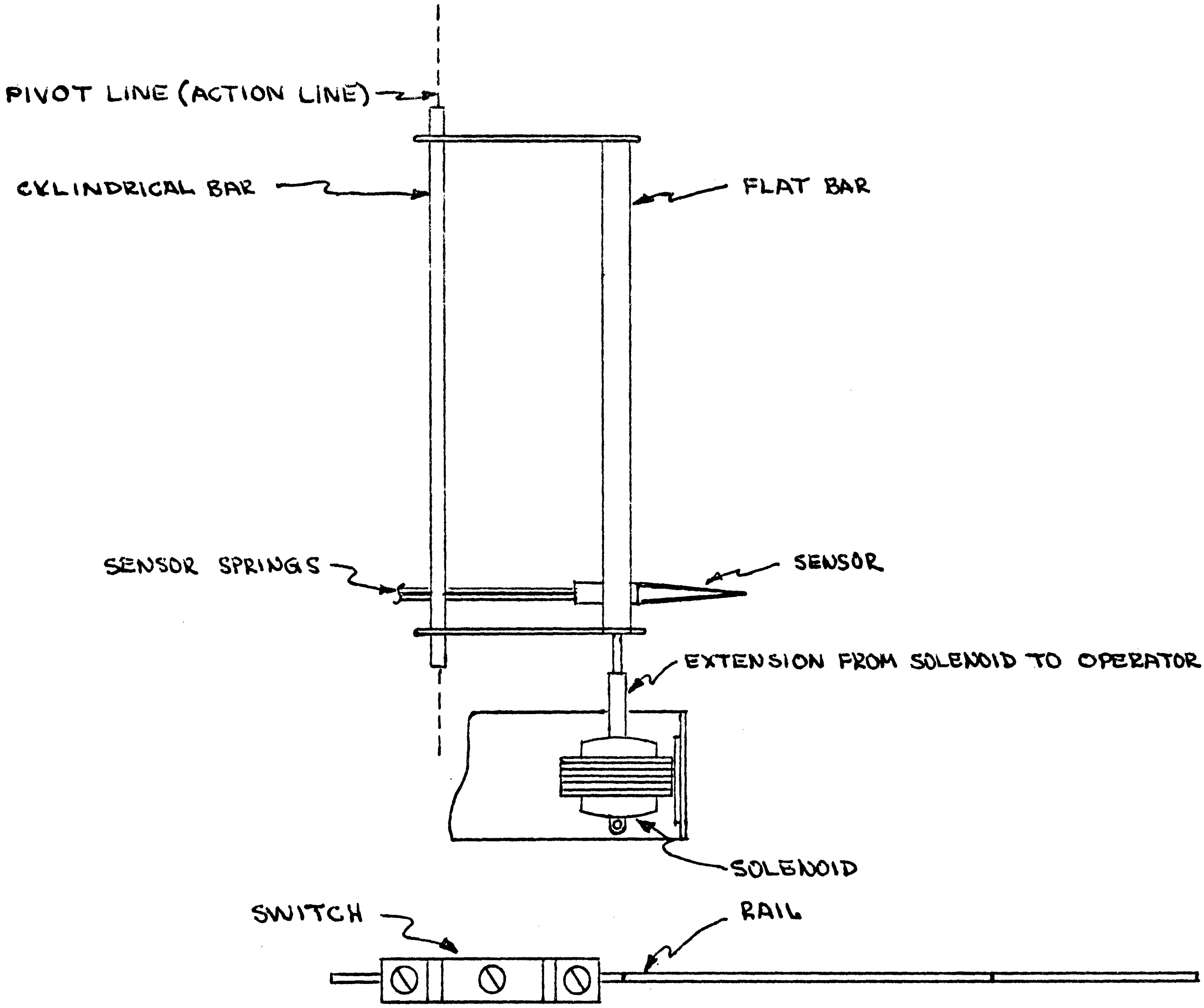


FIGURE 5.C - PLANE OPERATING SECTION (TOP VIEW)

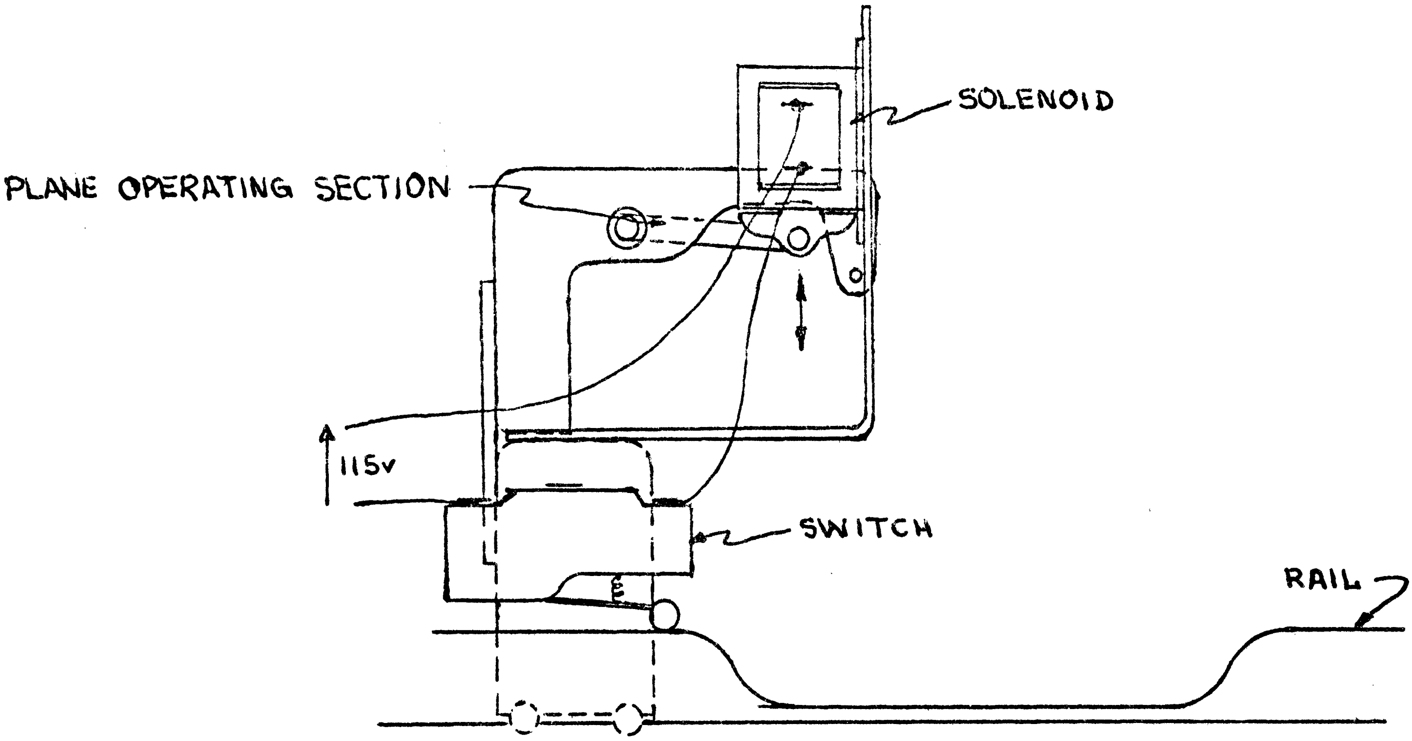


FIGURE 5.D - CONTROL CIRCUIT FOR OPERATING PLANE

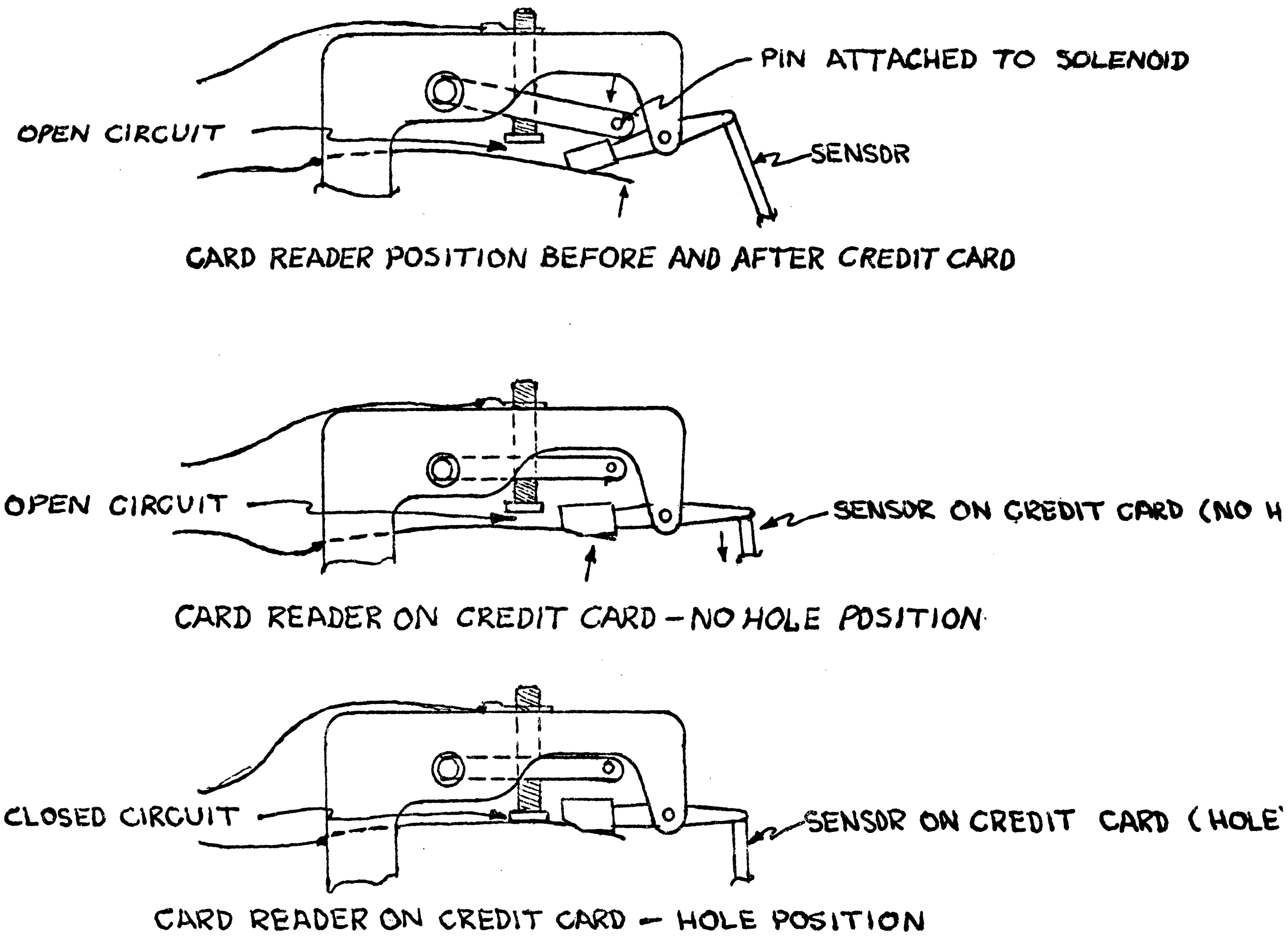


FIGURE 5.E

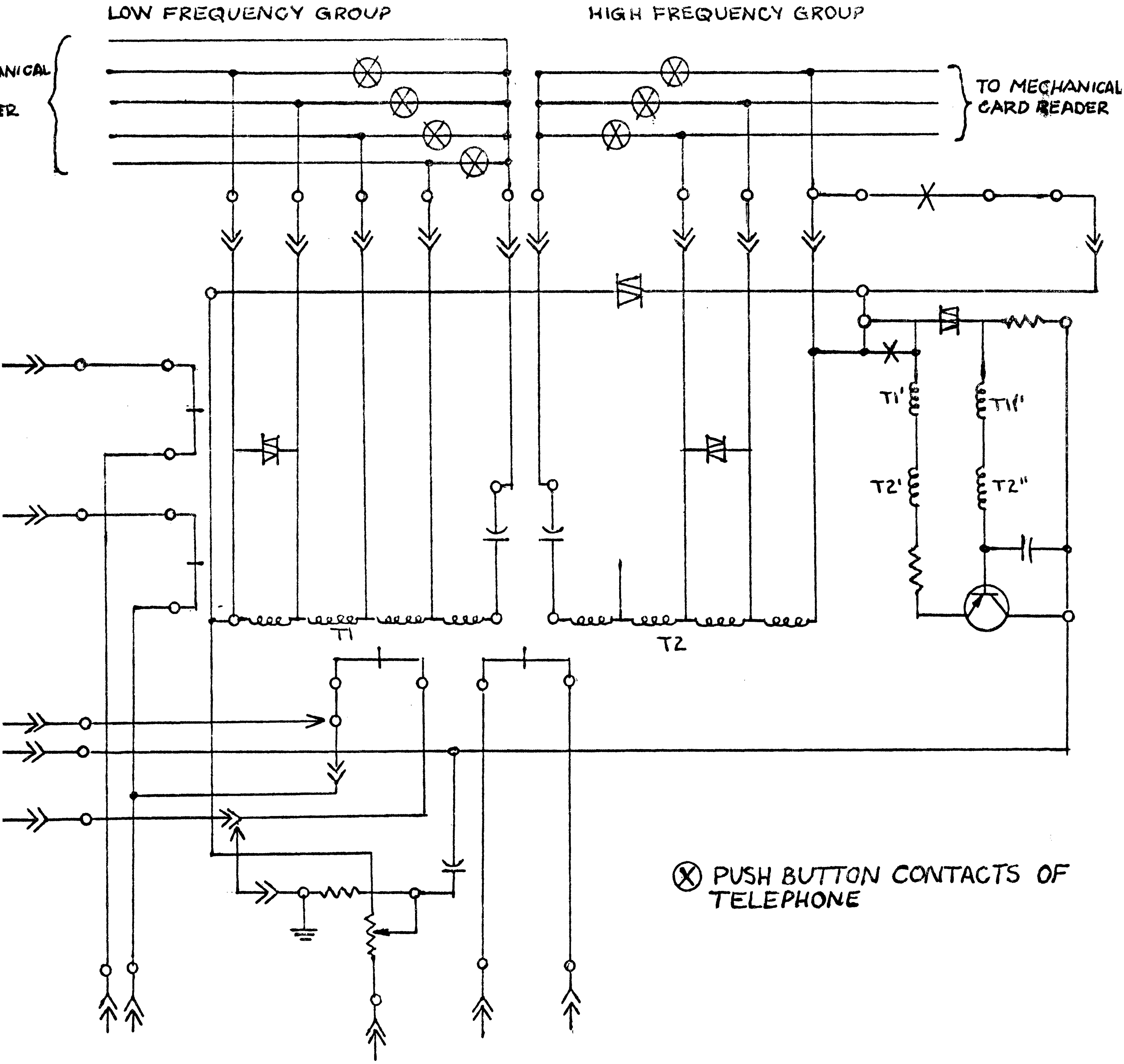


FIGURE 5.F - CARD DIALER CIRCUIT

CHAPTER 6

THE PHOTOCELL CARD READER

A. INTRODUCTION

A card reader utilizing a photocell was proposed as a simple but reliable means of determining an account number. A standard credit card allows a space approximately one inch by three inches in which to place an identifying number. Since holes may be punched easily in the card, holes were the most logical means of placing a number on the card. Since the card is to be compatible with touch tone phones which use a tone composed of two frequencies out of a possible seven frequencies, a system of seven photocells is used to trigger a tone of two frequencies which will correspond to a number from one to ten. This design allows the use of fewer photocells and other components, giving an increase in savings in addition to the increased reliability usually achieved by the use of fewer parts. A photocell is capable of giving large changes in resistance over a short interval and seemed capable of fulfilling the design criterion.

B. DESIGN

The initial design consisted of a photocell, a resistor, and a relay (see fig. 6-A). This design works well for one set of components, but there is a problem in aligning the photocell. The circuit is very sensative to small changes in light, but if the photocell is directed toward the light, the change in resistance is not enough to trigger the relay at the required rate. There is also the problem of changes in resistance due to tolerances and temperature. The circuit has to be biased close to the activation current of the relay and any small change in resistance can cause the circuit to malfunction. A one percent resistor is a solution to the problem, but the additional cost is more than the cost of a transistor which could be used as a switch.

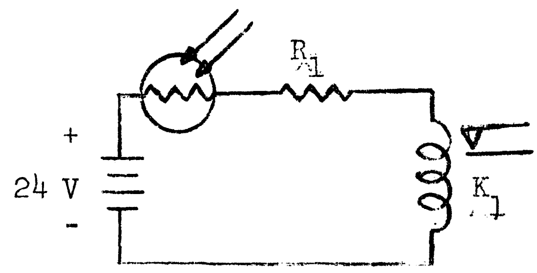


Fig. 6-A

The addition of a transistor led to the second design (see fig. 6-B). Better switching characteristics are obtained by biasing the transistor near the saturation region and letting the changing photocell resistance drive the transistor into saturation allowing relay K_1 to operate. Since the transistor switched in a narrow voltage region, it can be biased well into the cut-off region at dark conditions and well into the saturation region at light conditions. Because the photocell undergoes a large change in resistance between light and dark conditions, positive operation is assured despite the fact that the transistor is biased well into the cut-off and saturation regions. Since the transistor is biased in this way, the circuit is not affected by small changes in resistance due to tolerancing or temperature; this allows the use of low tolerance, inexpensive components.

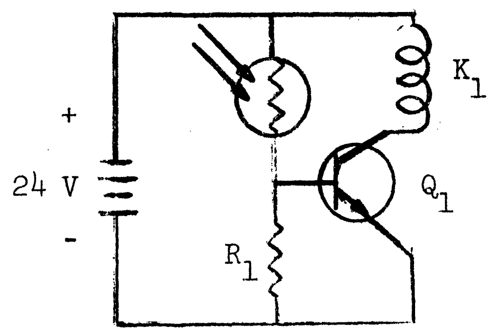


Fig. 6-B

The only problem which arises with this circuit is one in which the bias point of the circuit will drift with drifting power supply voltage. If the power supply is regulated in some manner, this problem will be solved.

Resistor R_1 governs the bias point of the transistor and also affect the speed of response of the circuit. The time constant of a switching transistor is determined by the ratio of Collector current to Base current. Varying R_1 varies the Base current and after extensive testing, 330 ohms was chosen for R_1. Changing R_1 produced either a turned-on state or a state of slow response. Since 330 ohms is a standard value and biasing the transistor any nearer saturation would endanger the reliability of the circuit, 330 ohms is used.

The transistor had to be able to switch rapidly but did not have to carry any great load. A high frequency audio transistor was chosen to give the required switching rates. The power level of the circuit is low and the transistor is subject to only momentary loads so an audio transistor is permissable. The transistor chosen for its small size, low price, and acceptable power level is a 2N3854A.

The photocell has to be small and inexpensive and capable of handling 24 volts. The size is the most critical requirement as the read head had to have seven photocells in a line within a one inch space. Initially a Texas Instruments Photo Device (type LS 400) was tried because of its small size, the results showed that the circuit was feasible, but additional elements would have to be added to gain satisfactory performance. At best, the circuit would not stand up to slight variations in resistance or light. Because of this lack of reliability, and the $10.00 price, the LS 400 was dropped from consideration.

The photocell used is an RCA SQ 2535. It is small in size and its resistance changes by a factor of 300 but it changes very rapidly. Despite its small size, it is necessary to enclose the photocells in a holder to be able to read seven characters in the space of one inch.

A Bakelite block was specified to hold the photocells (see fig. 6-C). By staggering the photocells at the top of the block and then drilling angled holes to the center line of the bottom of the block, both the proper spacing to read the card and the elimination of stray light is accomplished.

As the system goes into full production, it will be possible to have the block molded instead of drilled to save time and expense. It may also be possible to have the photoelements enclosed in a case which will eliminate the need for any further mounting blocks.

C. CONCLUSION-

As the circuit is designed, a response rate of twenty pulses per second is possible; this is twice the maximum usable rate and allows for a high degree of reliability.

The photocell card reader has proved to be a simple solution to the problem of identification of a credit card number. Despite the low cost of the unit, the design assures a high degree of reliability by the use of a method of operation which is independent of small changes in the circuit component values or the operating conditions.

PHOTOCELL HOLDER
SCALE: 2:1
MATERIEL: BAKELITE

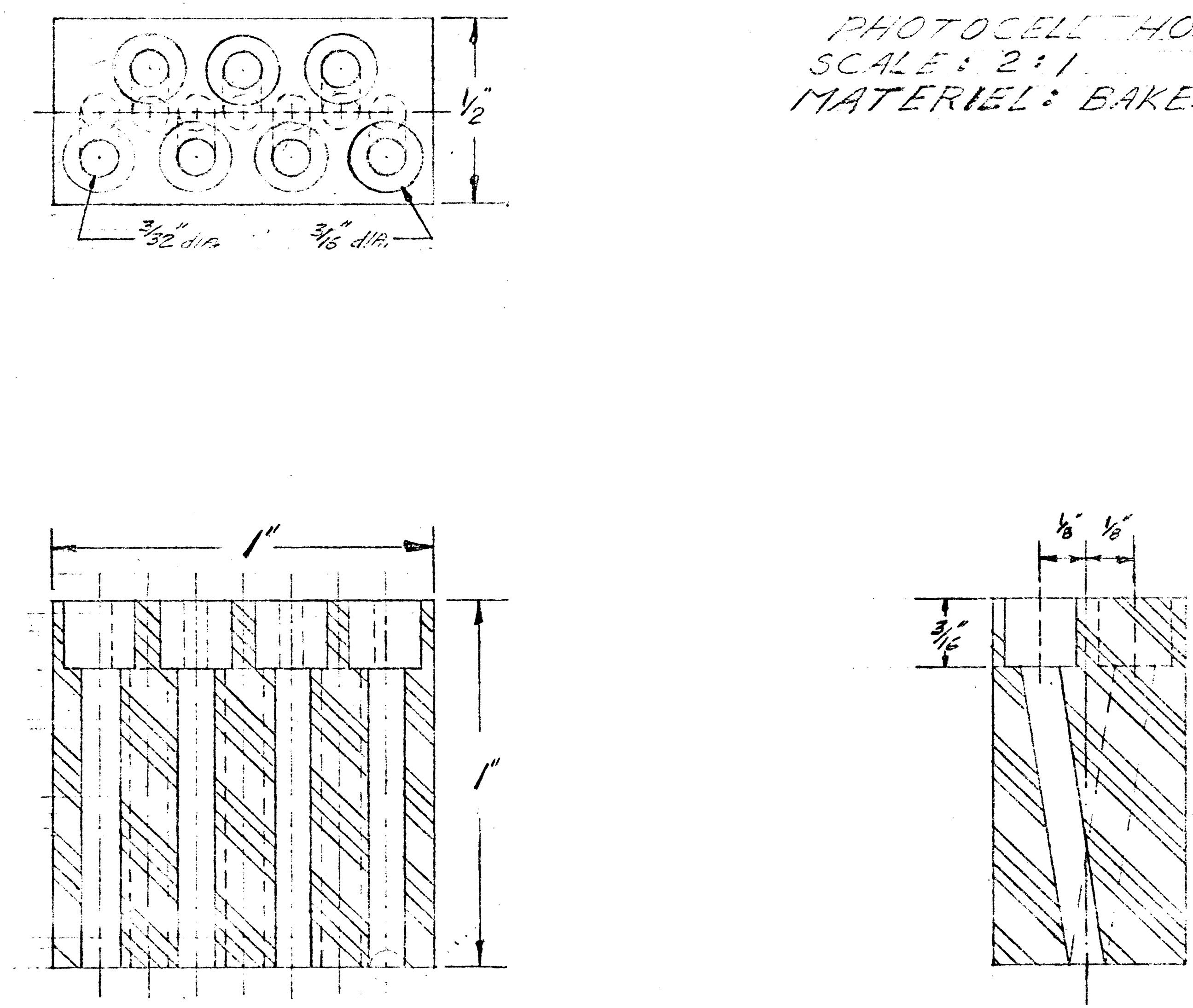


FIG. 6-C

CHAPTER 7

CAPACITIVE CARD READER

A. INTRODUCTION

The purpose of the capacitive card reader is the same as the other readers, to transfer information from a card into electric signals which can be used to trigger the touch tone oscillators. It accomplishes this from a different approach, for this reader is completely electrical in design, the only moving parts being relay contacts and electrons. The principal involved is really quite simple. The information on the customers credit card is contained in a pattern of holes arranged in seven rows and ten columns. The card forms the dielectric for seventy parallel plate capacitors which are likewise arranged in a 7 x 10 matrix. The dielectric varies depending on whether there is a hole or plastic between the small plates. The difference in dielectric causes a corresponding difference in capacitance which can be electrically sensed in a simple RC circuit. The features of the reading circuitry as well as the other subsystems will be described in detail later in the chapter. First I shall present a general outline of the entire system. This description will be clearer to the reader if he occassionally refers to Fig. 7-A.

The brain of the capacitive card reader is the switching subsystem. Its purpose is control. It sequences the action of the capacitive card reader by means of a stepping relay. When the relay is triggered it advances to the next switch position thereby changing the circuitry of the reader and effecting control. The capacitive card reader begins operation after the computer has been contacted. When the computer is on line, it sends back a signal which resets the stepping relay to the start position. This requires dialing the computer each time a credit check or credit account is performed and prevents the possibility of charging the person twice for one purchase. The reset circuitry

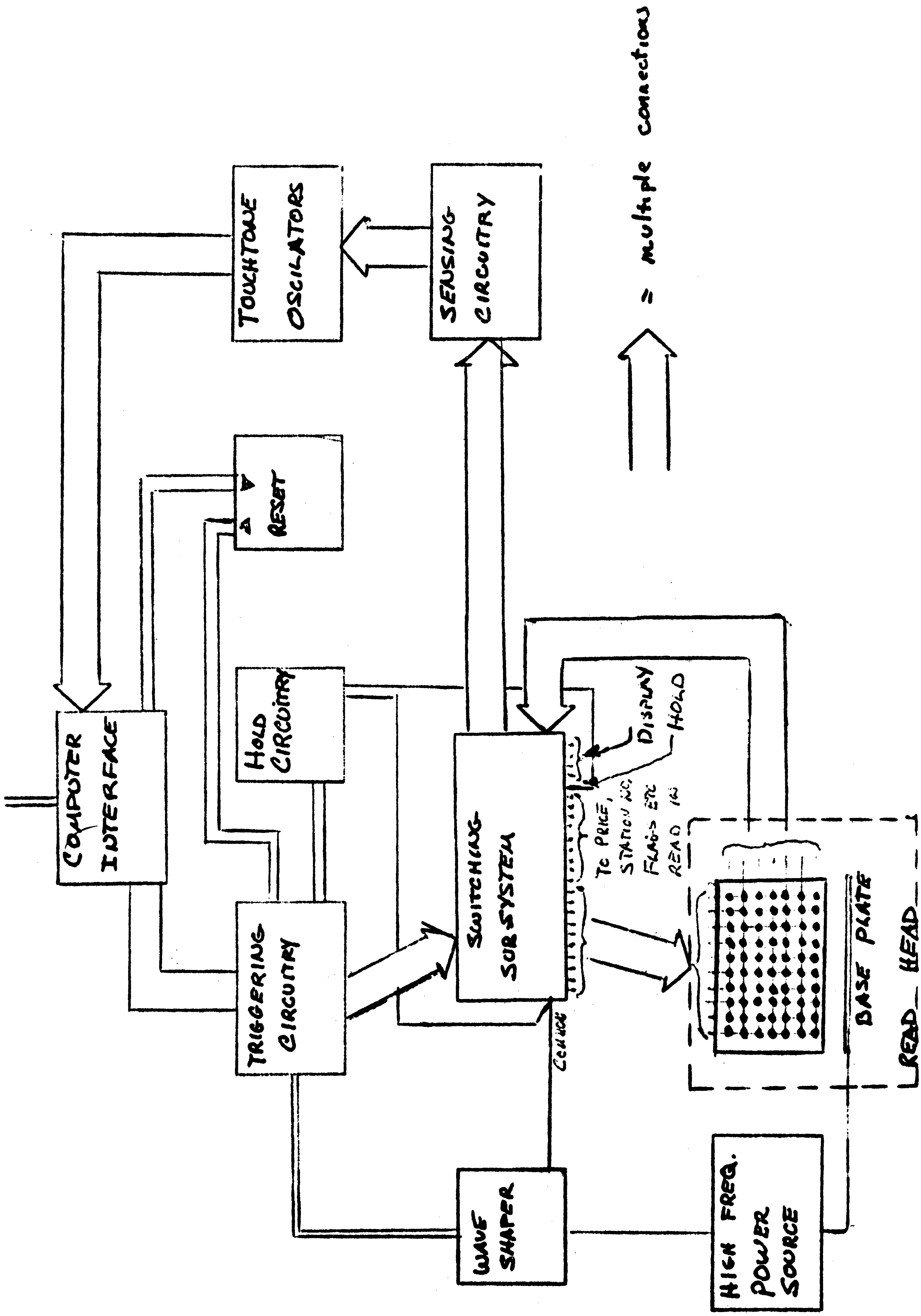


FIG. 7-A CAPACITIVE CARD READER SYSTEM

simultaneously activates the triggering circuitry. This subsystem produces an impulse wave form (Fig. 7-B) with a frequency of 10 cps which is used to fire the switching system and wave shaper. The switching subsystem performs two functions at this time. First, it switches a column of capacitors across the high frequency voltage source, and second, switches each capacitor to the sensing circuitry corresponding to its row. The sensing circuitry deciphers the electrical signals from the read head and serves as an interface to the touch tone oscillators. The wave shaper alters the output signal to satisfy the requirements of the Bell Telephone touch tone oscillators. The wave shaper alters the output signal to satisfy the requirements of the Bell Telephone touch tone system. Bell Telephone requires a frequency pulse not shorter than .040 sec. separated from the next pulse by at least .045 sec. Without the wave shaper the output would have a pulse length of approximately .10 sec. and no space between signals. (Fig. 7-B2). The wave shaper merely masks in the spaces. The final output then has pulses and spaces of approximately .050 sec. (Fig. 7-B2). After the ID number from the credit card has been read, the price, station number, and flags are read into the computer. Then the switching relay places the capacitive card reader into a hold state until the computer has time to perform the necessary operations on the data. When the computer answers back, the stepping relay is triggered by the computer through the triggering interface. The number of pulses in the signal from the computer will determine the number of times the relay will step. The various steps correspond to different states of credit, good, bad, stolen card, etc. The position the relay finally has will activate the appropriate display on the console. This reader does not specify the manner in which the receipt is written. It is not essential to this reader, and any number of alternatives could be chosen.

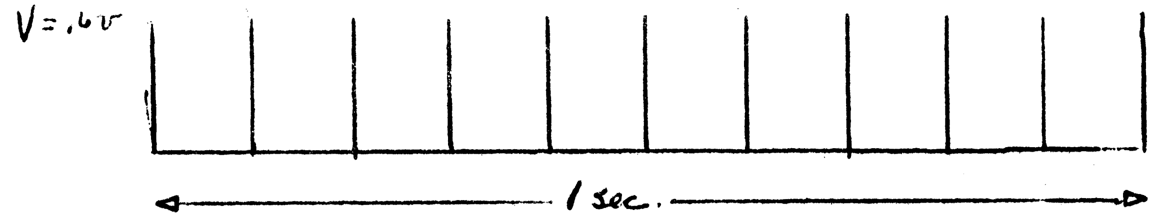


FIG. 7-B1 PULSE TRAIN

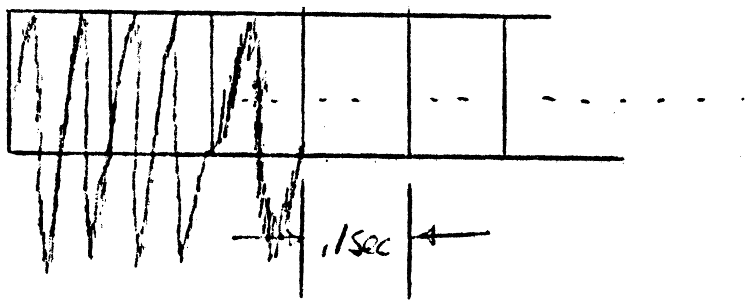


FIG 7-B2 VARIABLE FREQUENCY WAVE TRAIN

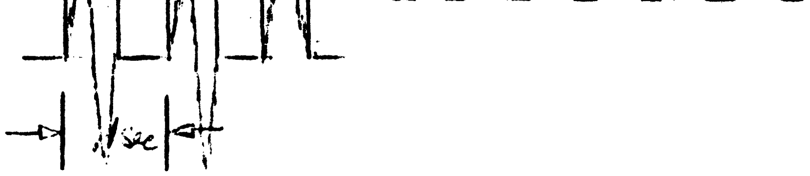


FIG. 7-B3 AC OUTPUT WITH SPACES

FIG. 7-B

B. INITIAL ATTEMPTS

Although the principle behind the capacitive card reader is itself very easy to understand, certain practical problems were obvious from the start. The first and most obvious was the small magnitude of capacitance with which we were dealing. The plates of the capacitors had surface areas of approximately .07 cm^2. The thickness of the plastic credit cards was approximately .1 cm. The permittivity of the hold (air) is 8.85×10^{-12} farads/meter, whereas the permittivity of common plastics vary between 2.7 and 7 times that of air (23.9 to 62.0×10^{-12} farads/meter). For an estimate, assume parallel plates of infinite extent. This approximation is not as bad as it may seem, for a fringe deflector plate was used to straighten the field lines between the plates, therefore making them appear as if they were segments of an infinite parallel plate capacitor. Calculating the capacitance from the formula

$$C = \frac{\varepsilon_o A}{d}$$

where A is the area of the plates, and d is the distance between the plates, we find the capacitance of the plates with air as dielectric to equal 6.2×10^{-4} pf, and the plates with plastic dielectric have capacitances of approximately 31×10^{-4} pf.

This small capacitance leaves a big job for the reading circuitry. The read circuit should be simple for economic purposes yet still capable of detecting the difference in capacitance. At first we checked into bridge circuits but found that the simple RC circuit could handle the problem just as efficiently but with less expense. Please refer to Fig. 7-c. We can measure the voltage across either the resistor or the capacitor. Since their sum equals the source voltage, they vary complementary to each other.

$$V(s) = I(s)\left[R + \frac{1}{j\omega C}\right], \therefore I(s) = \frac{V(s)\,j\omega C}{j\omega RC + 1}$$

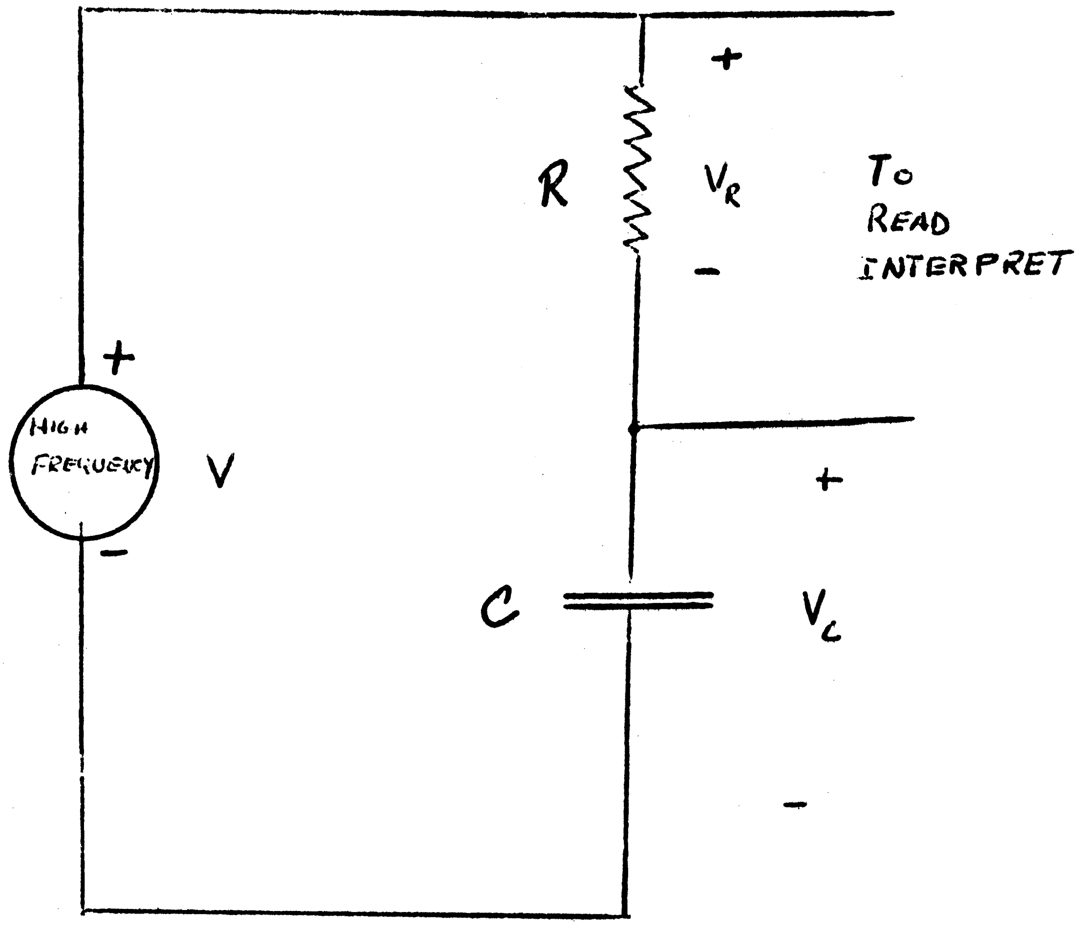


Fig. 7-C Read Circuit

Voltage across resistor:

$$V_r(s) = I(s)R = \frac{V(s)j\omega RC}{j\omega RC + 1}$$

C is very small (10^{-16}f). If ω = 100MHz and R = 100K, $\omega CR = 10^{-3} \ll 1$. Therefore $j\omega RC$ can be dropped from the denominator. $V_r(s)$ becomes:

$$V_r(s) = V(s)j\omega CR$$

The voltage across the capacitor is:

$$V_c(s) = V(s) - V_r(s) = V(s)\left[1 - \frac{j\omega RC}{j\omega RC + 1}\right] =$$

$$V(s)\left[\frac{1}{j\omega CR + 1}\right] \cong V(s).$$

Since the voltage of the source is practically independent of the capacitance in the circuit, the voltage across the capacitor will be fairly constant. Thus detecting the change in dielectric is most effectively accomplished by measuring the voltage across the resistor. Since

$$C = \frac{\mathcal{E}_o A}{d} \quad \text{we get} \quad V_r(s) = V(s)j\omega R\,{}_o\,\frac{A}{d} = K\,\mathcal{E}_o$$

Therefore when the capacitor reader sees a hole, the voltage across R will be approximately one fifth as great as when it sees plastic.

This voltage difference can be detected by the forward biased diode circuit shown in Fig. 7-D. V_F is given the value midway between $V_{r\ max}$ and $V_{r\ min}$. When $V_r = V_{r\ max}$ (plastic dielectric) the diodes back biased and no current flows. When $V_r = V_{r\ min}$ (air dielectric), current passes through the diode loop causing the reed relay to close, thereby activating one of the touch tone oscillators. The transistor is used to amplify the current to a value large enough to fire the reed

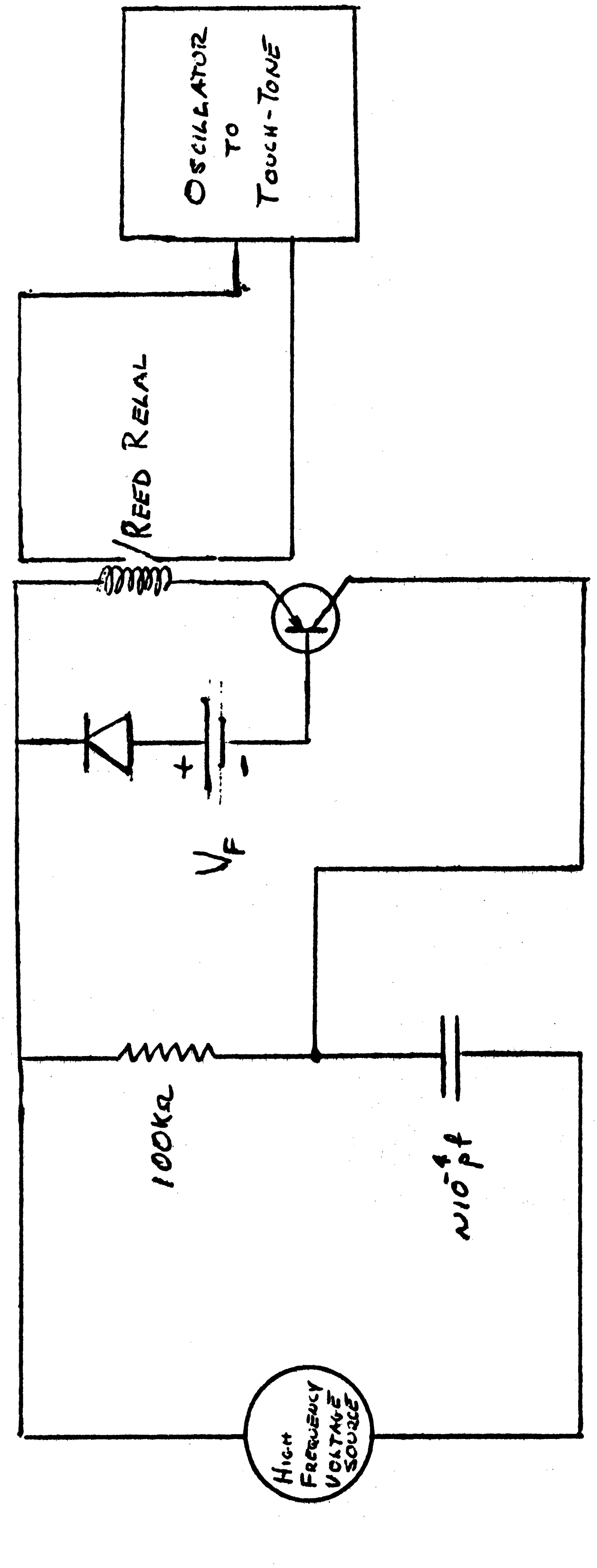


Fig. 7-D Read Interpret

relay. The seven rows of the matrix correspond to the seven oscillators. From the above analysis we have shown that we can handle the small magnitude of capacitance.

The other major problem involved isolation of the capacitors in the various matrix positions. It would be very convenient and economical to have the capacitors in a column all driven by one voltage source, and to have all the capacitors in a common row hooked to one sensing circuit. However, we must guard against placing all the capacitors in parallel thus obscuring any information we hope to obtain from the card. We finally derived an intricate switching system to separate the matrix positions on the card reader. Being that a picture is worth a thousand words, please refer to Figs. 7-E and 7-F. The heart of the switching system is an eight stage, twenty-four position stepping relay. The stepping relay connects one of the twenty-four positions on each stage to the common terminal on that stage. When the stepping relay is triggered, it advances to the next position. By this sequential switching, control of the card reader is maintained. Only ten of the twenty-four positions on each stage are used in the card reader itself, the others being used to read in the price, station number, flags, etc. These ten positions correspond to the ten columns of the matrix on the credit card. When the stepping relay is triggered it advances to the next column and the next number to be read. The first seven of the eight stages correspond to the seven rows of the matrix, and are used to successively connect the read resistors, a column at a time to the seven read circuits. The seven read circuits permit separation of the rows yet simultaneous reading of all the resistors in a column. The eight stage is the power stage. It switches the single power source to successive columns on the card. By this stage the columns are isolated from each other. The exact setup will be clear if you study the circuit diagrams in Figs. 7-E and 7-F.

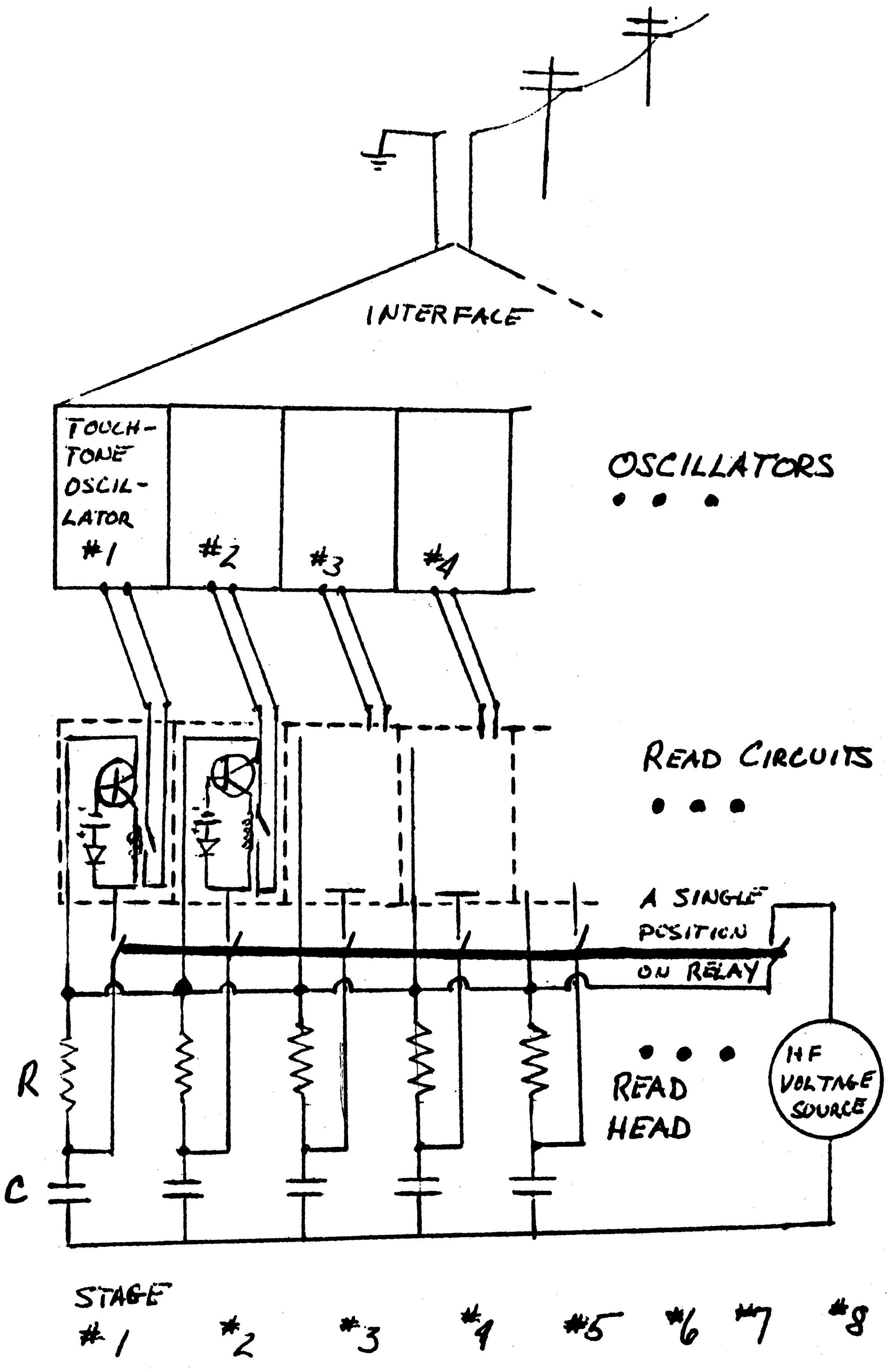


FIG. 7-E COLUMN OF SWITCHING SYSTEM

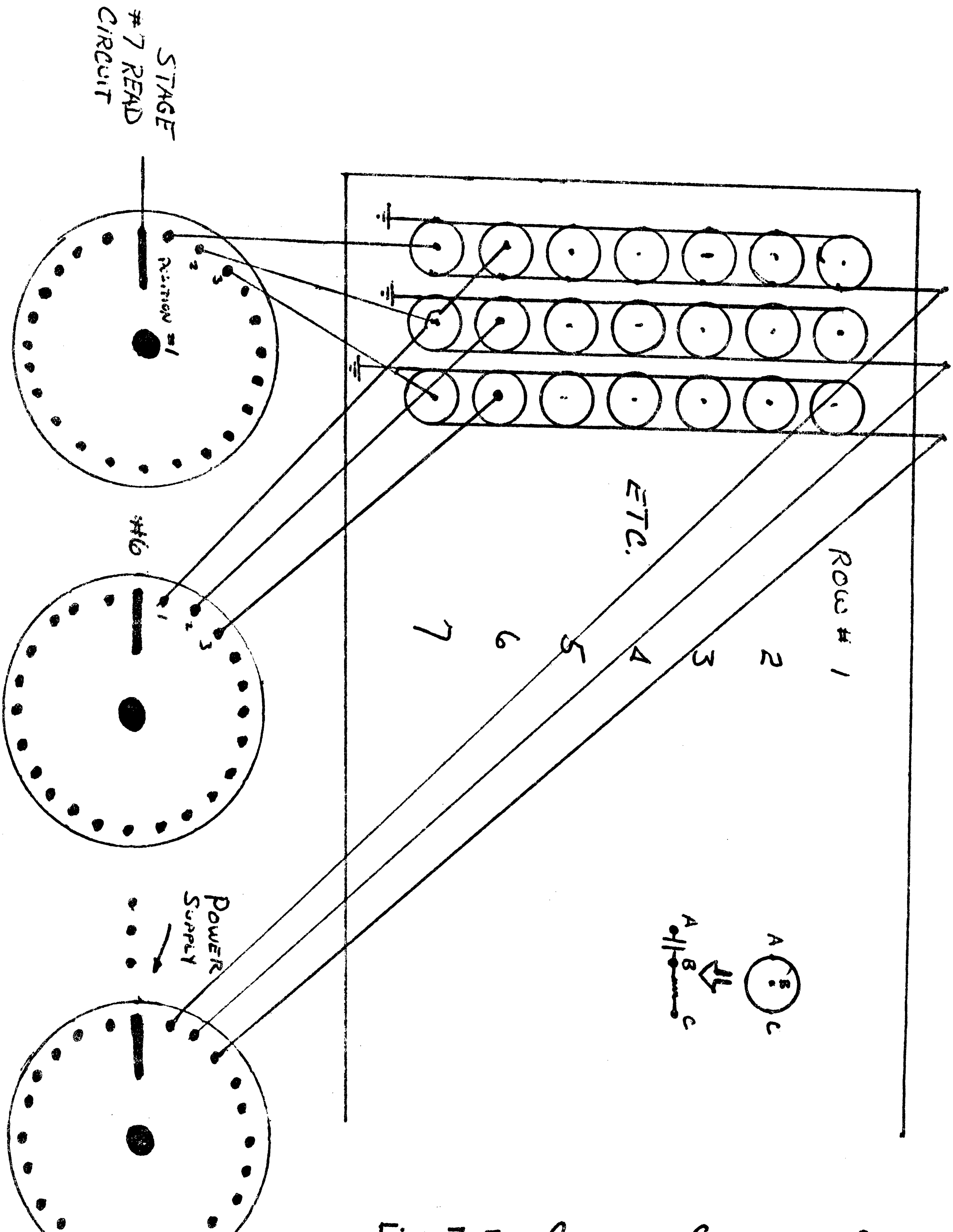


FIG. 7-F GENERAL SWITCHING SYSTEM

C. CAPACITOR PLATES

Note from the circuit diagrams 7-E and 7-F, one terminal from each capacitor is connected to a common node. This permits us to use a single brass plate for this half of the capacitors. This is definitely more economical than producing another set of very small plates and then aligning the two sets.

Two types of miniature plates were made. The first were rectangular in shape with a surface area of about $.03 cm^2$ (Fig. 7-Ga). They were made by flattening the end of copper wire, trimming it to the proper width, bending it in the shape of a T and then trimming it to the proper length. This has an advantage in that no soldering is necessary between the plate and the connecting wires. The plate is the same piece of metal as the wires. However, it does involve a lot of work to produce, and the 180° bend at the one end induces strain in the copper, thus making it fairly delicate. Another problem is that is is more difficult to punch a high density at small square holes in the field deflector plate without deformation than it is to drill circular ones. For this reason we chose round capacitor plates as pictured in Fig. 7-Gb. We also increased the area to $.07 cm^2$, thus more than doubling the capacitance of the rectangular plates. A fine coating of mylar was sprayed on the base plate. This prevents any chance electrical contact between plates or any short resulting from grease or moisture on the credit card. A picture of the upper half of the capacitive read head is shown in Fig. 7-Ge.

We attempted to measure the capacitance of these plates, but we couldn't obtain an accurate numerical value, even using an external high frequency voltage source to drive the bridge. However we could detect a small deflection in the galvonometer needle between the capacitors with polyesterene plastic as dielectric ($e = 2.7 \mathcal{E}_0$) and those with air as dielectric ($\mathcal{E} \cong \mathcal{E}_0$). This deflection encouraged us to continue.

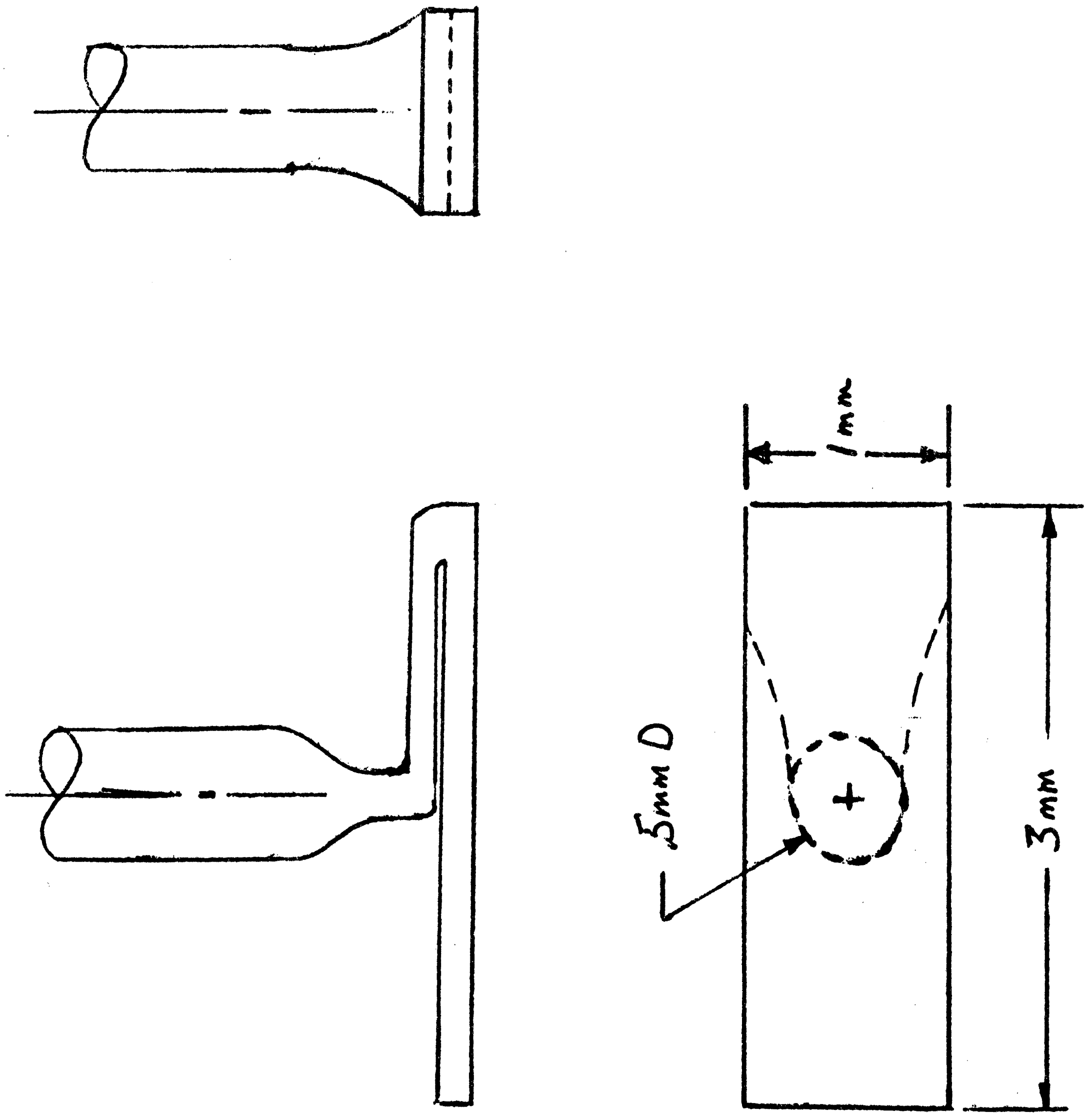


FIG. 7-G1 RECTANGULAR CAPACITIVE PLATE

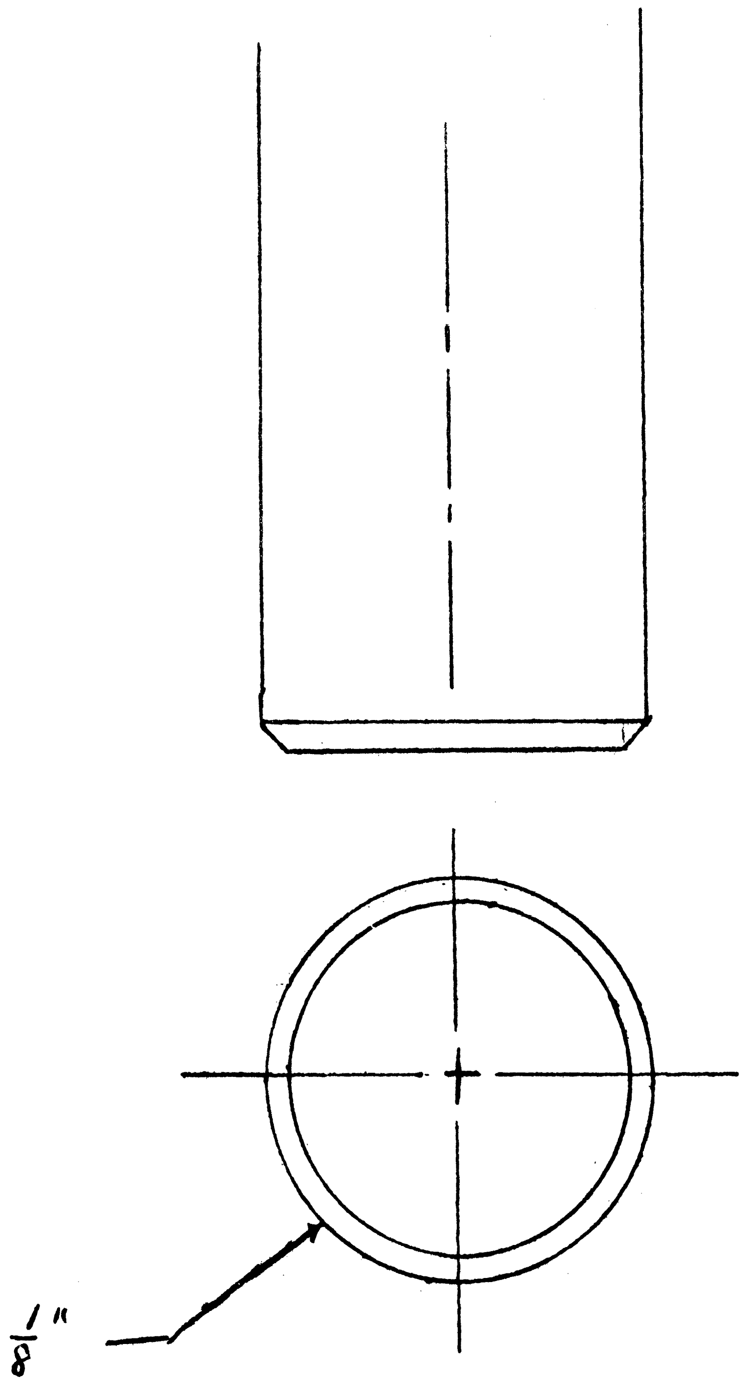


FIG 7-G2 CIRCULAR CAPACITIVE PLATES

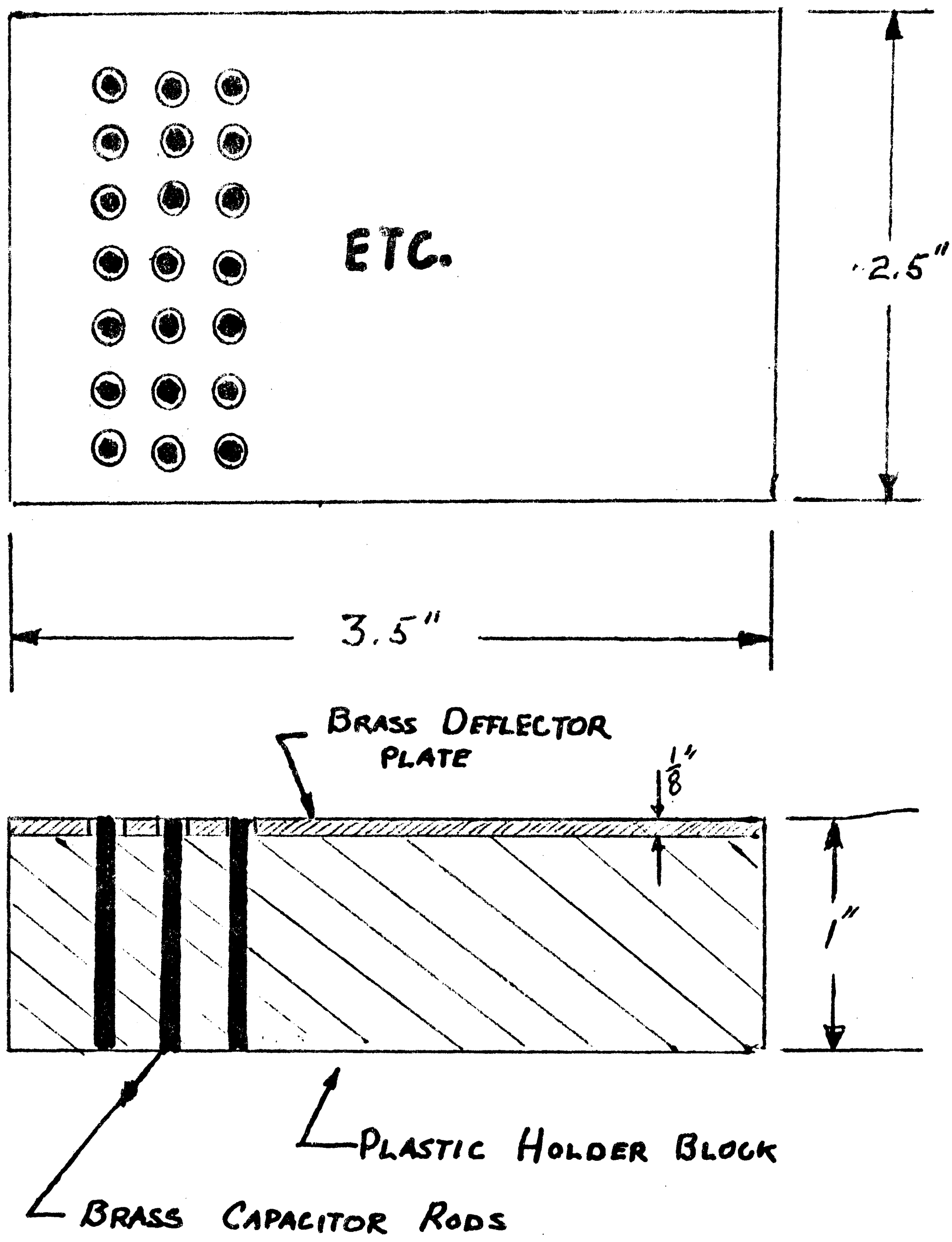


FIG. 7-G3 READ HEAD

D. FRINGE DEFLECTOR PLATE

There's a certain degree of fringing at the edges of the capacitor plates. The purpose of this deflector plate is to cut down the fringing without the deflector plate, the electric field lines would look like those pictured in Fig. 7-Ha. As the name implies, this plate will deflect these field lines into a more parallel configuration. This is done by applying the same voltage to the deflector plate as is applied to the capacitors with plastic dielectrics. The field lines will then look like those pictured in Fig. 7-Hb. There is a slight focusing of the field lines in the case of the hole. This will increase the effective capacitance of the hole dielectric capacitor, but this increase will be minute since there is only an extremely small potential difference between the deflector plate and capacitive plate. This is supported by our earlier calculations. We found the voltage across the capacitor to remain fairly constant with a change in dielectric. From these calculations we estimate the voltage difference to be about 9 millivolts, which is small compared to the voltage across the capacitor (10V). Since E = - V, we expect the field density to be about the same in either case, air or plastic dielectric.

In this way, the capacitors are made to look like segments in an infinite parallel plate capacitor.

E. RESETTING AND TRIGGERING OF THE STEPPING RELAY, WAVE SHAPER

The stepping relay, the core of the switching system, actually consists of two relays which are run on either 116VAC or 20 VDC. We used 115 VAC only because it was the type most readily available. It doesn't make any difference to the working system. One relay is used to step the relay, the other to reset the relay to the first position. The triggering is accomplished automatically by the circuit pictured in Fig. 7-J. We use a unijunction to trigger an SCR giving us an output shown in Fig. 7-Ka. When the current passes through the SCR, the two reed relays close. Reed Relay #1 closes 10 times/sec. When it closes, it connects the 115 VAC voltage source to the triggering relay in the stepper, thus advancing the stepping relay one position. See Fig. 7-L. Reed Relay #2 closes once every .10 sec. and remains closed for .05 sec. This relay forms our wave shaper. While it is closed, it connects the high frequency voltage source across the read head. While it is open, no voltage is supplied to the head, and therefore we get no output signal to the read circuitry. This gives us the wave form pictured in Fig. 7-Kb where each cycle represents another column on the card. Thus this one circuit serves as both trigger for the stepping relay and wave shaper.

We must also be able to trigger the stepping relay from the computer signal. The computer must likewise trigger the reset relay. These both work on the same principle. The computer will send back two different frequency signals. A filter is used to distinguish between the two. It will close one relay if a certain frequency is received and another relay if the other frequency is received. This filter is described elsewhere in the report. When one of these relays closes, the 115 VAC voltage source will be connected across either the stepping relay or the reset relay, depending on the frequency received. The relay which fires the reset relay also fires a relay which connects the triggering circuitry to its voltage source, thus activating the automatic triggering. A hold state is brought about by opening this relay in a similar fashion described above. This is pictured in Fig. 7-M.

F. OPERATION

This reader was a partial success. Although the triggering circuit, the wave shaper, and reset facilities all worked as described, the relative voltage difference between the hole and no hole state was not as large as was expected, nor was this difference consistent. The voltage at the hole state varied

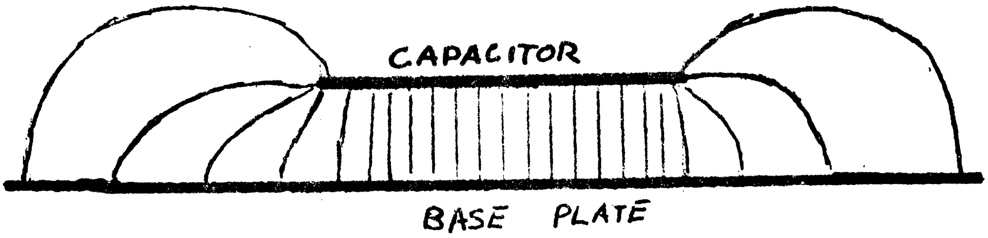


FIG. 7-H1 NORMAL FRINGING

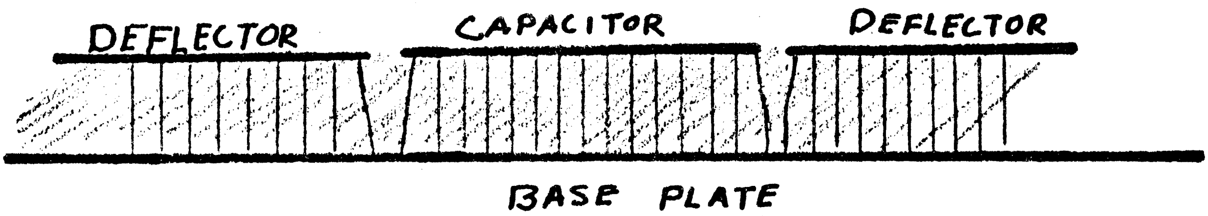


FIG. 7-H2 DEFLECTED FRINGING — NO HOLE

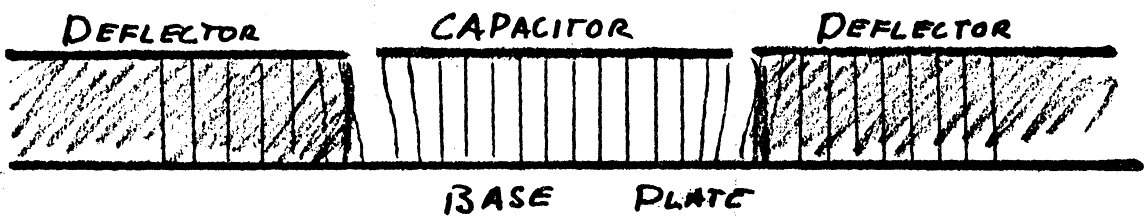


FIG 7-H3 DEFLECTED FRINGING — HOLE

FIG. 7-H FRINGING

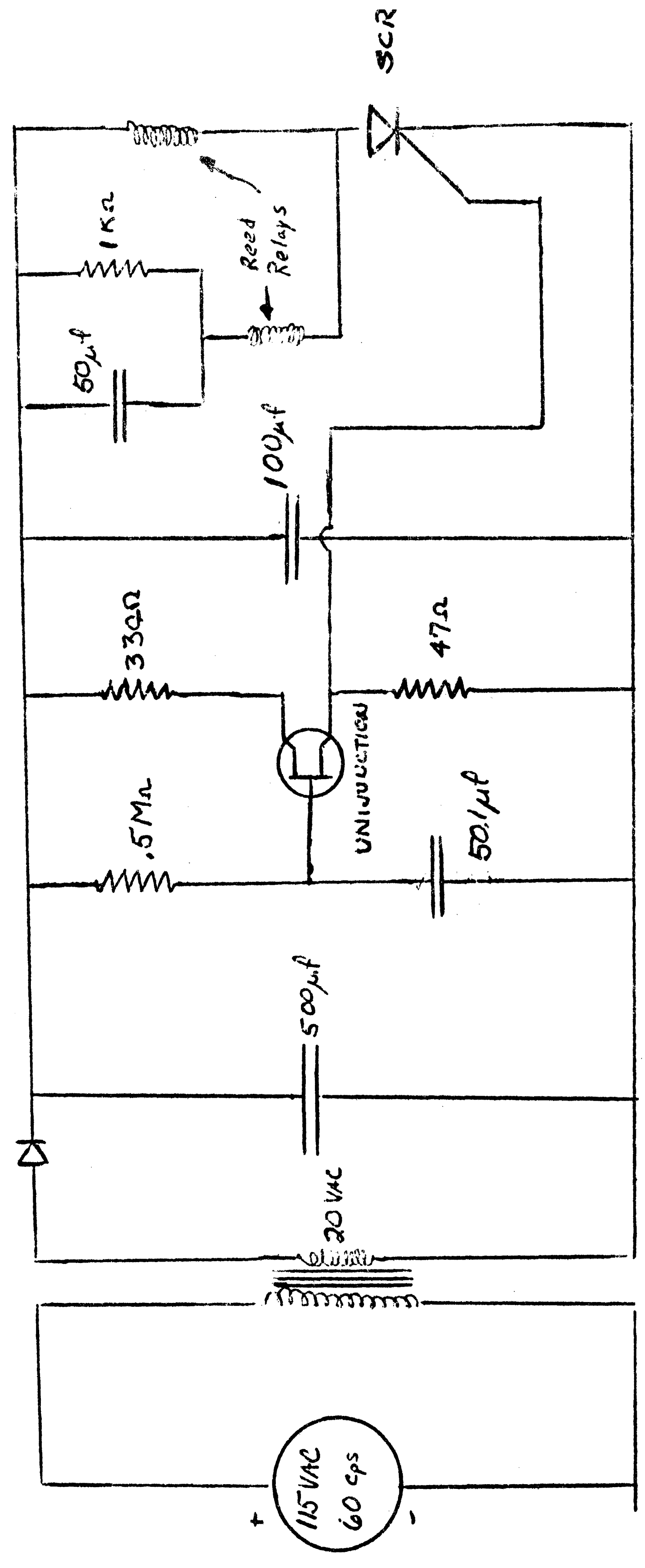


Fig. 7-J Triggering Circuit

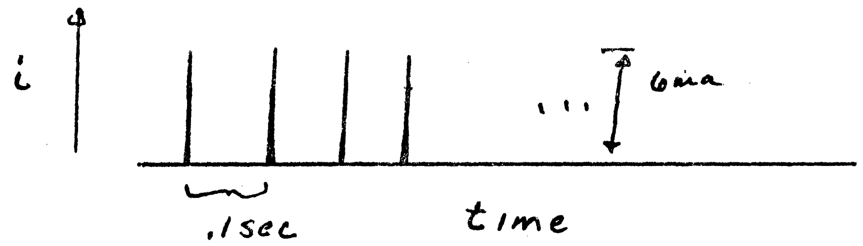


Fig. 7-K1 Output of Relay 1

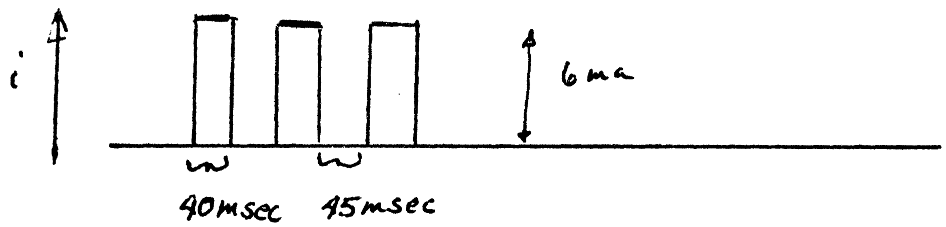


Fig. 7-K2 Output of Relay 2

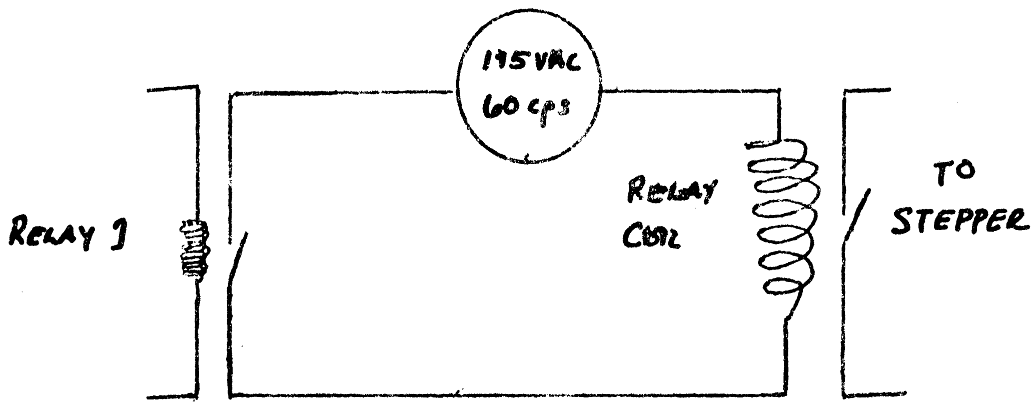


FIG 7-L STEPPING FIRE MECHANISM

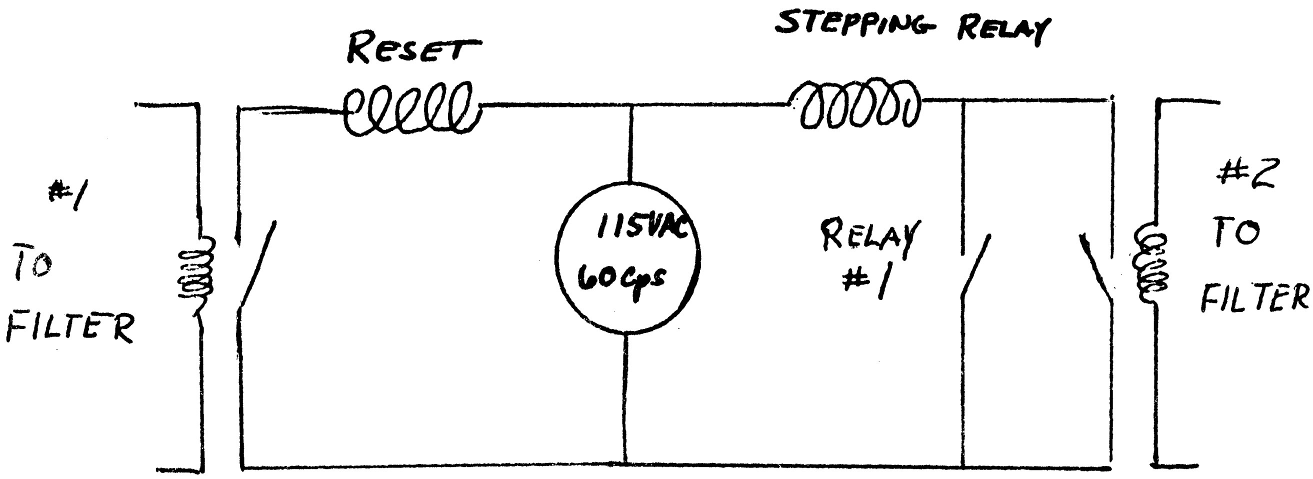


FIG. 7-M COMBINED TRIGGERING AND RESETTING

from between 20% and 0% lower than the voltage of the no-hole state. The lower magnitude of the difference was caused by the mutual capacitance in the read head between the capacitor rods. The variance in the magnitude of the difference could be caused by the following reasons:

1. non-uniform resistance values,
2. non-uniform capacitor plates,
3. non-uniform thickness of the mylar coating on the plates.
4. a variance of pressure between the read head and card,
5. variable stray capacitances near the head, customers' and salesmen's hands, etc.

We believe these problems could be solved. The question arose, is it economically feasible to continue this card reader. After considering the cost of materials already involved in the present reader, about $71 and an estimate of manufacturing costs, about $140, the present reader would cost approximately $210. The additional expense involved in solving its problems of inaccuracy would eliminate any hope we had to produce this terminal for a profit. The major advantage of the capacitive card reader is that it is totally electrical in nature. Therefore, it can read information from cards at speeds much greater than is required in this project. Therefore, what we are buying in a totally electrical card reader we are not using. This reader might be economically feasible in computer data read in systems where time is a premium but it cannot meet the goals of this project, with the current technology.

CHAPTER 8

MODIFICATION OF ADDRESSOGRAPH # 14-55 DATA RECORDER

INTRODUCTION

As received from the factory, the Addressograph model 14-55 data recorder is capable of performing two functions.

1. It prints information from raised alphanumeric characters on to a specially prepared receipt, by passing an inked roller over an embossed plastic credit card.
2. It prints 5 decimal digits, representing the total amount of the customers purchase, on to the same receipt as described above. These five digits are referred to as the veritable data, and are controlled by levers located on the top of the machine. (See fig. 8-1)

These two functions are performed when the operator manually moves the printing carriage over the receipt which lies over the plastic credit card and the veritable data. The pressing of the carbon paper receipt over the embossed credit card and raised price numerals results in the information being transferred on to the receipt paper. Note from figure 8-1 that the receipt covers only the bottom 2/3 of the credit card.

In addition to printing the credit card number and the purchase price, the terminal must be capable of converting this data into touch tone signals capable of being sent over conventional phone lines. It was decided, therefore, to mount the credit card reader on to the printing carriage, and to let the translation of the carriage carry the read head across the credit card. However, since the maximum data carrying capacity of the touch tone telephone line is ten decimal digits per second (see appendix C), the carriage cannot be moved across the credit card too fast. In particular, since the credit card contains a ten digit account number, along its 2 3/4 inch length, the carriage cannot travel faster than 2 3/4 inches per second. In actual practice, a typical operator pulls the carriage through this distance in 1/3 of a second or less.

Thus it is obvious that the first modification necessary to the data recorder is to automate the carriage mechanism so that it travels at a constant rate and at a specified speed. Automatically drawing the carriage across the card also gives the additional advantage of simplifying the sales clerk's job. All that the sales clerk has to do is just insert the credit card and receipt into the machine, set the price levers, and push the "START" button. After the "START" button is pushed, all operations are automatic and out of the sales clerk's control, thereby minimizing the opportunity for human error.

A second modification necessary is to automatically convert the purchase price, as set on the price levers, into touch tone signals. This is described in section two of this chapter.

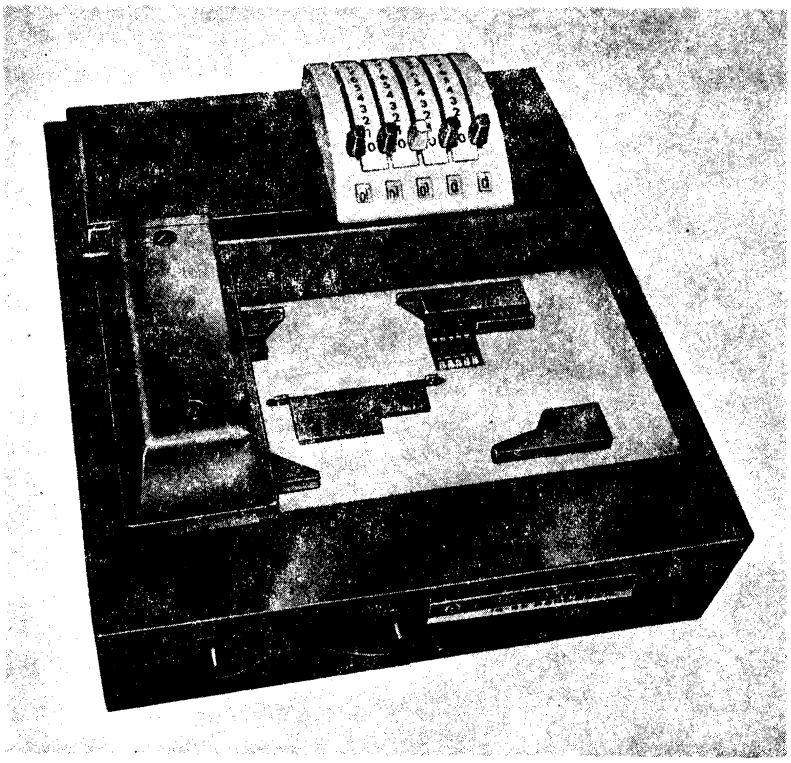
<u>SECTION 1</u> AUTOMATING CARRIAGE TRAVEL

Three basic approaches were studied in solving this problem. A brief summary of each follows:

A. ELECTRIC MOTOR DRIVING CARRIAGE IN BOTH DIRECTIONS

Actually two variations of this approach are possible. One method is to have a unidirectional motor drive a metal disk. A solid metal rod is then run from the disk to the carriage (see fig. 8-B). As the disk rotates, pin "A" first draws the rod to the right, and then, for the second half revolution, it pushes the rod to the left. To get the required carriage travel, pin "A" would have to be on a 2 inch radius, and the motor would have to have at least 150 in-oz of torque (i.e. 4 1/2# linear pull). A single direction motor of this type is manufactured by Hurst Mfg. Co. for $18 in quantity purchases.

A second method is to use a reversible motor driving a metal rod. The motor would rotate clockwise, pulling the carriage to the right, and then it would trip a switch and reverse itself, driving the carriage back to the left. A reversible motor of this type is also manufactured by the Hurst Mfg. Co. for $23.



Data Recorder Before Modification

FIG. 8-A

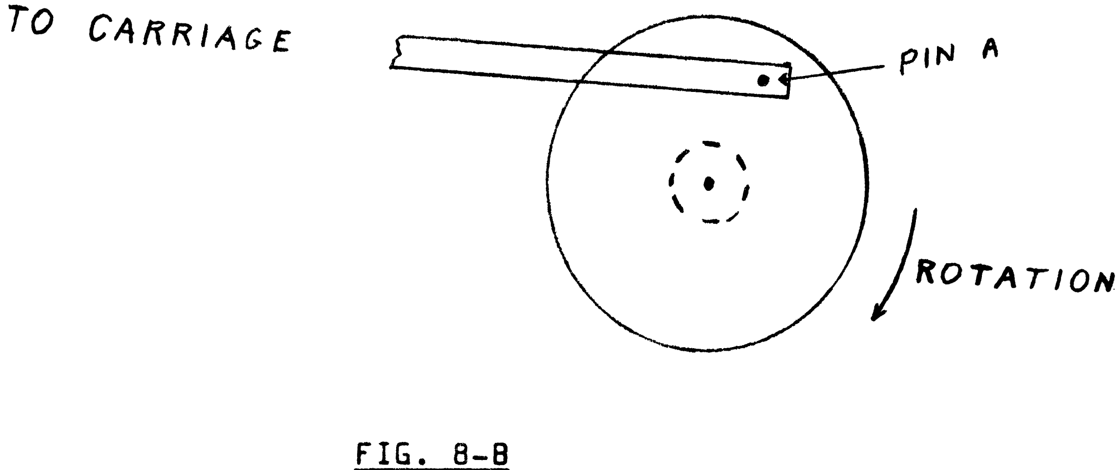


FIG. 8-B

Although both of these approaches would be feasible if we were to design our own data recorder, they would not work on the model 14-55 without completely redesigning the component layout on the underchassis. The mechanism that changes the purchase price (veritable data), is located underneath the chassis flush with the carriage track (see fig. 8-C). This would block any solid connecting rod that could be designed. Upon further investigation it was found that the only feasible method of connecting the carriage to a motor would be by a thin string or wire, located on the front side of the track (refer to fig. 8-3). This wire, if positioned carefully, would clear all the underchassis obstructions and drive the carriage. Since a wire is not stiff enough to push the carriage in both directions, it is necessary to employ two wires, one to pull the carriage in each direction.

B. ELECTRIC MOTOR WITH SPRING RETURN

This approach uses an electric motor to pull the carriage to the right, and then a spring mechanism to move it to the left.

Here, too, two approaches are possible.

i. One method is to have the motor, which is connected to the carriage by a wire, wind up the wire on a pulley until the carriage reaches the right hand position. Here the motor would reverse, and the spring mechanism would pull the carriage back to the left again.

ii. If a faster return is required, a magnetic clutch could be inserted in series with the motor shaft. Here, instead of the motor reversing itself when the carriage reaches the right hand side of its track, the clutch would release, thereby enabling the carriage to immediately spring back. In an effort to keep the costs down, prices were obtained from various clutch manufacturers. It seems that the least expensive clutch would cost between $25 and $30, depending on the quantity ordered.

As a rough estimate of costs, method "i" would run about \$24 for a motor, and about \$5 for a spring. Method "ii" would run about \$18 for a motor, \$25 for a clutch, and also about \$5 for a spring. For compactness a flat circular spring driving a pulley should be used instead of a long linear spring. (see fig. 8-c).

C. SPRING AND GOVERNOR METHOD WITH MANUAL RESET

INTRODUCTION

This method, by far the cheapest of the methods considered, uses a flat spring in series with a mechanical governor and pulley, to pull the carriage across the credit card at a constant rate. After use, the carriage is then manually pulled to the left, where a solenoid locks it into place, ready for activation. This mechanism was actually incorporated into the prototype model.

MECHANICAL SPECIFICATIONS

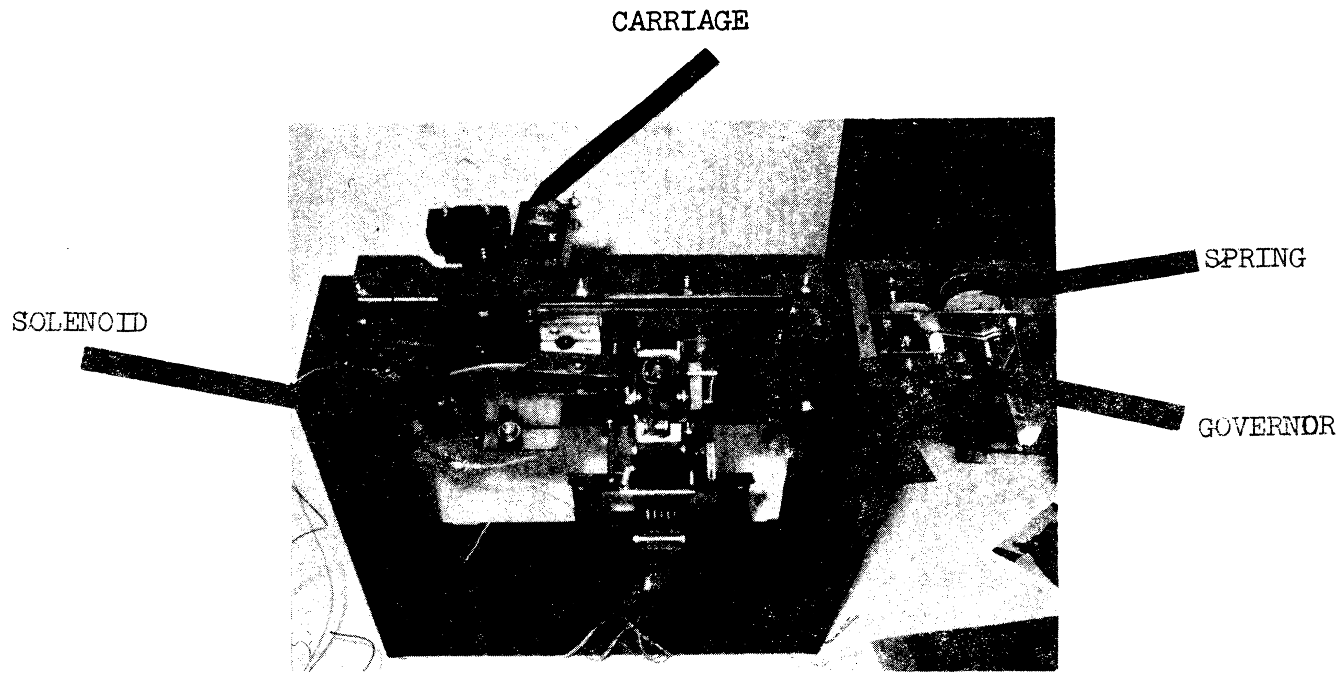
The governor should be a small and inexpensive device which, when attached to a pulley, should be capable of keeping the pulley rotating at a constant angular velocity under varying torque conditions. An ideal example of a governor of this type is incorporated in the Western Electric telephone dial. If one dials "operator" on a telephone, and releases the dial, it will "spring back" at a constant speed. If one tries to hurry the dialing process by forcing the dial back to its rest position, the dial will oppose being forced back by applying a reaction force to the finger equal to the applied force. No matter how hard one tries to turn the dial, it will always "spring back" at a constant speed. In fact, the telephone dial governor performed so well under all kinds of loading conditions, it was used in the prototype model.

In the laboratory the governor was subjected to different torques, ranging from as little as 5 in-oz to as much as 150 in-oz, with negligible effect on its angular velocity. The rotating speed is adjustable, however, by a small hair spring on the front of the governor mechanism. By tightening this spring, governing action did not occur until approximately 1 RPS was reached, while by loosening the spring, governing action would cut in at approximately 0.25 RPS.

The principle of operation of the governor is quite simple. Inside the governor are two miniature "brake shoes" (like in an automobile) about 1/2" in diameter. These two shoes are connected by gears to the shaft that needs to be governed. As the shaft starts rotating, the shoes start rotating, and centrifugal force forces the "brake shoes" against the stationary bronze "brake lining" that encloses it. The resulting friction opposes the rotation. The faster the shaft tries to rotate, the greater the friction force opposing the rotation, and thus a governing action takes place. The device is mechanically simple, reliable, and inexpensive. Although no cost figures were obtained from Western Electric, it appears that it must cost well under $5 to manufacture.

The spring used in the prototype model is a Neg'ator B. Motor, model A-2085-5, manufactured by the Hunter Spring Co. of Hatfield Pa. It is a constant tension spring with 5 lbs. pulling force, and sell for $15. For use in the Addressograph, however, constant tension is not required, hence, any spring with between 3 lbs. and 10 lbs. pull (over a 7 1/2" linear length) can be used. (A constant tension spring was used in the prototype because it was donated to our group).

In fact, a flat spring with "normal" characteristics, increasing torque with increasing rotational displacement, would not only be cheaper, but would actually be better suited for this kind of application. For in the addressograph there is a safety feature that prevents the carriage from being pulled across the credit card if the veritable data levers have not been reset since the last transaction. This prevents charging



UNDERCHASSIS OF ADDRESSOGRAPH DURING MODIFICATION

FIG. 8-C

a customer for a purchase made by the preceding customer. This safety mechanism makes the first 1 inch of travel more difficult than the rest of the carriage travel, requiring as much as six or seven lbs. pulling force. After this point, as little as three lbs. suffices to pull the carriage, hence a spring that obeyed Hook's law, providing greater pull at greater displacements, would be preferred over the more expensive constant tension spring.

To keep the carriage in a cocked position, a solenoid is mounted under the chassis. (see fig. 8-C). It holds the carriage at its extreme left hand position, and is activated by the computer's answer-back tone, which tells the terminal that the computer is on line and ready for the reading in of data. The only difficulty encountered with this solenoid was that the part of the plunger that came in contact with the carriage had to be made out of plastic rather than metal. For in the first model built it was found that the metal plunger, when touching the carriage, completed the magnetic flux path from the case of the Addressograph, to the core of the solenoid, to the plunger, thereby decreasing considerably the solenoid's pulling power. The problem was avoided by insulating the plunger.

To avoid the problem of a sales clerk commencing a transaction without the carriage being cocked, the "START" switch is wired in series with two relay contacts. These contacts are pushed together (making contact) by a tab on the carriage roller only when the carriage is in the cocked position. To facilitate carriage travel over the difficult first inch of travel, as described earlier, the relay contacts are spring loaded so as to provide an initial impetus to the carriage when it is released.

Total cost of such a system is

Governor	\$5
Spring	\$5
Solenoid	\$3
Relay Contacts	\$ .15

This is less than one-half the price of any other method of driving the carriage that was considered.

SECTION 2 CONVERSION OF VERITABLE DATA INTO TOUCH TONES

INTRODUCTION

During the first five weeks of the course, before the Addressograph data recorder was chosen as the basic building block of the system, efforts centered around reading the purchase price off of an adding machine type of keyboard. After the data recorder was purchased, a system was devised whereby the price information was read off of the veritable data levers located on the top of the machine (see fig. 8-A).

A. READING PURCHASE PRICE OFF OF AN ADDING MACHINE KEYBOARD

For simplicity of analysis, a ten button adding machine keyboard was assumed in use at the store's checkout counter. As the first number is punched on the keyboard, it closes switch contacts that automatically convert the decimal number into binary form. This binary number is then stored in a four flip flop buffer register. Six of these buffer registers are then connected so as to form a series of four bit shift registers. A group of buffer (storage) registers, connected together as a series of shift registers, is called a jam transfer buffer. When a shift pulse (or positive going level change) occurs, the contents of buffer register "1" will be shifted into buffer register "2". Simultaneously, the contents of buffer register "2" will be read into buffer register "3", etc. A decimal number from the adding machine keyboard is read into buffer register "1" at the same time as the shift operation. A more complete description of how a jam transfer buffer operates is given in Digital Flip Chip Modules, published by Digital Equipment Corporation of Maynard, Mass.

After the purchase price is read in, all the numbers will be stored in order in the first five buffer registers. Then a clock mechanism pulses the buffer registers so that their contents are transferred, one by one, into the sixth buffer register. This register is actually an overflow register, consisting of four flip flops and ten "AND" gates. The "AND" gates convert the contents of the sixth register into decimal form. The decimal number is then routed through seven more "AND" gates which activate the seven relays on the touch tone oscillator pad. (see appendix "C").

Because we have "AND" gates feeding into "AND" gates, it seems likely that the logic could be simplified by switching from "AND" logic to "NOR" logic. Since this method of veritable data read-in was abandoned when the Addressograph was bought, the conversion to "NOR" logic was not pursued further.

B. READING PURCHASE PRICE OFF OF ADDRESSOGRAPH'S VERITABLE DATA LEVERS

There are five veritable data levers located on the top of the Addressograph chassis (see fig. 8-A) on which any amount purchase up to $999.99 may be set. To transmit this information over the telephone lines requires a method of sensing the lever positions, and a method of sequencing this information to the touch tone oscillator pad.

Two methods of sensing a lever's position were considered. The first method uses the lever as the variable tap of a potentiometer. Underneath the plastic cover which spaces the levers (see fig. 8-A) five phenolic boards are inserted parallel to the levers motion. On each board a resistance wire is placed. A contact, with a wire attached, is fastened to the lever. As the lever is moved, this contact slides along the resistance wire attached to the phenolic board, acting like the wiper arm of a potentiometer. A potential of 10 volts D. C. is then placed across the resistance wire. The resistance wire and the contact on the veritable data lever thus form a potentiometer. The voltage between the lever contact and ground would therefore vary between one and ten volts, depending on the lever's position.

The five wires from the five levers are then brought out to a commutator which samples each lever reading in sequence. The voltage level is then fed into a voltage discriminator which reads the voltage level and activates the appropriate relay. As explained in appendix "C", these relays would short out the appropriate terminals on the touch tone oscillator pad, sending the signal over the phone line.

The voltage discriminator would be similar to the one used in the capacitive card reader described in Chapter 7. A series of ten diodes would be reversed biased, each one at a different voltage level (i.e. 1 V, 2 V, 3 V, ...10 V.) The voltage to be detected would then be applied to the diodes in the forward biased direction, causing conduction in those diodes whose reverse bias voltage was less than the voltage being detected. Switching transistors would detect the conducting diodes and then feed this information to "AND" gates which in turn would activate the appropriate relays.

A second method of price readout, the one used in the prototype model, operates the touch tone relays directly, without the need for a voltage discriminator network. Here, too, phenolic boards were inserted next to the veritable data levers, but instead of a resistance wire being mounted on them, two rows of rivet contacts were inserted opposite each of the lever's 10 possible positions (see fig. 8-D). These rivet contacts are the same type as those used on the board of stepping relays. The contacts on the phenolic boards are then wired so that each one activates one of the seven relays on the touch tone oscillator pad. The boards are mounted in the plastic top by inserting their back ends into a grooved plate which is screwed into the plastic. The front of the boards are pinned to the plastic cover. (see fig. 8-D).

Referring to figure 8-F, one notices the seven touch tone relay terminals labelled "A", "B", "C", "D", "X", "Y" and "Z". (For a complete explanation of how the touch tone oscillator pad operates, see the short explanation in Chapter 3 and the

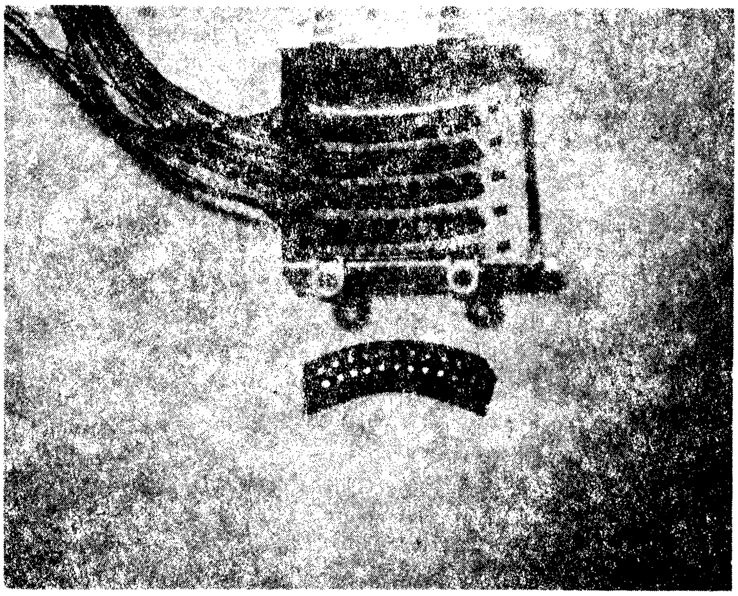


FIG 8-D

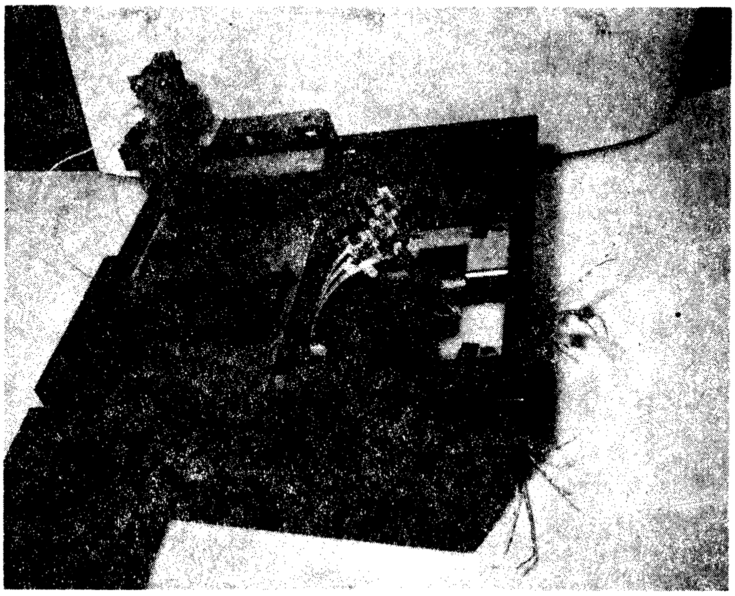


Fig 8-E

detailed explanation in appendix C). When terminals "X" and "A" are shorted to ground, the numeral "1" is sent over the telephone line. Similarly if terminals "C" and "Z" were shorted to ground, the numeral "9" would be transmitted.

Two wiper contacts are installed on the lever arms themselves (see fig. 8-E). These contacts make with the contacts on the phenolic boards. If the lever's wiper contacts are then grounded, they will in turn ground the mating contacts on the phenolic board, which, as mentioned earlier, will activate the appropriate touch tones.

To sequence out the data from the five lever positions, it is necessary only to sequentially ground the five pairs of wiper arm contacts. Various commutators were considered for this purpose, including the use of stepping relays, motor driven commutators and pulsed solid state "AND" gates. This latter method is discussed in Chapter 4.

In the prototype model a linear commutator was built as shown in figure 8-F. It consists of a 2 inch long phenolic board with seven pairs of terminals on it. Five of the pairs are connected to the five veritable data levers. The other two pairs will be discussed later. This board is mounted under the read head carriage track, immediately after the credit card. As the carriage moves to the right, it first reads the credit card and then passes over the contacts on the phenolic board. As it passes over the board, two spring contacts on the carriage sequentially short, in pairs, the board's contacts to ground, activating the touch tones. Using contacts on the Addressograph carriage as the commutator wiper not only assures that the data will be transmitted in its proper sequence, but it reduces the total cost of the commutator to under 50¢.

On the commutator illustrated in figure 8-F, two pairs of special contacts are shown. The first of these are connected by a DPDT key switch either to terminals "A" and "X" or terminals "D" and "Z" representing the numerals "1" and "0" respectively. The numeral "1" preceding the price readout tells the

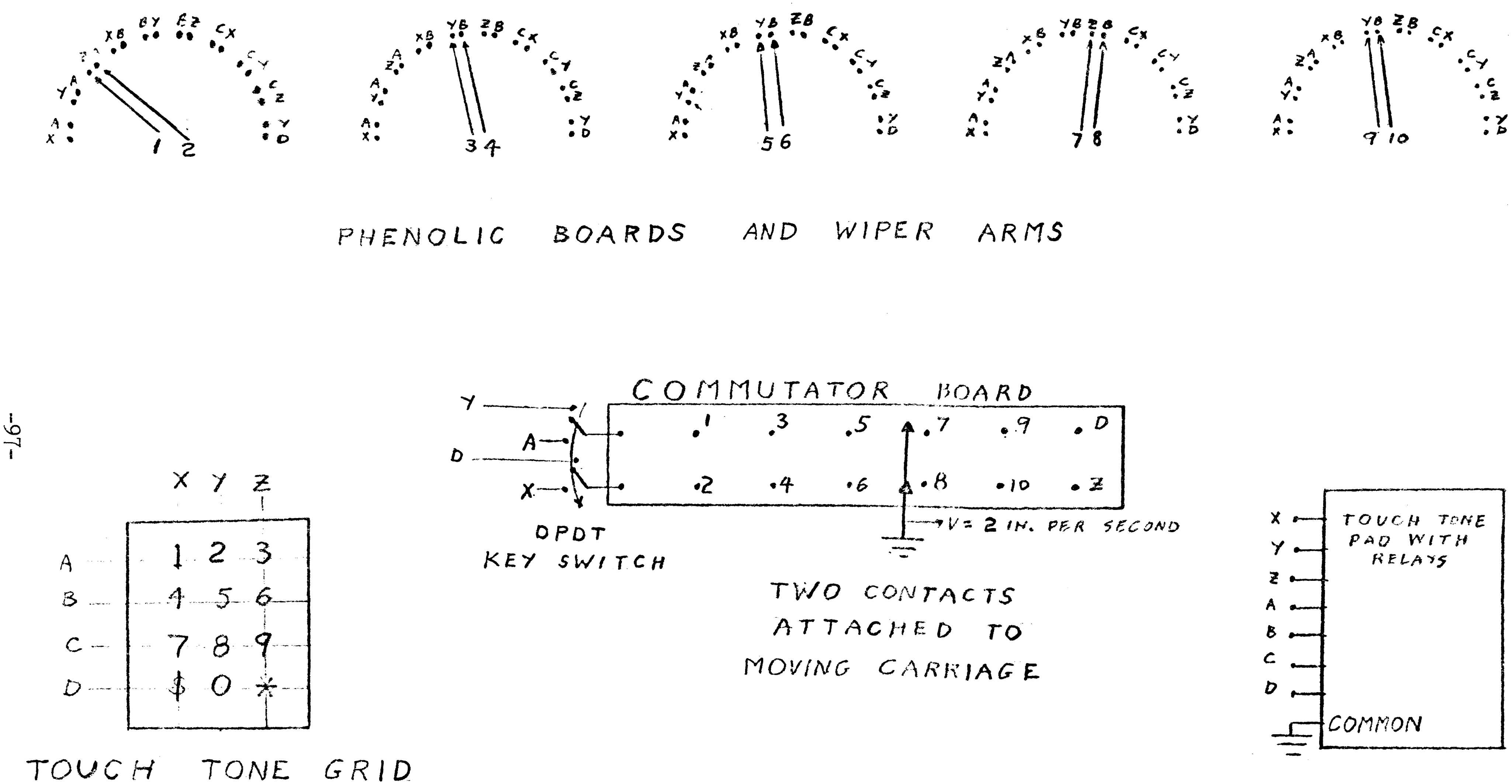

PHENOLIC BOARDS AND WIPER ARMS
COMMUTATOR BOARD
DPDT
KEY SWITCH
V = 2 IN. PER SECOND
TWO CONTACTS
ATTACHED TO
MOVING CARRIAGE
TOUCH TONE GRID
TOUCH TONE
PAD WITH
RELAYS
COMMON

FIG. 8-F

computer that the next five numbers (from the veritable levers) represent a purchase, and should therefore be debited to the customer's account. When the store manager turns the key switch (connecting terminals "D" and "Z" to the commutator) the numeral "0" precedes the price readout, signalling to the computer that the next five numbers should be credited to the customers account. (i.e. a refund transaction is taking place). The details as to how the computer handles this "credit flag" are discussed in Chapter 11.

The last pair of terminals on the commutator are always connected to terminal "D" and "Z" on the touch tone oscillator pad. This transmits an "*" over the telephone lines, signalling "end of transmission" to the computer.

CHAPTER 9

SIGNAL RECEIVER

A. INTRODUCTION

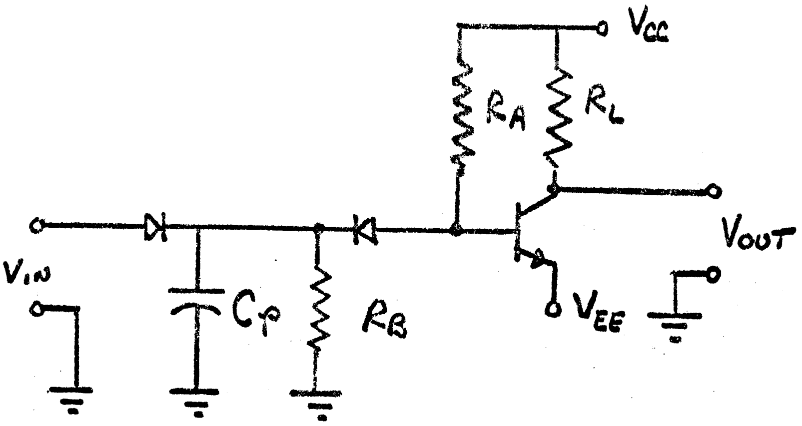
Very simply, the signal receiver of our terminal must be able to sample information on a telephone line and then provide a combination of relay contact closures which are a function of the signals on the phone line. Since a Bell System 403 data set will be at the other end of the transmission line, information will be sent at one of three discrete frequencies (1075 HZ, 1785 HZ or 2025 HZ). These audio frequencies may be pulsed to increase their information content.

B. BASIC DESIGN AND ANALYSIS

Since economy is a major constraint in the design, the first suggestion was to ignore frequency discrimination altogether, and handle information transfers by pulsing the answer-back signals. If we did this, our receiver could be very simple; a peak rectifier followed by an inverter. The circuit configuration is shown in figure 9-A. Although this scheme is very attractive because of its simplicity, we discarded the idea since it would be falsely triggered whenever we were sending information out over the line. Also, the logic to decode the pulses would negate any savings due to the simplicity of the receiver design.

The above discussion shows that our device will minimize the internal logic of the terminal if it has an output port corresponding to every answer the computer may want to send back to our remote terminal. In other words, if the computer needs to be able to give four different answers, our receiver should look like:

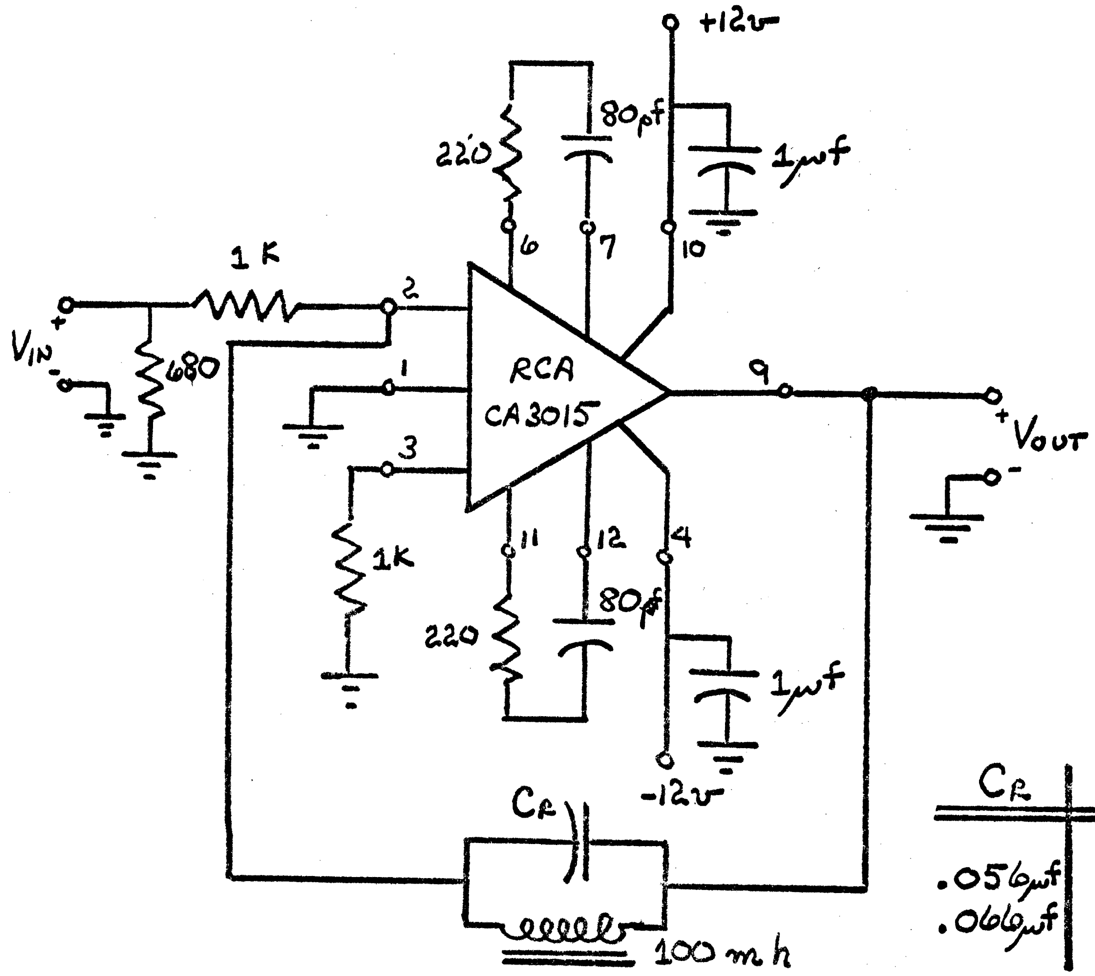
PEAK RECTIFIER & INVERTER



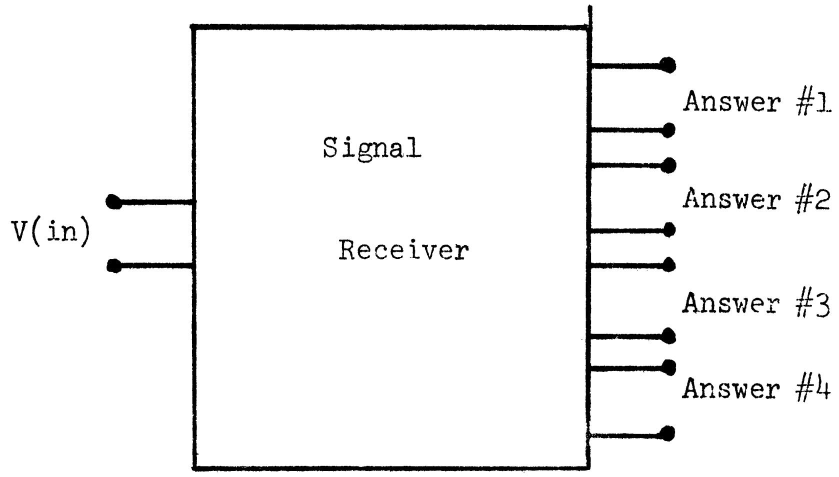
(FIGURE 9.A)

BASIC CONFIGURATION FOR THE SINGLE STAGE TUNED AMPLIFIER

(FIGURE 9.D)



C_R	$f_{RES.}$
.056µf	1785
.066µf	2025

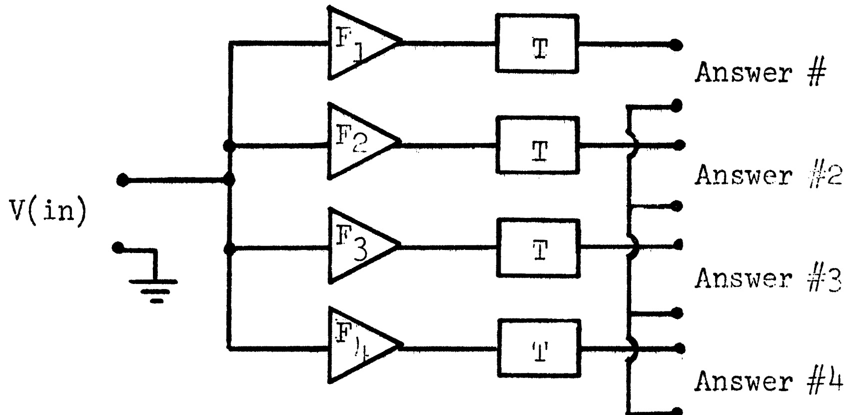


General Receiving Network

Figure 9-B

where terminal 1-2 would be shorted to imply answer #1, 3-4 would be shorted to imply answer #2, etc.

The simplest way we found to build the above system was to use a set of tuned circuits arrayed in parallel. Hence, the computer could give any one of the four answers by activating one of four possible frequencies. Now our receiver takes on this configuration.



Tuned Receiving Network

Figure 9-C

where  represents a tuned circuit resonant a Fhz,

and  represents a trigger circuit.

Two configurations for the basic tuned amplifiers we studied are shown in their final form in figure 9-D. The discrete component circuit would be cheaper than the integrated circuit approach at current prices; but, by the time this terminal reaches the manufacturing stage the two circuits should be comparable in price, and the integrated circuit approach is superior in overall performance. With this rational, it was decided to develop the integrated circuit tuned amplifier instead of the discrete component device.

C. INTEGRATED CIRCUIT TUNED AMPLIFIER

The integrated circuit chosen for the heart of the tuned circuit is a general purpose operational amplifier (RCA's CA3015). The configuration of this operational amplifier is a cascade of two differential amplifiers which gives large voltage gain. The differential amplifiers are then followed by a third stage in the form of an emitter follower to add current gain. In the CA3015 the open loop voltage gain of the whole package turns out to be 70 db.

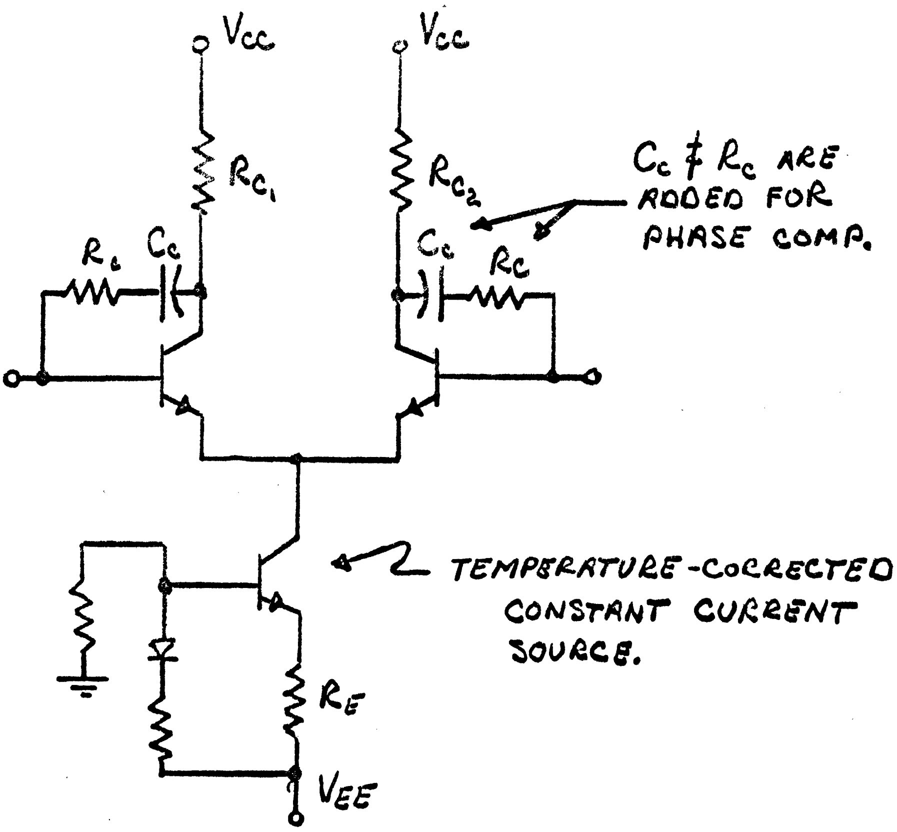
The procedure for applying a linear integrated circuit to a particular application is well documented in many reports. See references 3, 4, and 5 at the end of this chapter for a detailed discussion. The particular circuit I found suitable for our needs is shown in figure 3-D. However, there were several problems unique to this application and they are discussed in brief below.

1. The very high gain (70 db) of the operational amplifier made it very sensitive to outside noise and often caused it to degenerate into 10Mhz oscillations. The remedy here involves modifying the circuit's frequency response so that when the output of the amplifier is in phase with the input, the loop gain of the system is less than unity. A more practical way of saying this is that a Bode plot of the circuit must fall below 0 db before it begins to drop off at 12 db per octave.

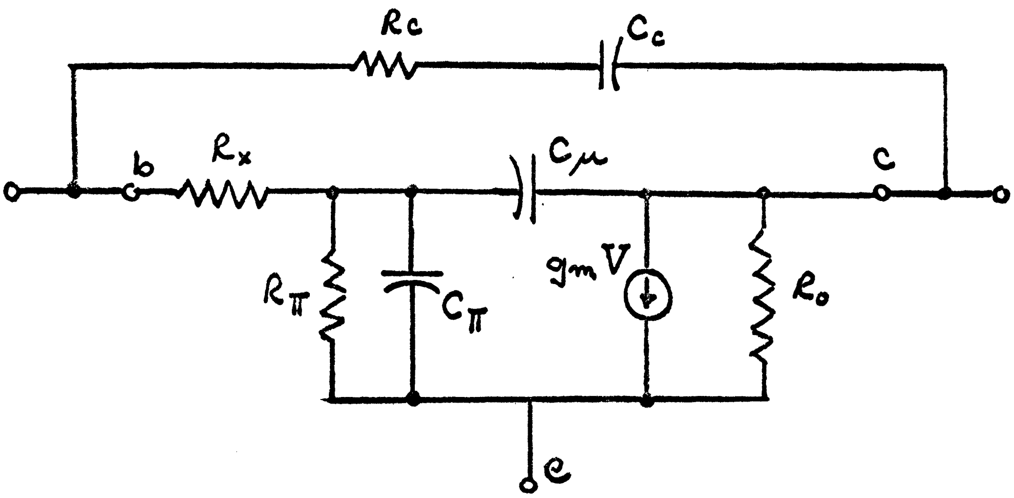
A conventional way to stop uncontrolled oscillation is to slap an R-A configuration from output to ground. However, in my case the capacitor required to do this was impractical. Hence, I used a Miller effect technique on the second differential amplifier to cut the gain of the amplifier at the troublesome high frequencies. The principle can be seen in figure 3-E.

MILLER EFFECT PHASE COMPENSATION

(FIGURE 9.E)



THE ABOVE IS A DIFFERENTIAL AMPLIFIER USED AS THE 2ND STAGE IN THE CA3015.



A HYBRID π MODEL OF THE TRANSISTOR SHOWS WHERE R_c & C_c ARE LOCATED W.R.T. C_μ

I have merely placed a resistor and capacitor across the base and collector terminals of each transistor of the differential amplifier. This lowers the break frequency of the amplifier to the point that the 180° phase shift point is now safely below the 0 db mark. The major advantage of this method is that small (80 pf), cheap capacitors could be used.

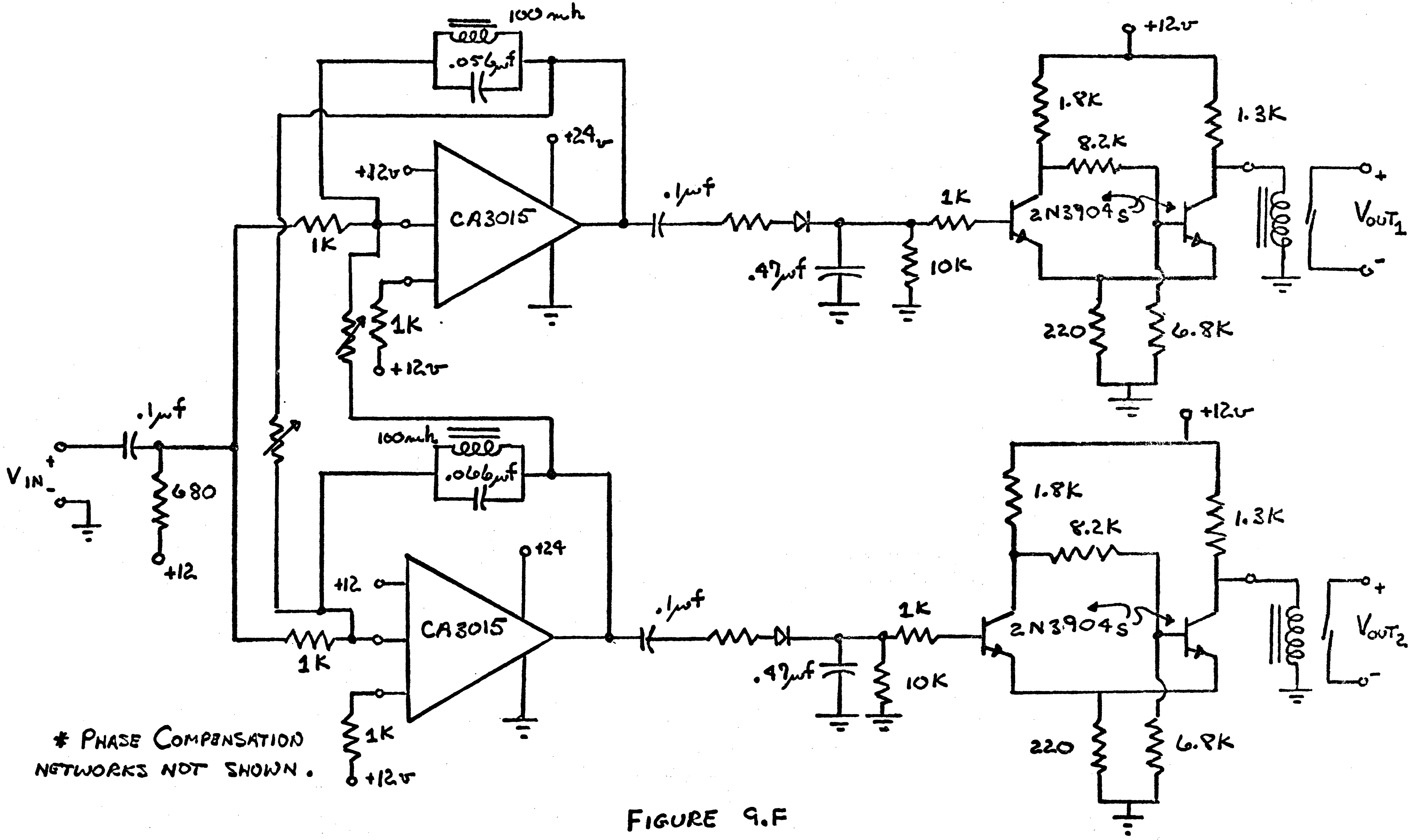
2. The tuned response of the amplifier was accomplished by making the feedback impedance Z(f) a function of frequency. Since the open loop gain of the operational amplifier is very large, to a close approximation:

$$A(w) = Z(f)/Z(in)$$

Therefore, the Q of the tuned circuit, as shown in figure 9-D, is very nearly as high as the LC tank used for the feedback impedance. Depending on the losses in the inductor, I can easily get Q's between 10 and 14 using standard components.

3. We decided to use two answerback frequencies (1784 HZ and 2025 HZ) in our prototype terminal. Therefore, two of the above described tuned amplifiers, as arranged in figure 9-B, should do the task. A more discriminative system can be obtained, however, by using each tuned amplifier to modify the input signal to the other amplifier. The circuit configuration is shown in diagram 3-F. At one of the two resonant frequencies, the output of the resonant tuned amplifier is exactly 180° out of phase with the input. (Z(f) is purely resistive). If this output signal is then fed to the input port of the non-resonant amplifier via R_c, and if R_c is readjusted until V(C) is equal to V(in), the only output at the non-resonant port should be low level noise. This turns out to be very nearly the case, as shown in the frequency response curves at the end of the chapter. Note that now our tuned circuits are not only peaked at desired frequencies, but they also drop down into the random noise level at certain "anti-resonant" frequencies. This feature is very significant because 1785 HZ and 2025 HZ are the only two frequencies which should occur in this audio region at any significant power level.

Complete Receiver Circuit



* Phase Compensation networks not shown.

Figure 9.F

The theory underlying this "cross-feed" technique is discussed in the supplement at the end of this chapter.

D. TRIGGER CIRCUIT

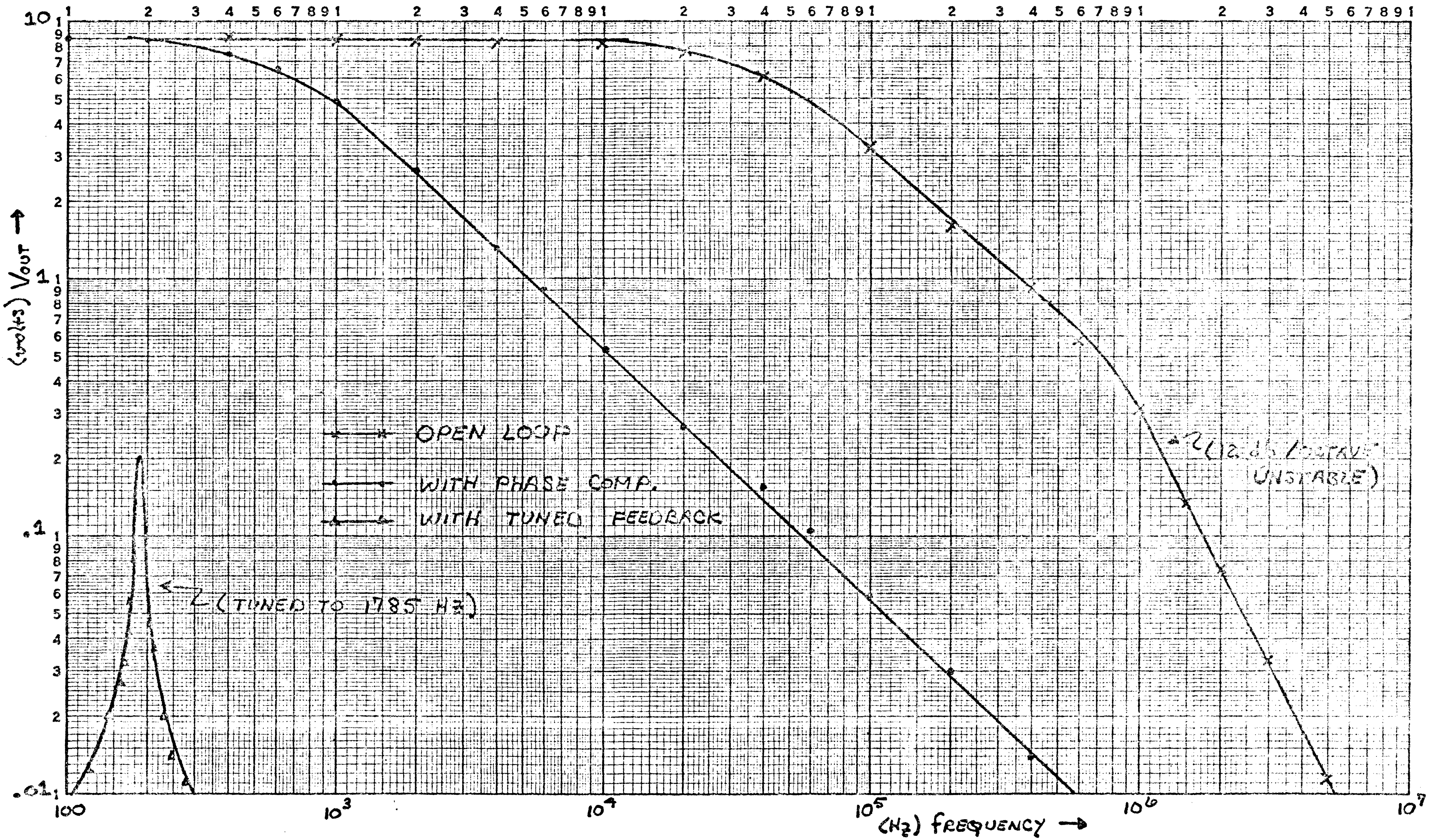
The output of the tuned amplifier must now be transformed into relay contact closures. This is accomplished by using peak rectifiers followed by Schmidt triggers to run the coils of reed relays. The complete circuit is shown in figure 3-G. The design of this circuit is of an elementary nature and for further discussion of these topics the reader is referred to references 1 and 2 at the end of the chapter.

E. COST ANALYSIS

The price of the parts for the signal receiver are given below. No attempt is made to estimate the manufacturing cost of the circuit since this will be covered in detail in appendix D.

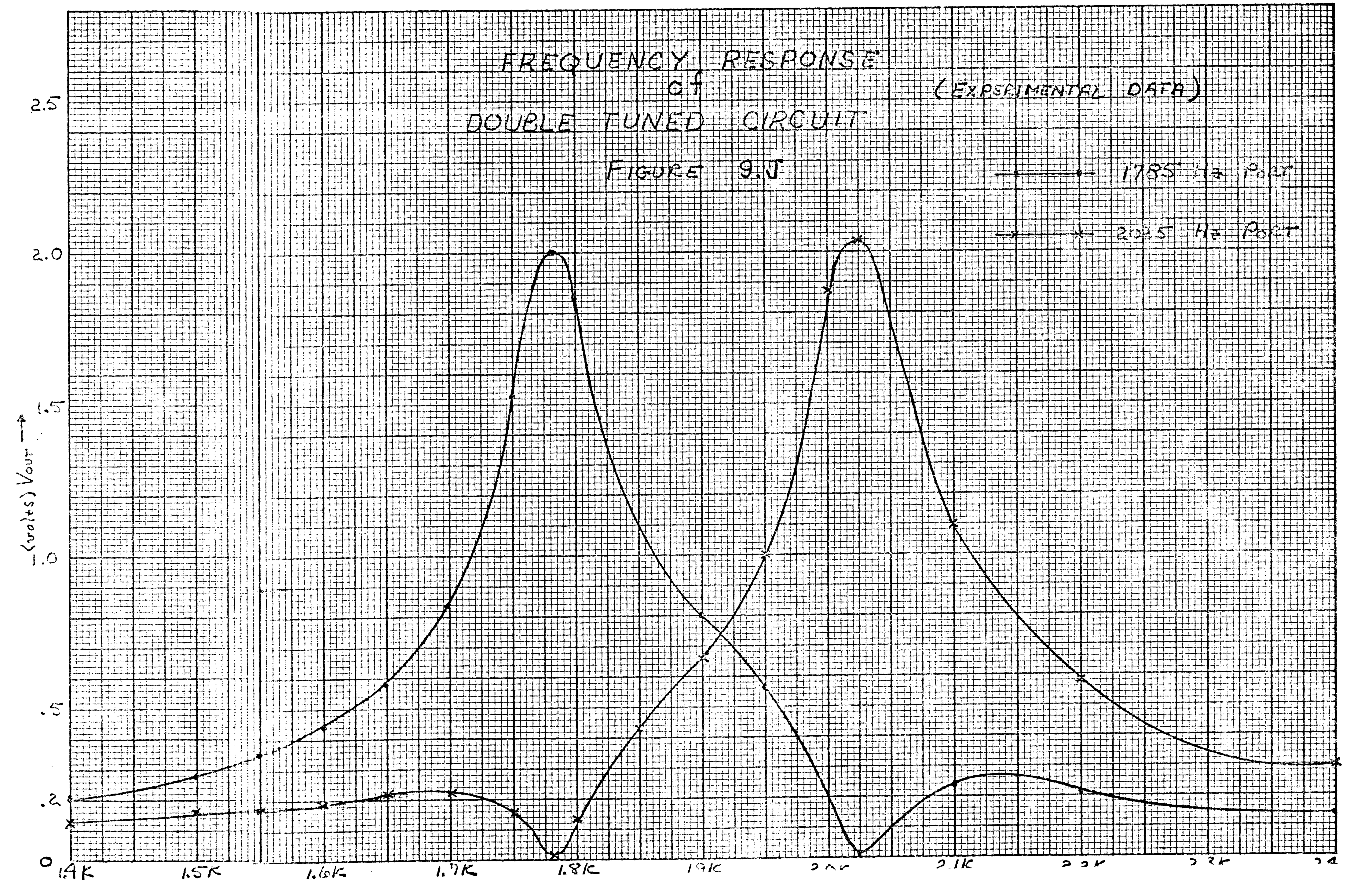
NUMBER OF PARTS	COMPONENT	PRICE/PART	TOTAL PRICE
2	CA3015	$1.75	$ 3.50
4	2N404	.23	.95
20	.25 watt, ± 10% Resistors	.042	.82
4	80 pf capacitors	.09	.36
2	.01 uf capacitors	.23	.46
2	reed relays	1.23	2.46
2	trim pots	.98	1.96
1	printed circuit board	1.00 (approx.)	1.00
			$11.51 (TOTAL)

EXPERIMENTAL FREQUENCY RESPONSE OF OP. AMP.



V_{IN} = .01 v

FIGURE 9.H


FREQUENCY RESPONSE
of
DOUBLE TUNED CIRCUIT
FIGURE 9.J
(EXPERIMENTAL DATA)
1785 Hz Port
2025 Hz Port
(volts) Vout
2.5
2.0
1.5
1.0
.5
.2
0
1.4K
1.5K
1.6K
1.7K
1.8K
1.9K
2.1K

SUPPLEMENT

(CALCULATION OF TRANSFER FUNCTION FOR TUNED CIRCUIT)

I SINGLE STAGE

1. $A(\omega) \triangleq \dfrac{V_{OUT}}{V_{IN}} \cong -\dfrac{Z_f}{Z_{IN}}$ FOR GAIN $\longrightarrow \infty$

2. $Z_f = \dfrac{1}{CS} \parallel R + LS$ (ASSUME COIL HAS A FINITE R)

3. $A(\omega) = -\dfrac{S + \frac{R}{L}}{C\left(S^2 + \frac{R}{L}S + \frac{1}{LC}\right)}$

4. $A(\omega) = \dfrac{L\omega_0^2\left(S + \frac{R}{L}\right)}{S^2 + \frac{R}{L}S + \omega_0^2}$ WHERE $\omega_0 \triangleq \dfrac{1}{\sqrt{LC}}$

II DOUBLE TUNED CIRCUIT

1. FOR THE CIRCUIT DISCUSSED IN THIS CHAPTER:

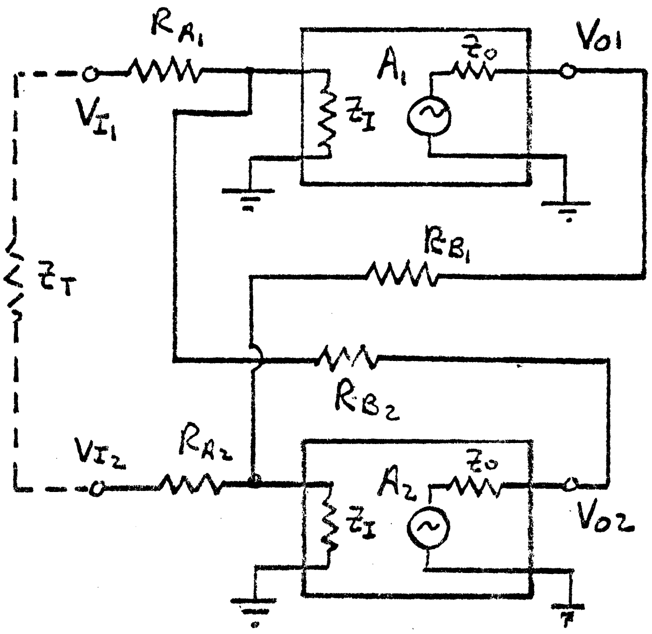
$R_{A_1} = R_{A_2} = R_A$

$Z_{I_1} = Z_{I_2} = R_I$

$Z_{o_1} = Z_{o_2} \cong R_o$

$V_{I_1} = V_{I_2} = V_I$

$Z_T \rightarrow \infty$



2. $V_{O1} = A_1(\omega)\left[\dfrac{(R_{B2}+R_o)\parallel R_I}{R_A + (R_{B2}+R_o \parallel R_I)} V_I + \dfrac{R_I}{R_I + R_{B2} + R_o} V_{O2}\right]$

3. $V_{O2} = A_2(\omega)\left[\dfrac{(R_{B1}+R_o)\parallel R_I}{R_A + (R_{B1}+R_o \parallel R_I)} V_I + \dfrac{R_I}{R_I + R_{B1} + R_o} V_{O1}\right]$

4. $R_{X1} \triangleq \dfrac{(R_{B1}+R_o)\|R_I}{R_A+(R_{B1}+R_o)\|R_I}$; $R_{X2} \triangleq \dfrac{(R_{B2}+R_o)\|R_I}{R_I+(R_{B2}+R_o)\|R_I}$

$R_{Y1} \triangleq \dfrac{R_I}{R_I+R_{B_1}+R_o}$; $R_{Y2} \triangleq \dfrac{R_I}{R_I+R_{B_2}+R_o}$

5. NOW REPLACING V_{O2} IN #1 BY EQN. #2 :

$$V_{O1} = A_1(\omega)\left[R_{X2} V_I + R_{Y1}\left(A_2(\omega)[R_{X1}V_I + R_{Y2}V_{O1}]\right)\right]$$

6. $$V_{O1} = A_1(\omega)\left[V_I\left(R_{X_2} + R_{X1}R_{Y1}A_2(\omega)\right) + R_{Y1}R_{Y2}A_2(\omega)V_{O1}\right]$$

7. $$V_{O1}\left(1 - R_{Y1}R_{Y2}A_1(\omega)A_2(\omega)\right) = A_1(\omega)V_I\left(R_{X2}+R_{X1}R_{Y1}A_2(\omega)\right)$$

$\therefore$ 8. $$\frac{V_{O1}}{V_I} = \frac{A_1(\omega)\left(R_{X2}+R_{X1}R_{Y1}A_2(\omega)\right)}{1 - R_{Y1}R_{Y2}A_1(\omega)A_2(\omega)}$$

9. NOW TRANSFORM #8 INTO THE S-DOMAIN :

a. $$\frac{V_{O1}}{V_I} = \frac{\dfrac{R_{X2}\omega_1^2(S+\frac{R}{L})}{(S-S_1)(S-S_2)} + \dfrac{R_{X1}R_{Y1}\omega_1^2\omega_2^2(S+\frac{R}{L})^2}{(S-S_1)(S-S_2)(S-S_3)(S-S_4)}}{1 - \dfrac{R_{Y1}R_{Y2}\omega_1^2\omega_2^2(S+R/L)^2}{(S-S_1)(S-S_2)(S-S_3)(S-S_4)}}$$

b. $$\frac{V_{O1}}{V_I} = \frac{R_{X2}\omega_1^2(S+R/L)(S-S_3)(S-S_4) + R_{X1}R_{Y1}\omega_1^2\omega_2^2(S+\frac{R}{L})^2}{(S-S_1)(S-S_2)(S-S_3)(S-S_4) - R_{Y1}R_{Y2}\omega_1^2\omega_2^2(S+\frac{R}{L})^2}$$

c. $$\frac{V_{O1}}{V_I} = L\omega_1^2(S+\frac{R}{L})\frac{R_{X2}(S-S_3)(S-S_4) + R_{X1}R_{Y1}L\omega_2^2(S+\frac{R}{L})}{(S-S_1)(S-S_2)(S-S_3)(S-S_4) - R_{Y1}R_{Y2}\omega_1^2\omega_2^2(S+\frac{R}{L})^2}$$

---

* NOTE:
$S_1, S_2 = \dfrac{-\frac{R}{L} \pm \sqrt{\frac{R^2}{L^2} - 4\omega_1^2}}{2}$; $S_3, S_4 = \dfrac{-\frac{R}{L} \pm \sqrt{\frac{R^2}{L^2} - 4\omega_2^2}}{2}$

$\dfrac{R_1}{L_1} = \dfrac{R_2}{L_2} = \dfrac{R}{L}$

10. WITHOUT SOLVING THE EQN. ANY FURTHER WE CAN SEE:

A. THERE WILL BE ZEROS IN THE REGION OF S_3 & S_4. WE CAN MAKE THESE ZEROS ARBITRARILY CLOSE TO THE IMAGINARY AXIS BY THE PROPER SELECTION OF FEEDBACK RESISTOR R_{B2}.

B. POLES ARE IN REGIONS SURROUNDING S_1, S_2, S_3, S_4.

C. EXPERIMENTAL DATA SHOWED POLES S_1 & S_2 TO BE SHIFTED VERY LITTLE FROM THEIR ORIGINAL POSITIONS

D. THE ZEROS IN THE S_3 & S_4 REGIONS WERE MUCH CLOSER TO THE IMIGINARY AXIS THAN WERE THE POLES IN THIS REGION.

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CHAPTER 10

A. INTRODUCTION

A key problem in the design of the remote credit terminal was the integration and sequencing of the individual sub-systems. A method was needed to combine the functions of the automatic dialer, the card reader and price readout, the data receiver and display. A method was also needed to sequence each unit to produce uniform data output and input.

Two systems were discussed and recommended to meet these requirements. The first was a system composed of electronic components and the second was composed of electro-mechanical components. The former system was eliminated as a possible working design for the following reasons:

1. The system would be costly and complex.
2. Being complex, the system would more likely have failure of components.
3. The system would be too sensitive to changes in temperature and humidity.

The latter system was chosen for the following reasons:

1. The system is simple and inexpensive.
2. The system is reliable and consists of few components.
3. The system is not appreciably effected by large changes in temperature and humidity.

The electro-mechanical system consists of a stepping relay, a manual reset switch, and a delay timer. The stepping relay is sequenced through its contact positions by the "Start" switch and then by a switch controlled by tones sent by the computer. The timer resets the relay contact position if the computer doesn't send back the "on-line" tone within five seconds after the computer is called. The timer also resets the relay after the "Credit Good" light has been on for five seconds. The manual reset switch is used if there is an error in the system or if any indicator light other than the "Credit Good" light is on. (See figure 10-B for the circuit diagram). Figure 10-C and 10-D shows the housing for the system. The automatic dialer and the data phone are incorporated within the same housing as the stepping relay (See figure 10-C). With further refinements in circuit and equipment layout, the total unit size can be reduced greatly.

B. DESCRIPTION OF SYSTEM OPERATION

Initially the stepping relay is in position "1" (See figure 10-E). At this position the telephone line is disconnected. When the credit card, the receipt, and the price is set, the start button can be depressed. This triggers the automatic dialer. Within five seconds, either an "on-line" signal is sent from the computer applying voltage to the carriage release on the reader mechanism, or the relay will be reset by a five second delay timer. After the carriage is released and has completed the data transmission, signals again are received from the computer. In this series of signals the credit condition of the individual is sent back in the form of keyed audio signals. Each time the signal is keyed by the computer the step relay jumps one step. Every two keyed signals relates to a condition of credit. For example: The step relay is in position "3" when the information returns from the computer. The first credit condition "Credit Good" is at position "5", the next is "Lost Card" which is at position "7". This continues, placing credit responses at every odd numbered position. The even numbered positions after "3", position "13", and all numbered positions after "15" are common and are connected to the "Error" light and buzzer. This is protection in case a signal is lost or gained during the transmission of data. With this safety factor, the error rate in transmission is reduced by half.

If the purchaser's credit is good, a five second delay timer resets the step relay. All other positions on the relay must be reset with the manual reset switch. The attendant must manually reset the carriage by moving it back to its original position. A contact switch is positioned at the starting position of the carriage so that the switch closes when the carriage is returned. This contact switch is in series with the "Start" button so that the carriage must close the switch in order for the computer to be called.

C. THE POWER SUPPLY

The power supply must provide a constant voltage to each sub-system regardless of variations in line voltage.

A circuit consisting of a step-down transformer and four Zener diodes is used to provide a constant voltage to each component (see figure 10-A). The transformer reduces the line voltage to a more usable value, and also helps to limit the effects of voltage spikes on the line. Diodes D_1 and D_2 rectify the reduced voltage, and Capacitors C_1 and C_2 smooth the waveform. Resistors R_1, R_2, R_3 and R_4 limit the current in Zener diodes D_3, D_4, D_5 and D_6.

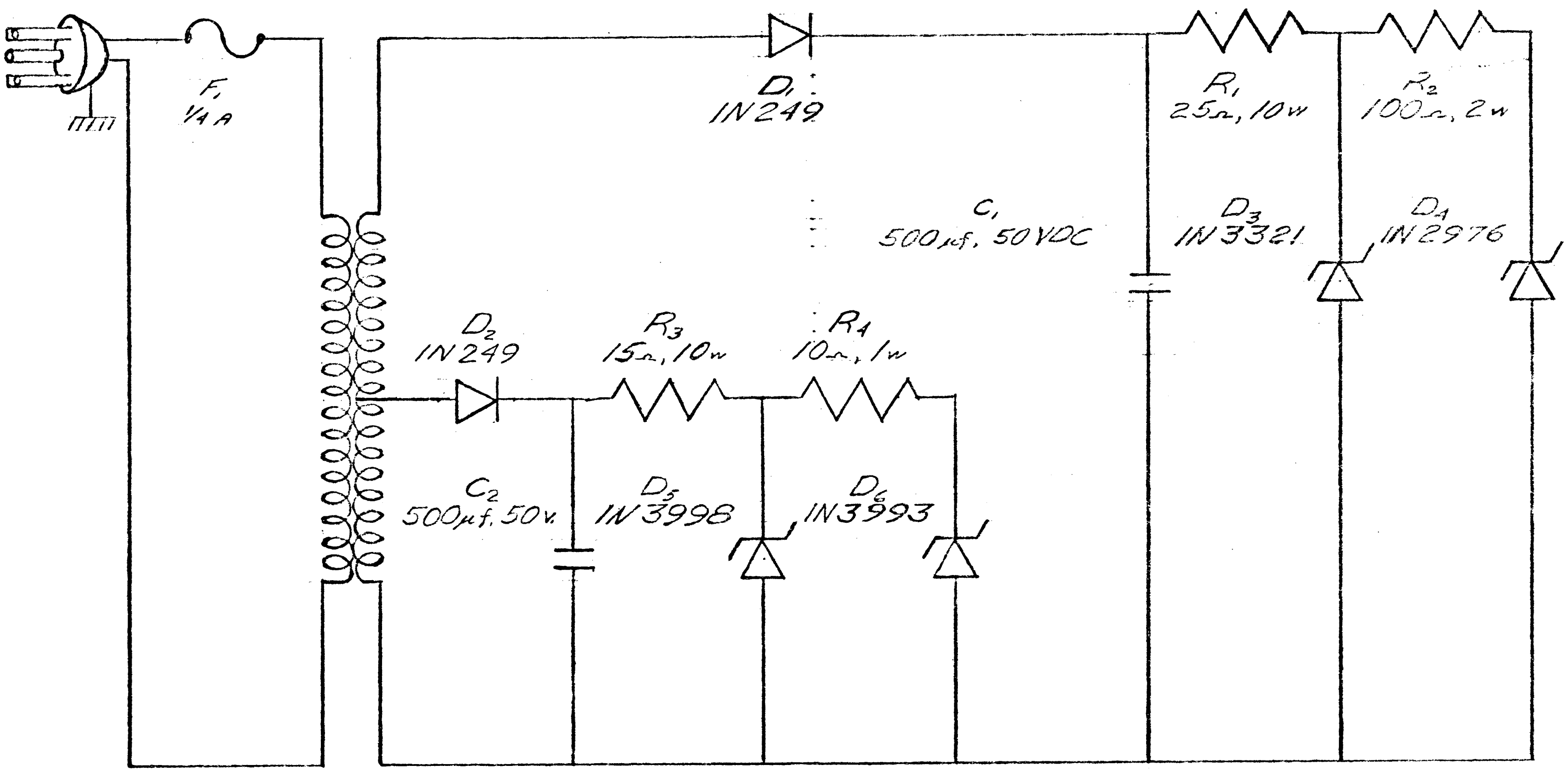
The secondary winding of the transformer will pass two amperes, diodes D_1 and D_2 will each pass twenty amperes, and the Zener diodes will each pass more than two amperes. The design insures that fuse F_1 will blow before any damage is incurred by any other component.

The power supply is designed to use Zener diodes instead of special transformers or voltage dividers to insure that a constant voltage can be supplied to the critical areas of the system such as the logic packages or the photo-cell reader. A specially wound transformer would provide the proper voltages, but it would also pass any interference on the line to the system possibly damaging some of the components. The extra expense incurred by specifying Zener diodes is overshadowed by the availability of the components and the increased reliability that they impart to the rest of the system.

At the time of this writing, the testing of all possible sub-systems is not complete. To prepare for any sub-system that might be used, the power supply is designed to deliver the four voltages which might be needed. If it is found that a voltage is not needed, the Zener diode and accompanying resistor may be removed with the only change being a reduction in cost.

THE POWER SUPPLY

FIG. 10-A



ALL TOLERANCES ±10 %

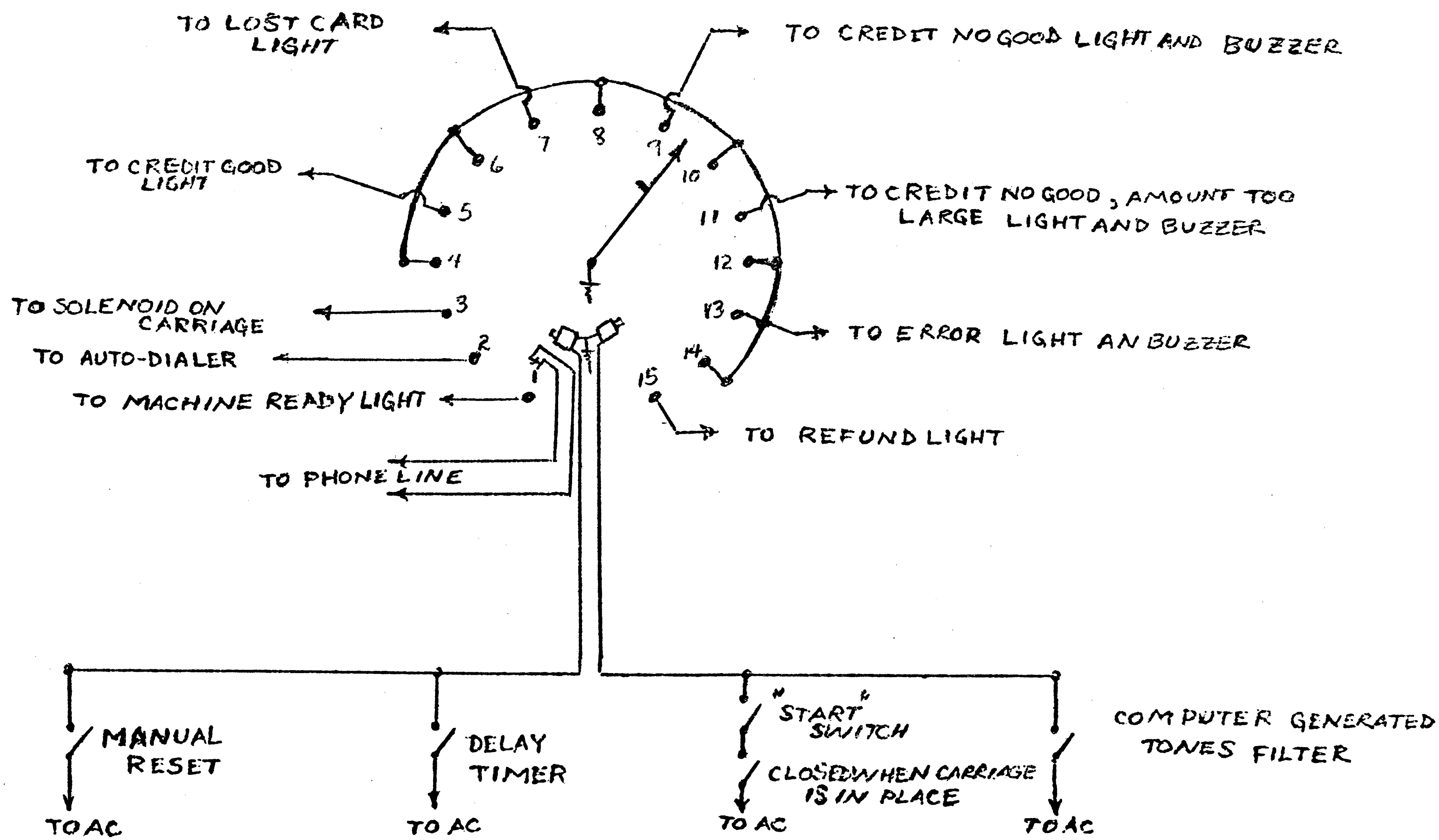


FIGURE 10-B STEPPING RELAY SCHEMATIC

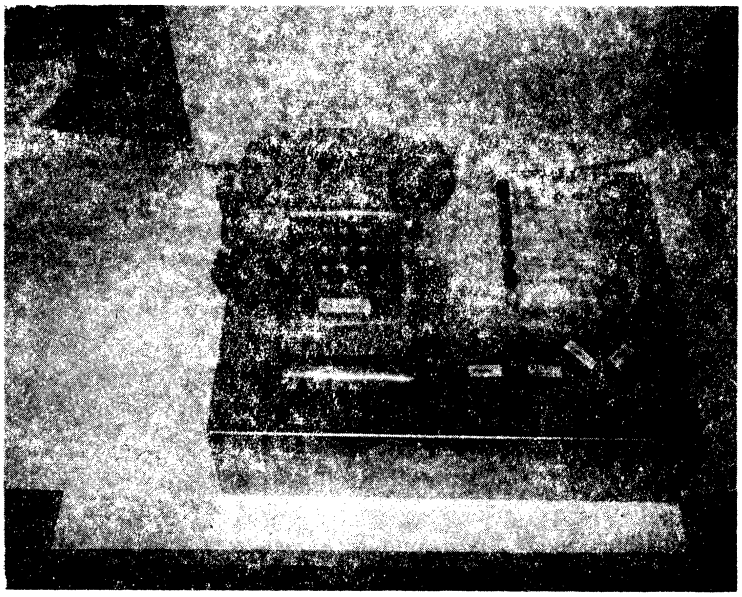


Figure 10-C Sequencer Housing

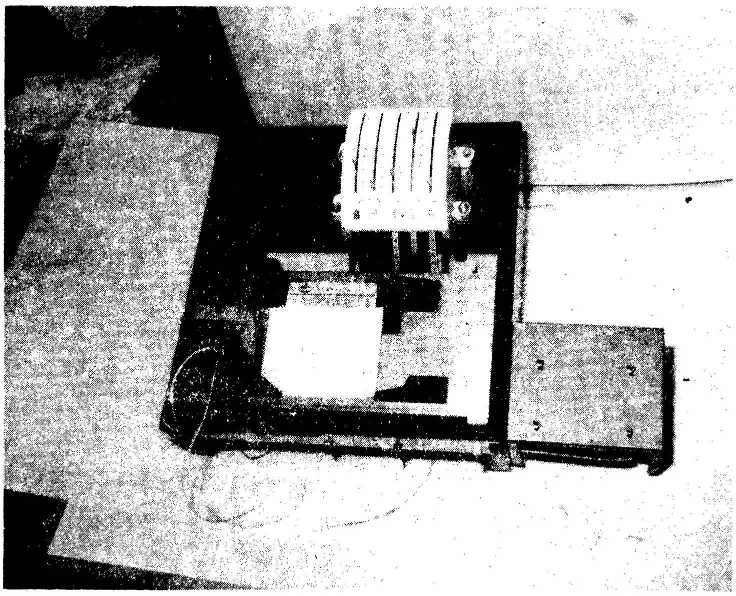


Figure 10-D Altered ADDRESSOGRAPH

RESET STIMULUS FROM	STEP STIMULUS FROM	POSITION	RESULT
DELAY OR MANUAL		1	MACHINE READY LIGHT "ON" PHONE LINE DISCONNECTED
	"START" SWITCH	2	STARTS AUTO-DIALER
	COMPUTER ANS. "ON-LINE"	3	APPLY VOLTAGE TO CARRIAGE RELEASE
DELAY	COMPUTER GENERATED TONES	5	CREDIT O.K.(START DELAY) RESET AFTER 5 SEC.
MANUAL	COMPUTER GENERATED TONES	7	LOST CARD (BUZZER SOUNDS)
		9	CREDIT NO GOOD (BUZZER)
		11	CREDIT N.G. AMT TOO LARGE (BUZZER)
		13	ERROR REPEAT TRANSMISSION (BUZZER)
		15	REFUND COMPLETE (BUZZER)

TIME

FIGURE 10-E TIME DIAGRAM OF STEP RELAY

CHAPTER 11

COMPUTER SYSTEM

INTRODUCTION

It has been stated earlier in the paper that a common fault of present credit card systems in the United States is default on credit purchases. This system is being developed to cut down the amount of money lost in this fashion by checking whether the customer's financial situation is such to warrant granting credit. The purpose of the computer system is to actually carry out this checking procedure in a fast, dependable and economic fashion.

MACRO-SYSTEM

The extent to which this system might be applied depends on the demand and costs. It could cover the entire United States or be contained within a single firm. Both systems service similar demands, but the most economical solution depends on the extent the credit system will be employed. The centralized computer which handle credit checks for all people and all firms that extend credit would certainly be more complicated than a credit check system developed for use by only one firm and its clientel. Thus it would require more sophisticated and more expensive equipment. Both have their merits, and the choice would depend on the size of the firm and its influx of business. A large firm like Standard Oil would choose the larger system for an efficient nationwide checking system, but a firm like Green's Cleaners, who sell their service to a fairly small local would subscribe to the smaller system. Another solution to this problem would be combine the nationwide network with the local networks in such a way as to permit nationwide service without raising the cost of local service. This can be accomplished in the following system. Every city would contain its own computer varying in size depending on the size of the city. The residents of this city and of nearby villages which are not large enough to warrant a computer would obtain a certain memory location in the computer's core when he obtained his credit card. In this memory block would be contained his file of financial data. This file contains the information the computer will use to decide whether or not to extend credit. All business firms in the community who extend credit to the customers would have remote terminal access to this computer. Thus any local credit transaction, i.e. those involving customers and firms of the same community, would be handled only in this local computer. Thus we still have the advantages of the relatively simpler local computer system. Now consider the position of the person who is traveling and would like to buy gasoline in a community other than his own. Clearly the local computer cannot decide to extend this person credit, for it knows nothing of the person's financial situation. The way this credit check is handled is the following. The firm contacts the local computer. The local computer identifies the person's ID number as one not contained in it storage. It then calls the correct computer over the telephone lines and relays the input data to that station. After that computer has performed the credit check, it would relay its answer to the local computer which would in turn relay it to the terminal in the firm. Another possibility would be to use part of the credit card number itself as the telephone number of the computer storing that person's data. This would effectively give every terminal access to all the computers. The present terminal does not have this facility, but for a few more dollars, it could be included as part of the design. This would eliminate part of the task of the computer system, and slightly increase the speed at which credit checks could be made. However, it would make the terminal slightly more expensive. This would be a disadvantage to firms who only offer credit to the residents of the community, say for example a plumbing service which has no demand from customers outside the community. To solve this problem, two different models could be built, one with the feature of variable automatic dialing, the other solely for local service. In this way certain firms would not be required to purchase a feature they weren't going to use. That concludes the basic description of the communications systems involved with credit checking.

One other communications problem remains. If someone buys gasoline from Standard Oil on credit, how will Standard Oil know it has made a sale. There are two ways this can be handled. First, there's the present system in which a copy of the receipt is sent to the central office of the firm. The problem can also be handled much the same as the above problems were. Each firm which is willing to extend credit will have one or more credit numbers, depending on the size of the firm. All items produced by a certain firm would contain the number of the account to which the debt is due. This would be transmitted to the computer as part of the input data. At the end, the local computers will print out credit statements to the local credit holders. For the section of the computer devoted to firms, the stored information would be relayed to two computers, one centralized in the east, the other in the west. These would print out statements to all of the firms in the United States. This accounting feature can be added to the simple credit check system without appreciable difficulty.

To discuss all the problems involved in this accounting system in detail would take a great deal of time. However, you can understand the general handling procedure if you remember that any exchange of money (or credit) necessarily involves two parties, the "buyer" and the "seller". The computer system forms the communication line between the storage blocks of the buyer and seller. Transactions occur when certain numbers change in the appropriate storage areas. All procedural problems are solved by software which is based on this general concept.

Note: The terms "buyer" and "seller" are general terms and refer to customer and merchant, branch office and central office, gas station and its oil company, etc. Here I'll conclude the general discussion of the macro system and move on to the micro-system, the computer system in any one city.

For the sake of clarity, we divide the description into three functional areas. (1) storage, (2) input-output, and (3) operations control, i.e. software.

STORAGE

From the above discussion you no doubt realize that a large demand is placed on the storage facilities of a computer. Besides storing the financial data of the local credit card holders, it must store the software program for its control and calculatory operations, the ID numbers of computers in other localities, and the ID numbers and storage cells of local firms. There are several devices already developed which can handle this job. They are generally divided into two groups determined by the means of access to storage, (1) Sequential (2) random access. In Sequential access, the locations in storage are searched sequentially from a starting point until the correct location is found. In random access, the storage area is divided into smaller referenced areas, thus permitting more direct access to the desired location. The difference between these two groups is analogous to the difference between looking for a word in the dictionary word by word and looking for it under the correct letter.

A means of storage which bears particular value is magnetic strip storage. The following information was obtained from the booklet, <u>CREDIT BUREAU OPERATIONS ON THE IBM SYSTEM/360</u>.

INPUT-OUTPUT

The input to the computer system is in the form of touch tone signals. An appropriate interface must be used to transform these signals into an input acceptable to the computer. A system for a small city could involve a PDP-8. This is what we've been working with. The appropriate interface for the PDP-8 is the Western Electric 403D Data Set.

The remote terminals obtain access to the computer system simply by automatically dialing the interfaces telephone number (or having another computer dial). When contacted the interface will return a signal to indicate it's ready to receive the data. If it is busy with another call, it will return the busy signal.

The interface accepts signals of 40 msec. in duration with an interpulse time of 45 msec. and whose total power may vary 40 db. When it receives a touchtown frequency signal it translates the signal into the digit system by setting the appropriate bit in the twelve bit register which is buttered to the accumulator in the computer. In other words, if a touch tone signal representing the number four was received, the fourth bit of the accumulator would be set to 1, all others are 0. This actually represents Z^4 in the computer's binary code. The interface also sets a flag bit, which tells the computer it has data ready for it. The computer is constantly scanning the flags of all input devices. When one is thrown and if the computer is operating with "interrupts on", the current action of the computer will halt, the address of the instruction which would have been executed next if the computer had not been interrupted will be stored so the computer can continue with what it was doing after the input device is serviced.

A subroutine in the computer will then translate the accumulator contents into the number four. It does this by rotating the accumulator until it finds the "one" bit. We obtain the desired number by counting the number of positions shifted. This number will then be stored in a temporary storage location in the computer. The computer will count the total number of numbers transmitted from each device. When it receives a complete message it will check the customer's ID number to determine if his account is contined in its storage. If it is, the location of the input data storage block will be placed in another push down list where it more or less waits in line to be checked by the credit checking program of the computer. Then the computer will continue doing what it was doing before the interrupt, that is, checking the credit of a formerly received block of data. There is no chance that the computer will be swamped from input data. If all devices were delivering data as fast as they could (one number every 95 msec.) we would have an average of one bit of information received by the computer $\frac{95 \text{ mSec.}}{64}$ or 1.5 mSec. The cycle time of the DDP-85 is 1.5 μsec. thus it has time for 1000 cycles between interrupts. The longest instructions require three cycles, therefore, we have time for over 333 operations between interrupts which is plenty for our purposes. If the customer's account is not in the computer, the computer will first check to see if it is an invalid credit card. If it is, it will send back the correct error response to the terminal. If the card is valid the computer will search a list to find what computer has this account and transfer this data to that computer across the telephone lines. The second computer would treat the data as a high priority customer. This data would not have to wait in a pushdown list for service. This is to save on long distance telephone service. The second computer would send the result of the credit check back to the first computer which would relay it to the terminal. As was mentioned before, this feature could be eliminated from the software if the credit card itself determined the computer contacted. The 403D data set is also an appropriate interface for output information. It has three answer back frequencies, 1017, 1785 and 2025Hz. According to the state of the credit, the computer will cause the interface to send out a certain number of frequency pulses (in our case 2025Hz). The terminal will relate the number of pulses to the state of credit and activate the appropriate display.

For communication between computers, a faster means than touch tone can be used, for example, teletype (DEC 33ASR). Although not essential, it would shorten data transfers between computers. That sums up the general description of input and output.

COMPUTATION--OPERATION CONTROL

This program controls the computer during the actual credit checking procedure. Its operation is quite simple. It begins the credit check by obtaining a new set of data from its storage. Recall earlier that after a complete set of data arrives in the computer, the address of the storage block is placed at the end of a pushdown list. If there are no numbers in this list, the computer will wait until enough data is read to form a complete data set. If there are completed data sets, the computer will take the number of the first such set placed in the list and use it as the location in the input data it will be using. This data includes the credit card number, the station number, the price, (tax information), and certain control flags. Part of the credit card number is the account number of the customer. The computer uses it to obtain the permanently stored data in the magnetic strip cells of the system. Among the information stored in the cells is the amount of money the person has in his account (positive balance) or how much he owed the account (negative balance) and an index of his financial risks. This index bears a bit of explanation. Not all people have the same financial security, therefore, it would be unjust to extend equal credit to all. The index merely indicates the person's credit standing, and sets a limit to the amount of credit he can have. For example, group 1 may contain people who at any one time may not incur a debt to the system over $250 whereas group 5 may extend credit up to $5000. The computer compares the sum of the person's balance and the price of the article to the index limit. If the sum exceeds the limit, the person will not be extended credit and the appropriate signal will be returned to the terminal. If the sum is less than the limit the price will be subtracted from the balance and the result will replace the number in the balance location in storage. The computer will then return the signal indicating good credit and pass on to the next credit check.

One other feature of operation is the ability to add money to one's account. This is accomplished by setting one of the flags mentioned earlier. If this flag is thrown, the checking subroutine will be bypassed and add the number which was read in as price to the balance. Thus this system can act as both a credit bureau and a checking service, in short an electronic bank.

PARTICULAR SYSTEM

For demonstration purposes, we obtained permission to use a PDP8S computer in Haven Hall which already has a 403D data set connected to one of its input terminals. (Input 13). A soft ware program is currently being written and debugged for this particular demonstration. It will follow the same operating procedure described above but on a greatly reduced scale of magnitude. The major changes are the following.

(1) There's only one input device to the computer servicing touch tone which is accessible to us. Therefore, if we should obtain an interrupt from any other device, we will ignore it and continue with the former program. Only when device 13 causes the interrupt will the computer actuate its data read program.

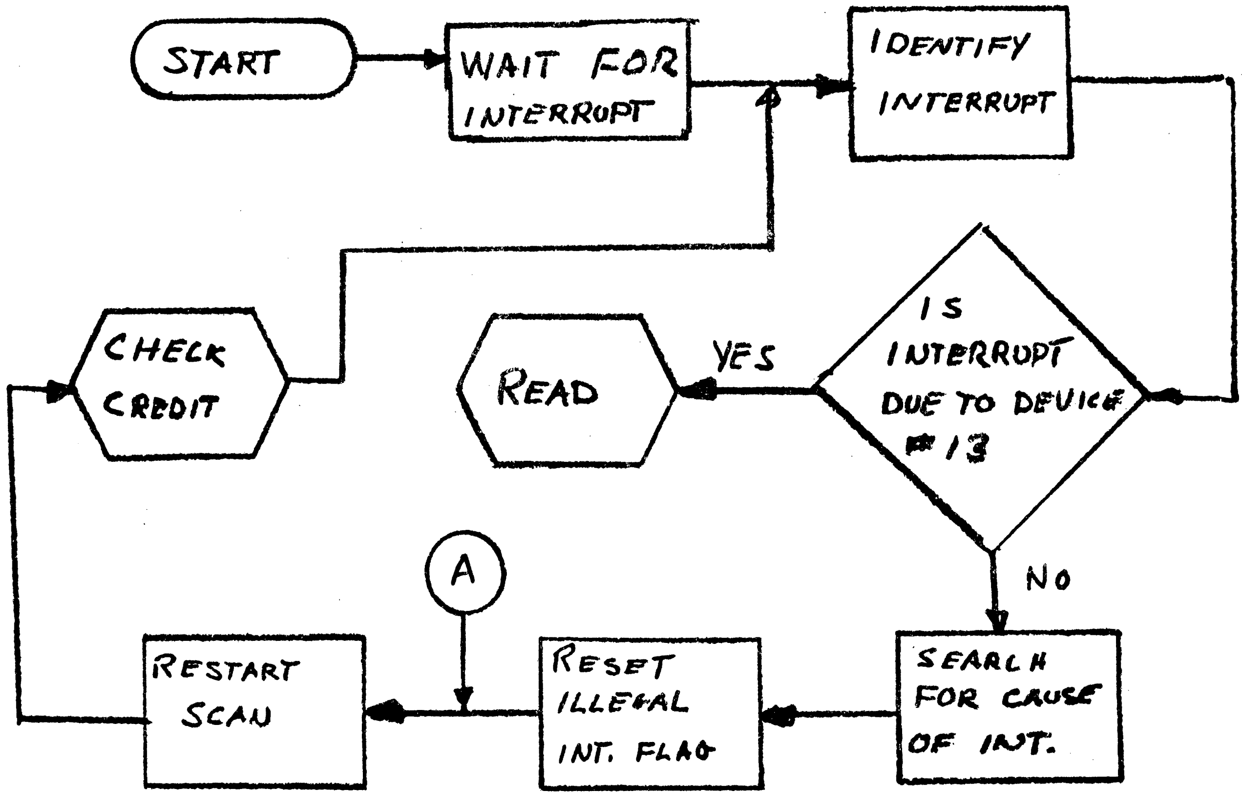
(2) This system will not check the validity of the input credit card number, nor will it directly check to see if the account is contained in storage. It will search the locations reserved for storing the permanent data assuming it will find the corresponding account number. If it fails, it will return the appropriate error signal.

(3) Since we will be using only one remote terminal we can by-pass the second pushdown list. Only one credit check problem will be presented to the computer at a time. Therefore, we have no need to develop a first come, first serve facility.

All other features are essentially the same as the general system described above. Work is also being done in writing the software programs for the general nationwide system. Flow diagrams for both of these systems are included at the end of this chapter.

FIG 11-A FLOW CHART – DEMONSTRATION PROGRAM

INTERRUPT:



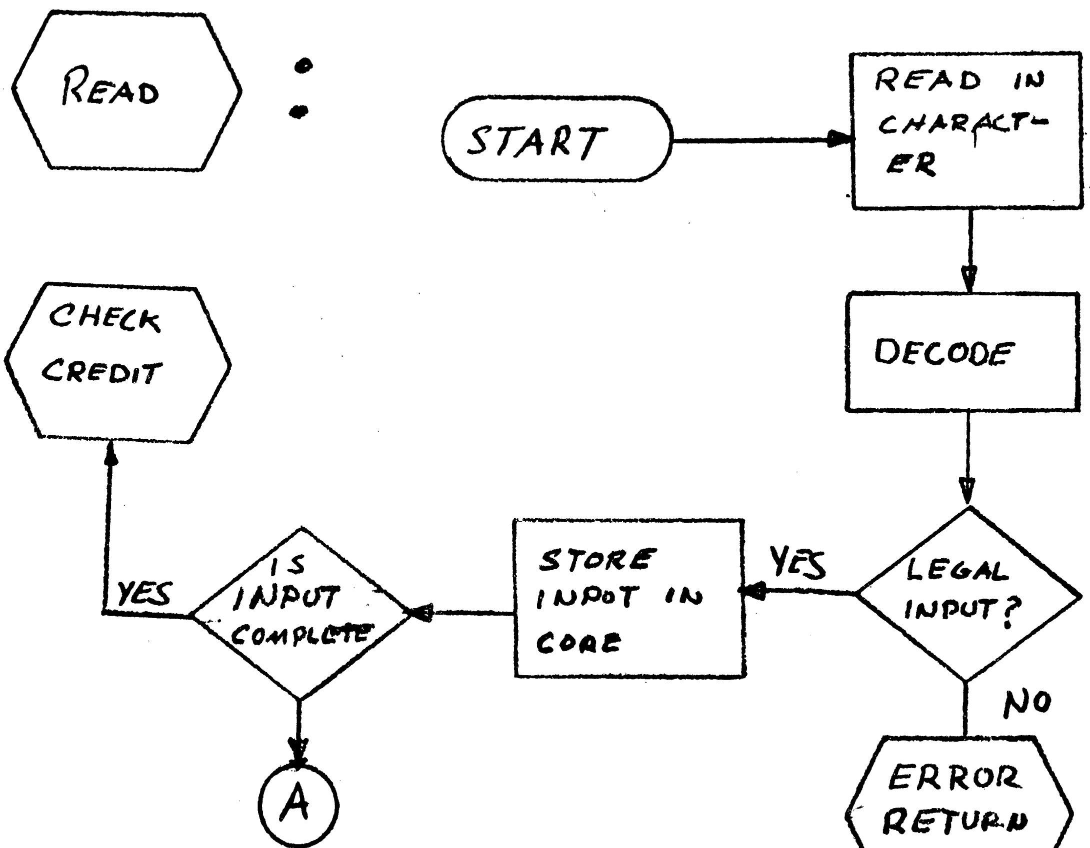


Fig 11-B Demonstration Program (cont)

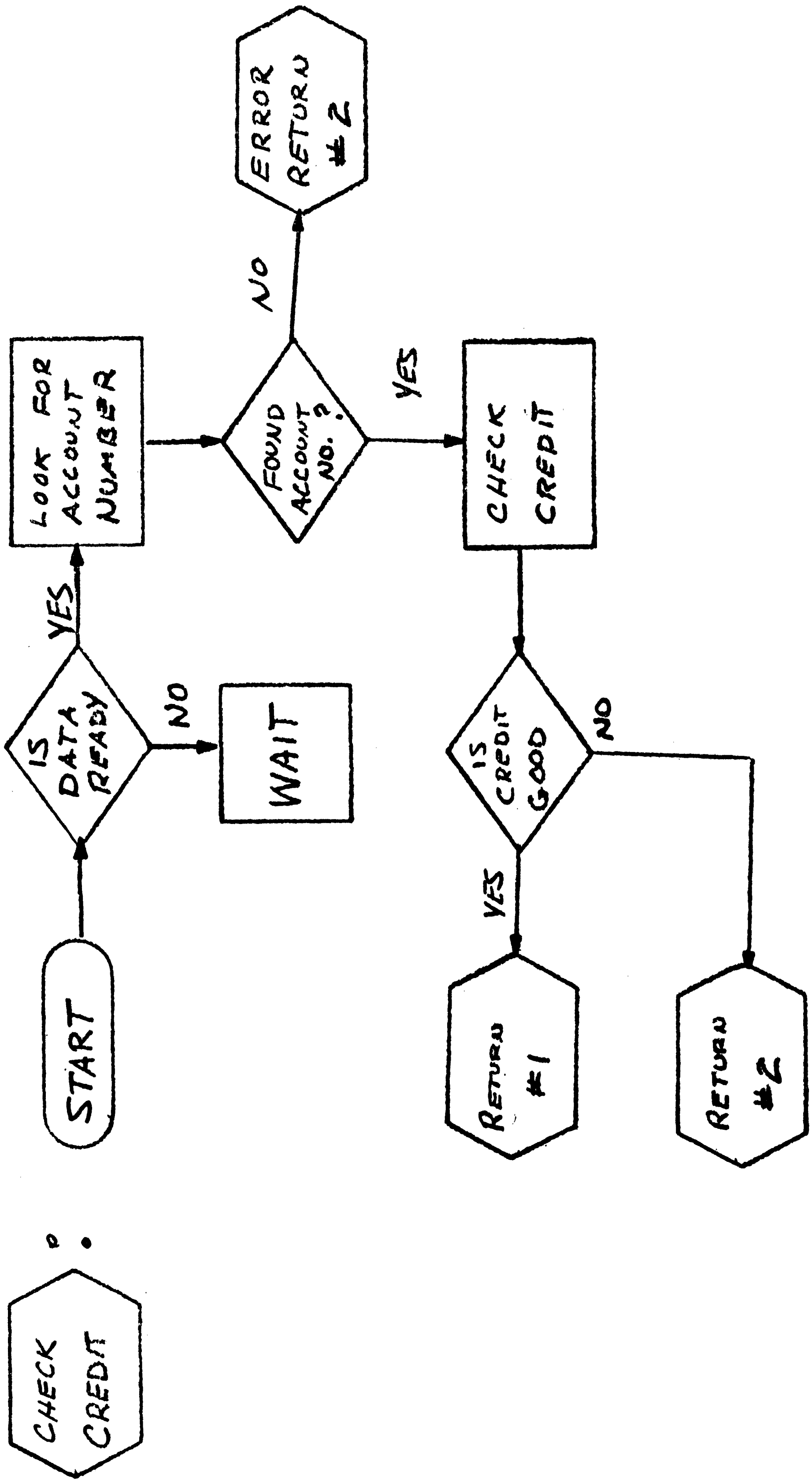


FIG 11-C OUT PUT SUBROUTINES

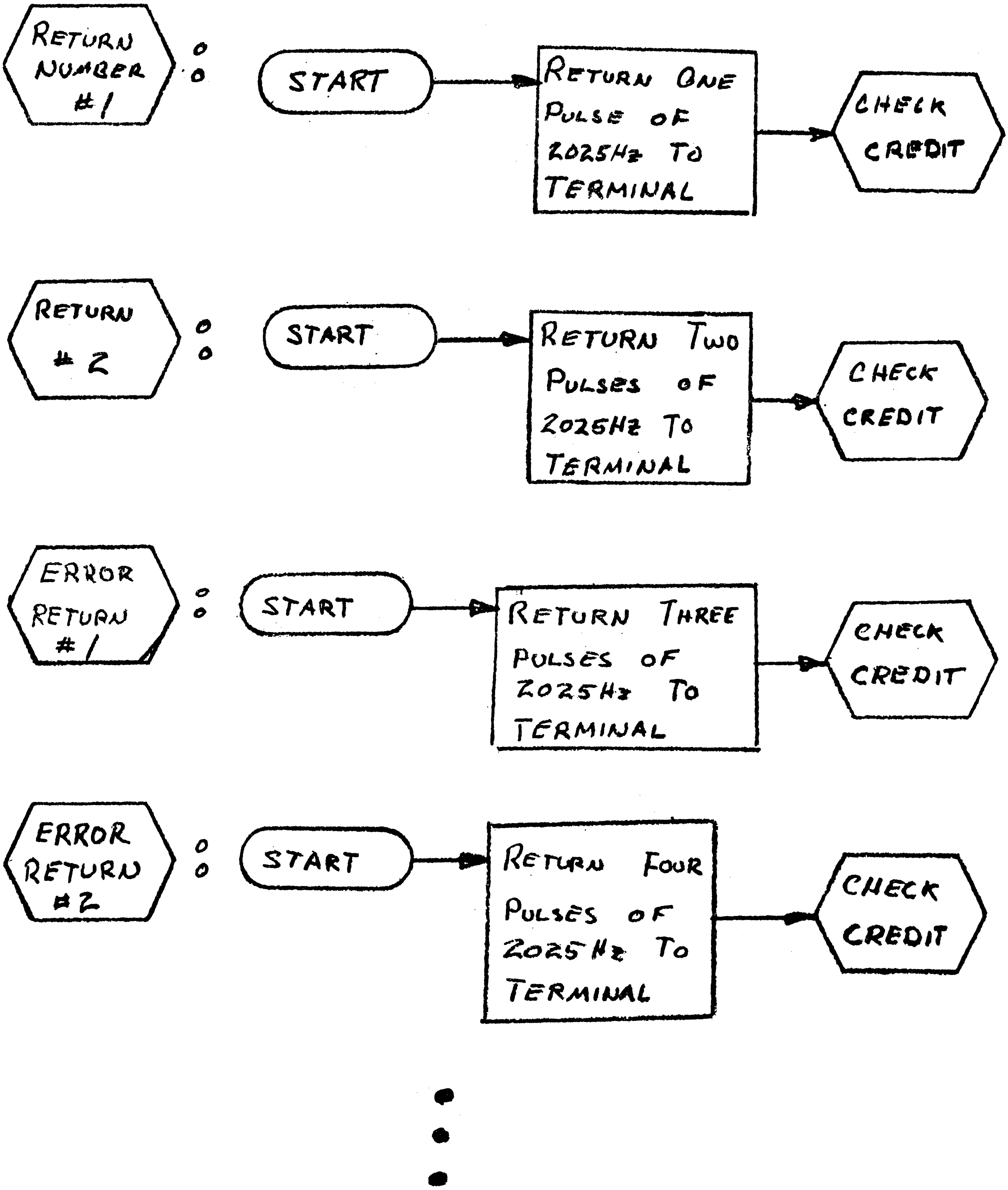
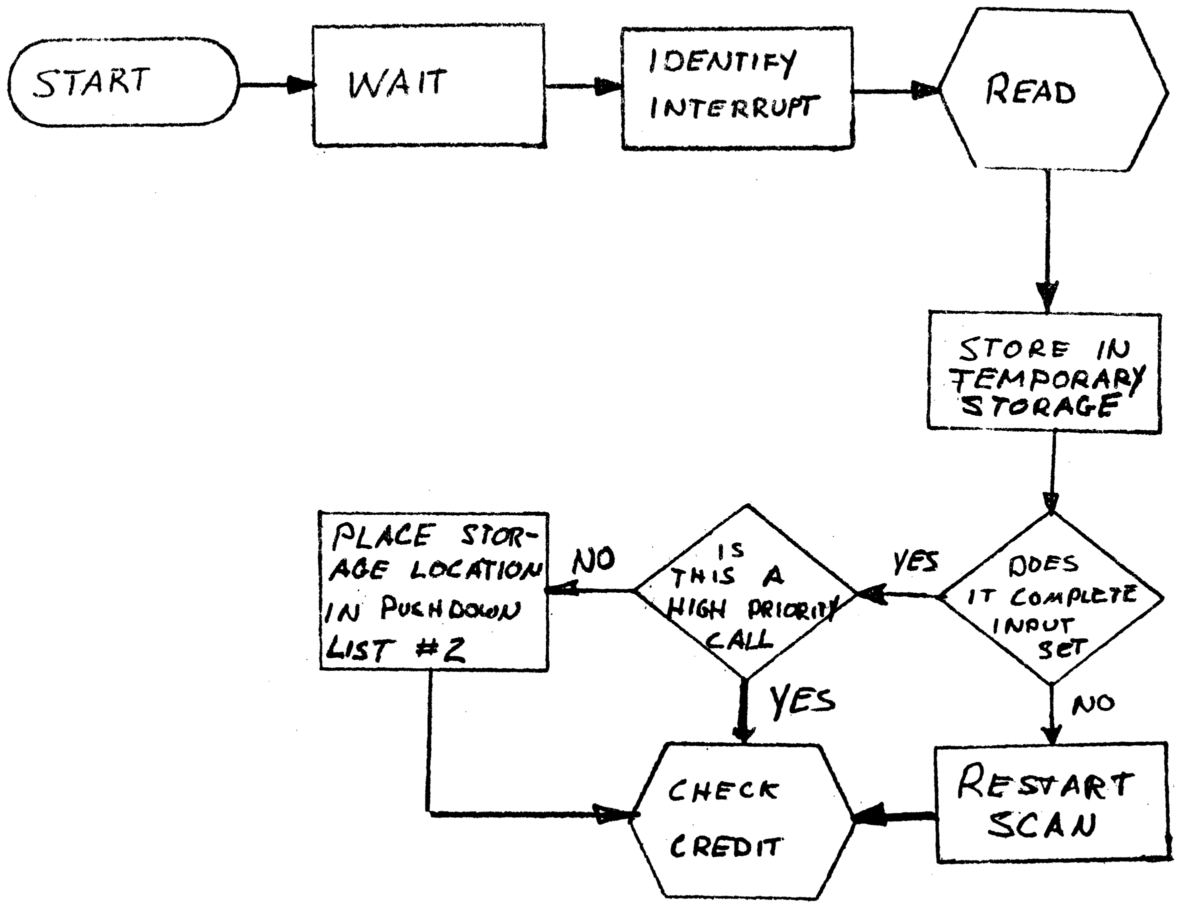
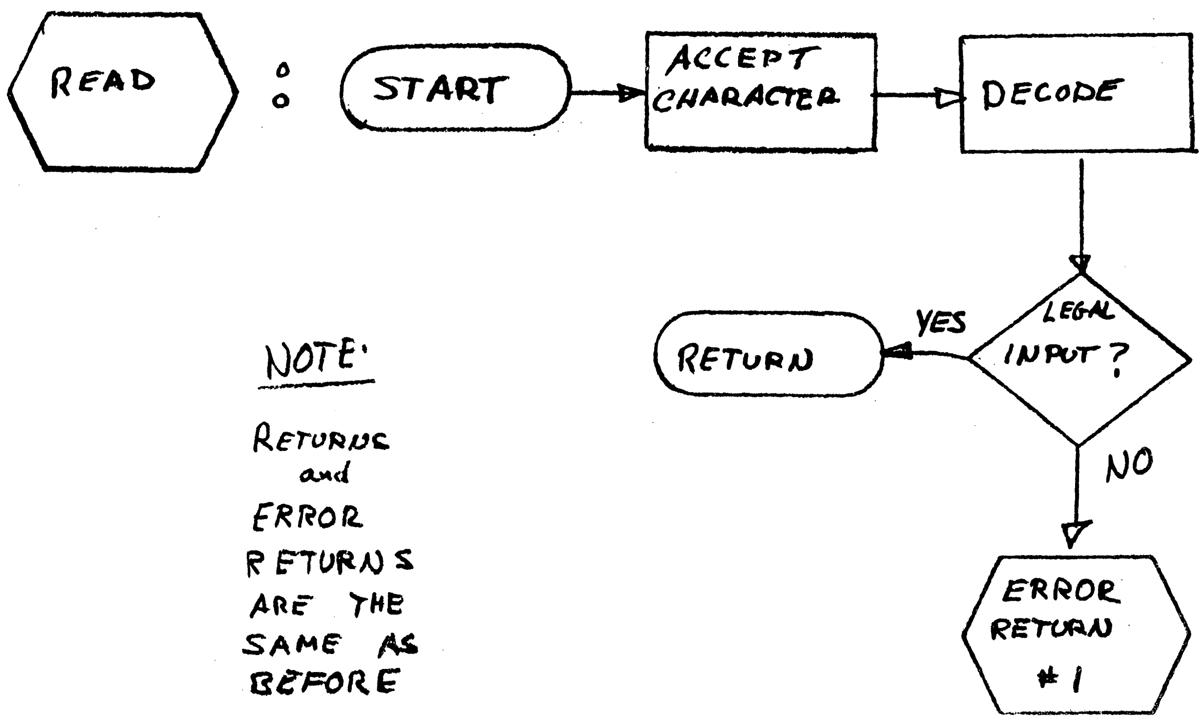


FIG 11-D GENERAL FLOW CHART

INTERRUPT



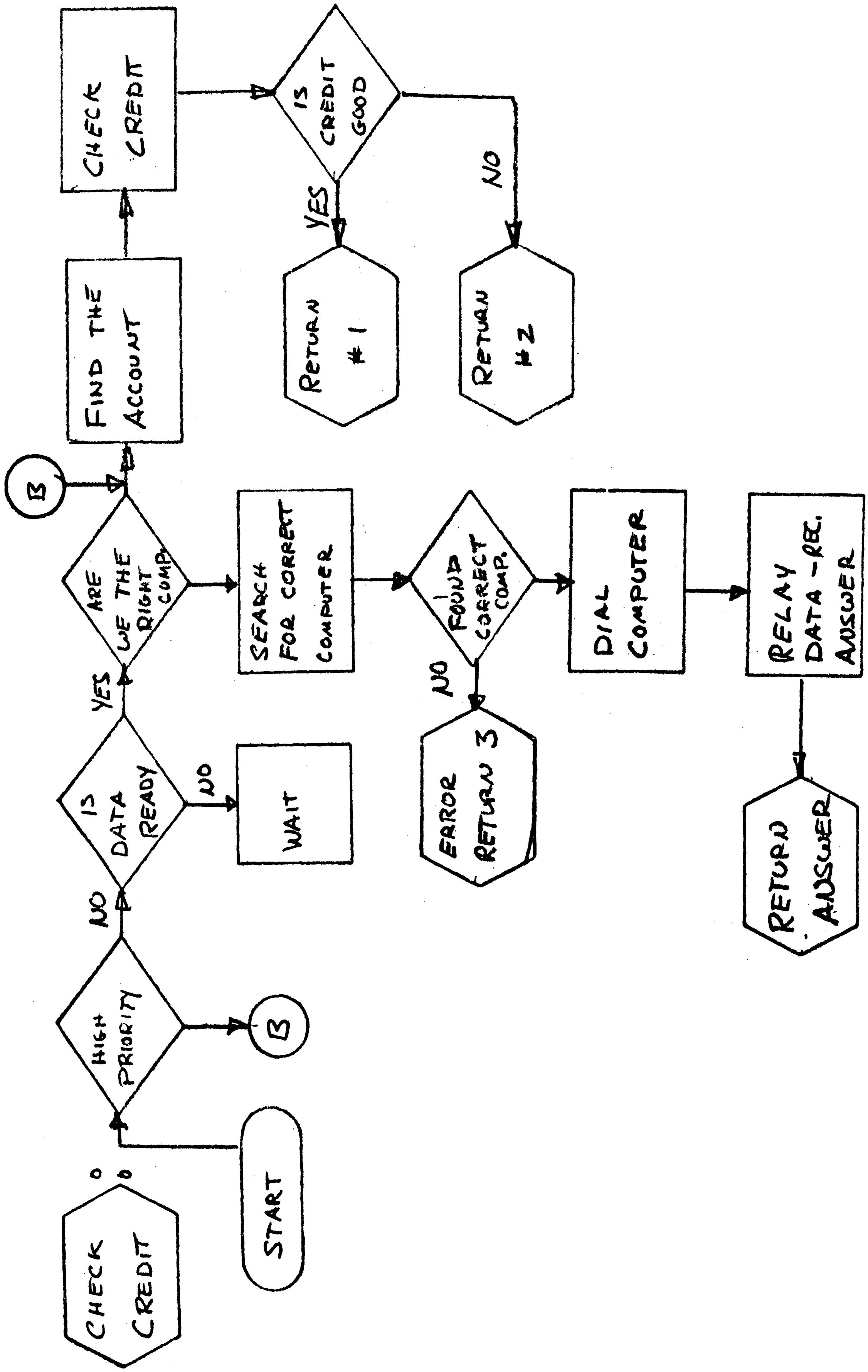


NOTE:

RETURNS and ERROR RETURNS ARE THE SAME AS BEFORE

GENERAL FLOW CHART: (CONT)

FIG 11-E



APPENDIX B

ORGANIZATIONAL STRUCTURE OF DESIGN GROUP B

A. INITIAL ORGANIZATION

For the first two weeks of the term, the class met as a whole unit. During this period we determined what project to undertake, did some cursory research to determine the feasibility of tackling the project in one term, defined the project's scope, and settled on the manpower breakdown for the remainder of the term.

After the preliminary groundwork was done, we decided to split the class into two competing, seven-man groups. Each group was given the same task of designing and building a prototype model of a credit card checking terminal. The following is an outline of the internal organization structure of one of these groups, officially designated as "Group B."

B. ORGANIZATION OF GROUP B

The first week that the seven of us in Group B met we roughed out block diagrams and flowcharts, similar to figures 3-A and 3-B, in an attempt to define the tasks that were ahead of us.

The conclusion of these discussions can be seen in the Job Breakdown Chart (figure B-A) on the next page. Note that an attempt was made to include all jobs related to the course that would be required for the successful completion of the project.

This Job Breakdown Chart was then used to develop a PERT type of flowchart. The PERT chart shown later in this appendix (figure B-B) is not a conventional PERT network. For our purposes I decided to orient the event blocks so that horizontal distance implies time. I did this in an effort to insure that the deadlines imposed by the chart were sufficiently spread out over the term and did not all cluster at several points. Rather

JOB BREAKDOWN -- FOR CREDIT CHECKING TERMINAL

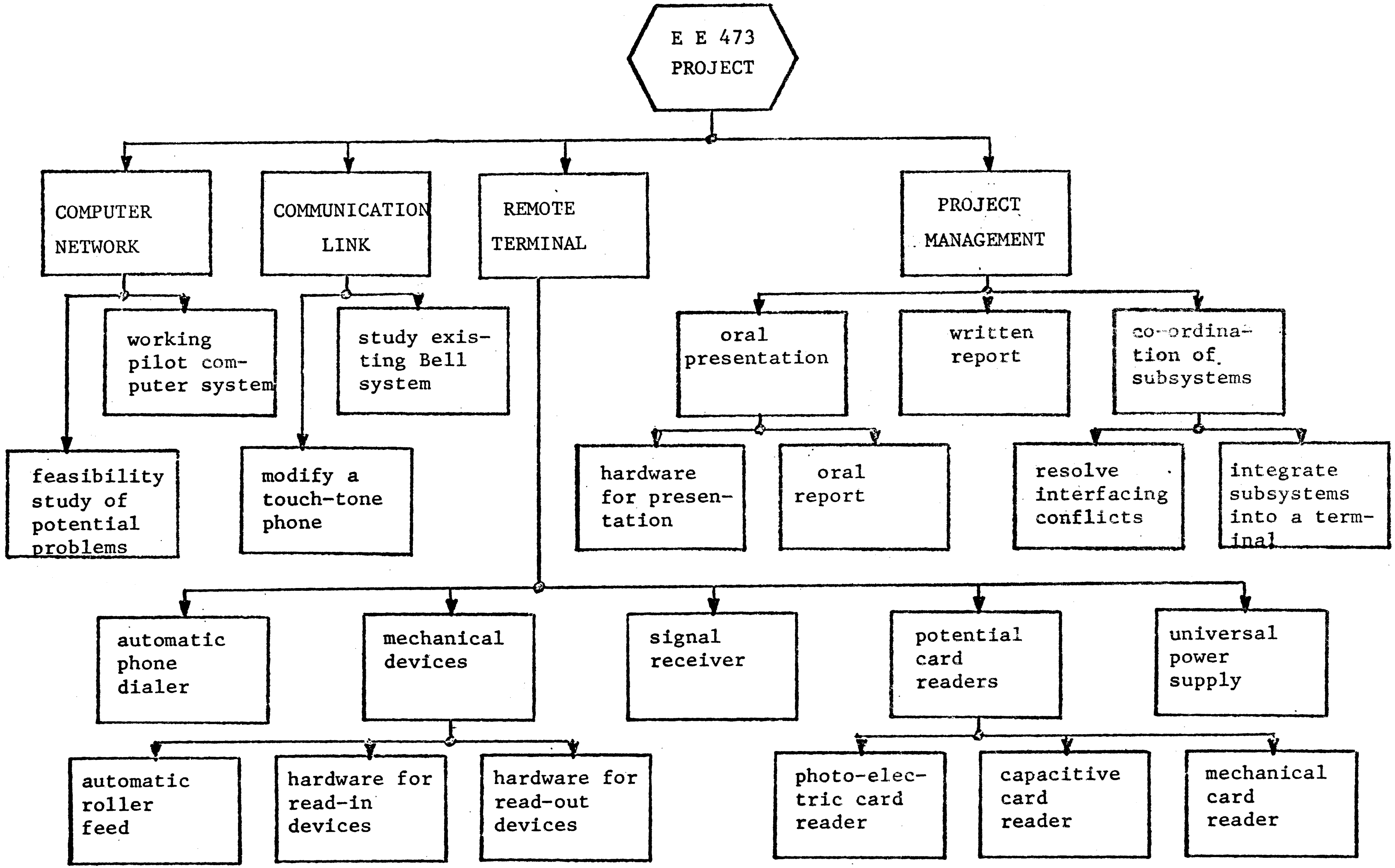


FIGURE B.A

than impose absolute deadlines with the PERT chart I felt progress would be a little strained if we assumed each of the activities (time between events) would be of a probabilistic, rather than an absolute nature. Therefore, any block on the PERT chart, except the first and the last, can be assumed to be free to drift forward or backward one time interval. One time interval is defined here as the amount of time between successive class meetings.

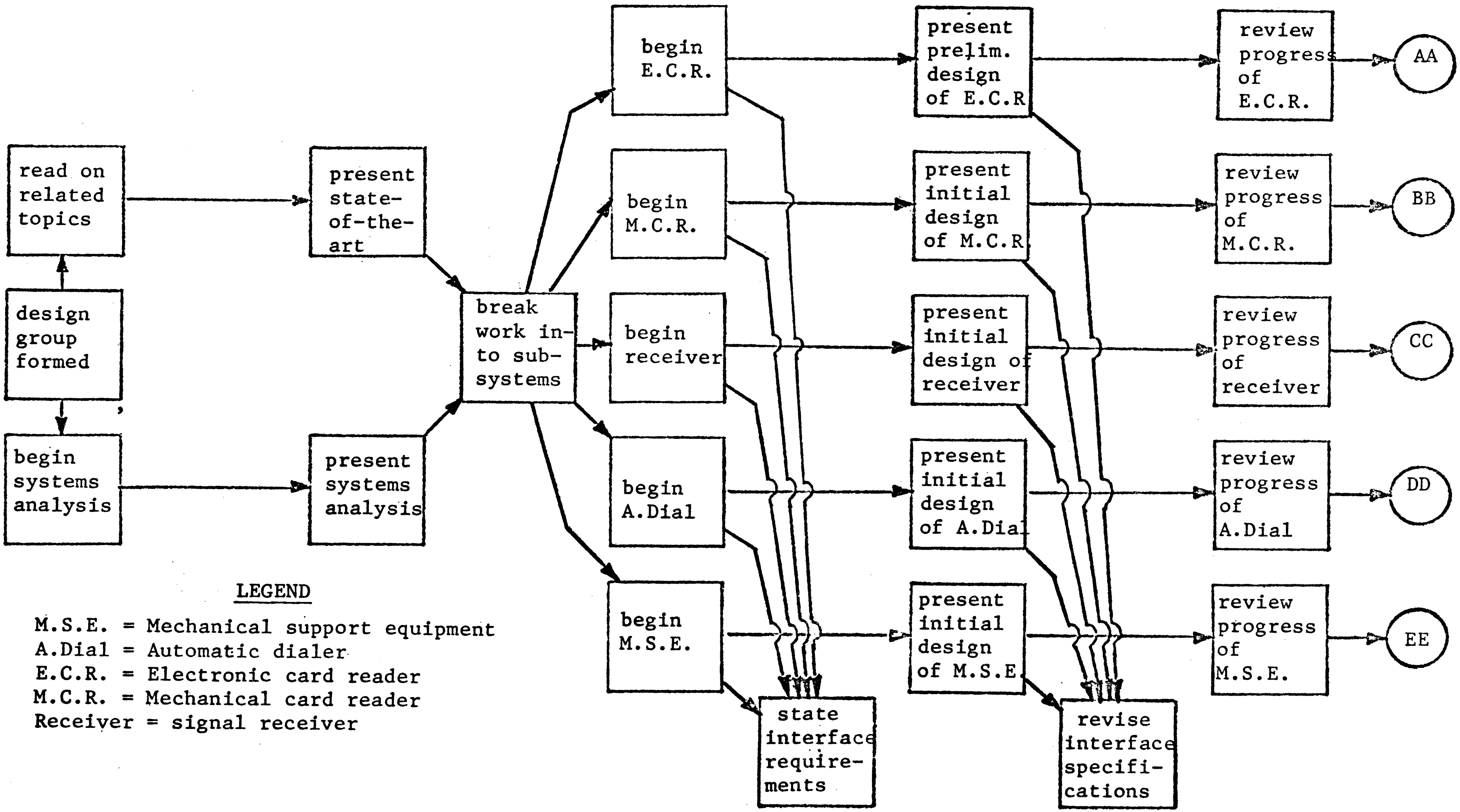
It might be argued that the five parallel paths running through the center of the chart should be combined to make the chart shorter and more readable. However, one of the major purposes of this particular PERT chart was to show each man where his individual responsibility fell in relation to the rest of the group. In other words, each block is an event associated with an individual or team working on a single subsystem.

This brings up the question of exactly which individuals did what tasks in this project. There was a large amount of aid given to members of a team working on one subsystem by other members of the group even though those other members were responsible for different subsystems. Therefore, the listing below gives the major responsibility breakdown, but the frequency of a members name is in no way proportional to the amount of work he did:

	TASK	INDIVIDUAL(S) RESPONSIBLE
1.	Project Leader	Sam Fuller
2.	Automatic dialer	Jim Van Loo
3.	Capacitive card reader	Carl Bloch
4.	Photoelectric card reader	Ron Brodowicz
5.	Mechanical card reader	Bob Meneghini
6.	Signal Receiver	Sam Fuller
7.	Price read-in; automatic roller feeder and general mechanical systems	Dan Pinkert & Roy Neubauer
8.	Work related to Addressograph device	Dan Pinkert

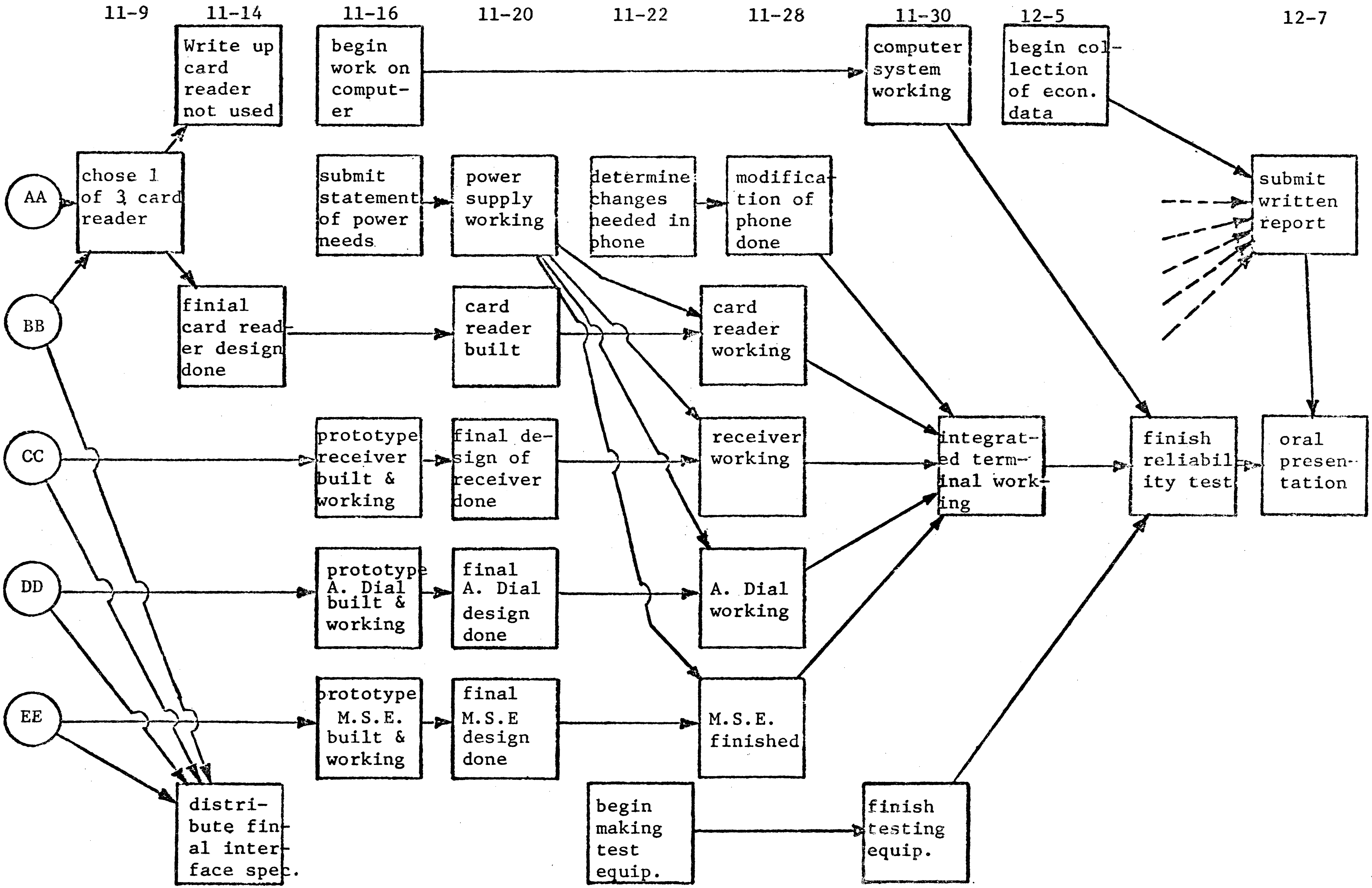
PERT CHART FOR GROUP B -- CREDIT CHECK TERMINAL

figure B.B



LEGEND

M.S.E. = Mechanical support equipment
A.Dial = Automatic dialer
E.C.R. = Electronic card reader
M.C.R. = Mechanical card reader
Receiver = signal receiver



11-9
11-14
11-16
11-20
11-22
11-28
11-30
12-5
12-7
AA
BB
CC
DD
EE
chose 1 of 3 card reader
Write up card reader not used
finial card reader design done
distribute final interface spec.
begin work on computer
submit statement of power needs
prototype receiver built & working
prototype A. Dial built & working
prototype M.S.E. built & working
power supply working
card reader built
final design of receiver done
final A. Dial design done
final M.S.E design done
determine changes needed in phone
begin making test equip.
modification of phone done
card reader working
receiver working
A. Dial working
M.S.E. finished
computer system working
integrated terminal working
finish testing equip.
begin collection of econ. data
finish reliability test
submit written report
oral presentation

9. Bell telephone information...............Roy Neubauer
10. Computer systems.........................Carl Bloch
11. Power supply.............................Ron Brodowicz

The related documentation for the above tasks was completed by the individuals responsible for the specific jobs. However, there are several other chapters included in the report which are not related to a particular hardware task. They were assigned as follows:

CHAPTER	INDIVIDUAL(S) RESPONSIBLE
Chapter 1	Jim Van Loo
Chapter 2	Dan Pinkert
Chapter 3	Ron Brodowicz & Sam Fuller
Appendix D	Bob Meneghini

C. EVALUATION OF ORGANIZATION

The above sections outline the method of organization which our group used; but, in no way do they suggest its weak or strong points. This section is inserted to discuss the effectiveness of our organization structure.

Three basic diagrams (figures 3-B, B-A, and B-B) proved to be essential in the early weeks of the course. Although some students tended to balk at a formalized approach to original design work, the following steps saved us critical time:

1. Develop a flowchart stating precisely what the device must accomplish. Do not include any assumptions about hardware; it is just a flowchart of the logical steps the device must perform.

2. From the above flowchart a meaningful list of the needed hardware subsystems can be determined. This step is outlined in more detail in sections B and C of Chapter 3.

3. Once the hardware requirements and the type of documentation required are known, a Job Breakdown Chart can be developed. (See figure B-A).

4. With the aid of the Job Breakdown Chart a PERT chart can be drawn. Any one of several sources give a good description of the design of PERT charts. (Professor Butler, EE 301, has a report on file in the EE office which has an excellent bibliography on this topic.)

One critical item we did lack was an effective method or review with which we could evaluate our progress in relation to the PERT chart. Without a reviewing technique it was too easy to let parts of the project slip when other classes demanded time. An effective review procedure would also point out flaws in the PERT chart, and thus provide a means to update the chart.

APPENDIX C

BELL SYSTEM INFORMATION

A. The design of this credit check system requires that a low speed data receiver be used. The Bell System's family of DATA-PHONE* data sets, known as Data Set 403-type, met this requirement. The following are the requirements to which this data set was developed.

B. RECEIVER REQUIREMENTS

1. Receive multifrequency signals generated primarily by the TOUCH-TONE telephone set over the DDD telephone network or private switched network facilities. The receiver should respond to valid signals of 40 msec and whose total power may vary by 40 dB. The channel bandwidths of the receiver should be $\pm(0.017f_o \pm 15Hz)$, where f_o is the nominal signalling frequency and 15Hz is allowance for carrier offset. The allowance provides for the expected deviations in the received signals and also variations in the receiver due to temperature changes, component aging, manufacturing deviations, etc.
2. Deliver output indications (data) to the customer for approximately 37 msec, regardless of input signal duration in excess of 40 msec. Also, deliver to the customer a Data Carrier Detector (DCD) indication 2 to 3 msec after the data indications. The DCD is reset by the disappearance of input signal or the end of the 37 msec output timer, whichever occurs last.
3. Interface with a large variety of business machines on either a voltage or relay contact interface. The word "interface" refers to the interconnection point between a data set and a business machine.

* TOUCH-TONE and DATA-PHONE are registered service marks of AT & T Co.

4. Be capable of differentiating between valid signals and speech, noise or echo signals. Worst case echoes may be expected with delays up to 40 msec and an amplitude 14 dB below the amplitude of the signal.
5. Have three different answer-back channels available to communicate with the transmitting station.
6. Provide standard control functions for automatic operation such as Ring Indication, Out-of-Service, Data Set Ready, Data Receive and Data Terminal Ready.
7. Connect with a master control console in multiple receiver installations and with a data auxiliary telephone set for single set installations which provide Talk, Test, and Data mode controls and also the telephone set.
8. Have a telephone line terminating impedance of 600 or 900 ohms. It should also provide its own protection against lightning surges on the line. The return loss of the data set should be greater than 20 dB within the signalling band of 600 to 2100 Hz. Also, the data set must have the capability of being remotely tested from a Bell System Data Test Center.
9. Other requirements--The data set must operate from a 117 vac 60 Hz power source and over an ambient temperature range of 40^{o}F to 120^{o}F and a relative humidity of 20 to 90 percent. Also, during power failure the interface leads to the business machine should be transferred away from the business machine to prevent the transmission of erroneous information, but telephone service should remain operative.

C. The Data Set 403-type can be categorized into two parts: A basic receiver and the interface coupler. The basic receiver is further broken down into three sections: (a) Line Control Circuits, (b) Receiver Channel, and (c) Answer-back Channels. The data set is designed to be the basic unit of systems requiring any number of receivers with the same or different interfaces.

1. Line Control Circuit

A basic requirement of the data receiver is that all calls coming into the data set must be under direct control of the customer; therefore, he must be permitted to accept or reject any call and also be permitted to accept these calls manually or automatically. The line control circuit provides the customer with these options and also provides the interface with control for switching between the data-receive portion and the answer-back channels of the data set. Figure C-2 shows a simplified block diagram of the line control circuit.

2. Answer-Back Channels

After the Line Control Circuit has signalled the calling station that the data set has answered an incoming call, the transmission or reception of information may take place. A need for transmission of information exists from the data set receiver to communicate with the calling station. This communication takes place in the form of tone signalling. Three answer-back channels exist in the data set to satisfy these needs.

3. Receive Channel

The basic requirement, as explained previously, is to detect information transmitted by any TOUCH-TONE type telephone set over the DDD telephone network or the private switched network facilities reliably. To meet this requirement, the receiver, as shown in Figure C-1, was designed.

The data set is placed in the receive mode by an ON condition on the Data Receive lead. When the Data Receive lead is OFF, the data set is in the answer-back mode. The constituent parts of the receive channel are the AGC amplifier, band elimination filters, limiters, detectors, signal and output timers, the data carrier detector.

3a. AGC Amplifier

The input signal to the data receiver is amplified to a fixed level by the AGC amplifier. This circuit compensates for transmission loss variations of different connections through the switched telephone network. For an input signal variation of 41 dB, the output varies $\pm$ 1.0dB. The AGC has an attack time of 2 to 4 msec and a long release time. The sensitivity of the receiver is controlled mainly by the AGC and is 0 to -41dBm, or -6 to -47dBm when a 6 dB pad in the front end of the AGC is removed. The slow release characteristic of the AGC is used to provide protection against digit simulation due to echo signals.

3b. Band-Elimination Filter and Channel Limiters

The band-elimination filter, which is driven by the AGC amplifier, separates the received signals into their respective high and low groups. The signals are then passed to the channel limiters. Also, any received noise and out of group noise will be passed to both channel limiters. The limiters supply a constant output square wave provided the input is above a design threshold. The threshold circuit is used in conjunction with the slow release time characteristic of the AGC to provide protection against duplication of input information caused by echo signals. Protection is provided against echo signals with delays up to 40 msec and levels no stronger than 14 dB below the original received signal. In addition, through the instantaneous limiter action, some immunity is provided against digit simulation by voice signals. Equalization is also provided in the limiters to compensate for the uneven attenuation characteristic of the telephone plane.

3c. Channel Detectors, Signal and Output Timers, and Data Carrier Detector

The output of each channel limiter goes to a group of four series-tuned networks used for recognition of the signalling frequencies. Each tuned network output connects to a detector whose operating threshold is approximately 2.5 dB below the peak output from the tuned networks. This threshold insures one and only one detector in each group will operate. Once the detector operates, it will remain operated for as long as the signal is present at the detector. Next, an AND gate is used to verify that one detector is operated in each group. This is verified for a timed interval of 40 msec. Next, the output timer is turned on which in turn operates and holds the correct output driver in each group for 37 ± 2 msec. The Data Carrier Detector will be reset by the output timer at the end of its timing transition or by the ending input data signal, whichever is last. Feedback from the output drivers to the operated detectors causes the detectors to remain operated should the input data signal disappear during the 37 msec output period. To prevent the operation of the other detectors, the threshold level is raised 1 dB above the tuned network outputs.

D. INTERFACE

The requirement that the data set should interface with a wide variety of business machines was met by designing a family of interface couplers that plug into the frame containing the basic receiver.

E. TOUCH-TONE FREQUENCIES

Figure C-3 shows the frequency plan of the audio-frequency tones utilized in TOUCH-TONE service. Fundamentally, the eight frequencies are arranged in two groups of four frequencies, one low group and one high group. A character or digit is represented by two frequencies, one from each group. This yields 16 possible combinations or characters. Many factors were considered in the selection of frequencies.[1] Among the factors were transmission characteristics of a typical telephone line, avoidance of certain combinations of frequencies that occur frequently in speech, and the selection of frequencies not harmonically related. Figure 3 shows the decided assignment of the 10 numerals and two special characters, *(Star) and the # (Number Sign).

1. Signalling System and Receiver for TOUCH-TONE Calling
R. N. Battista, C. G. Norrison, and D. H. Nash, IEEE Transactions, Part I, Communications and Electronics.

Context of this appendix taken from THE TOUCH-TONE TELEPHONE TRANSMISSION OF DIGITAL INFORMATION, by J. H. Soderberg, R. R. Campbell, and F. E. Bates.

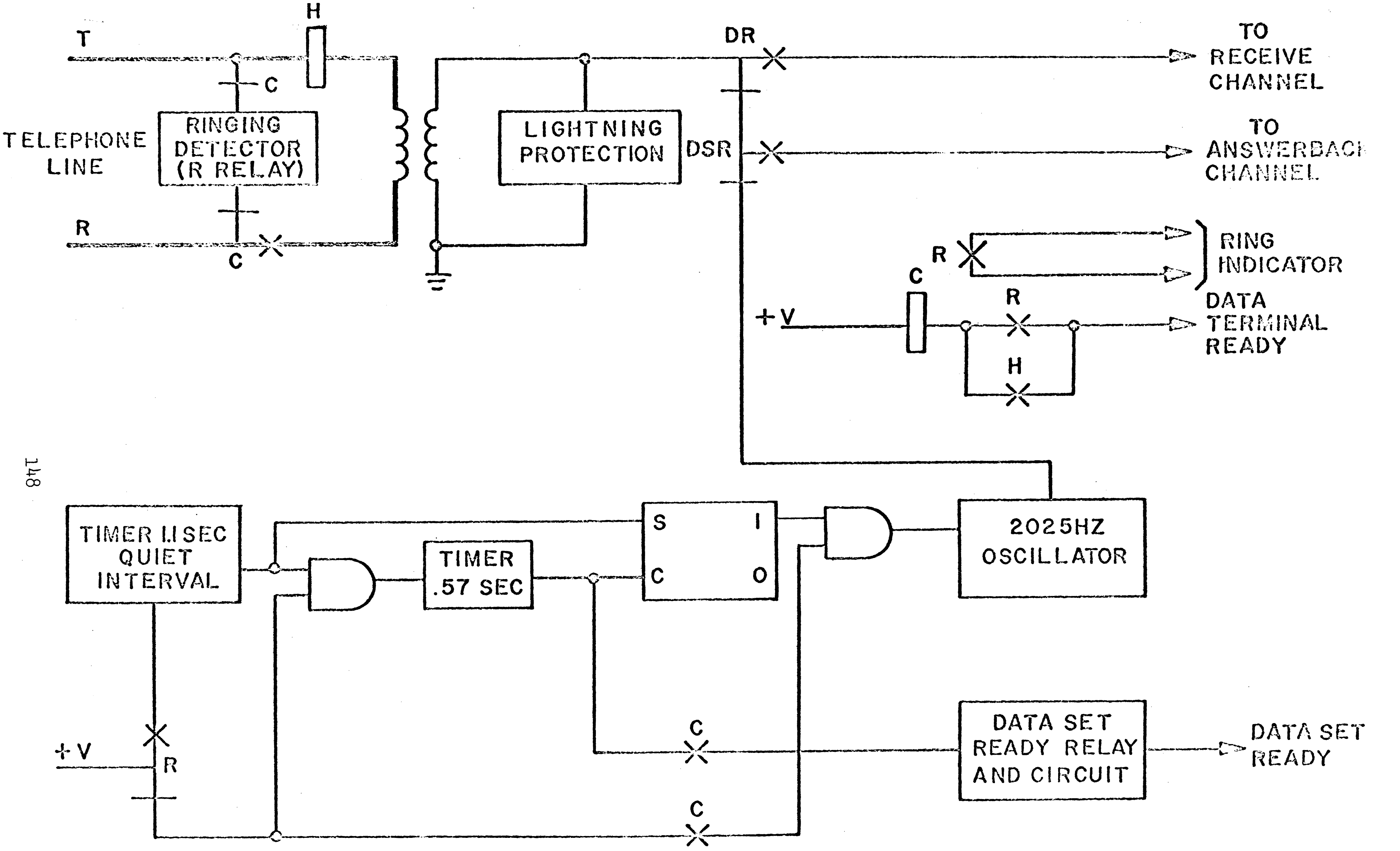


FIGURE C-A BLOCK DIAGRAM OF LINE CONTROL CIRCUIT

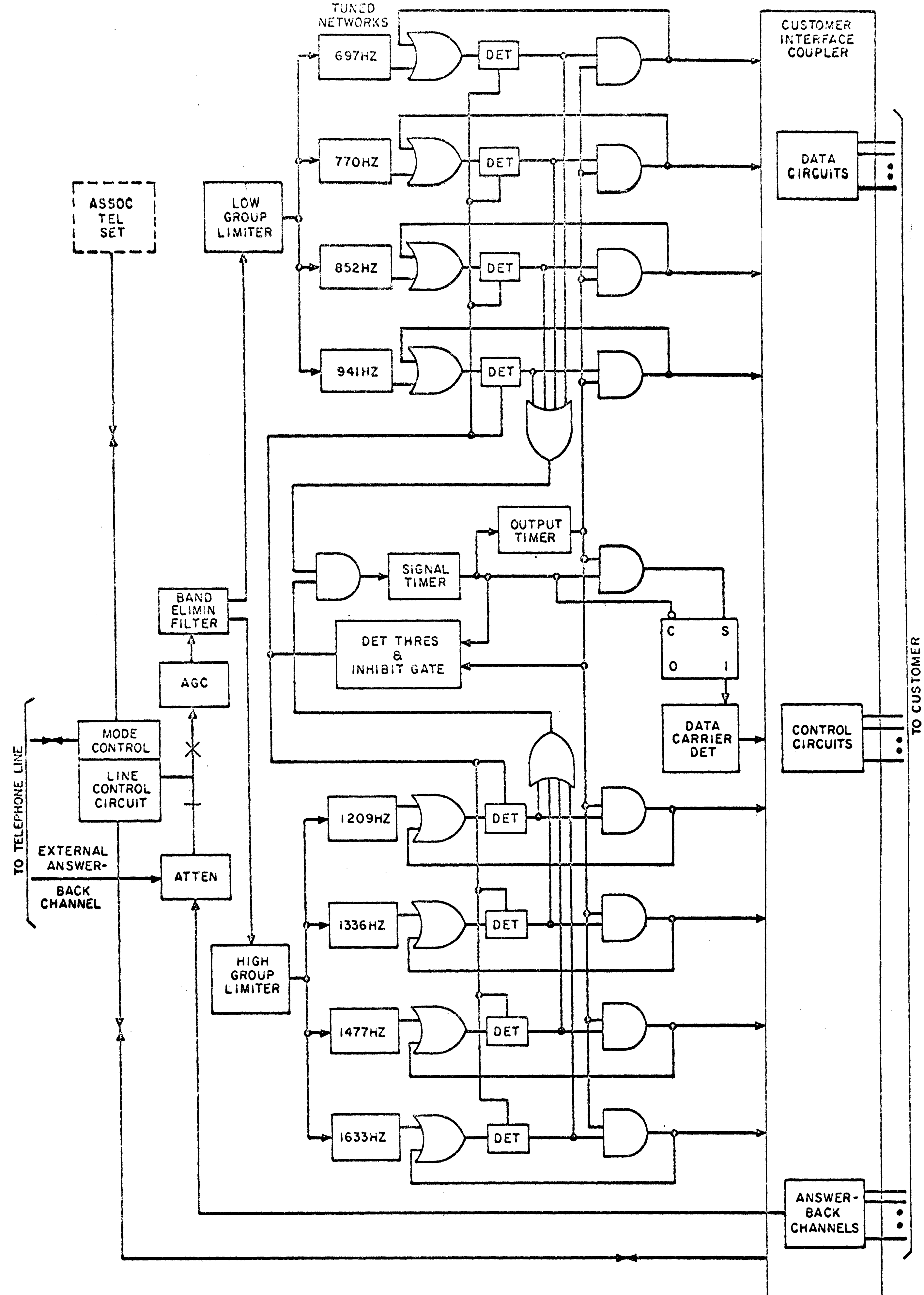


FIGURE C-8 BLOCK DIAGRAM OF DATA SET 403D-TYPE RECEIVER

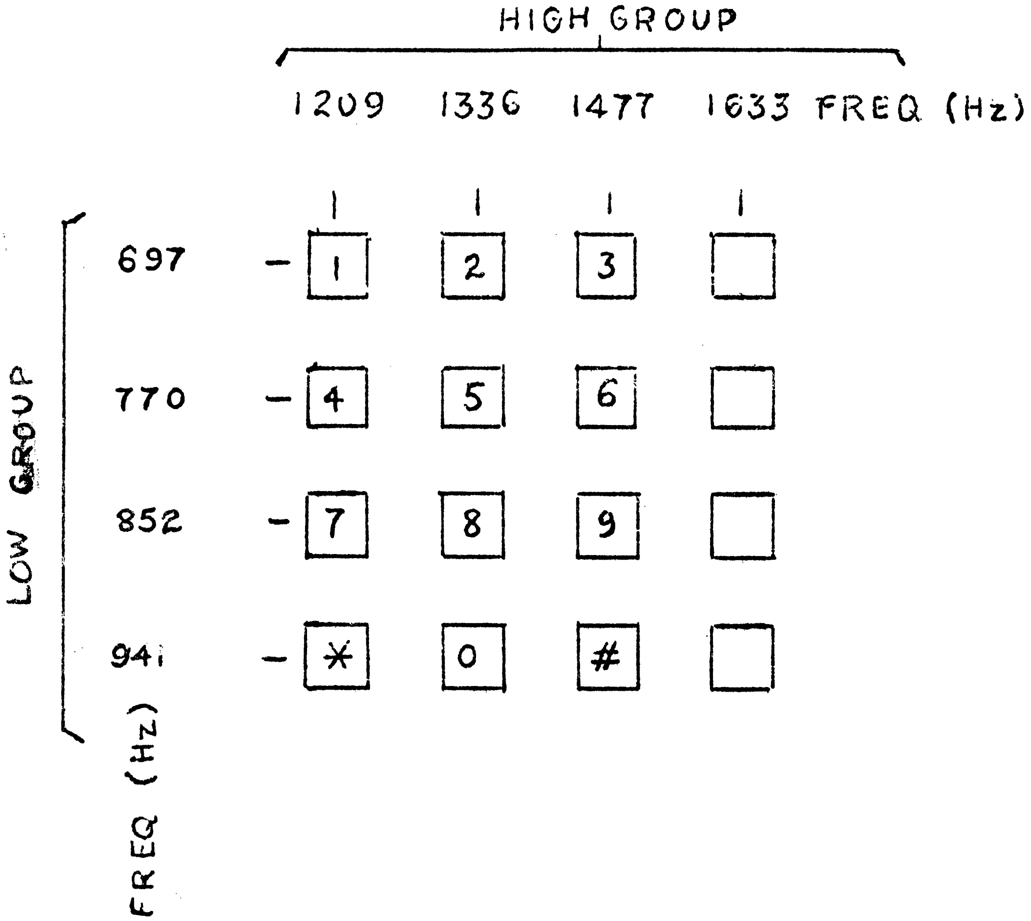


FIGURE C-C ARRANGEMENT OF TOUCH-TONE DIAL AND FREQUENCIES ASSIGNED

APPENDIX D

ECONOMIC ANALYSIS

One of the more important criterions of this design project is that the terminal must be economical to produce and it must be economically feasible to business. "The manufacturing cost of the device must be quite low..." To determine the economic feasibility of the credit check terminal, Standard Oil Company provided the following information:

Total volume sales	$2,100,000,000
Total volume sales per service station (32,000 service stations)	$65,600
Total credit card sales	$700,000,000
Credit card sales per service station	$21,900
Total loss due to bad credit cards	$3,815,000
Loss due to bad credit cards per service station	$120

The loss due to lost and stolen credit cards is .045% of the total credit card sales and the loss due to "bad credit card holders" is .5% of the total credit card sales.

It takes 90 to 120 days from the time these "bad credit card holders" make a purchase and the time that the service station is notified. With immediate feedback the Standard Oil Company estimates that most of the .5% loss of the total credit sales could be eliminated. This would result in a savings of $3,500,000 per year.

The Standard Oil Company employs about 200 people in their accounting system just to take care of the incoming payments and accounting. A credit check terminal that would provide an instantaneous accounting system would result in additional savings by eliminating almost 100 of these people and thereby reducing their overhead and their payroll.

Therefore, estimating the total savings per year to be $4,000,000 would result in a $120 savings per service station per year.

The cost of the credit check terminal is listed below. The credit check terminal consists of the following major components: the automatic dialer, the mechanical card reader (or the photo-cell card reader), the addressograph, the signal converter, the system control panel, and the power supply. The retail and wholesale (in quantities of 500 or more) prices of these components are listed below.

Automatic Dialer

Item	Retail	Wholesale
8 - JK flip-flops	$13.00	$ 9.20
2 - 2 input nand gates	3.50	2.50
2 - IC's	3.50	2.50
8 - transistors	6.00	3.75
	$26.00	$17.95

Mechanical Card Reader

Item	Retail	Wholesale
1 - program assembly unit	$20.00	$16.00
1 - solenoid	3.20	2.50
1 - switch	2.80	1.70
brackets and rail	2.00	1.00
	$28.00	$21.20

Photo-cell Card Reader

Item	Retail	Wholesale
7 - photo-cells	$16.75	$11.55
7 - transistors	4.65	3.00
7 - relays	31.00	21.60
7 - resistors	.45	.15
mounting board	1.10	.70
	$53.95	$37.00

Addressograph

Item	Retail	Wholesale
1 - addressograph	$79.00	not available
1 - spring mechanism	15.00	11.00
5 - price readout units	5.00	3.00
	$99.00	

Signal Converter

Item	Retail	Wholesale
2 - integrated circuits	$ 3.50	$ 2.50
24 - resistors	1.20	.95
8 - capacitors	2.15	1.80
4 - transistors	.75	.65
2 - relays	9.00	7.20
misc.	4.50	3.70
	$21.10	$16.80

System Control Panel

Item	Retail	Wholesale
8 - lens	$ 2.00	$ 1.60
1 - switch	2.76	2.20
8 - sockets	9.84	8.00
10 - lamps	4.15	3.40
1 - chasis	6.40	5.00
1 - buzzer	1.85	1.50
	$27.00	$21.70

Power Supply

Item	Retail	Wholesale
6 - diodes	$27.90	$16.70
resistors	1.00	.50
2 - capacitors	2.90	1.20
1 - transformer	6.55	3.00
	$38.35	$21.40

Therefore, the approximate cost of our system is $200. Based on this figure and the figure of $125 that the average service station would save per year, the terminal would pay for itself in about 19 months.

In conclusion, it is to be noted that the terminal with an accounting system would indeed be economically feasible for businesses and that the price of the terminal is well within the range set as a part of the design criterion for this project.

INTRODUCTION

Group A

When our group first approached the problem as stated in the Appendix A, it became obvious that there were many methods of designing and building a remote credit terminal that would meet the needs of consumers of our product. Our first attack on the credit terminal design competition was a preliminary study on the type of credit card reader that would be installed in the remote credit installation. We considered mechanical card readers as compared to electronic card readers and as a group decided to build an electronic type of card reader that would be superior in final cost and having a low maintenance rate. We did a detailed study on three types; 1. magnetic, 2. capacitive, and 3. photoelectric. After three weeks of experimentation with these, the members of our group decided on the magnetic card reader due to its ease in mounting to present day credit recording systems and its cost. A brief presentation of the capacitive and photoelectric card readers are presented near the latter part of this report.

The second phase of our research was on the connection of our electronic card reader to the proper logic to coordinate calling a computer automatically, the transmission of the credit card number and the proper price information to a central computer. Having sent the proper information to the computer in a predetermined sequence, the remote credit terminal awaits a signal back from the computer to determine if an error has been transmitted, or if the credit sale should be validated or invalidated.

CHAPTER 1

LOGIC FLOW SYSTEM

In designing the overall logic of the system we had to keep in mind: (1) the function of the device and (2) compatibility with the method of transmission of data over the phone line. Since we had chosen Bell Telephon's X403 B data set for transmission, our logic had to interface properly with it. Basically the X403 B is a touch tone phone, modified so that external relays can operate the tone oscillators. For each digit sent two tone oscillators must be turned on. This is done in two operations: (1) One of four taps on coils for oscillators "A" and "B" are connected to "A" common and "B" common thus setting the frequencies for the particular digit. (2) An excitation contact is opened removing a DC current from the tank circuits tuning coils and allowing the oscillator to oscillate. For these purposes, eleven leads are brought to the outside: four leads to A taps, three leads to B taps, an A and B common, and two leads to the excitation contacts. These leads are connected to relays at the output of the device. Our logic must then perform two operations: (1) Close the appropriate relays in groups A and B, (2) then the excitation relay must then be opened for the "on time" and closed before A and B relays open. This may be done at a minimum rate of (50)ms on time and 45ms "nest time" for each digit. (A complete explanation of the X403B is contained in the "Preliminary Bell System Data Communications Technical Reference, Data Sets X-403B and X403C Interface Specification, April, 1966.

OPERATION

Upon command of the operator, the remote credit terminal must first dial the central computer, and when the computer is on line and ready to receive data, then transmit the credit card number, price, and location. Then one of three signals (error, go, or no go) must be received back from the computer and indicated by the device. A go signal means credit is good and the printing mechanism is released and any signal other than a go signal will not release the printing mechanism. In accomplishing these functions, a balance between the amount of automation and operator control must be established. We decided to use the operator within the boundaries of the following assumptions and limitations:

(1) The operator has enough education and intelligence to operate a normal cash register.

(2) It must be impossible to validate a card if the operator makes a mistake.

(3) Operator time should not be great enough to raise operating costs to an appreciable degree.

(4) Operator functions will be used only to cause appreciable savings.

With these considerations we decided to deviate in two ways from a completely automated system. Since the operator must insert the card and actuate the device we decided that using the operator as a detector for dial tone and computer "ready" signals would not increase operator times and would greatly reduce circuitry and manufacturing costs. Use of the operator would eliminate three tone dectors (dial tone, busy signal, and computer return), switching networks and dummy loads for holding the line, and a repetitive dial mechanisms in case the computer was not reached. The following is the logic flow of the system used: Fig. 1 contains the main block diagram.

(1) The operator inserts the credit card which actuates a micro switch turning on the power and generating a one shot pulse presetting all logic.

(a) The operator sets the price for model B.

(2) The operator lifts the receiver on the X403B and awaits a dial tone.

(3) Upon receipt of a dial tone, the exclusion key on the X403B is lifted and the control button pressed on the device. this starts the automatic dial operation.

(4) The operator awaits reception of a tone indicating the computer is on line. In addition to saving circuitry, having the operator fulfill this function allows greater

flexibility in central data set selection.

(a) If no tones are received the operator hangs up the receiver. This actuates a one shot which resets all logic circuits and allows the procedure to be repeated. The operator then returns to step #2.

(5) After receiving the correct tones the operator hits the control button again. This cycles the main control sequencer into its second position, actuating the card reader.

(6) After reading 10 credit card digits the main sequencer is pulsed to the third position. This actuates the card reader a second time. This allows the computer to compare numbers to help prevent random error introduced by noise.

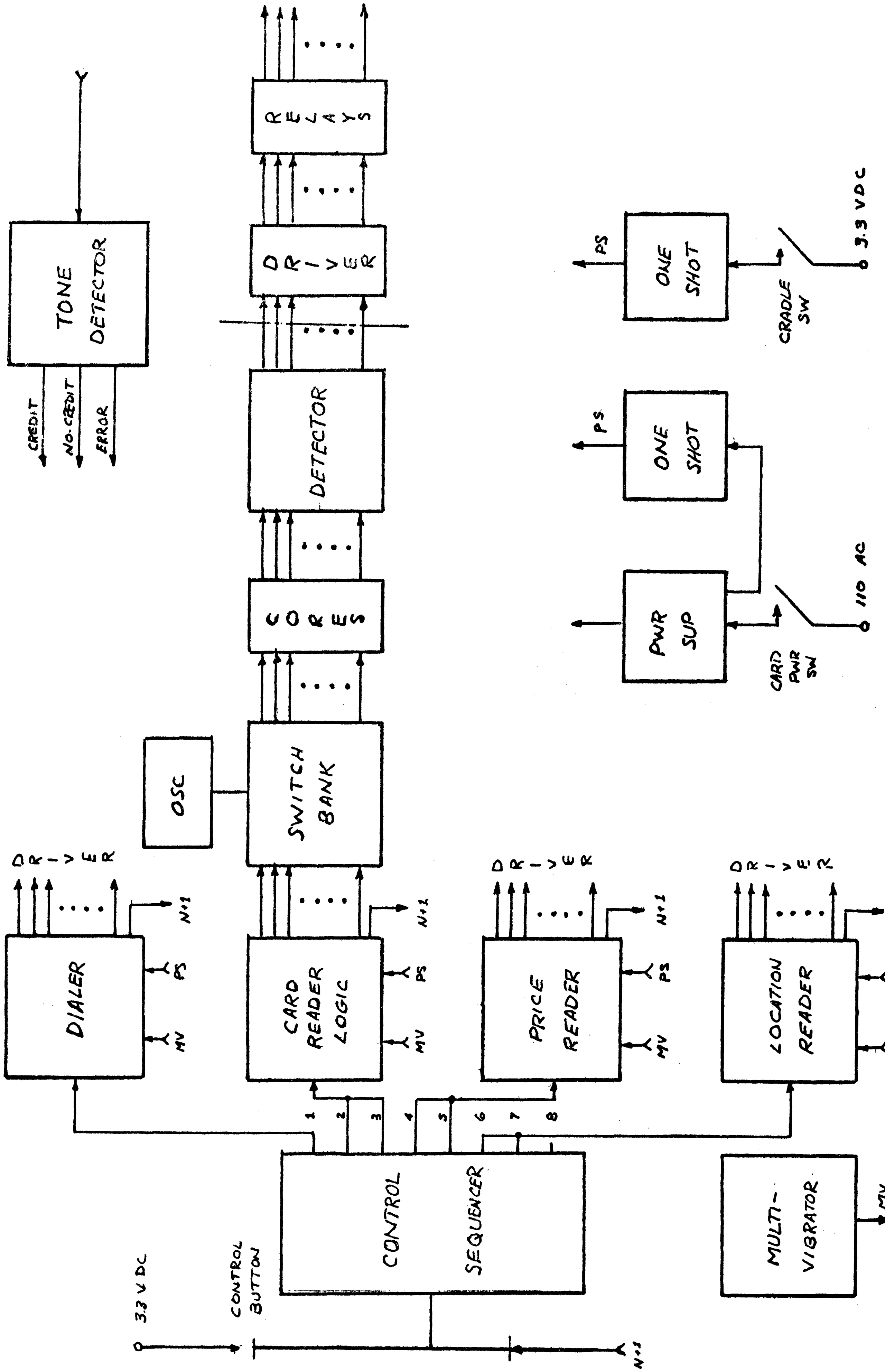
(7a) After a second reading of the card, the main actuator is shifted to a fourth and last position. This position "holds" the logic until the computer has processed the data.

(7b) For model B the fourth and fifth positions of the main sequencer activate the price reader twice and the sixth position holds the logic. (7c) For model B1 the sixth and seventh positions actuate the location reader and the eighth holds the logic..

(8a) If credit validation is received, the printing mechanism is unlocked and imprinting accomplished. (8b) If an error signal is received, the control button is hit again. This recycles the main sequencer to card read position and all data is again read into the computer.

(9) Removing the card at any time terminates the process by removing power.

The main sequencer allows the unit to be built up of a series of subassemblies; each subassembly is built on a printed circuit card or series of cards. This serves several functions: east of design and contruction, reduction of maintenance costs, and increased flexibility in function. Each unit built can function as either Model A, B, B1, and modified C unit by merely adding cards and changing the error recycling jumper on the main sequencer. This eliminates redundant production of different boards which have the same basic function; and greatly reduces costs. It also increases interface


TONE DETECTOR
CREDIT
NO. CREDIT
ERROR
RELAYS
DRIVER
DETECTOR
CORES
SWITCH BANK
OSC
DRIVER
N+1
DIALER
PS
MV
CARD READER LOGIC
PRICE READER
LOCATION READER
1
2
3
4
5
6
7
8
CONTROL SEQUENCER
MULTI-VIBRATOR
3.3 VDC
CONTROL BUTTON
ONE SHOT
CRADLE SW
PWR SUP
CARD PWR SW
110 AC

flexibility. If the central processor returns non-standard tones, a different tone dector card can replace the standard one with no other modification of the circuit. Two dialing cards have been designed, one for touch tone and one for digital dialing. The appropriate card, depending upon the local service is then plugged into the dialer location in the card rack.

Our model does not function correctly as model C. The central processing program written to handle the accounting and credit check can accept data punched in over the touch tone keyboard. However, there is no permanent record of such entries and there would be no control over error. Because of the arbitrary printing requirements of model C, a general unit fulfilling requirements for A, B, and C would be too expensive for use as models A and B. We chose, therefore, to design the unit to function as models A, B, B1, and partially as C. A separate unit is then required to satisfy the requirements of unit C. One system suggested makes use of either an adding machine or cash register as a printer/keyboard. The automatic dialer, card reader, and location modules from the previous unit are then employed in the Model C unit; but the price modules and gas station type printer are not needed. Each key of the cash register or adding machine is then electrically or optically (using fiber optics and photo diodes) given a digital code and connected to the external relays of the X403 B through the appropriate logic. Before registering a credit card purchase:

(1) The operator lifts the receiver and after hearing a dial tone pulls out the exclusion key.

(2) The operator pushs the control button actuating the automatic dialer.

(3) Upon reception of tones from the computer, the operator hits the button again, automatically reading in the card number and location.

(4) The purchase is "rung up" on the cash register; and all information is transmitted to the computer for accounting operations.

(5) If credit is valid, the computer permits the cash register to validate the charge slip.

(6) If not, the sale is voided.

As mentioned earlier our unit is broken up into self contained modules. These are shown in the general block diagram and listed here. Each will be explained in detail.

(1) Main sequencer and control multivibrator

(2) Touch tone dialer

(3) Digital Dialer

(4) Card reader (more than one card)

(5) Price reader

(6) Location reader

(7) Power supply and one shots for presetting logic (initial and redial)

(8) Tone detectors

(9) Relays with drivers

CHAPTER 2

COMPONENT SELECTION

The selection of components must be made giving primary consideration to making sure that the component selected will perform the task that it is supposed to perform. This must include being compatible with the other elements present in the circuitry, as well as functioning over long periods of time. If then after these considerations, several components are found to have the same relative merits, the primary factor that will be used in determining which components will be used must be economic. This is true, since other things being equal, that is the functioning of two units is the same, the least expensive one will yield a product which can be marketed at a lower cost, yielding a better position in the competitive market.

In general for the integrated circuits that are used, the dual in line packages will be used even if they are slightly more expensive, for they allow placing more elements on a printed circuit board. This will be a great advantage in several places where there are large numbers of integrated circuits to be placed on one printed circuit board.

For the sequencing devices that are found throughout the terminal unit, there are several types of flip-flops that are used. In the building of circuitry for a prototype a Fairchild 9926 clocked J-K flip-flop was used. This device had a preset and a preclear, but was essentially used as a R-S type flip-flop. Because of time consideration in the building of a prototype, the existance of the Motorola MC702, which is a R-S type flip-flop, was unknown at the time of ordering. Thus, it is not in the prototype, but would appear in the final production model of the credit checking device, due to its adequate fulfillment of the operating requirements, and its much lower cost. The actual cost of the entire unit, as well as the cost of separate parts will be found elsewhere.

The J-K clocked flip-flop that was employed in the prototype will be the same as in the final model, that being the Fairchild 9923. This element was less expensive than any other comparable device. This device, although not available in the dual in line package at present, might possibly become available if large enough quantities were desired, and seeing that space consideration are quite important often enough, this may be the case shortly. In any eventuality, the cost was significantly low enough to warrant the purchase of the Fairchild 9923 over any device presently available in the dual in line package.

The next types of components to be considered are the logic elements. In the inexpensive medium power type of component range, there are only NOR gates available in the resistor-transistor logic series. The functions needed were mainly AND type, so in general three NOR gates would be needed to get the equivalent of an AND circuit. The cost of this would then become prohibitive. Thus, the final device, as well as the prototype will contain diode-transistor logic in the medium power range. These devices will be compatible with the rest of the circuitry, in that their input and output currents and voltages will be approximately the same. The only major difference will be in the supply voltage that is needed. In the diode-transistor gates this will be five volts, while for the flip-flops previously mentioned it will be only three and six tenths volts. This will present no problem for there will be available supplies of four and fifteen volts, and the required five volts can be gotten from the fifteen volt supply by use of a potentiometer. The specific elements that were used were the Fairchild 9946, 9962, 9930. These are respectively quad two input NAND gates, three-three input NAND gates, and dual two input NAND gates. In the event that a positive AND function is needed, an inverter can be used. One is the Motorola MC727 quad inverter which is about the cheapest, and comes in the dual in line package. The next element is the driver, which is used to get the current to preset the flip-flops. The Fairchild 9900 was used for this, as it is very inexpensive and satisfies the functional criteria. The NOR gate that was used was the Fairchild 9914, which was adequate and inexpensive.

The final components to be selected other than resistor or capacitors are diodes. Any low cost diode with operation at one volt and one milliampere of current will suffice, if it is good up to twenty-five milliamperes and five volts.

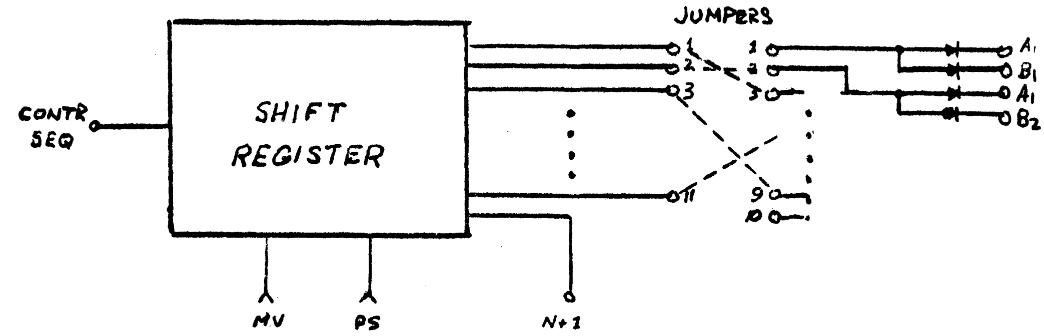
CHAPTER 3

CHOICE OF LOGIC CIRCUITRY

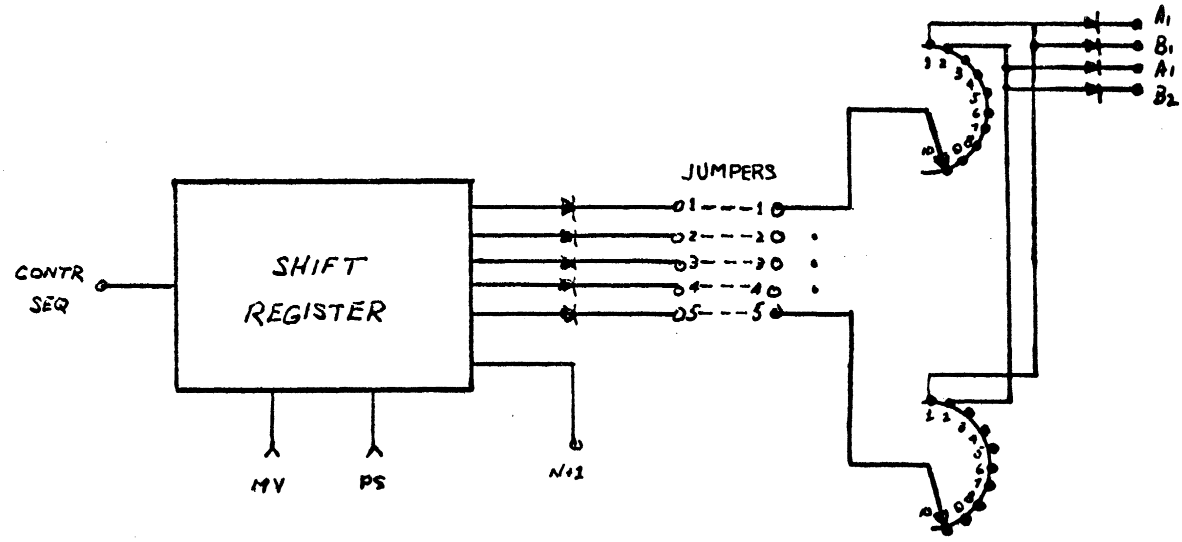
All logic operations consist basically of generating a sequence of digits; hence a basic circuit block of all the logic modules is a simple sequencer. We located two basic types of sequencers: a shift register and a binary counter followed by a diode matrix. The latter method at first appeared to be the best method. It would have been the cheapest and most compact if we could have found diodes in integrated chips. Such chips are available but demand is low and prices high. Motorola manufactures 8 diodes in its MC1118 block which sells for $29.10 in 1-25 quantities. Such costs are prohibitive. Individual diodes would have been cheap; but with the costs and size of mounting 66 diodes in a matrix we decided to use a shift register. It is common to all the logic cards.

The touch tone dialer, card reader, price reader, and the location reader are all similar. Each consists of the shift register of a different "bit count" with a slightly different output interface. The circuits are shown in figure 2. For the tone dialer, each sequence position is wired to its appropriate digit at installation in order to set the desired number. This is accomplished by simply jumpering between two of the terminal posts provided on the board. The same procedure is used with the location number. With the price dialer the outputs of the shift register are connected to the common pole of a ten position switch. This switch is a combination printer/rotary switch. When the operator sets the appropriate price in the machine the switch is rotated to its proper digit. Each output from the switch is connected through diodes to the appropriate A and B relays. The outputs of the shift register for the card reader are connected to a bank of transistor switches with a common sine wave oscillator. As each transistor is turned on, the sine wave is applied to a column of ferrite cores, then the output from the two cores with the cards magnetic material over them is able to be detected. This procedure is explained under the description of the card reader.

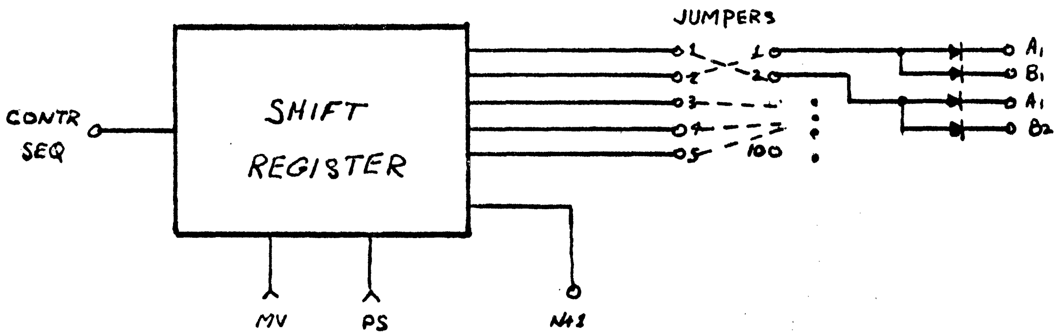
The sequencer common to all these units is shown in fig. 3. The control sequencer supplies a starting 1.5 VDC voltage to the input of the circuit. This is differentiated to a pulse which



TOUCH TONE DIALER



PRICE READER

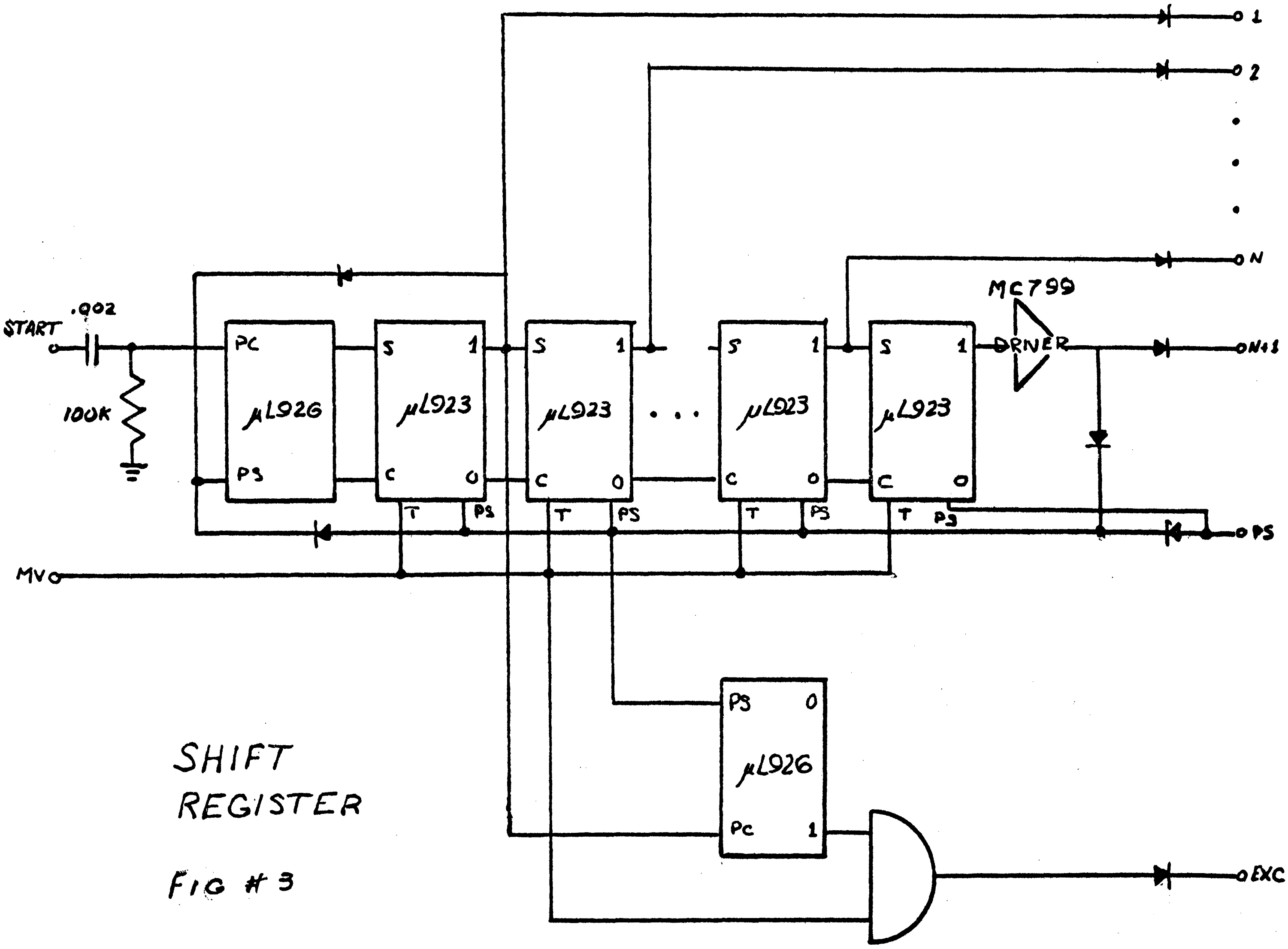


LOCATION READER

FIGURE 2

preclears the initial RS flipflop to a high state. This places a high signal on the S input of the first input of the JK flipflop. This flipflop will now clock on the next down pulse of the multivibrator. This free running multivibrator is common to all units and its time constants control the hold times of the final output relays. Each sequence position and hence two of the A and B output relays are on for a full cycle of the multivibrator. See fig. 4. The output of the multivibrator is connected to the excitation relay through and "AND" gate. The excitation relay is allowed to follow the multivibrator when an RS flipflop supplies a high state to the AND gate. This flipflop is normally preset to low state preventing the excitation relay from being operated until the flipflop is set by the first sequence pulse. It is then turned off by the n+1 sequence pulse. At the first clock pulse after the initial RS flipflop is set high, the first JK flipflop gives a high output. This high output then presets the initial RS flipflop to low state and sets the input of the second JK flipflop to high state. On the second clock pulse the first JK will switch to low state and the second JK will switch to high state. This pulse will then travel down the sequence of JK's until it reaches the n+1 position. The integer n varies with the number of digits to be sent--for the card reader, n = 10; price reader, n = 5; location reader, n = 4. The n+1 pulse is used to preset the first n flipflops and to trigger the main sequencer to its next position, it shuts itself off on the next clock pulse. A driver stage is needed here since the fan out (maximum number of similar logic units with a fan in of one which may be driven) of the Fairchild 9923 flipflop is only 5. Up to 12 flipflops each with a fan in of three must be driven in our application.

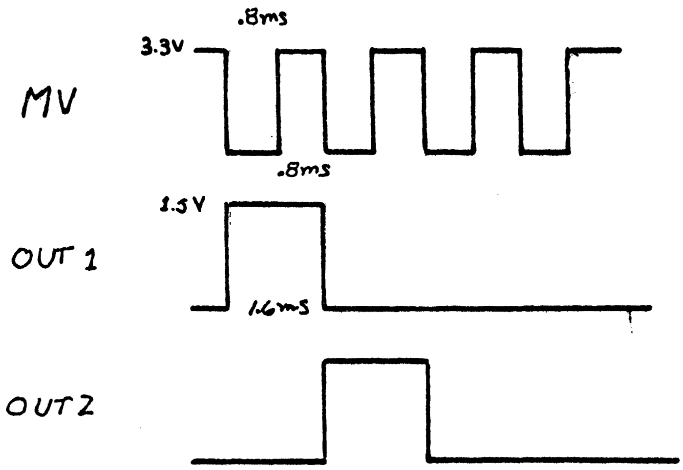
The power requirements for each unit are determined from the Fairchild loading sheets. With 3.3 VDC applied to each collector, each base of the flipflop will draw 0.500 ma. when in a high logic state. Since each flipflop has one of its inputs and the clock base turned on, the total current drain will approximately be #ff x 1.0 ma. This is sumarized for each unit in the following table:



SHIFT
REGISTER

FIG # 3

TIMING FIG # 4



Card reader (w/o output transistors)	-	15ma - 50mw
Tone Dialer	-	16ma - 53mw
Price Reader	-	9ma - 30mw
Location Reader	-	8ma - 27mw

The control sequencer is an 8 bit shift register. It operates as described for the other logic units with the exception that it is clocked by a pulse from the control switch or from the n+1 return pulse from the logic modules described earlier. The control button supplies a 4.0 VDC voltage to the main control card. This is differentiated and used to trigger a one shot multivibrator which clocks the sequencer. As the sequencer moves from its low state to position 1 the tone dialer is actuated, then to position 2 the card reader is actuated, then to position 3 the card reader is actuated again, etc. If the multivibrator time constant is t seconds, the time delay between each series of digits (telephone number, card number, etc.) will be 2t seconds. First there will be t seconds from the end of the nth pulse to the down pulse of the n+1 pulse which clocks the control sequencer. After the time delay of the differentiator, the next logic module will be turned on, but it will not clock until the next multivibrator down pulse t seconds later; hence, the total time delay is 2t seconds.

After all the digits are sent, the sequence is in its last position. If credit is validated the unit must shut off, but if an error is returned, all information must be repeated except the dialing function. Hence, if the control button is hit a third time, we want the sequence to go to the second position and not the first! This is accomplished by taking the "0" output of the last JK flipflop which is at zero state and connecting it to the C input of the second JK flipflop. Then at the next trigger the second flipflop will reverse output states starting a new pulse down the counter. Because the same number of sequence steps is not required for each unit A, B, or B1, provision is made to jumper from the 4th, 6th, or 8th JK "0" pad back to the

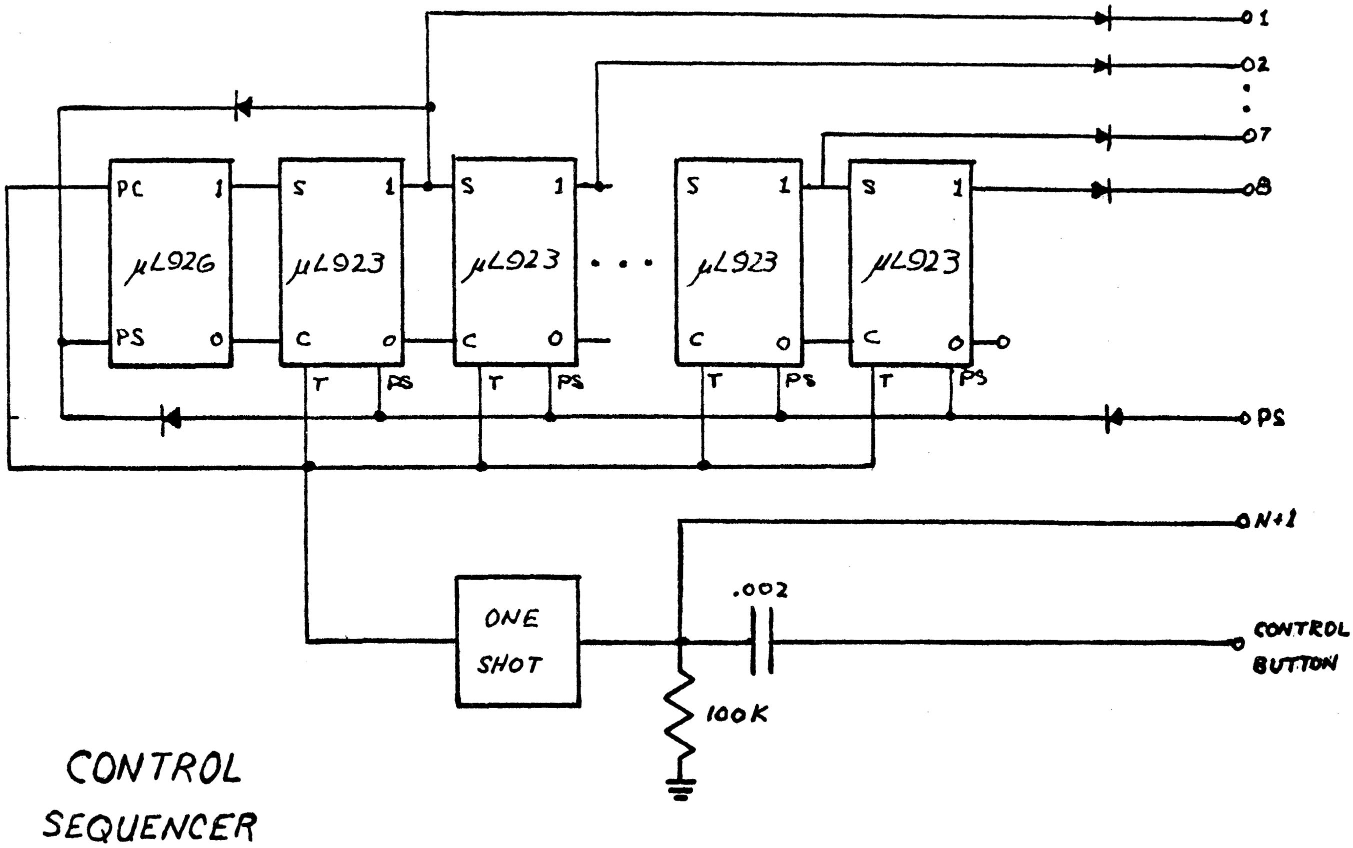


FIGURE 5

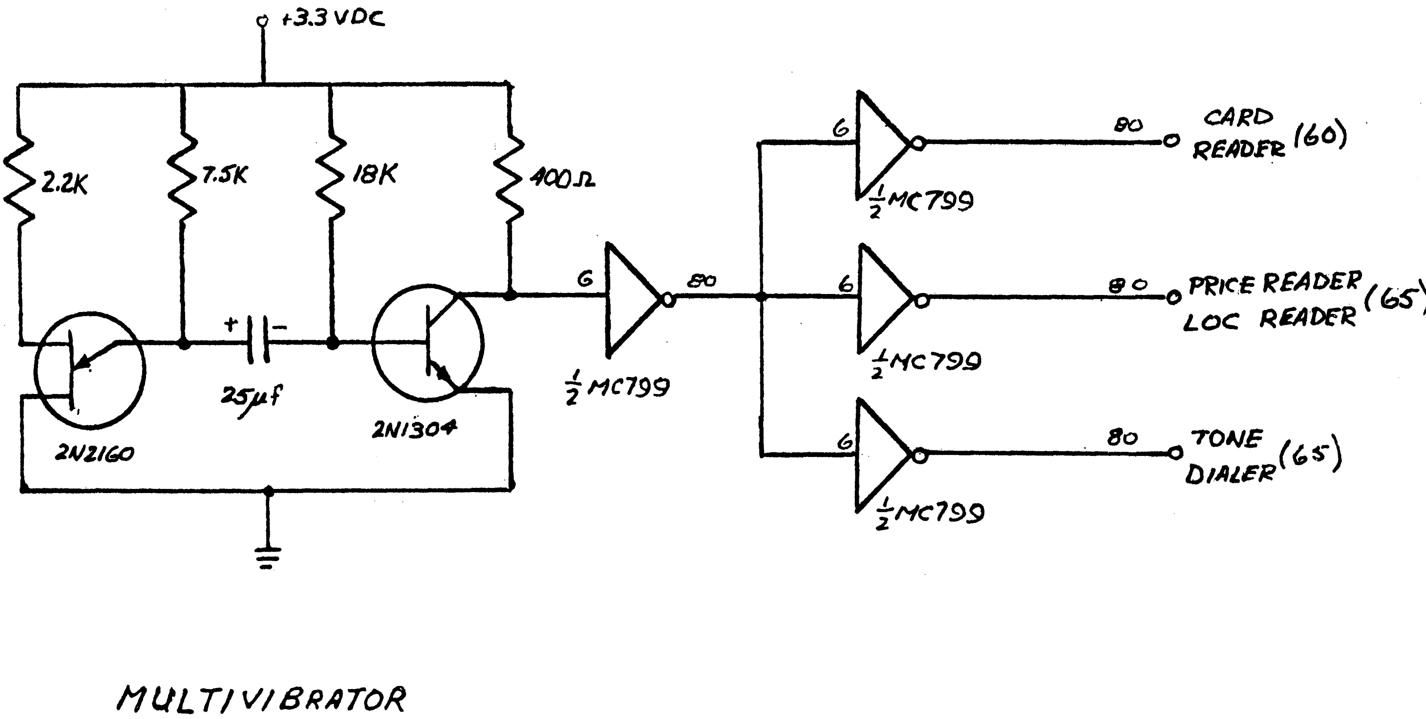
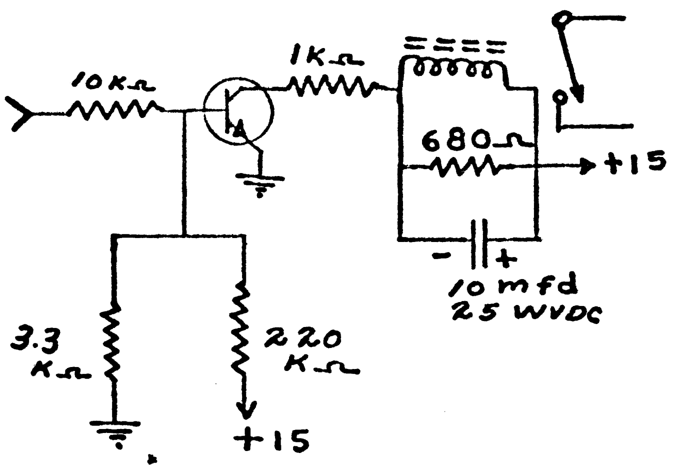
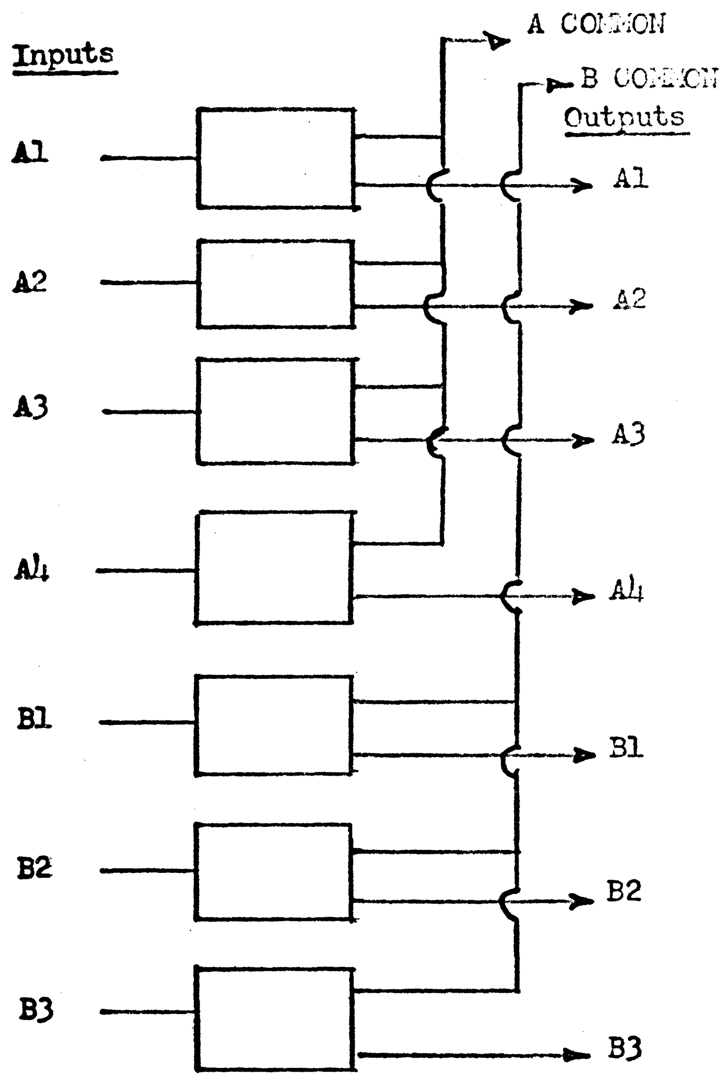


FIGURE 6

second JK C input pad. Unit A requires only four functions; dialing, two card readings, and a hold position, therefore a jumper is made from #4 to #2. For unit B a jumper is connected from #6 to #2. Besides plugging in the additional boards this is the only change needed to convert from unit A to unit B.



Basic relay and driver circuit for group A and group B relays.



General Block Diagram of the connedtions of the basic relay and driver circuit as shown on the left. The A's & B's indicate connections of the relays to the X-403-B.

FIG. 7 RELAY AND DRIVER CIRCUITS

CHAPTER 4

MAGNETIC CARD READING SYSTEM

The purpose of this system is to decode ten decimal digits of information from the credit card and use this information to close the appropriate relays to send the decimal digit over the phone line by use of touch tones from the X403B data phone.

The principle of operation of the magnetic card reader is as follows: Each decimal digit is incoded in the card by means of two small pieces of transformer core steel buried within the card. The presence of these pieces of steel is detected by use of a slit toroidal core transformer. The transformer is placed in such a position that the buried steel completes the flux path of the flux in the toroid. The higher flux in the toroid causes an increase in inductance in the secondary of the transformer which acts to tune the L-C circuit attached to the secondary. This in turn causes an increase in amplitude which can be detected by a level detector, rectified, and used to drive a transistor switch which in turn operates a relay. A block diagram of the overall magnetic card reading system is shown on the next page followed by a detailed description of the circuitry involved.

THE CREDIT CARD

This system is designed to use standard 2 1/8 X 3 3/8 inch credit card used by the Gulf Oil company and others. The card has room for a ten digit account number in 3/16" letters and the customers name in 1/8" letters across the bottom of the card. These would be raised letters which could be used to print this information on a sales slip. The rest of the card would be used to encode the account number by means of small pieces of steel burried in the card. Since the touch tone phone is set up on a 3 X 4 matrix with each tone being produced by beating one tone from group A (the group containing three tones) with one tone from group B (the group with four tones); it will be necessary to operate seven relays in order to be able to transmit any decimal digit using the X403B data phone. This means that each column (corresponding to one of the ten decimal digits of information) will have to contain seven possible positions for a piece of metal. Of these seven possible positions, two will

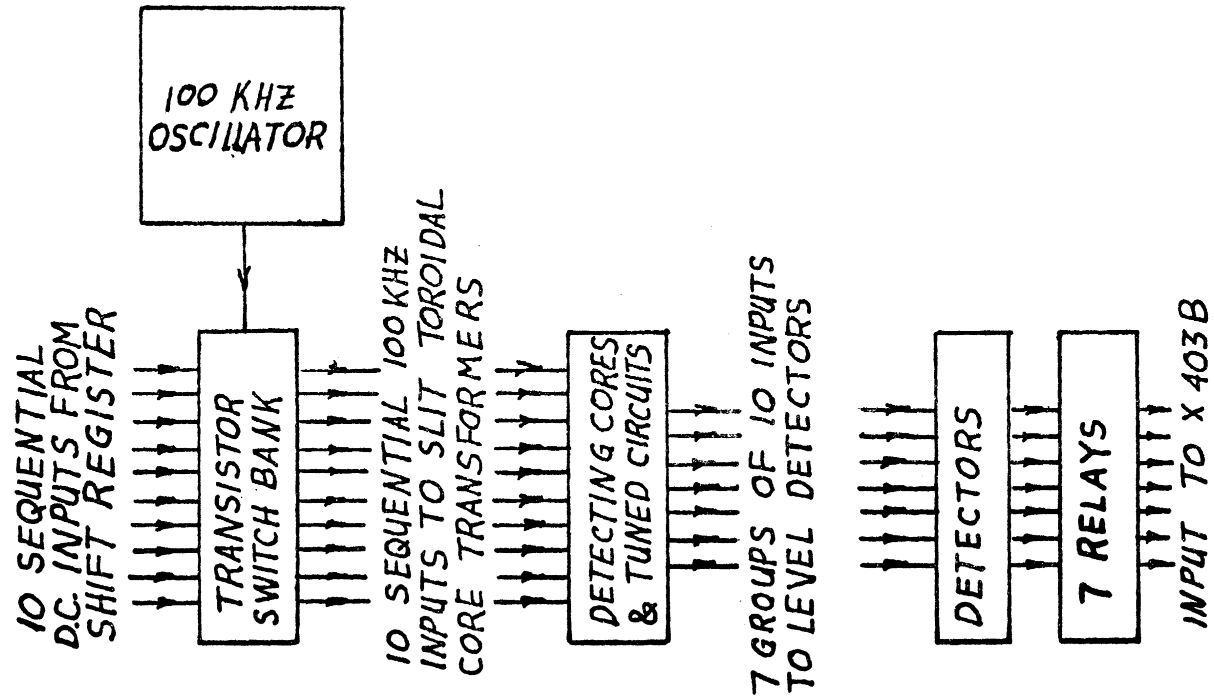


FIGURE 1

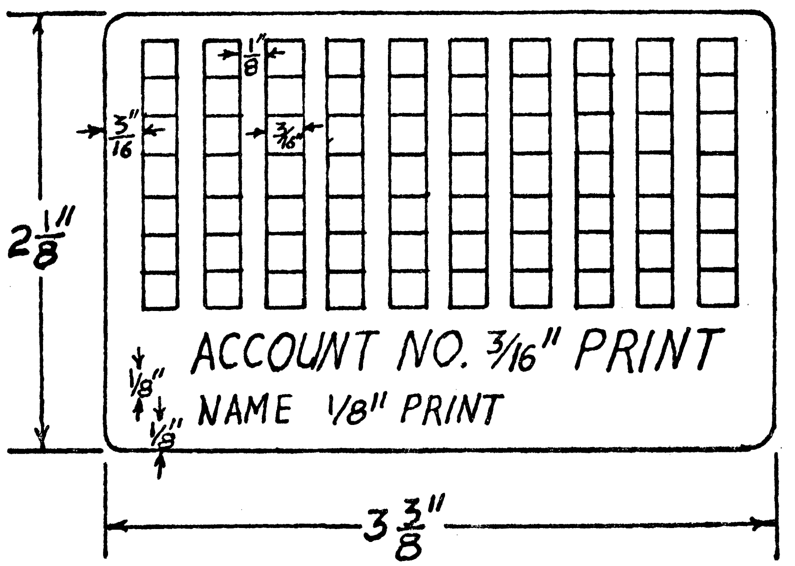


FIGURE 2
EACH SQUARE REPRESENTS A POSSIBLE POSITION FOR A PIECE OF METAL.

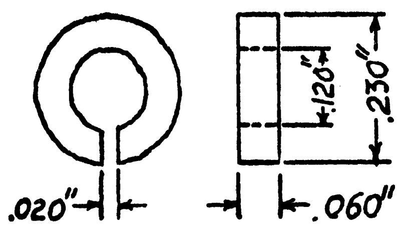


FIGURE 3
DIMENSIONS OF SLIT TOROIDAL CORE

have to actually contain a piece of metal. Since there are ten decimal digits on the card, there will have to be seventy possible positions on the card where pieces of metal can be placed. As can be seen in figure two, ten columns of 3/16" squares with 1/8" between columns will provide the necessary seventy positions on a standard credit card. On the experimental credit car that we made, we cut 3/16" square pieces of metal cut from the core on an old transformer. We then covered the entire card with masking tape for lack of a better material. This is a rather time consuming procedure, and in production it would be better to mold the card with the metal in place, or deposit the metal on one half on the card and then press the other side of the card in place.

SLIT TOROIDAL CORE TRANSFORMER

A. Principle of operation

Figure three shows a slit toroidal core. This can be made into a transformer by winding a primary and a secondary coil on the core. The magnetic flux around the toroid will be inversely proportional to the reluctance it encounters. This can be seen from the definition of magnetic reluctance: $R = NI/\psi_m = l/\mu A$; where NI is the number of ampere turns in the coil, l and A are the length and cross sectional area of the flux path with permeability μ, and ψ_m is the magnetic flux. If there is more than one flux path in the magnetic circuit, as there is in the slit toroidal core, then the reluctances add as do resistances in series. Therefore the flux in the core can be writen as: $\psi_m = NI/(R_a + R_c)$ where R_c is the reluctance of the core, and R_a is the reluctance of the slit or air gap in the core. As can be seen from the definition of reluctance, the reluctance of a given path is inversely proportional to the magnetic permeability of the material in the path, μ. Since the permeability of iron is much higher than that of air, (by a factor of ten or more) the reluctance R_a will be at least ten times higher than it would be if the slit were filled with iron. This means that if a piece of high permeability material, such as iron, is brought near the slit it will serve to reduce the reluctance R_a which will serve to increase the flux in the core. Since the inductance of a coil is directly proportional to the flux through the coil, $L = \psi_m N/I$, the inductance of both the primary and the secondary coil will be increased. As will be shown below, this increase in inductance will be used to tune an R-C circuit, and the change in amplitude will be used to signify the presence of a magnetic material near the slit of the core.

B. Analysis of the transformer circuit.

In order to determine what type of response we might expect from the transformer circuit, we wound up a transformer using ten turns of number 36 wire on the primary side, and 100 turns on the secondary. The dimensions of the core that we used are shown in figure three. Using a General Radio bridge we measured the inductance of the transformer at 100KHz with the following results:

	With air gap open	With iron over air gap
Primary inductance	5uh	8uh
Secondary inductance	114uh	170uh
Mutual inductance	16.5uh	30.5uh

Using the above values of inductance I modeled the transformer by its T equivalent. This T equivalent transformer was then connected to an oscillator on the input (modeled by a voltage source in series with a 600 ohm resistor) and an oscilloscope on the output (modeled by a megohm resistor in parallel with a 47 pf capacitor). This circuit is shown in figure five, and the results of an analysis using the computer program CIRAN are shown in figure four.

As can be seen from figure four, if the oscillator is tuned to 1.8 MHz the gain of the transformer circuit will be +17db when there is a piece of iron over the slit in the transformer, and -4db when there isn't. This means that the presence of a piece of iron near the slit in the transformer will cause an increase of 21db (about a factor of ten) in the voltage across the secondary. This difference in voltage can be detected and used to drive a relay which in turn will operate an X403B dataphone.

VOLTAGE TRANSFER FUNCTION V_{OUT}/V_{IN} OF A MAGNETIC DETECTOR MODELED BY A T EQUIVALENT TRANSFORMER.

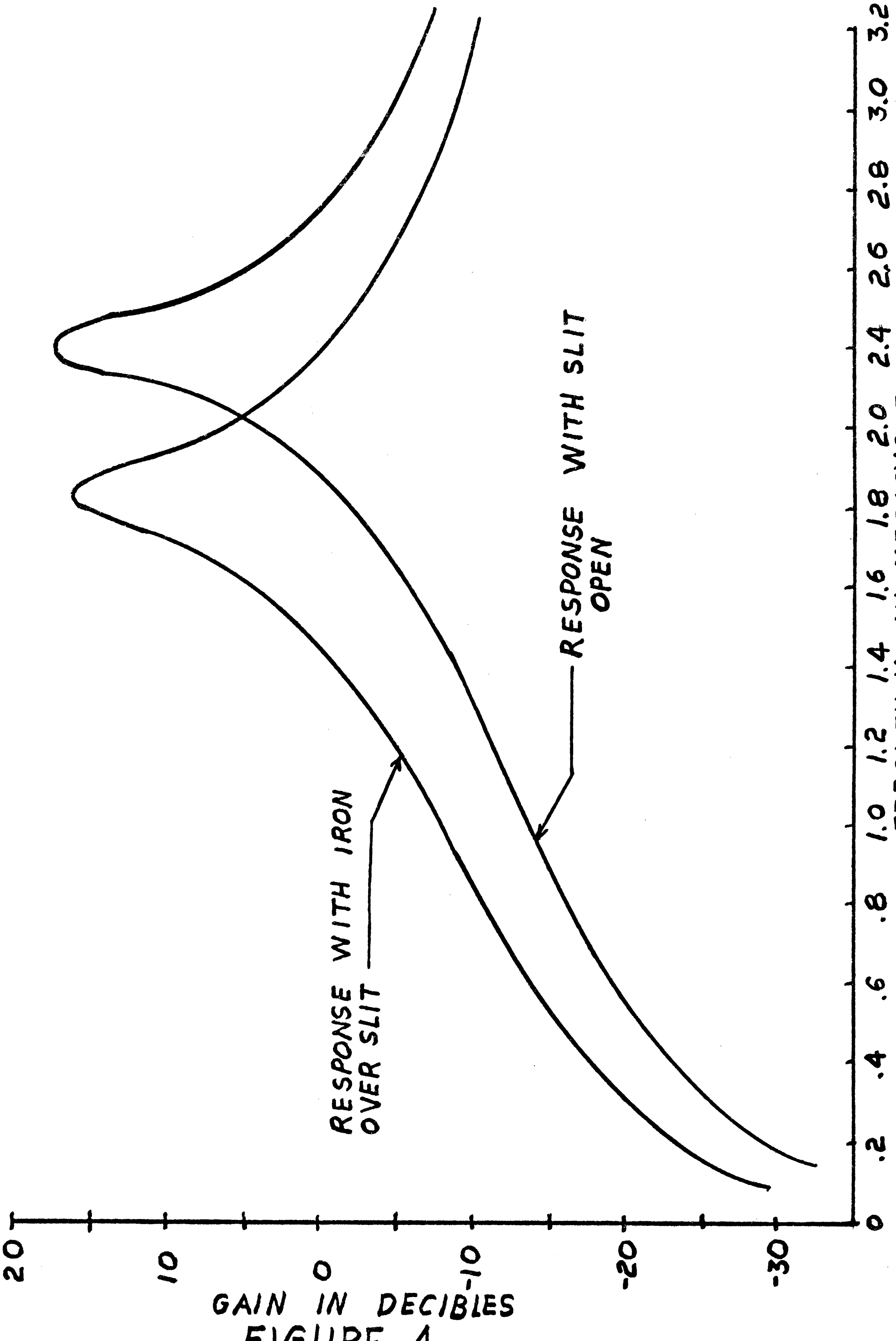
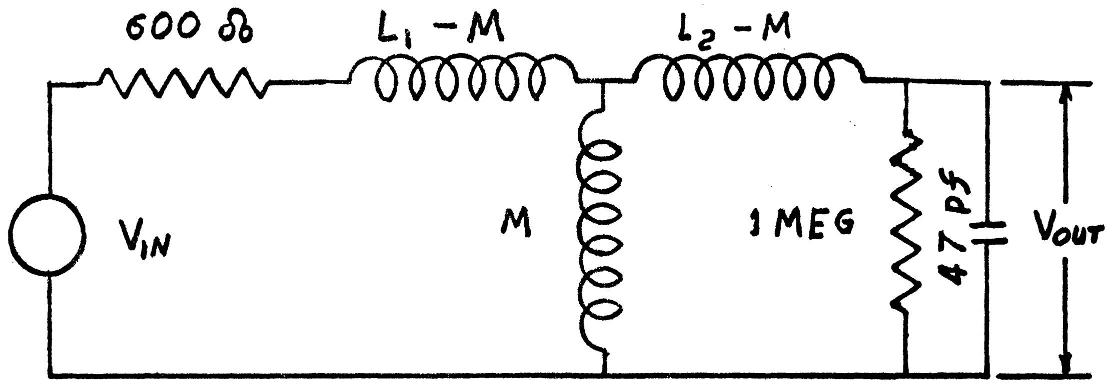


FIGURE 4



L_1 = PRIMARY INDUCTANCE L_2 = SECONDARY INDUCTANCE
M = MUTUAL INDUCTANCE

FIGURE 5

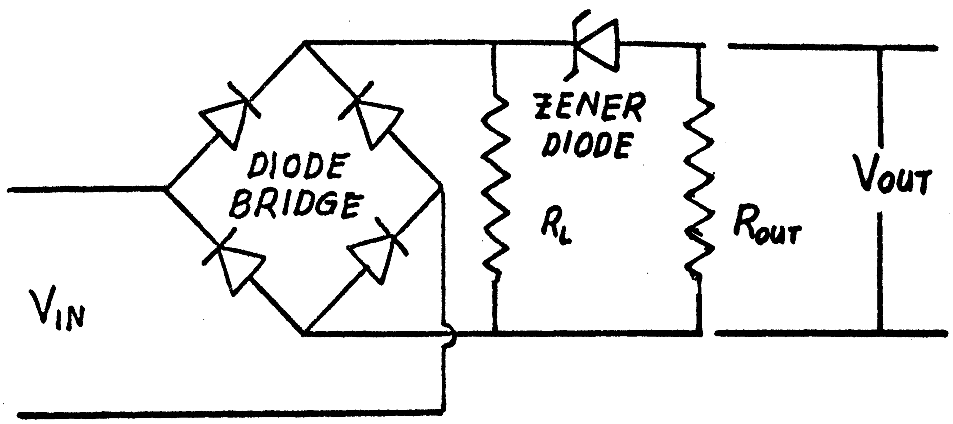


FIGURE 6

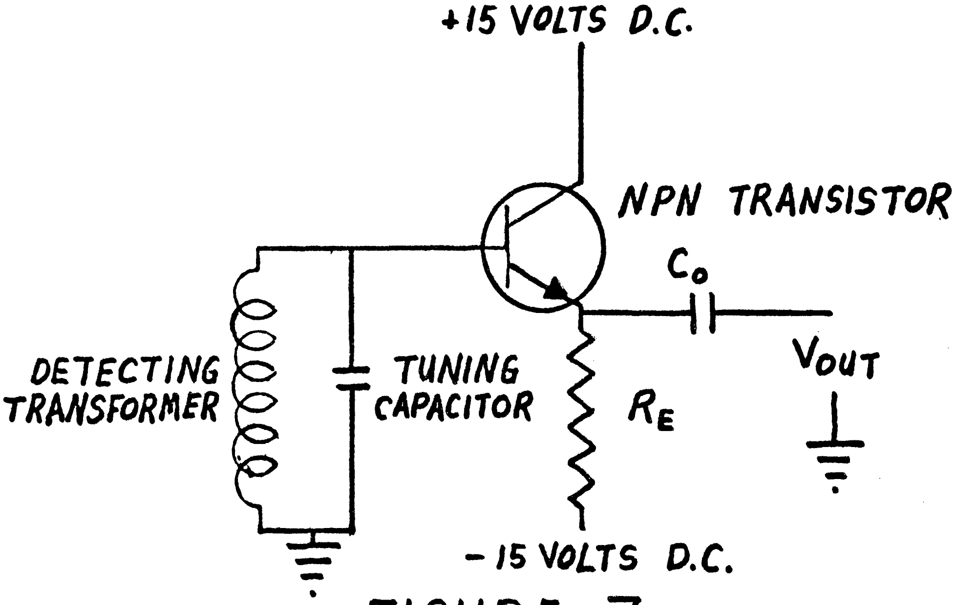


FIGURE 7

THE DETECTING CIRCUIT

The purpose of the detecting circuits is to detect any change in voltage occuring across the output of the transformers, and close the appropriate relays to send this information over the phone lines. There are seven rows and ten columns of transformers, one transformer for each possible position of a piece of metal in the card (see figure two). The transistor switch bank shown in the block diagram (Fig. 1) switches the output of the oscillator from one column of transformers (with their inputs connected in series) to the next. The detector's job is to detect which two of the seven transformers in each column have metal buried in the card beneath them, and close the proper two (out of seven) relays to operate the X403B dataphone.

It is obvious from the above discussion that there will have to be seven similar detecting circuits, and that each circuit will have to be able to detect a change in amplitude at any one of ten possible positions. The easiest way to do this would be to connect all of the outputs of the transformers together in series. A change in the inductance of any one of the ten secondaries would appear as a change in total inductance. This method is not feasable since the inductance changes by less than a factor of two, and this small of a change in inductance would be masked by the inductors in series with it and would result in a change of less than 5% in the total inductance.

In order to overcome the masking effect of the inductors in series it is necessary to isolate the tuned circuits on the secondaries from each other. This can be done by rectifying the output of each tuned circuit before they are added together. Figure six shows a diode bridge connected to a zener diode level detector which could be used for the purpose of isolation. Each of the ten transformers in a row could be connected to a separate diode bridge. The outputs of the ten diode bridges could share a common load resistor R_L, and an input voltage at any one of the ten inputs would produce a rectified output voltage across R_L. If the voltage across R_L was greater than the breakdown voltage of the zener diode, the zener will break down and a voltage will appear across R_{out}. Thus the zener diode provides a simple level detector which can be used to detect an increase in voltage across any one of the ten inputs.

To test this detector we built up ten diode bridges and connected them all to a 1K load resistor. For the level detector we used a 12 volt zener and a 1K resistor. Testing this circuit out with an oscillator we found that the circuit worked fine up to about 100KHz. The feedthrough from one channel to the other was negligable, and there was no output until the voltage at one of the inputs exceeded 12 volts peak. When we hooked one of the cores to the input of one of the diode bridges we found that we could not detect the presence of metal near the slit. We traced this problem to the fact that the 1K load resistance, which was effectively connected across the transformer output, lowered the Q of the tuned circuit to a point where no change in amplitude could be detected. Connecting a variable resistance across the tuned circuit we found that the load resistance had to be at least 90K in order to prevent lowering the Q of the circuit. Since a load resistance of 90K across the diode bridge would not allow the diodes to turn on hard enough to adequately rectify the input voltage; this detecting scheme was abandoned in favor of a high impedance detector.

Figure seven shows an emitter follower circuit which could be used to isolate one detecting transformer from the others. This circuit has the advantage that the high input impedance does not destroy the Q of the resonant circuit. Each of the ten transformers in one row must be connected to their own emitter follower circuits, and the output of each circuit will be connected through an output capacitor C_o to a common point from which V_{out} will be measured to ground. The output impedance of an emitter follower is quite low, therefore if a signal is applied at the terminal pair across which V_{out} is measured the load it will see is just the capacitance C_o in series with a small resistance. Thus each of the nine emitter follower circuits which are not excited will appear as a capacitance across V_{out}. This means that the output voltage, V_{out}, is the voltage which appears across a capacitance $9C_o$ which is coupled through a capacitance C_o to a low impedance source. If the emitter voltage is considered to be V_e then the output voltage will be:

$$V_{out} = V_e C_o/(9C_o+C_o) = 0.1V_e$$

We built up a detector using 2N1304 transistors with $R_e = 15K$, and $C_o = 0.1uf$. This circuit worked well in that an input to the base of any one of the ten emitter follower circuits produced a proportional voltage at the output voltage terminal pair, and produced no detectable change at any of the other nine inputs. The main problem with this circuit was that the output waveform was distorted. This was traced to the fact that the AC load line of the transistor was determined almost entirely by the capacitance C_o. Since it's reactance was quite low compared to that of R_e, the AC load line had a much greater slope than did the DC load line. Since the transistor was only drawing one milliampere of current, the steep AC load line would cause the transistor to cut off for negative excursions of the input voltage.

One method of solving the problem of distortion is to increase the slope of the DC load line by decreasing R_e. This method was not too satisfactory in that R_e had to be lowered to 500 ohms in order to produce a sinusoidal output. This meant that the quiescent current was about 30 milliamps which quickly destroyed the transistor.

Another method of solving the problem of distortion is to increase the reactance of the output capacitors to a value which is greater in magnitude than R_e. In this way the slope of the AC load line will be determined more by R_e than by C_o and distortion will be eliminated. The impedance of the output capacitors can be written as $Z_o = 1/2\pi f C_o + 1/2\pi f 9C_o$. If we let $Z_o = -j50K$ ohms, solving for C_o at a frequency of 100KHz yields $C_o = 35pf$. The impedance which V_{out} appears across is now $1/18\pi f C_o = 1/18\pi 10^5 x\ 35 \times 10^{-12} = 5K$ ohms. This means that any detecting circuit which is used to detect V_{out} must have an input impedance on the order of 15K in order not to load down the capacitance across which V_{out} appears and destroy the effectiveness of the capacitive voltage divider.

The output voltage V_{out} may now be rectified and detected using a diode bridge and a zener diode as discussed earlier in the report. The fact that V_{out} appears across a voltage divider which reduces its value to about 10% of the input voltage makes it necessary to add a single stage amplifier with a gain of about 20db between the output terminals and the input to the diode bridge detector. A capacitance of 0.01uf across R_{out} in figure six will provide a DC level to drive the transistor drivers for the relays (if $R_{out} = 1K$).

POSITIONING AND MANUFACTURE OF SLIT TOROIDS

The physical size of the slit toroidal transformers is determined by the fact that 70 of them must be positioned above the credit card. From figure two it can be seen that the maximum outside diameter of the cores will be about 1/4". The dimensions of the core that we actually used are shown in figure three. We obtained a sample of 100 of these cores from The Arnold Engineering Company. The AECo part number of these cores is AM12D02002, and they cost 4 1/2¢ each in lots of 25,000. The slit was cut in the cores by using a 0.020" diamond wheel mounted on a surface grinder. The cores were held in position in a "V" block with bee's wax.

Cutting the cores is time consuming and would add several cents to the cost of each core. One way to avoid this extra cost would be to manufacture the cores with the slit already in them. Since the cores are pressed from ferrite powder, it would be relatively simple to make a modification to the mold so that the cores would have a slit molded into them. According to Mr. Sneed of Arnold Engineering Company this could be done to a dimensional accruacy of 1 or 2% without raising the price of the cores.

The easiest way to position the cores is to mold them in plastic in columns of seven. The maximum width of these columns would be 5/16 inches. These columns of seven could be put together in groups of ten to make a complete detecting head. The finished dimensions of this head would be 3 1/8 x 1 9/16 x 14 inches. The extreme compactness of the detecting head allows it to be mounted in an Addressograph Multigraph model 12 - 55 variable amount data recorder with only minor modifications.

An alternate method of mounting the cores is to put them together in columns of seven using epoxy cement. This is the method that we used since we did not have the equipment to mold them in plastic.

If copper studs are molded into the columns with the cores, the columns can be mounted together on a printed circuit board and would be easily interchangeable.

CHAPTER 5

OSCILLATOR AND CORE INPUT SWITCHING

The input to the cores of the card reader is to be a 100 KHz signal. To accomplish this an oscillator and transistor switching circuit is used. The oscillator, shown in Fig. A, is simply Colpitts type oscillator. An emitter follower stage is used to offer a high impedance load for the oscillator so changes in the switching circuit will not affect the oscillator frequency.

The switching circuitry, shown in Fig. B, consists of ten identical switching circuits. One circuit, or switch, for each of the ten columns. In each circuit the first transistor is controlled by the output of a shift register. With the shift register off, the transistor, Q_1, is biased off and no signal is passed to transistor Q_2 or the cores for that column. When the shift register is turned on, for reading that column, transistor Q_1 is biased on by this signal and allows the oscillator output to be passed to Q_2. Transistor Q_2 is a current amplifier for the cores.

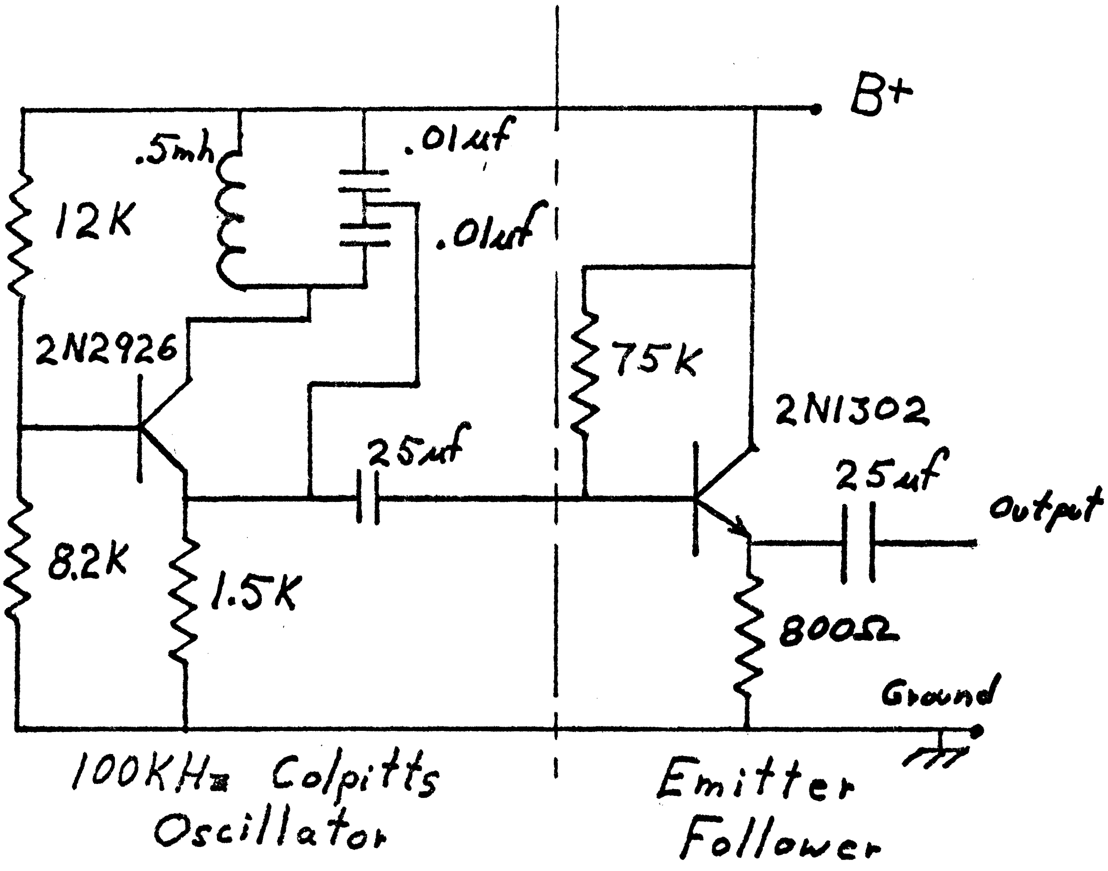
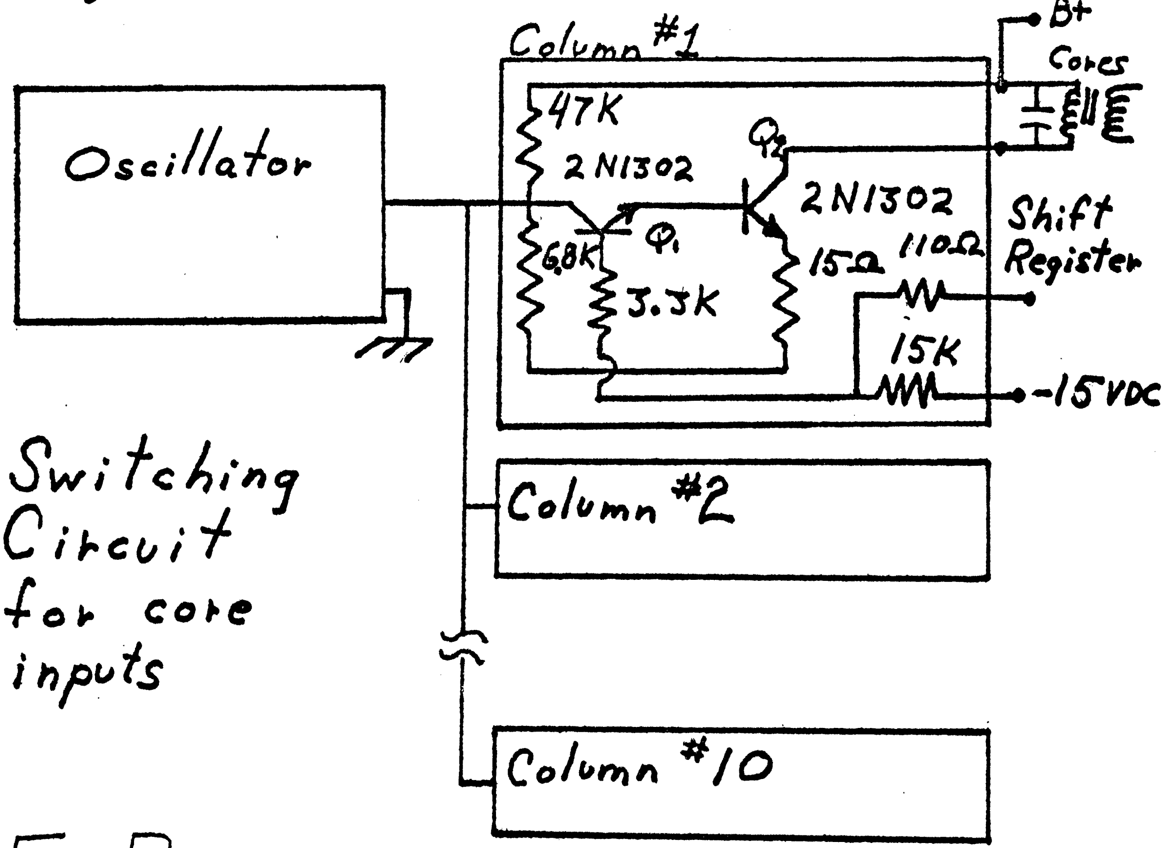


Fig A



Switching Circuit for core inputs

Fig B

CHAPTER 6

PRESET CIRCUIT

After the terminal reads a credit card and all the required information is sent to the computer, the terminal will be turned off. When the terminal is turned on again, all the flip-flops will be in an undetermined state causing incorrect information to be transmitted to the computer.

To prevent this from happening, a monostable, or one-shot, multivibrator is used to set all the flip-flops to zero when the power is turned on. As is employed here, the stable state is off. The monostable is switched to its unstable state by a trigger impulse at its input. How long it stays on depends on the time constant of the monostable. The pulse generated is fed to the preset terminals of all the flip-flops. The pulse used to trigger the monostable is generated from the DC supply voltage by feeding it into a differentiating network, which consists of a resistor and capacitor as shown in Fig. (1), with the corresponding waveforms.

As this pulse is fed into the monostable with the circuit shown in Fig. (2), the following happens.

The bias network holds transistor Q_2 in saturation and Q_1 at cutoff in the stable state. When the above pulse is applied to the base of Q_1, Q_1 begins to conduct. The decreasing collector voltage of Q_1, which is coupled to Q_2 through the capacitor, causes the base current of Q_2 to decrease which causes the collector current of Q_2 to decrease also. The increasing collector voltage of Q_2 is coupled to the base of Q_1 through R_3 and this causes the forward base current of Q_1 to increase even more, eventually driving Q_1 into saturation through this regenerative action.

The capacitor C then discharges through R and Q_1; the resistance of Q_1 will be small since it is in saturation. As the potential across Q_2 becomes positive it will conduct again. The decreasing potential of Q_2 is coupled to the base of Q_1 through R_3 and Q_1 is driven into cutoff while Q_2 becomes saturated; thus the stable condition is present again. It will remain in this stable state until another positive trigger is applied to the base of Q_1. How long Q_2 remains in cutoff, and producing an output pulse, is determined by R and C.

The monostable was originally designed using discrete components, but after realizing the compatability problems involved with circuits using discrete components, it was decided to use integrated circuits. It is possible to use integrated circuits throughout the terminal that use the same value of V_{cc}. When discrete components are used in different circuits throughout the terminal, utilizing a common supply voltage becomes a definite problem.

We decided to use Fairchild flip-flops which operate on a supply voltage of 4.0v. Thus it was only natural to go to Fairchild in designing the integrated circuit monostable.

We made use of a dual nor gate. The one shown in Figure (3) is the one we used. You simply add your own R and C to determine the pulse duration desired. Also when using integrated circuits, all terminals that are not in use must be grounded. This reduces the possibility of picking up any stray signals. Since there are four transistors available in the package, you can isolate the input circuit from the rest of the circuit, thus eliminating any detrimental effects that may arise when the input is connected. After the necessary connections are made to the dual nor gate, the circuit in Figure (4) is obtained.

Another definite advantage of using integrated circuits from the same vendor throughout the terminal unit is the fact that fan-in and fan-out has been determined by the manufacturer eliminating the problem of trying to determine how many elements you may have in parallel with a given element before the given element ceases to provide enough current to drive the elements in parallel with it. This is of great concern here since each flip-flop that has to be preset will be hooked in parallel with the monostable. Since the fan-out and fan-in of the dual nor gate and the flip-flops are given, this is no longer a problem. All the fan-out and fan-in factors, or input load and output drive factors have been normalized using as a basis the current required to turn on a low-power gate

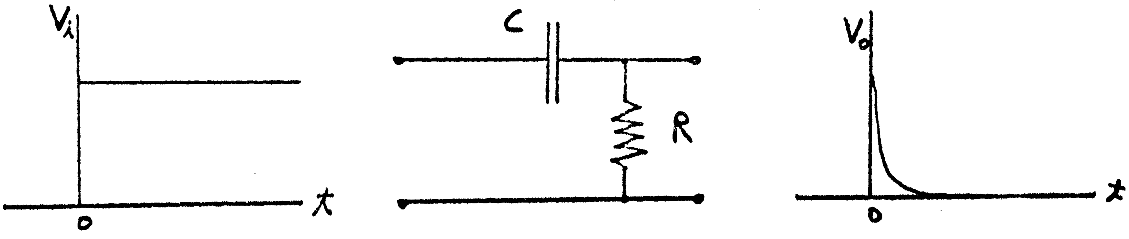


FIGURE 1

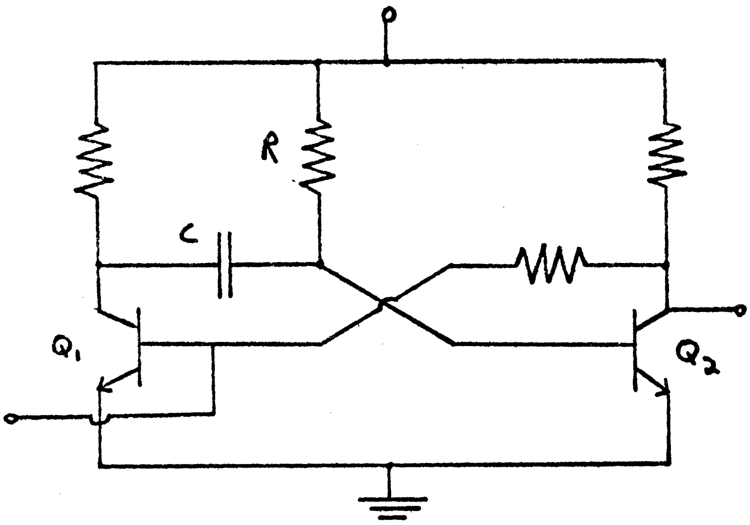


FIGURE 2

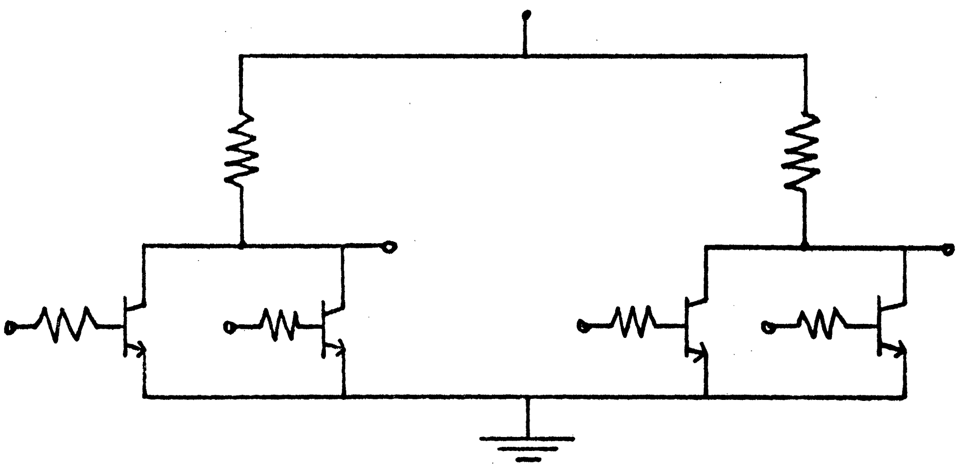


FIGURE 3

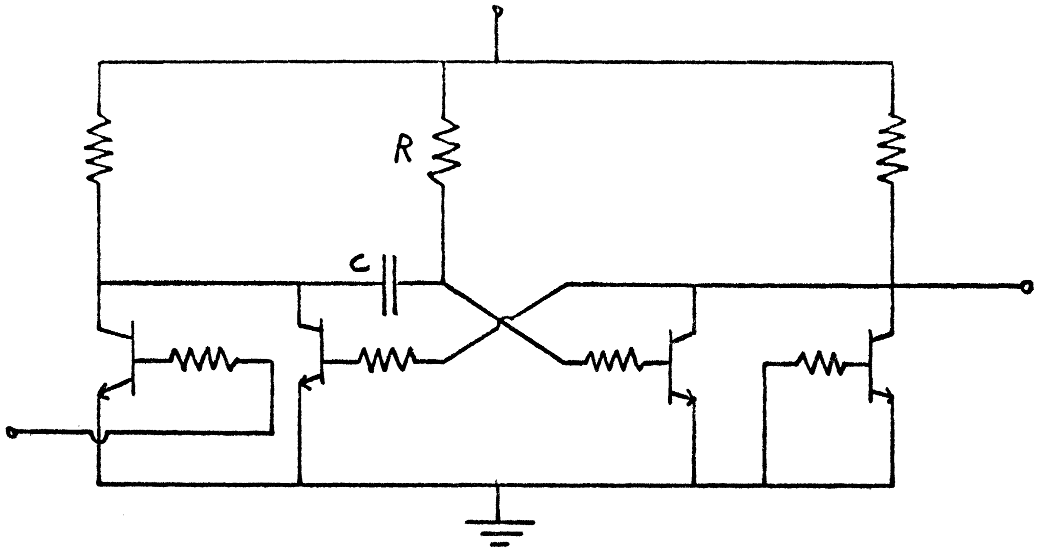
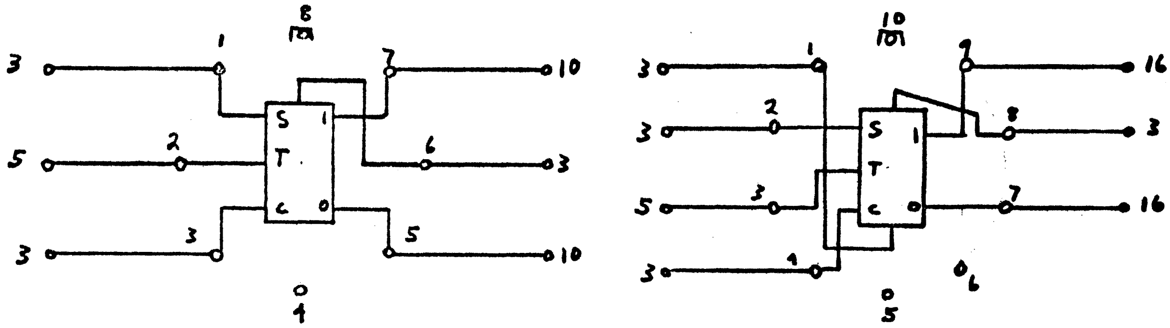
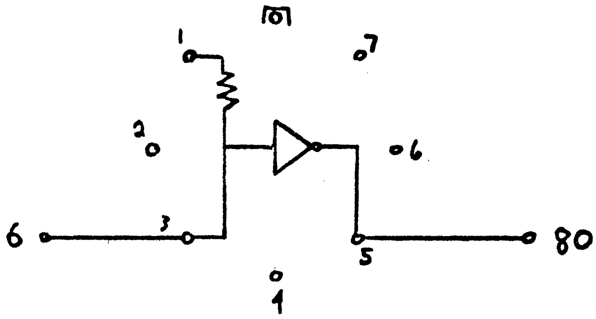


FIGURE 4



9923 9926

FIGURE 5



9900

FIGURE 6

transistor.

The 9923 and 9926 flip-flops have the fan-in and fan-out factors shown in Figure (5). Since a maximum of 62 flip-flops are in use at any given time, an output drive factor of 186 is needed to preset the flip-flops. Since the 9914 nor-gate has a fan-out of only 16, some sort of current amplifier will be needed to increase the fan-out. The Fairchild 9900's fill this requirement. They have an output drive factor of 80 as shown in Figure (6).

This is also an inverter, so two of them in series must be used in order to have the required positive pulse to preset the flip-flops. The output drive factor of 80 still does not meet the required drive factor of 186 so the arrangement in Figure (7) is used to insure proper fan-out.

The time constant of the mono stable is approximately 1.55 milliseconds. This is more than adequate since the pulse duration required to preset the flop-flops is in the nanosecond range.

The resistor and capacitor in the differentiating circuit are not of a critical value, as long as thr RC time constant is small enough to give a sharp narrow pulse.

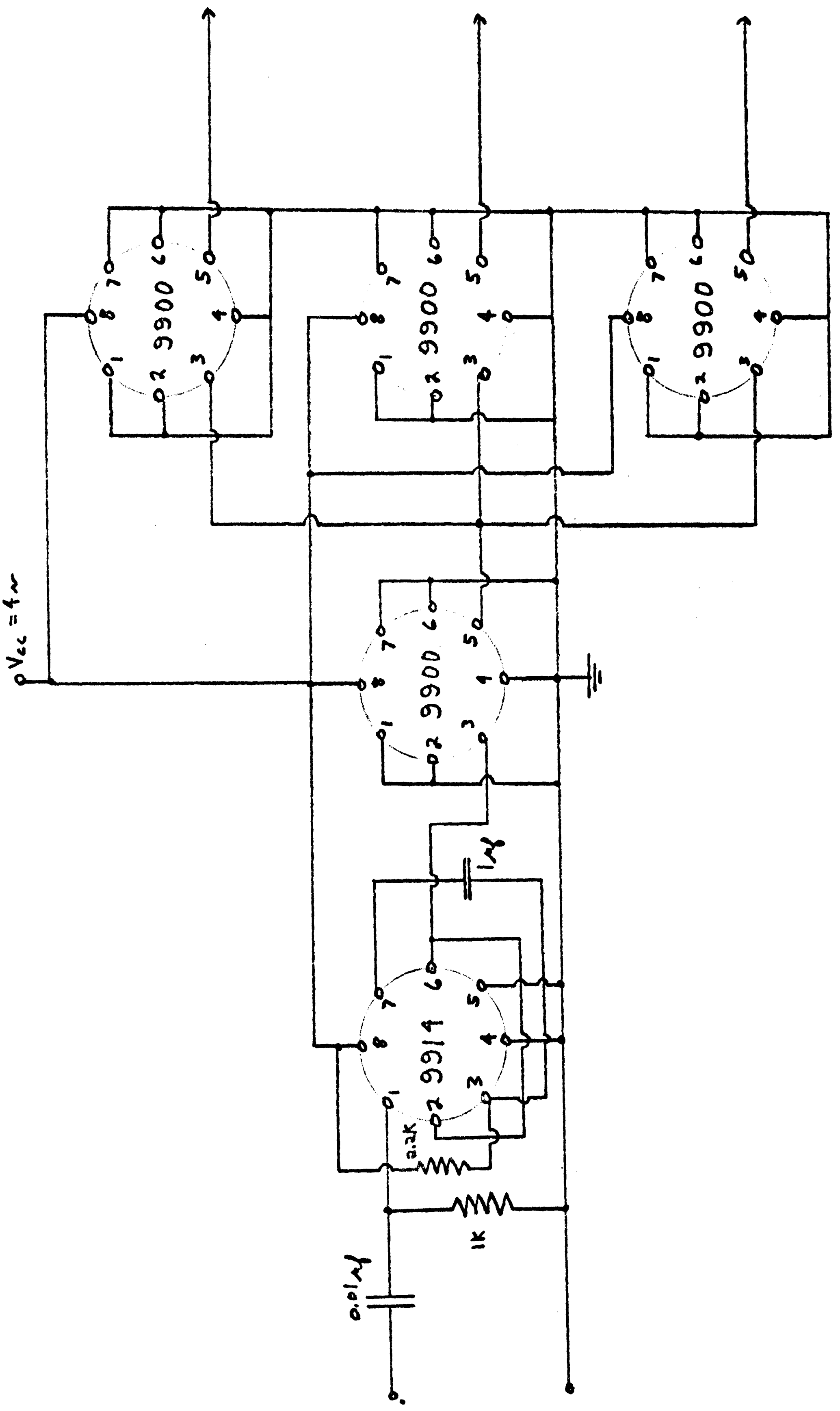
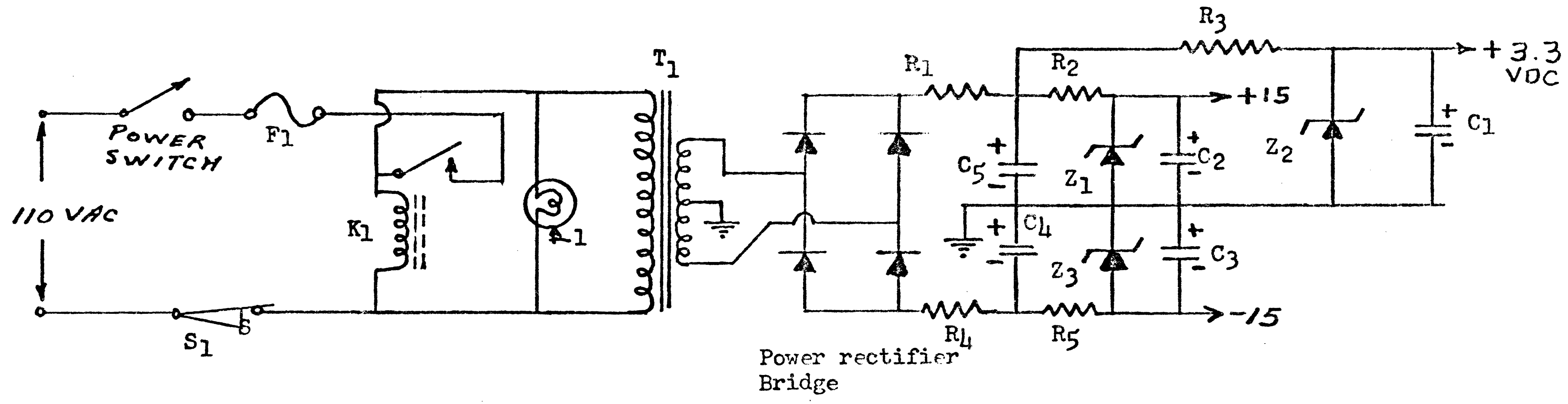


FIGURE 7



C_1-100mfd, 10 wvdc
C2, C3- 100 mfd, 25wvdc
C4, C5- 100 mfd, 50wvdc
F1- 1 amp, 250 vac
K1- 110 vac coil, spst,
contacts 1.5 amp @ 150 vac
L1, Pilot indicator lamp, 110 vac
R1, R4- 18 ohms, 1.5 watt
R2, R5- 680ohm, 1 watt
R3- 1.5 K ohms, 2 watts
S1- Microswitch
T1- Power transformer, 110 vac
to 50 vac @ 1 amp
Z1, Z3- 15 volt, 1watt zener diodes
Z2- 3.3 volt, 1.5 watt zener diode

POWER SUPPLY
FIG. 8

CHAPTER 7

TONE DETECTOR

After the credit card is read and the proper information is sent to the computer, the computer must indicate the credit status of the person in question. It does this by sending back tones of different frequencies. If the persons credit is good, a tone of 1400 Hz will be sent back, and if bad, a tone of 2200 Hz will be sent back.

We are reading the card twice to make sure there is no chance of error. If the computer receives a different number each time the card is read, an error signal of 2800 Hz is sent back, and the card will be read over again until the numbers read each time are the same.

A tone detector is used in the terminal to detect which tone is sent back. The circuit is basically three parallel resonant circuits in parallel, each tuned to one of the tones to be sent back.

The telephone line voltage of 1.414 v p-p is amplified to 8 v before it is fed into the resonant circuits. The output of the resonant circuit is then fed into a full wave rectifier and filtering capacitor to obtain a DC voltage. This DC voltage is then fed into a Fairchild 9900 integrated circuit driver. This driver has an input drive factor of 6 which is relatively high, so a 9914 integrated circuit nor gate with an input drive factor of 3 and an output drive factor of 16 is used to bring the signal up to the required level to drive the driver. Another advantage of using the 9914 is the fact that it and the 9900 both invert the signal fed into them, so the input and output signals have the same polarity.

The 9914-9900 combination functions in the same manner that a Schmitt trigger does. That is, there is no output until the input exceeds a set trigger level. As soon as the input exceeds the trigger level there is an output, which is approximately V_{cc}. The trigger level of the 9914-9900 configuration is the input drive factor of the 9914. This way there will be no voltage output from the detector until the frequency is approximately 10% from one of the resonant frequencies. The higher the Q of the coil, the smaller this percentage will be.

The circuit diagram of one of the three tone detectors is shown in Figure 1, and the circuit diagrams of the 9914 and 9900 are shown in Figure 2.

The use of integrated circuits also brings the cost of this unit down. A price analysis is given on the following page.

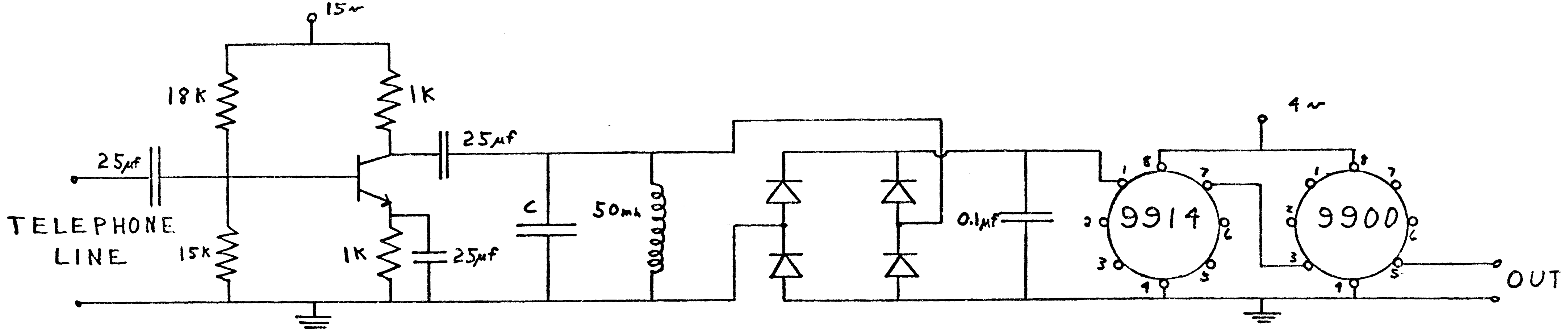
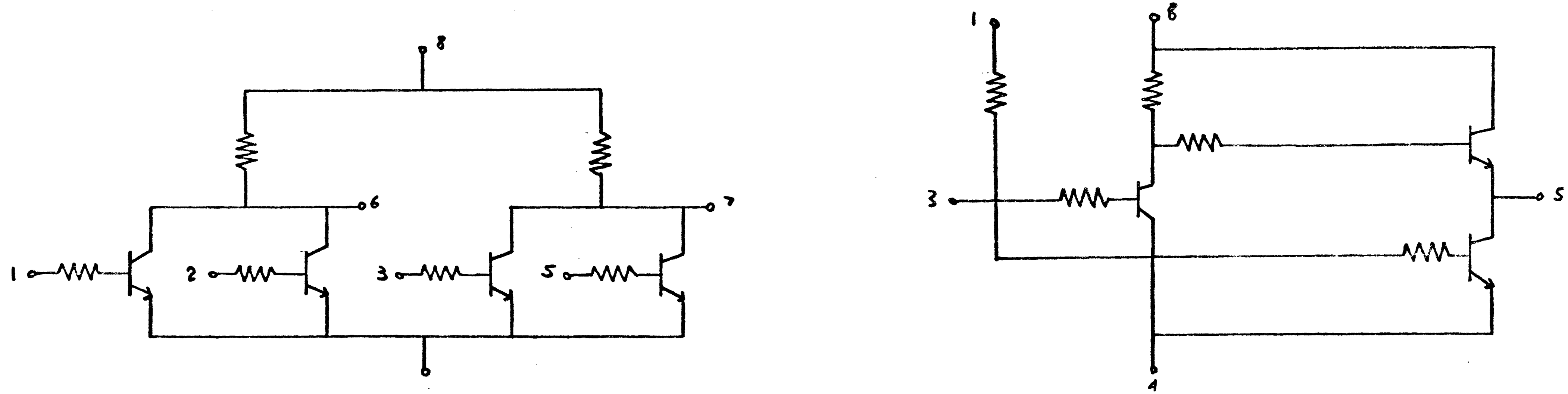


FIGURE 1



9914

9900

FIGURE 2

CHAPTER 8

AUTOMATIC DIGITAL DIALER

In the operation of a remote terminal credit checking device one must allow for the possibility that the area where this device is being used has not yet been equipped with touchtone dialing facilities. It is for this possibility that this dialer was conceived. There were several criteria that were used when designing this device. They were concerned primarily with the reliability that was needed in the dialing of the desired telephone number.

The system was designed so that the operator of the credit terminal was not to have access to the number dialed. Thus for this unit to be manufactured, it was assumed that the number to be dialed was known at the time of manufacturing, and was not to be changed for years under normal operating conditions. Within this framework the block diagram of the device can be studied to see basically how the unit works. Following in Figure 1 one finds the block diagram of the dialer as in its final form.

When the device is initially turned on, there will be a presetting pulse, which will be sent to all parts of the credit terminal, of which the automatic dialer may be one. In the following block diagram this flow of information is denoted as entering at point A, where it then presets the whole dialer. At a later point in the sequence of events of the whole device, a control pulse of duration fifty milliseconds approximately, will be sent to the sequencer portion of the automatic dialer, and this entry point to the device is shown at point B. The circuitry is arranged to allow this to start the functioning of the dialer which will then automatically go on to completion. From the block diagram, Figure 1, it is evident that there are two outputs from the sequencer, one is to a relay attached to the telephone line, and this will act to place the numbers dictated to it by the sequencer during its functioning into the transmission system, which in this case is just a normal telephone line. Finally the signals will reach the telephone company's central

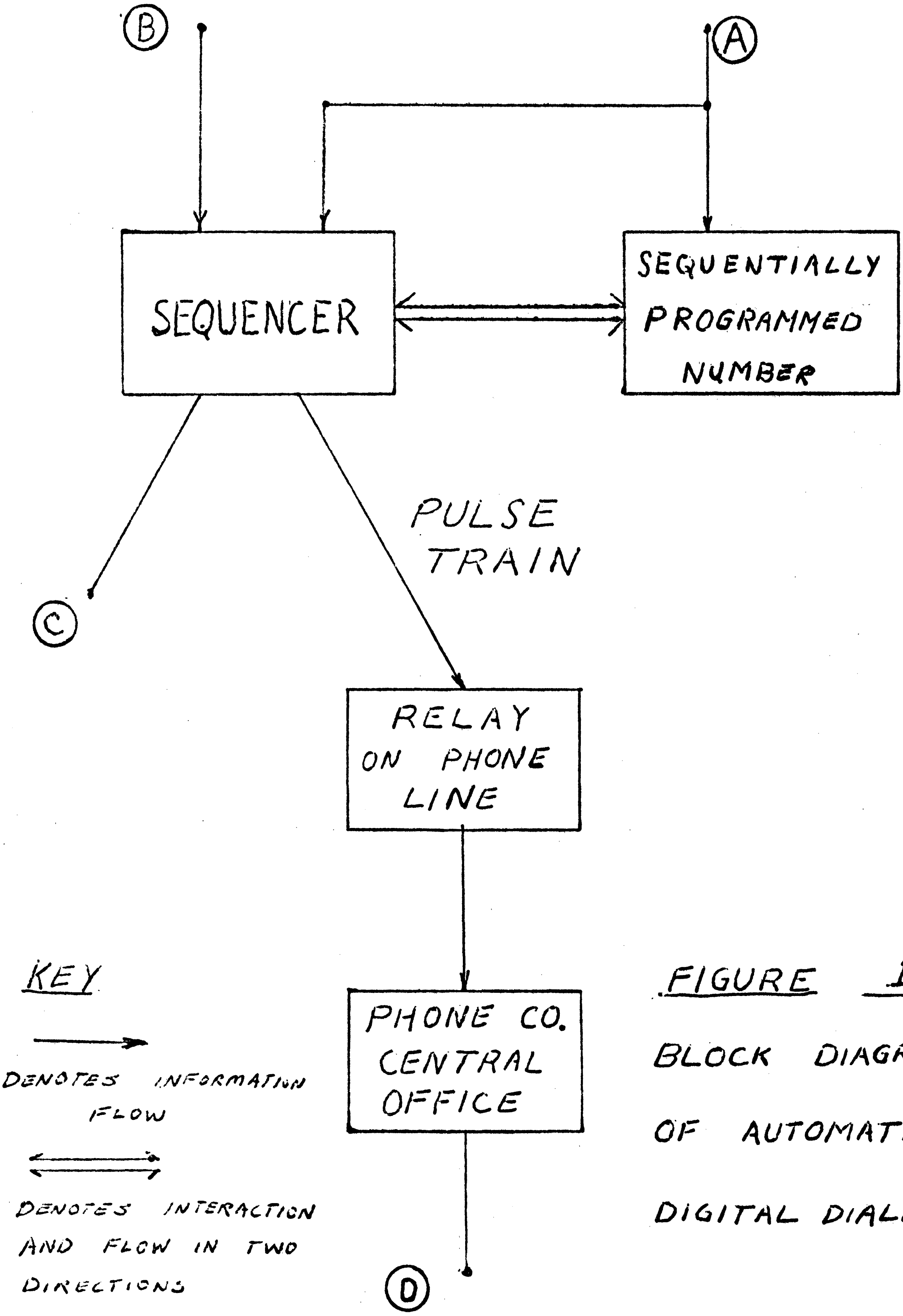


FIGURE 1

BLOCK DIAGRAM OF AUTOMATIC DIGITAL DIALER office for the exchange in that area, where they will be interpreted as if they came from any rotary dialing device, for these signals are electrically the same in duration, and amplitude. The point D denotes further flow to, the number dialed, namely a computing center. The other output of the sequencer is evoked only when a complete telephone number has been dialed. This signal, denoted at point C in Figure, will act to signal the main sequencer in the terminal unit that the telephone number has been dialed and the functioning of the dialer is completed, and it will also shut down the dialing unit. Thus control will now be returned to the main sequencer, which now may send a control signal to some other portion of the device and start its action. After a cursory look at the functioning of the automatic dialer, the circuitry may now be considered in some more detail. As previously stated, it is essential to achieve an output signal that conforms to the telephone company's standard signal received from a rotary dialer, in order to facilitate the connection between the terminal device and the processing center being properly achieved. The appropriate duration of the pulse that is sent over the telephone line is sixty milliseconds for an on time, and then fourty milliseconds for an off time. On an old rotary dial telephone, the times observed were as follows. The on time averaged fourty-five milliseconds, while the off time averaged seventy-five milliseconds. This would then allow one a variation of about fifteen percent in the area of longer length of pulses, and correspondingly one may assume a variation of approximately the same order in the direction of shorter pulse length.

Thus a multivibrator that must be free running will be designed to meet these criteria, where the pulse on and off time will be restricted to plus or minus about five percent of the known values if possible. The actual design of this multivibrator will be treated in another section of this report.

In Table 1 one can find the time that should be expected to produce the digital pulse train by a rotary dialer and also the time expected by the automatic dialer. One then can see that there is a savings of several seconds, which will facilitate faster customer service, which must be a prime factor in the design of the device concerned with person to person sales.

TABLE 1

DIALING TIMES

Number of Digits	Time to Dial (in seconds) Rotary Dialer	Automatic Dialer
7[1]	8.4	4.5
10[1,3]	12.1	6.5
11[1,2,3]	12.7	6.7

1. Assuming no zeros or ones in the first two numbers, and no zero in the third number of the exchange.
2. Assuming that a one is dialed to get long distance before the area code.
3. Assuming that there is either a one or a zero in the second position in the area code.

Taking a look at the circuit now, the device that is actually used to do the sequencing is a shift register. Its function should be described in the section dealing with the overall logical operation of the entire unit, so it will only be briefly reviewed here. From the circuit diagram that follows, one sees that there are several slight modifications from a normal ring counter to allow for the operational functions that are needed.

The first modification that exists is that there is an R-S flip-flop that is put before the actual shift register. The function of this element is to make the unit act as a shift register, that is a device which has only one position in the on state while all the others are in the off state. In essence what this does is to hold the output of the first flip-flop on the high side in the off position by placing an on signal on the

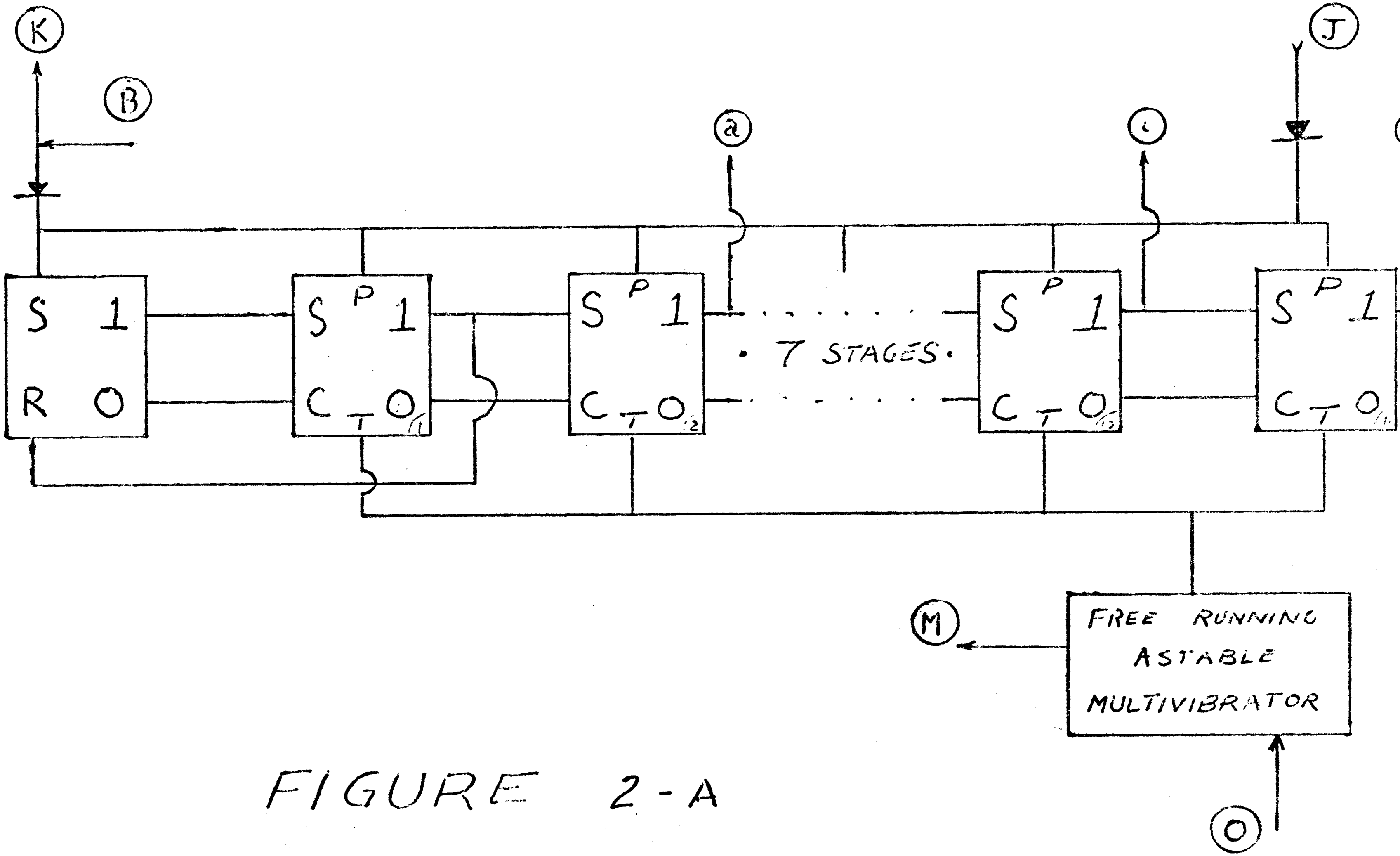


FIGURE 2-A

SHIFT REGISTER #1

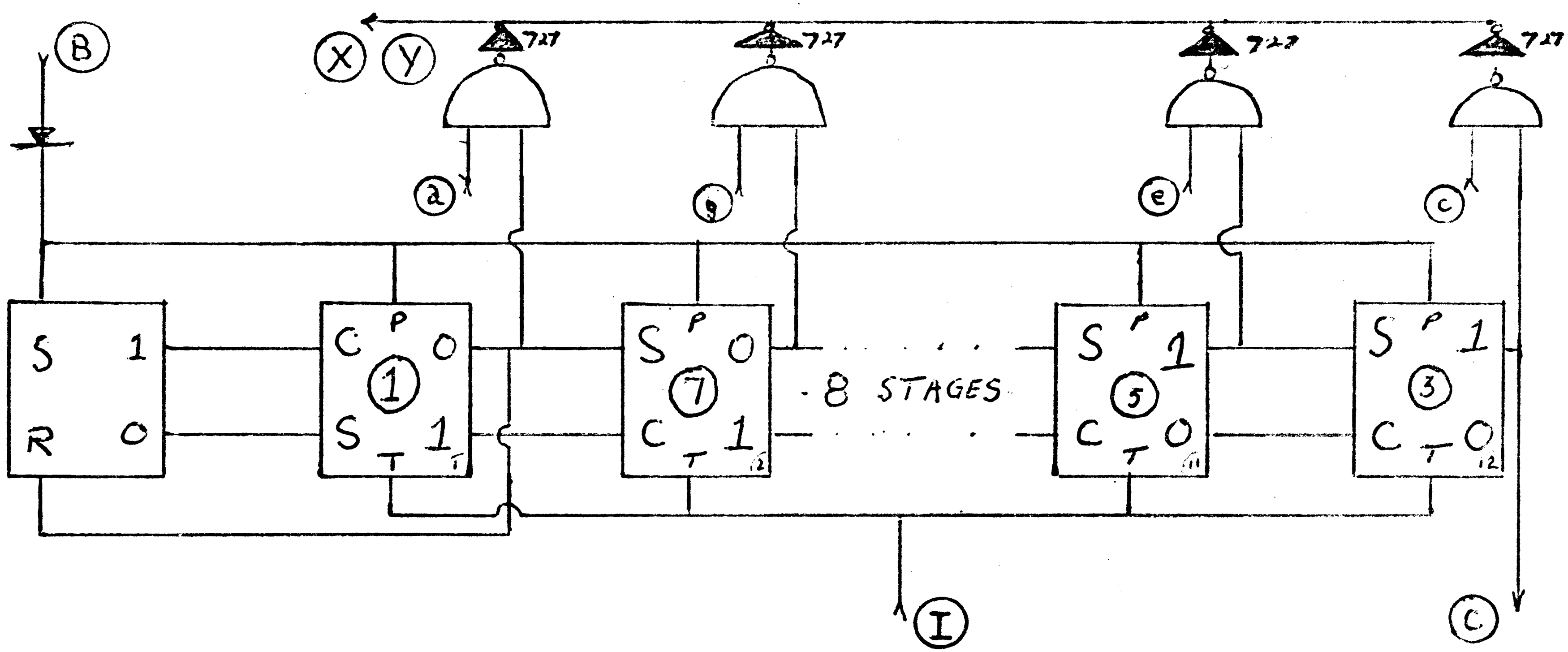


FIGURE 2-B

SHIFT REGISTER #2.

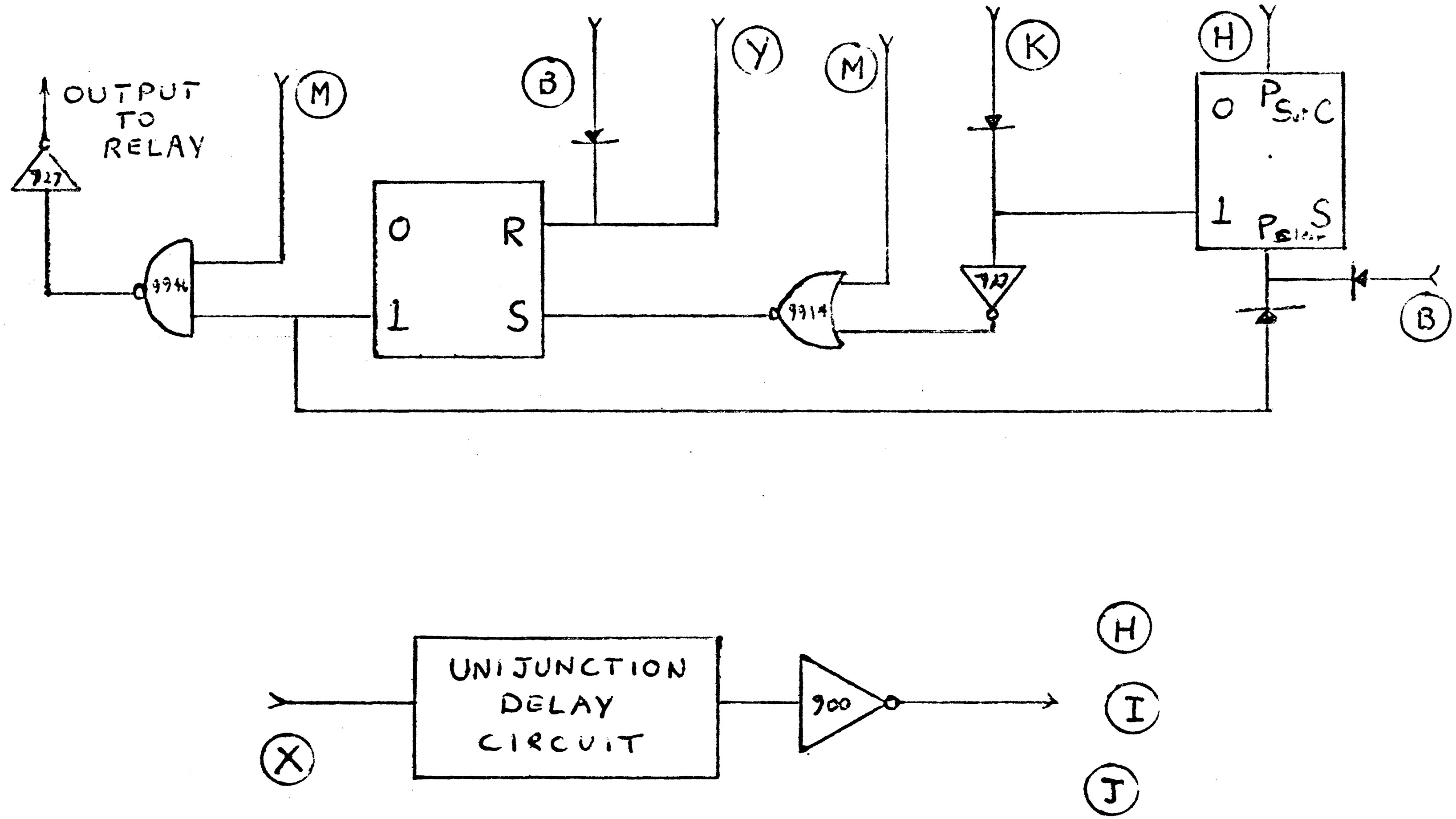


FIGURE 2-C

ASSOCIATED CIRCUITRY

clear input of the flip-flop, after an initial output is placed on the first stage. This first shift register is preset from the inputs B and J. The first preset method is via the initial presetting of the entire unit, and the second method is directed by the operation of the second shift register. The essential function of the first register is to yield outputs from each of ten separate states, which may be used to control the number of pulses that eventually reach the relay on the telephone line. In the diagram O will be the control pulse that will turn the multivibrator on, and M is the multivibrator output.

Looking at the second shift register diagram in Figure 2, one sees within the flip-flops circled numbers. These numbers are the preprogrammed telephone number that will be automatically dialed. The register configuration is exactly the same as in the other shift register, except that the outputs of these stages are coupled according to the known number of pulses to be dialed at each stage in the sequence of the dialing of the telephone number. In the figure, the shift register shown has the capability of dialing eleven digits, then through exit point C may return control to the main sequencer in the terminal. If a number to be dialed has fewer than this number of digits, then the number of stages in this unit may be cut down to one more than the number of digits to be dialed, in addition to the initial R-S flip-flop at the beginning of the shift register. The final flip-flop serves to yield a control signal after all information has been developed by the dialer, that being the pulse train going to the relay on the telephone line.

Returning to the circuit diagram as a whole, rather than broken down into separate portions one sees that after the proper number of pulses is reached for a given position in the second shift register, then a gate and inverter combination yields a signal which acts in two ways. The first method of action is through Y which shuts off the output. The other event that occurs is via point X which starts a unijunction transistor type delay circuit which will creat a pause of one hundred milliseconds. This pause is needed by the telephone company to determine what numbers are being digitally sent over the phone lines. After this pause, then the first shift register is again readied for operation by presetting through J. The second shift register is moved down to the next number in its sequence also. Finally the output circuitry is again set so that if events occur normally the right output will be produced.

The output circuit must be very reliable for any stray signals may be misinterpreted by the telephone company yielding a wrong number. Thus in the design of this portion of the circuitry allowance was made so that the output sequence will start only when the multivibrator is in the off position, which will preclude any half pulses from being transmitted. This is especially needed at the initial turning on of the multivibrator. For further information about the automatic dialer the circuit diagrams should be studied.

CHAPTER 9

DATA RETRIEVAL AND PROCESSING

One may now turn to what is done with the information that has been sent over the telephone lines. This information has been transmitted in a certain order which is known. Then there is no great problem in processing it, but rather the problem lies in decoding, or changing the code that comes in from the telephone line to useful information in the computer. In Figure 1 one can see that the first instrument that comes in contact with the information flow is a data phone. In our case this will be the X403A which is primarily a receiver. The purpose of this device is to receive the call and forward a signal to alert the following devices that there is a call on the line, and to convert the touch tone, if any, signals that are coming in over the telephone line into a two out of seven code. The two out of seven code denotes the two oscillator frequencies and gave the original touchtone signal. After this device there are two possible routes that may be followed. One involves the capability of an audio response which will be discussed in detail later, and the other entails the use of just the data phone to transmit back to the original caller one of three tones.

The second arrangement needs only a simple computer like the PDP-8. What can be done in this case is to wire up a matrix that can convert the two out of seven code into a one out of twelve code. This can then be directly used by the computer to know exactly which of the twelve buttons on a data phone was struck, or which touchtone frequencies were sent by an automatic mechanism which has the same coding as the touch tone signals. Thus, through this conversion then all the data that was transmitted can be stored sequentially in the computer in 12 bit groups and acted upon accordingly.

Looking now at the other possibility, that being with a capability for voice transmission, there are several more units needed. First the data phone will feed into the audio response unit, which may be an IBM 7772. This unit will convert the two out of seven code which it is receiving into an eight bit binary code. This code is then passed on to the multiplexor channel of the IBM System 360 from whence it can pass into the machine for processing.

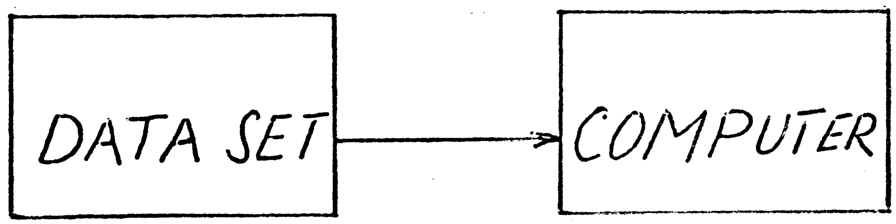


FIGURE 1-A SIMPLE COMPUTER LAYOUT

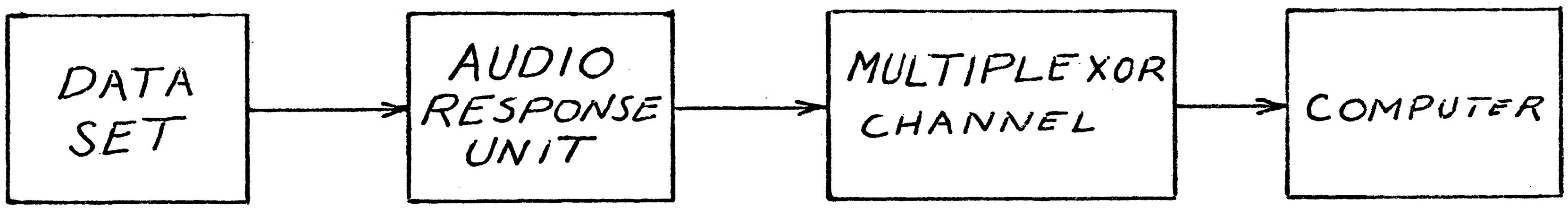


FIGURE 1-B COMPLETE COMPUTER LAYOUT

In either case, there must be support programming for the computer to realize that there is an external device sending it information and waiting for a reply. There are several commands that the audio response unit can give and these are designed to perform its major function only, that being to accept an inquiry and yield an audio response back. The smaller type of computer would almost have to be used only for this type of work, for its storage capabilities and capacity would not be great enough to allow too much other functioning.

The support programming might contain features such as checking to see if the terminal device was really a valid one. In any event, there would be on file in this computer a program to analyze the data that came in. The key to this program is that all the data comes in within a given format. That means that everything can always use the same program. The processing and actual format will be discussed later, while the purpose of the programming will be covered now.

With the exception of model A all of the other proposed models will be capable of some types of accounting, for example model B will allow customer billing only, while model B-1 will allow customer billing as well as the crediting of the merchandising outlet. The program will first check the credit of the number that is sent to it. There will be in storage in the machine a list of bad numbers, since they will be generally quite small compared to the total number of credit cards that have been issued and not use up much storage. It will be possible to make several lists for credit up to certain amounts if this is desirable for certain applications.

The rest of the program will take the information that comes in and first check to see if the second transmission of the information matches the first, since all of it is transmitted twice to prevent errors. With the audio response unit, it will then be possible to return a statement saying exactly where the error arose during the processing, while with the smaller computer, there is only a capability of sending back three tone, which must correspond to credit acceptable, credit not acceptable, or finally there was an error somewhere in the passage of the data between the machine and the terminal unit, or in its inception at the terminal unit.

The output of the computer must eventually allow for the billing function to be performed. This may be accomplished on the IBM System 360 through the use of disc storage. This type of device has a large storage capability and can be kept so that it can be read out whenever desired. The information that can be kept on file is the current status of all the accounts if this is small enough, otherwise all the transactions of the past few hours can be constantly read out into a special, or possibly a normal printing device to make up bills. This type of machine is available and is used by the telephone company in its billing system. A normal print out device could have its output paper printed with a bill or possibly two or three across the page. The computer could then be programmed to print out in the desired format to yield actual bills that could be sent out to the purchaser.

One may now return to the actual format of the data as it will be received from our terminal device. First of all, there will be no spaces placed in by the computer unless this is specified in the support programming, but actually none is needed if one knows where all the data coming in is stored. There will be a problem in considering models B, B-1, and C, C-1, for certain data is transmitted at one time, but then not at another. One possible solution is to have some type of signal first sent before the address code if it is present. Another possibility would be to check the input as it comes into the data phone, or the audio response unit to bee if there was a four digit number present, or a five digit number. This would be adequate, since the address code is four digits, while the price information is five digits. If there was a set order of address code first and price next, if the four digit number was present then the information would store in one location; and if it was not present, then the price information could be stored in another location bypassing the address location.

Any accessory information that was fed in by keyboard or other method would have to be programmed for in a manner similar to any of the other information, with most probably a special code in front of it to key the processor as to what format the information was being set in. Processing of this type of information would be similar, also utilizing disc storage facilities.

The action of the computer is beyond this report, as well as not being too relevant. Any program to use the data would be quite simple since there is really nothing done to the data except possibly an addition if current records of customers' accounts were kept. all that this type of program would contain would be are statements to check the two transmissions of the data for differences, and this could easily be established by taking the difference of the binary bits in these locations, and if it was not zero then give an audio response giving the site of the error. Almost all the other statements would just be simple input output statements.

This in general sums up the operation at the other end of therminal device, with the exception of the support programming, and this is beyond the scope of this report, which is essentially concerned with the construction and planning of a remote credit terminal, rahter than with the commuting aspects of the data processing.

CHAPTER 10

OPTIC CARD READER

The purpose of this card reader is to read the location of holes in a credit card to obtain the card number. This number is sent to a central computer via telephone lines by means of touch-tone signals.

The method employed to read the number is by means of a light source and photocells. A general block diagram of the system is shown in Fig. A. In this diagram the switching circuit is shown as the first block, but another switching system was also examined, Fig. B. The second system was one in which a switching network was used to select which set of photocells would be used as the input to the Schmitt Triggers. The two systems will be more fully described at a later time.

CREDIT CARD

In the system, a credit card of nearly standard size would be used. The card would be 2 1/2" x 3 1/4". The card, shown in Fig. C, would require space for the location of the holes to carry the number information. Seventy possible locations are required for the system used. In the system, two holes are located in each number column; one hole in each of the two groups of locations. One group having four locations, the other three locations. This procedure gives you twelve possible combinations from the seven locations. The card would be made of an opaque plastic.

HOLE DETECTOR, PHOTOCELLS AND LIGHT SOURCES

The hole detector would consist merely of a block that would hold the card in the proper position for reading. In addition, it would also supply a path for the incoming light and also have, built into it, the seventy photocells to detect the holes. A sketch of the block is shown in Fig. D. As seen in the sketch, the photocells are on a hinged block that flips on top of the card once it is inserted for reading. The block moves back out of the way so that the roller mechanism may be used after the credit is checked.

In the top view the photocells are partially shown in position. The photocells used were Clairex Type 3. The photocells are mounted on 1/4" centers. This spacing is used to make the hole locations as compact as possible. The outer flange of the photocell is .21" in diameter. The inner diameter is approximately .18". The photocells used were of a type that had a frequency response in the region of visible light, allowing incandescent lamps to be used. The photocells also were of the type that allowed sufficiently fast switching time.

The lamps used in Fig. A were of the minature type (No. 1488). We found that we were able to detect, at the output of the Schmitt Trigger, lamps flashing at a rate of from 20 to 30 Hz. Therefore no apparent problem would result at the 10 Hz rate that we planned to use. In the system in Fig. B a single constant source of light is used and the photocells are switched to determine which are inputs to the Schmitt Triggers.

LIGHT PATH

To allow a freer choice in the location of the light source, a study was made into the use of fiber optics as a means of guiding the light from the source to the detector. In our experimenting we used various sizes of fiber optics. We had three sizes of Corning fiber optic material: #5010, #5011 and #5012. We discovered that we were able to control the Schmitt Triggers with the two larger sizes but not the smallest (#5010). We decided to use #5012 so as to be able to carry the maximum amount of light to the detector, since size of the optic was not that important. #5012 has an outside diameter of .119", making installation in the hole detector no problem.

In our experiments we found difficulty in operating the Schmitt Trigger with #5010. We believe the main reason for this difficulty was the fact that we were unable to form good polished ends with the samples we had. We decided to use #5012 to give us a good safety factor in the amount of light that reaches the photocells.

It might also be noted that thought had been given to the possibility of using a system where fiber optics would have been on both sides of the credit card. The fiber optic on top would receive light from the fiber optic on the bottom if a hole was present. The top fiber optic would then end at a photocell. It was hoped that several fiber optics could have been aimed at a single photocell, therefore making the system less expensive. We abandoned this method when high losses resulted from jumping the air gap at the optic-to-optic point as well as problems in aiming more than two or three optics on a single photocell. The aiming was very critical and would result in high manufacturing costs.

SWITCHING CIRCUITS

The system in Fig. A required a switching circuit as an input to the lights. This circuit would consist of a shift register and amplifiers to turn the lights on in sequence from #1 to #10. The ten photocells in each row would be wired in parallel. This would give, as an output, the numbers on the credit card. By adjusting the shift register the proper signal duration and spacing would be accomplished.

The system in Fig. B used a switching system at the photocell point of the system. In this system, shown in Fig. E, the output of a shift register is used to control ten transistor switches which in turn determine which group of seven photocells are used as input to the Schmitt Triggers. This method allows light to be present at all ten columns, because if a photocell does see a light source it won't affect the Schmitt Trigger until the transistor switch is turned on by the signal from the shift register. This system is superior to that of Fig. A in the sense that it doesn't rely upon the switching capabilities of a light source. It also is not affected as greatly by lamp failure. It's only disadvantage is the increased cost of the ten transistors, but this is a small price to pay for the increase in reliability and capability. Our decision to build a magnetic card reader resulted in the work stopping on this system. Any problems with this switching method were not discovered.

SCHMITT TRIGGER

The Schmitt Trigger is simply a device to control a relay by, in this case, a photocell. It gives control of the operating point, or the light level required to turn the relay on, and also the differential point. These adjustments, shown in Fig. F, were determined and then fixed for the final design. Where only one photocell is shown, it should be noted that this block is intended to mean either of the two methods described earlier. (A) Ten photocells in parallel, or (B) the photocells and transistor switches. In either case, seven Schmitt Triggers and relays are required; one for each of the seven tones to be turned on.

The system, except the shift register, was designed to work from a common 12 VDC supply and, for the lamp in Fig. B, 110 VAC. The shift register would be powered by the supply for the rest of the logic circuits in the equipment.

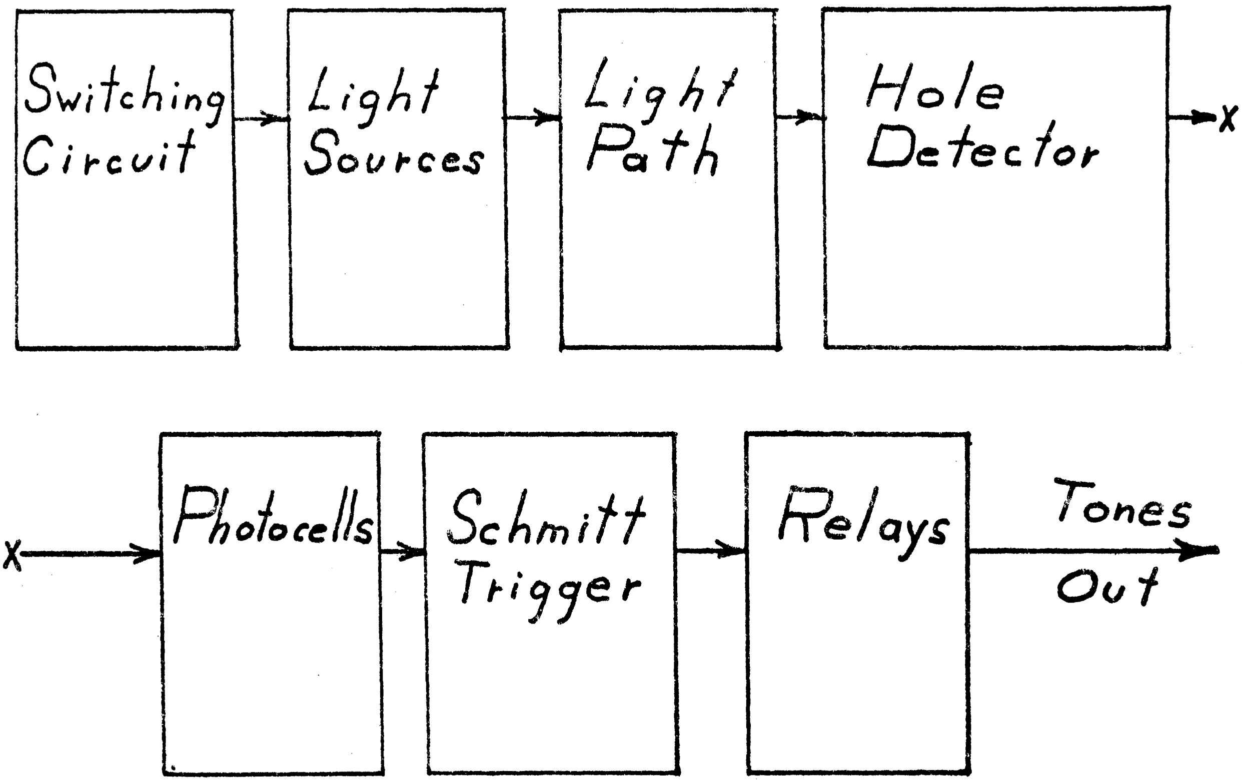

Switching Circuit
Light Sources
Light Path
Hole Detector
X
X
Photocells
Schmitt Trigger
Relays
Tones Out

Fig A

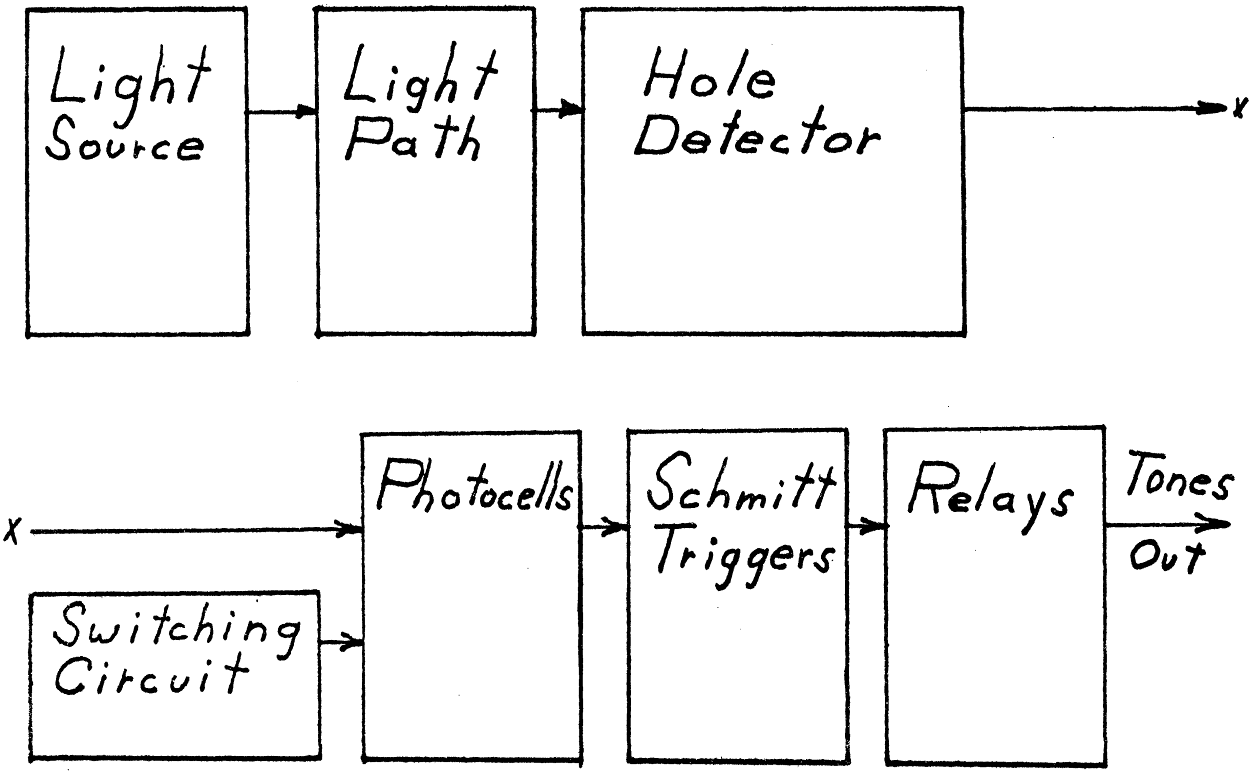
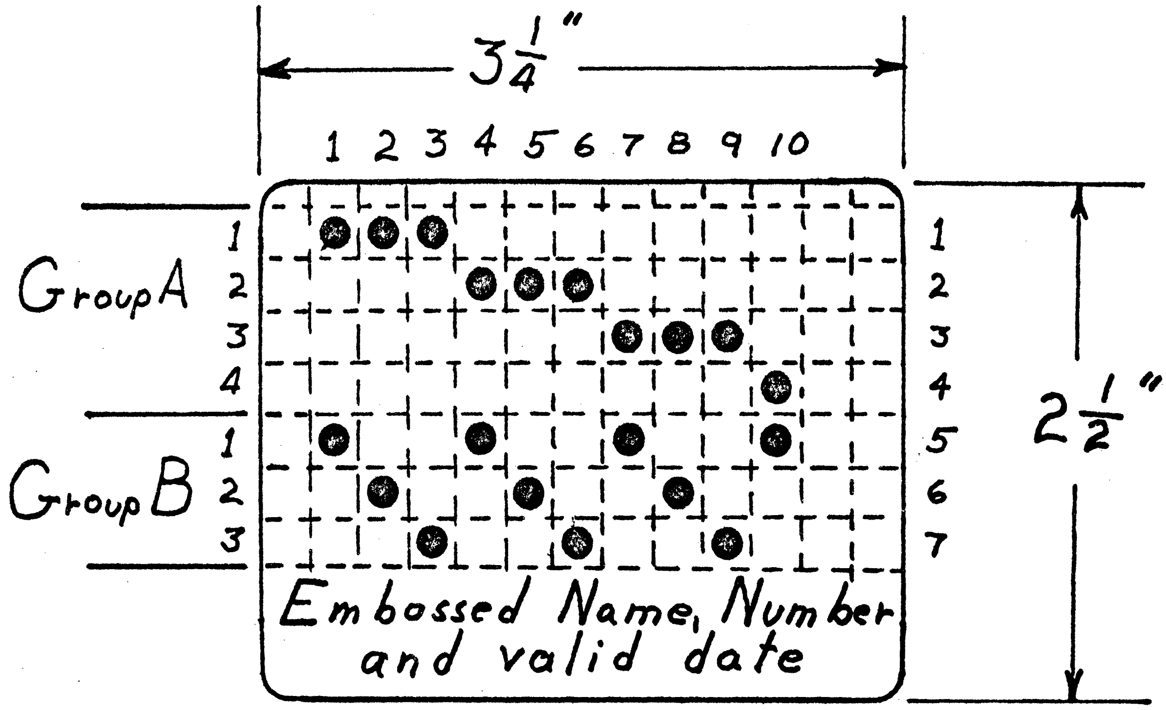

Light Source
Light Path
Hole Detector
x
x
Photocells
Schmitt Triggers
Relays
Tones Out
Switching Circuit

Fig B



10 × 7 Hole Locations
Each number is represented by two holes in each column. One hole in each of the two groups. (Groups A + B)
(The column numbers are shown by holes in each column.)
The holes are $\frac{1}{8}''$ dia. on $\frac{1}{4}''$ centers

Fig C

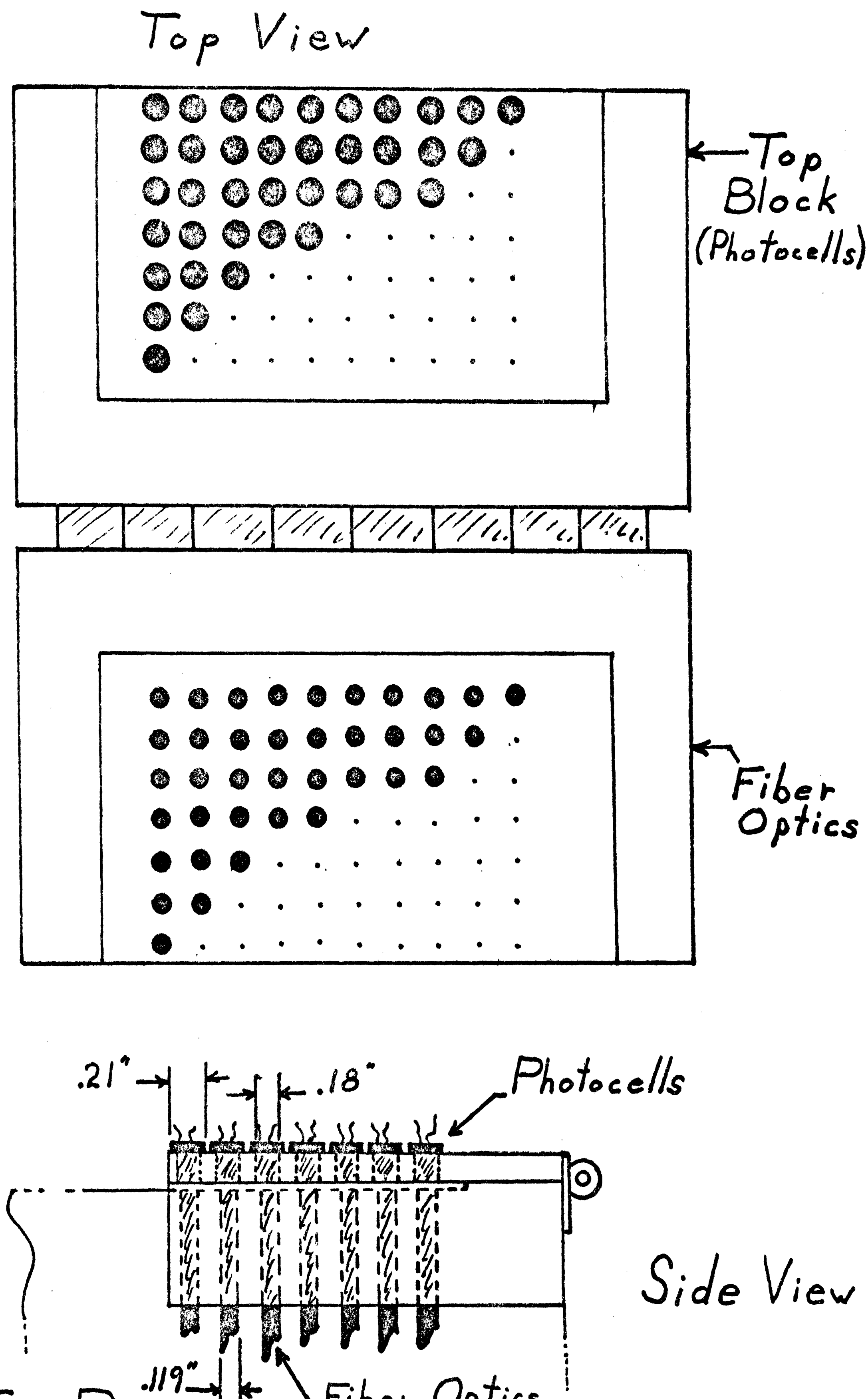
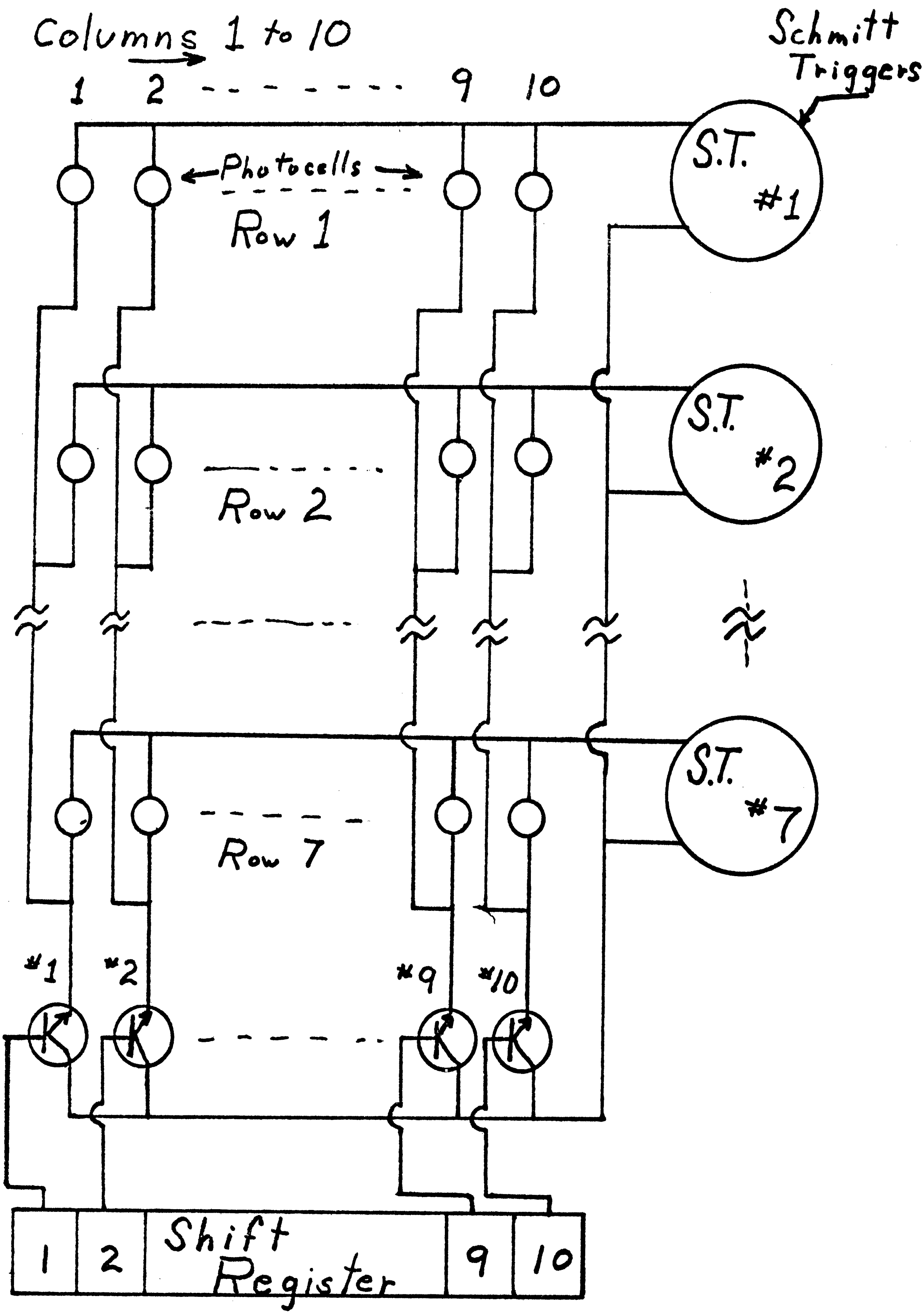
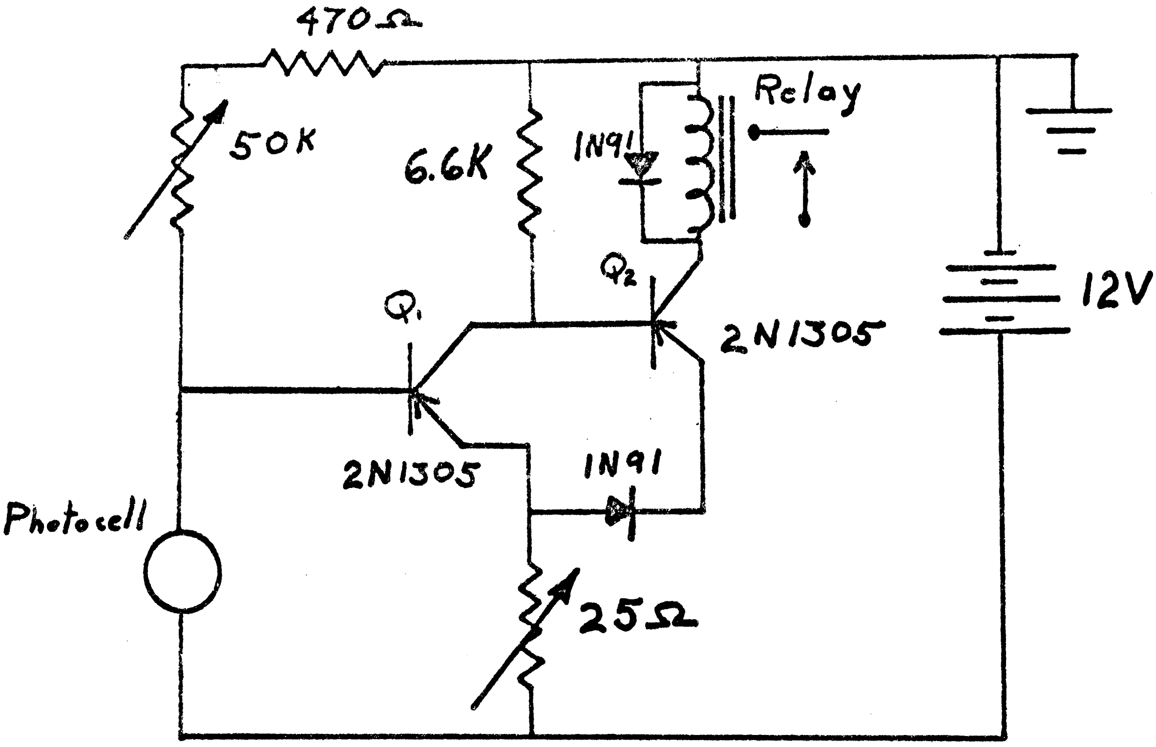

Top View
Top Block (Photocells)
Fiber Optics
.21"
.18"
Photocells
Side View
.119"
Fiber Optics

Fig D



Columns 1 to 10
1
2
9
10
Schmitt Triggers
Photocells
Row 1
S.T. #1
Row 2
S.T. #2
Row 7
S.T. #7
#1
#2
#9
#10
Shift Register
1
2
9
10

Fig E



Schmitt Trigger Switching Circuit

Fig F.

CHAPTER 11

CAPACITIVE CARD READER

One of our first attempts at reading a user's credit number was based on the fact that there is a difference between the relative dielectric constants of air and most common card materials. We thought that if we had a plastic card with holes punched in it, we could somehow detect the differences in capacitance resulting from this difference in dielectric constants between the hole and non-hole regions.

CREDIT CARD

We assume the card will be made of plastic, will be of a standard size, and will have the user's credit number encoded on it by means of a group of square holes punched in it. (See the CREDIT CARD section in the discussion of the magnetic card reader for a description of the card). There will be a difference in capacitance between those regions where the holes are punched and those where they are not, since the hole regions are filled with an air dielectric and the non-hole regions with a plastic dielectric. We assume that by proper choice of hole size and card material we can achieve a 1:10 capacitance ratio between these two regions, say perhaps 1 pf versus 10 pf.

DETECTOR CIRCUIT

In order to make use of the capacitance difference mentioned above, let us consider the simple R-C circuit shown in Fig. 1. If we apply an input in the form of a ramp function, we derive the output response as: $e_o = ERC\ (1-\exp\ (-t/RC))$. This output is shown in Fig 2. We note that, other factors being equal, the output voltage is proportional to the circuit capacitance, and thus that two different capacitors in the circuit will produce two different output signal levels.

INPUT SIGNAL

We are now in the position that we need to find an easily producible input waveform that satisfies the following: it must contain a ramp function, must be able to be switched from one input terminal to another, and the necessary circuitry must be inexpensive and easy to build. Perhaps the first solution that comes to mind is a square wave with finite rise and fall times. Laking a better starting point for specifying the dimensions of the square wave, we choose a 1 usec rise time and a 20 volt maximum amplitude. (It is interesting to note that this rise time is equal to one time constant for a 10 pf capacitor in series with a 100,000 ohm resistor.) This waveform is as shown in Fig. 3. In order to give any transients time to die out, we choose the minimum amount of time spent at the 20 volt level equal to 10 usec (or 10 time constants of the 1000,000 ohm resistor and 10 pf capacitor). Thus, the minimum period of the square wave is 1+10+1+10 = 22 usec, or the maximum frequency is 45.4 KHz.

OUTPUT WAVEFORM

Comparing Fig. 2 and Fig. 3, we see that the output response of the circuit in Fig. 1 will appear as in Fig. 4. Note again that the use of two different capacitors in the circuit will produce outputs that are similar in form, but different in amplitude.

Suppose now that the two different capacitors that have been mentioned are those of the hole and non-hole regions of the card. Let us make some calculations in order to see what levels of output we should expect for these two capacitors. We choose R = 100,000 ohms.

For the 1 pf capacitor, we have $RC = (10^5)(10^{-12}) = 10^{-7}$ sec = 0.1 usec. Thus there are 10 of these time constants contained within the 1.0 usec rise time of the ramp portion of the input signal, and the output voltage should rise essentially to its steady state value of: $e_o = (E\times10^6)\,RC = (20\times10^6)(10^5)(10^{-12}) =$ 2 volts, within the 1.0 usec rise time of the input signal. (The 10^6 factor arises from the fact that the ramp reaches the value E in 10^{-6} sec rather than in 1.0 sec as in Fig. 2. It is a acaling factor.) For the 10 pf capacitor, the time constant is $RC = (10^5)(10^{-11}) = 10^{-6}$ sec = 1.0 usec. There is only one of these time constants contained within the 1.0 usec rise time of the ramp portion of the input signal, and the output voltage will reach a value of: $e_o = (E\times10^6)RC(1-\exp(-1)) = (20 \times 10^6)(10^5)(10^{-11})(1-0.368) = 20 \times 0.632 = 12.64$ volts, within the 1.0 usec rise time of the input signal. We should certainly be able to detect a difference between these two output signals.

In the above analysis, we immediately see that we have a problem in trying to detect a hole. Note that the output voltage for the hole locations (the 1 pf capacitor) is <u>less</u> than the output voltage for the non-hole locations, and thus that any sort of level detector we build will respond to the presence of a non-hole, rather than a hole. This problem can be overcome, however, by detection of the non-hole locations followed by inversion of the detection signal. This would produce no signal for the non-hole locations while giving a positive detection signal for the hole locations.

For a level detection circuit, consider that shown in Fig. 5. Diode D will remove the negative-going portions of the output signal in Fig. 4, leaving only the positive excursions. These positive pulses will appear across the resistor R only when their amplitude is greater than the zener voltage V_z, since for values of e_o less than V_z, the zener acts as an open circuit and the entire e_o appears across it, rather than across the resistor. Therefore, if V_z is chosen greater than e_o for the 1 pf capacitor but less than e_o for 10 pf capacitor, there should be a signal of magnitude (e_o-V_z) across R only when the 10 pf capacitor is present, i.e. when we have found a non-hole. This voltage could then be amplified, used to trigger some other circuit which produces a d.c. level, and then inverted as discussed previously. The output we would expect from this detector, before the inversion state, is shown in Fig. 6.

In order to test out theory at this point, we needed some sort of fixture that would both hold the credit card and provide a set of capacitor plates at each possible hole location. We made two printed circuit boards as shown in Fig. 7. When the two boards are placed on top of each other, the copper strips will "intersect" in an array of small squares that will act as capacitor plates at each possible hole location. Each of the rows on the output board is to be connected to its own detector circuit of the type shown in Fig. 5.

Suppose now that the boards are held together with th card in place between them, and that one of the input columns is excited with the input signal in Fig. 3. An output signal will then appear on each of the rows on the output board, its magnitude depending upon whether or not there is a hole at that position in the column that is being excited. The signal level present on those rows where there is a non-hole will be great enough to pass through the detector, while on the rows where the holes are present, it will be too small to produce any output. The group of outputs of these detectors can then be treated and inverted and then used to activate the necessary circuitry to produce the touchtone signal corresponding to that digit of the user's credit number that appears in the column being excited. By sequentially exciting the ten columns, the entire credit number can be read.

Once the equipment was built, however, the results were rather disappointing. We could detect no discernable difference between holes and non-holes when we used the plastic card. We thought this might be due to too small a capacitance difference between the two regions, perhaps as a result of too small a relative dielectric constant of the plastic material. We thought that we could increase the capacitance of the non-hole regions by decreasing the thickness of the plastic (since capacitance is inversely proportional to plate thickness). But if we went to a thinner card, the hole regions would also be decreased and the capacitance ratio would remain the same. Suppose, however, that the card was made of metal of the same thickness as the plastic card, but with a thin coating of dielectric material deposited on both sides of it. Then for the non-hole regions we would have effectively two capacitors in series, each with a very high capacitance due to the extreme thinness of the deposited dielectric coating, connected by the metal of the card.. But we would have the same capacitance for the hole regions as before, since the air dielectric would have the same thickness, equal to that of the credit card. We talked to Professor Diamond about this idea, and he said that it might work and that he could indeed deposit such a coating for us. But with a breakdown strength of only 1000 volts/meter, a 10,000 angstrom thick layer of dielectric material (the maximum he could deposit) could withstand only a 1 millivolt signal applied to each layer of dielectric, or only 2 millivolts to the card since there are two such layers. He suggested that we instead use an anodized aluminum card, which would probably meet our needs, or even consider changing to a magnetic system. Circuit impedances would then be lower, and lead capacitance from the detecting head might not be a serrous problem. Unwilling to give up, however, we found a piece of anodized aluminum and put it in our test fixture (Fig.7) so that half the input columns were covered by the card, and half were not. With a 20 volt square wave excitation signal on the input columns covered by the card, we found that a 3 volt output signal was produced by the detectors at the end of each output row, while with the input signal on the columns not covered by the card, a 1 volt output was produced. (It should have been zero but due to capacitive coupling between rows, columns, or whatever, it was not). With these results in mind, we quickly cut some holes in the card and positioned it in the fixture once again. Upon scanning the rows and columns we found that the hole locations in the first row (as detected by output levels on an oscilloscope) matched perfectly with the hole locations in the drawing of the card that we had. Congradulating ourselves on our success, we showed the other members of our group what we had done and took the fixture apart to show them how we had done it. We were not quite so delighted when we found that the card had been put in upside down and backwards, and that the system seemed to be choosing its own outputs at random. It was at this point that we decided to seriously consider Professor Diamond's earlier suggestion.

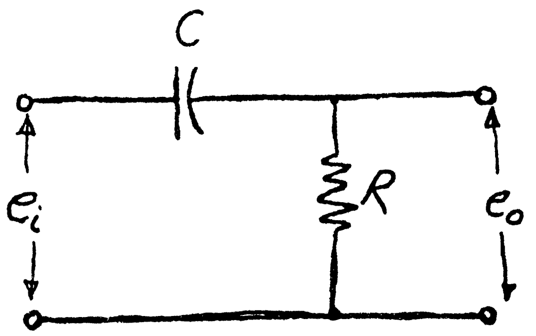


Fig 1

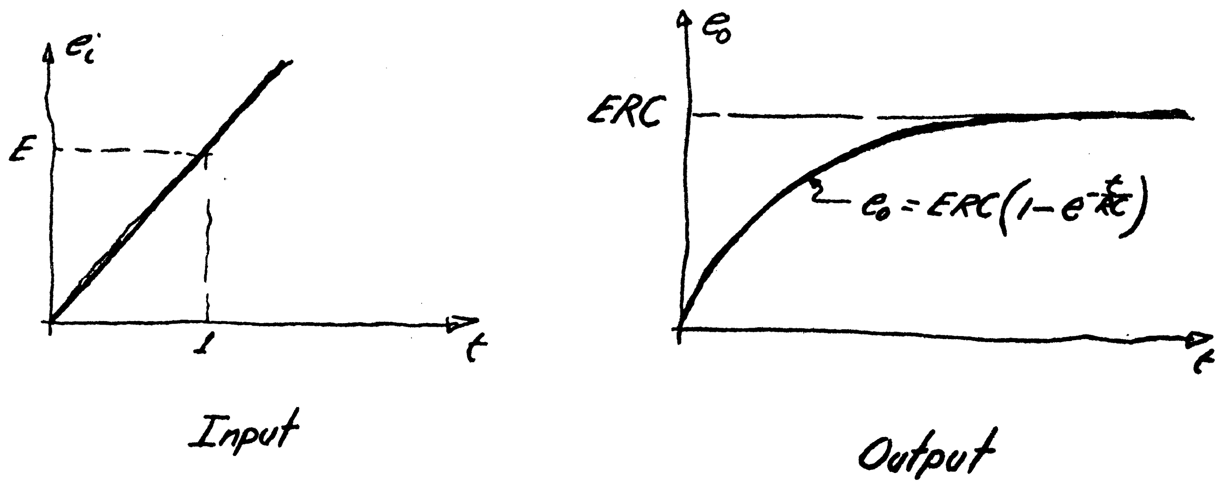


Fig 2

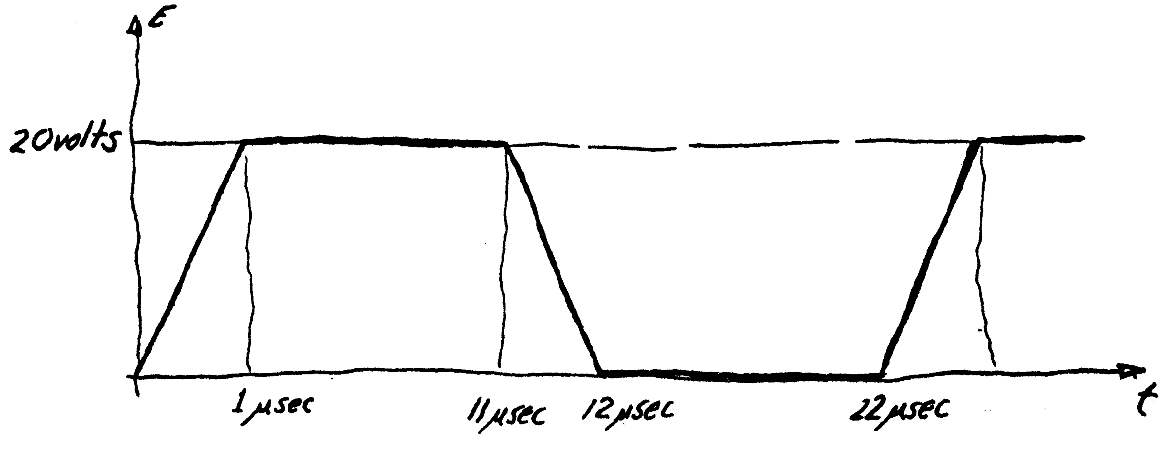


Fig 3

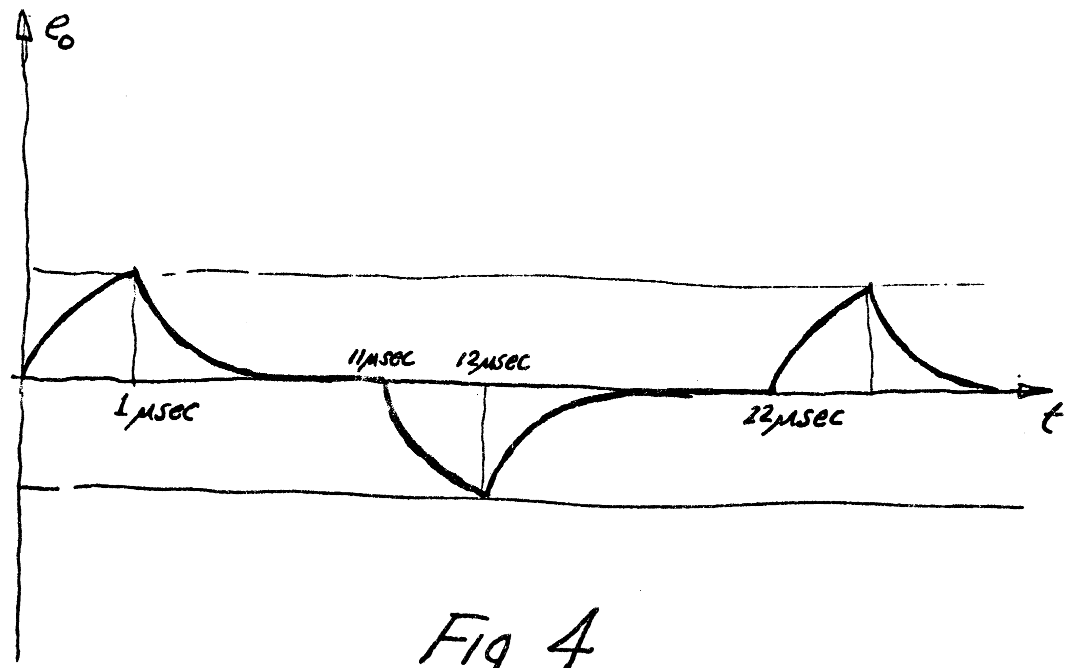


Fig 4

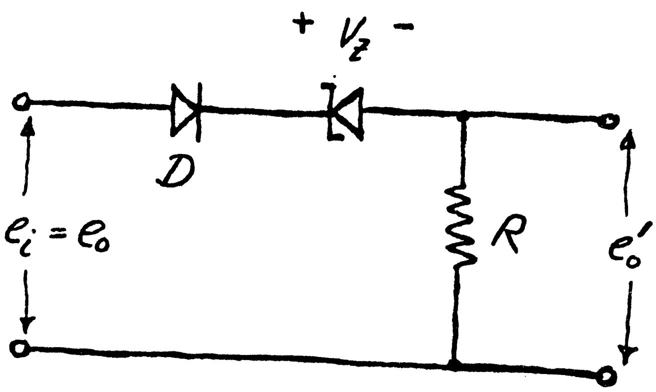


Fig 5

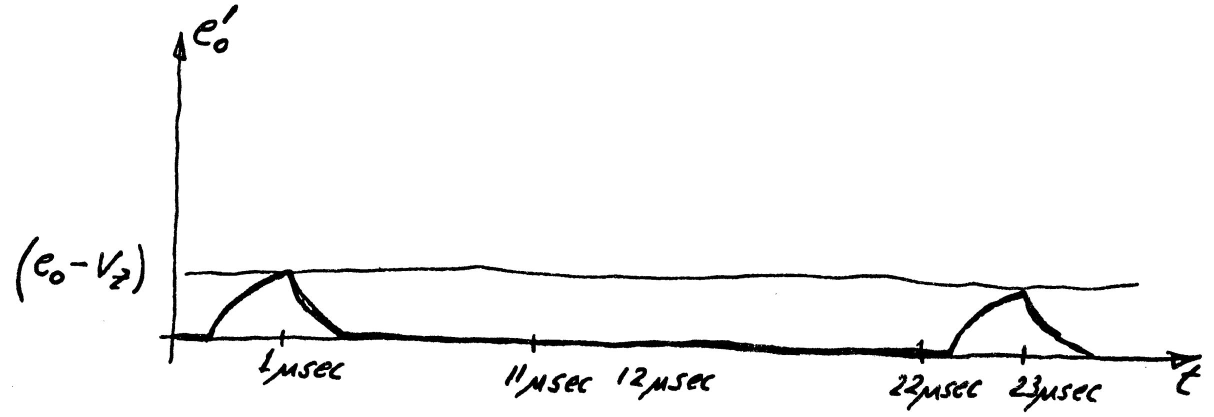
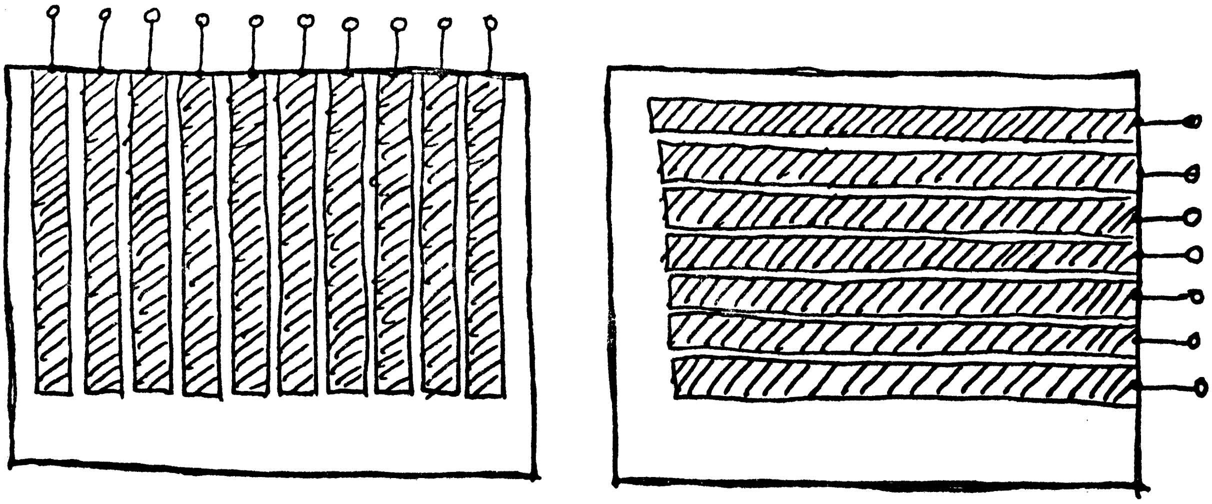


Fig 6



Input Board

Output Board

Fig 7

CHAPTER 12

ECONOMICS OF A REMOTE CREDIT TERMINAL

When many small retail outlets, gasoline stations, and even the larger chain stores are losing several thousand dollars annually because of stolen credit cards or people going on an overly extensive charging spree it becomes necessary to reduce these losses to a minimum thru the use of our modern day technology. With the advent of computers having increased statistics filed on people (i.e. their financial records, family status, employment status and often much more information than these) it becomes possible for credit to be controlled through the centralization of this information. The next consideration must be the transmission of credit information to a central data processing center from the place of purchase of a consumer good on credit. The method of transmission of this credit information is through the use of a Bell Telephone X403B data set and the associated electronic circuitry which we call the remote credit terminal.

We are considering our economical analysis on a large scale usage of the terminal device. It has been designed to be adaptable for the use by a small gas station, a medium size retail outlet or a national merchandise chain by minor modifications in the electronics. This was done to make any particular user of our unit have an increased interest because of its immediate adaptability to their present needs and being adaptable for more complex needs in the future if they should become desired.

By the use of a remote credit unit that is semiautomatic the operator is able to accomplish many other duties while at the same time increasing the accuracy of recorded credit sales and receiving rapid notification if a customer is using a stolen credit card or is trying to charge another item to their already overdue account.

All this sounds very good philosophically; however, how is it going to be economically a good venture to produce this unit? The answer to this question is an immediate YES. In justification of this answer we need to consider the initial unit cost, depreciation, and the dollars of savings it shall yield. The following tables will present the costs of units A, B, B-1; total costs of unit C and C-1 are dependent on many varying needs of the user and therefore, only some of basic unit cost will be indicated.

TABLE #1

Parts/Costs for Magnetic Card Reader used in Units A, B, B-1, C, C-1

Part	Price Each	Quantity	Costs
Slit toroids	$4\frac{1}{2}$ ¢	70	$ 3.15
Transistors (2N3391)	32¢	91	29.10
Capacitors 6800 pf, 5%	7.6¢	70	5.32
36 pf, 5%	13¢	70	9.10
Resistors, $\frac{1}{4}$w, 5%	6.2¢	140	8.20
Diodes	15¢	41	6.15
Zener Diodes	78¢	7	5.45
J-K Flip-Flops	60¢	11	6.60
R-S Flip-Flops	50¢	2	1.00
NOR Gate	50¢	1	.50
Locig Driver	54¢	1	.54
Printed Circuit Boards	50¢	3	1.50
Coil	24¢	1	.24
Trim Capacitors	10¢	5	.50
Teim Resistors	3¢	45	1.35
2N1302	15¢	22	3.30
2N2926	15¢	1	.15
Oscillator (100 Khz)	1.80	1	1.80
		TOTAL	$83.95

TABLE #2

Parts Costs for Price Reader Used in Units A,B,B-1

Printed Circuit Board	50¢	1	$ .50
Diodes	7¢	8	.56
Resistor	3¢	1	.03
Capacitor	10¢	1	.10
J-K Flip-Flop	60¢	5	3.00
R-S Flip-Flop	50¢	2	1.00
3 Dual input NOR Gates	50¢	1	.50
	54¢	1	.54
		TOTAL	$ 6.23

TABLE #3

Parts Costs for Location Reader Used in Units A,B,B-1

Part	Price Each	Quantity	Costs
Printed Circuit Board	50¢	1	$ .50
Diodes	7¢	8	.56
Resistors	3¢	1	.03
Capacitor	10¢	1	.10
J-K Flip-Flop	60¢	5	3.00
R-S Flip-Flop	50¢	2	1.00
3 Dual input NOR gates	50¢	1	.50
Logic Driver	54¢	1	.54
		TOTAL	$ 6.23

TABLE #4

Parts/Costs for Tone Dialer Used in Units A,B,B-1,C,C-1

J-K Flip-Flop	60¢	12	$ 7.20
R-S Flip-Flop	50¢	2	1.00
3 Dual input NOR gates	50¢	1	.50
Logic Driver	54¢	1	.54
Diodes	7¢	15	1.05
Capacitor	10¢	1	.10
Resistor	3¢	1	.03
Printed Circuit Board	1.00	1	1.00
		TOTAL	$11.42

TABLE #5

Parts Costs for Tone Detector Used in Units A,B,B-1,C,C-1

Printed Circuit Board	$1.00	1	$ 1.00
Capacitors	.10	6	.60
Disc Ceramic Electrolytic Capacitors	.20	9	1.80
Resistors, 10%	.03	12	.36
Coils	.90	3	2.70
Diodes	.15	12	1.80
Dual 2 input NOR gate	.50	3	1.50
Driver Inverter	.54	3	1.62
Transistors	.32	3	.92
		TOTAL	$12.34

TABLE #6

Parts Costs for Power Supply Used in Units A,B,B-1,C,C-1

Part	Price Each	Quantity	Costs
Fuse & Holder	$ .50	1	$ .50
N.C. Micro switch	.80	1	.80
Relay	1.80	1	1.80
Pilot Lamp & Holder	.40	1	.40
Transformer	2.60	1	2.60
Full Wave Bridge	1.20	1	1.20
Electrolytic Capacitors	.20	5	1.00
Resistors	.03	4	.12
Zener Diodes	.78	3	2.34
		TOTAL	$10.76

TABLE #7

Parts Costs for Preset Circuits Used in Units A,B,B-1,C,C-1

Driver Inverter	$ .54	3	$ 1.62
Dual 2 input NOR gate	.50	1	.50
Capacitors	.15	2	.30
Resistors	.05	2	.10
		TOTAL	$ 2.52

TABLE #8

Parts Costs for Control Sequencer Used in Units A,B,B-1,C,C-1

One Shot Multivibrater	$.25	1	$ .25
Diodes	.07	9	.63
J-K·Flip-Flops	.60	8	4.80
R-S Flip-Flop	.50	1	.50
3 Dual input NOR gate	.50	1	.50
Logic Driver	.54	3	1.62
2N2160	.40	1	.40
2N1304	.20	1	.20
Resistors	.03	4	.12
Electrolytic Capacitor	.20	1	.20
		TOTAL	$ 9.57

TABLE #9

Parts Costs for Driver & Relays for Units A,B,B-1,C,C-1

Part	Price Each	Quantity	Costs
Diodes	$ .07	28	$ 1.94
Transistors	.20	8	1.60
Resistors	.03	40	1.20
Relays	1.40	8	11.20
Capacitors	.10	8	.80
		TOTAL	$16.74

TABLE #10

Cost Analysis of Optical Card Reader

Shift Register	$ 8.00		
10 Lamps	1.00		
10 Lamp-sockets	1.00		
Fiber OPTICS	5.40		
70 Photo Cells	56.00		
14 Transistors	4.50		
14 Diodes	2.10		
21 Resistors	.63		
7 Relays	8.75		$ 87.38
Manufacturing Costs			$ 35.00
PROFIT			$ 25.00
	TOTAL COST		$147.38

TABLE #11

Costs of Remote Credit Terminal Models A, B, B-1

Sub Unit		
Magnetic Card Reader	$83.95	
Price Reader	6.23	
Location Reader	6.23	
Tone Dialer	11.42	
Power Supply	10.76	
Preset Circuits	2.52	
Control Sequencer	9.57	
Tone Detector	12.34	
Driver and Relays	16.74	$159.76
Manufacturing		$ 60.00
PROFIT (20%)		$ 44.00
	TOTAL COST	$263.76
X403B DATA Phone		$14/month

In considering our unit to have a useful life of approximately eight years the original unit cost is nominal or may be considered as about 32 dollars per year. This along with the rental of the data phone from the Bell Telephone Company is very close to $200/yr. If we consider a small retail outlet that is losing 1200 to 1400 dollars per year thru people using invalid or stolen credit cards, this represents a net savings of 10 to 1. This alone is enough justification for the use of our unit in economic savings, but it also has the other advantages of being a rapid and efficient method of centralizing credit control more accurately than is possible today by other methods.