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NORTH AMERICAN INSTRUMENTS, INC.
2420 N. Lake Ave.
Altadena, California

WIND STRUCTURE STUDY FOR ROCKETS

Department of the Army, Signal Corps
Contract No. DA-36-039 SC-52[illegible]99

Multi-Channel Data Recording System
Second Quarterly Progress Report
For Period July 21 through October 20, 1953

Object

To determine the wind value which can be used in adjusting a rocket launcher so that the rocket trajectory can be corrected for low level wind effects.

Department of the Army Project No. 3-17-02-001
Signal Corps Project No. 1052A

Submitted for the Project by
Philip A. Shaffer, Jr.   Clarence L. Wheeler

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ILLUSTRATIONS

Purpose

The objective of this study is to determine the time and space variation of wind near the ground and to determine the wind value which can be used in adjusting a rocket launcher so that the rocket trajectory can be corrected for low level wind effects. The results of this contract are essential to provide necessary design data for a wind correction fire control computer conducted under Contract DA-04-495-Ord-352.

The work under this program can be essentially broken down into the following categories:

(a) Design of a suitable measuring and recording system

(b) Instrumentation of a test area

(c) Recording of typical wind fields

(d) Analysis of data and recommendations

This report deals primarily with phase (a), namely, the design of a suitable measuring and recording system. It is planned to utilize the two-component anemometer designed under Contract DA-04-495-Ord-352, described in North American Instruments, Inc. Quarterly Report for the Third Quarter, dated June 1, 1953. The details of the recording system are outlined in this report.

Abstract

A ninety-six channel data recording system is described which first commutates parallel carrier information channels into serial carrier representation, then converts the data to digital form, and records the pulse-coded information on magnetic tape. A companion data punching system for transcribing the tape-recorded information into IBM punched-card form is outlined.

Publications, Lectures, Reports, and Conferences

Mr. A. A. Arnold visited this activity on October 14 and the general plan concerning this proposed research was discussed and the field site in Santa Barbara was visited.

Introduction

This report is concerned with the data handling requirements which arise in a research program aimed at the measurement and analysis of surface winds. The immediate military purpose of the program is to attain a sufficient understanding of surface wind behavior to permit the specification of the design and placement of wind instrumentation to be used in connection with fire control equipment governing the firing of rockets. Present information concerning the spectral nature of these winds is not sufficient to permit the design of wind correction computers on an objective mathematical basis, nor is current knowledge adequate to establish the feasibility of such corrections. The wind study program intends to augment this information greatly, it is hoped, to the end that such designs and evaluations may be made reliably. The data handling instrumentation discussed in this report is essential to the success of the wind study program for reasons made evident in the following sections. The wind study program, the anemometers developed for use in wind measurement, and the elements of a proposed data recording system have been discussed in earlier Quarterly Reports (Refs. 1, 2); the present report augments the earlier description of the data handling system (Refs. 3, 4).

The Data Handling Problem

Before going into a discussion of the system to be used in handling the wind velocity information, it is well to examine the nature and magnitude of the data reduction problem. The information to be recorded is generated by sixty anemometer elements and by several auxiliary instruments which measure temperature, humidity, and other meteorological variables; the total number of information channels will be between seventy and ninety-six, the capacity of the instrumentation now being constructed. To provide the desired bandwidth of one cycle per second, each channel must be sampled at least twice each second--the present design provides three samples per second. Each channel is to be recorded "to one percent"; in the present design this phrase is taken to mean that the recorder shall not introduce an error as great as one percent of full scale value (100 millivolts RMS input).

The sampling process which we have just described, results in the acquisition of approximately two million decimal digits per hour, exclusive of coordinating variables such as time, number of anemometers, and so forth. This information rate is perhaps not very impressive until one begins to contemplate the task ahead--after recording! What to do with it all. An IBM reproducing punch is capable of punching one hundred 80-column cards per minute--or almost half-a-million decimal digits per hour at maximum utilization. Thus one may estimate that it would require at least one 8-hour shift of efficient IBM operation to transcribe into punched-card form the information collected during a one-hour run of the wind instrumentation. This schedule, which includes no computational operations, might prove feasible for limited operation of the wind instrumentation, were it not for the necessity of performing extensive computations in the reduction of the myriad observations to their statistical essence.

The computational goal which one sets for the wind study program, depends entirely on the computational facilities available, but it can never be very modest and at the same time significant because of the number of variables which play important roles in the understanding of surface wind behavior. Thus one would like to examine statistically the interrelations between components of velocity and of turbulence, thermal lapse rate, as these vary with both time and position; since the wind velocity constitutes a vector function of four parameters (x, y, z, t), the cross- and autocorrelations necessary to characterize the wind phenomena are very great in number, and it is not practical to contemplate doing a very complete analysis. If we were to restrict the problem to that of calculating spatial correlations between observation pairs made in the same horizontal plane or in the same vertical array, we would have to perform

$$5\binom{12}{2} + 6\binom{10}{2} = 600$$

correlations, each of which comprises a sum of over ten thousand 2 x 2 digit products -- for each hour's worth of recorded data.

From the brief exposition given above, it is apparent that the processing of the wind data in extent sufficient to provide only the simplest of statistical results requires the use of the most advanced types of data handling and computational equipment. Indeed, no equipment which is available today is adequate to record and process the data acquired during a few months of operation of the wind instrumentation. It is for this reason that North American Instruments, Inc. has found it necessary to undertake the design of a specialized system of recording and computing instrumentation; the nature of this system will be discussed in the following sections.

Data Reduction System

The complete data reduction system must contain not only a recording device of adequate capacity to accommodate the information at the rate generated but also a reducing or processing facility which can transform the raw data into the desired finished result at a rate compatible with the permissible time delays and total operating time. A program in which the data gathering period lasted only a short time might tolerate a prolonged processing period, but when the experimentation continues, the processing operations must keep up to date or fall hopelessly behind at the start. The wind study program contemplates continued experimentation, perhaps for several years; the data processing must not lag far behind the recording, therefore.

In order to speed up the handling of large amounts of data, we have selected magnetic tape as the recording medium. This medium is well suited to high speed feed rates as well as low speed ones, and it can be written upon, read from, or erased with unequalled ease by entirely automatic devices. Thus it is possible to record, transcribe, duplicate, sort, compute, and perform other operations without necessitating the clumsy interference of a human operator, except to direct the operations, not perform them.

To perform successive operations upon analog-type data (typified by amplitude or frequency modulated signals) necessarily results in a loss of accuracy. For this reason, the wind measurements are first converted from their initial form (amplitude modulated carrier) to digital form, and the information is put on tape in pulse-coded form. From this point on it is possible to perform operations without fear of derogation of the data, regardless of the speed at which the process is conducted, or in what form the digits are represented (card or tape holes, tape magnetization, voltage waveforms, etc.).

Because many different types of operations may be performed on the same experimental data, it is desirable to be able to feed the data into as many types of machines as possible; magnetic tape held digital information may be fed to electric typewriters, pen recorders, IBM equipment, and analog or digital type computers at widely different speeds without necessity of special synchronization.

During initial phases, the data handling system will consist of (1) a recording system which converts parallel analog information channels into a sequence of pulse-codes in a single magnetic channel, and (2) a device for rapid conversion of the tape borne pulse-code data into IBM cards for subsequent computational reduction.

Standard IBM punched card techniques are not sufficient to perform the full computational program; they must be considered as a stop-gap facility, pending the construction of specialized high speed correlators capable of performing the computations directly upon the tape held information.

The Multiple Channel Recording System

The principles of operation of the recording system may be described with reference to Fig. 1, a block diagram of the system. The ninety-six signal channels enter the schematic at the top; the channels are commutated as though by a 32-position three-pole rotary switch into three output channels. The actual commutation is done electronically; the input amplifiers increase the signal levels prior to switching, while the gate tubes determine when each signal is transmitted. The sequence of switches prior to the input amplifiers permit all channels to be switched simultaneously to a standard signal source, an operation of use in preventive maintenance and monitoring.

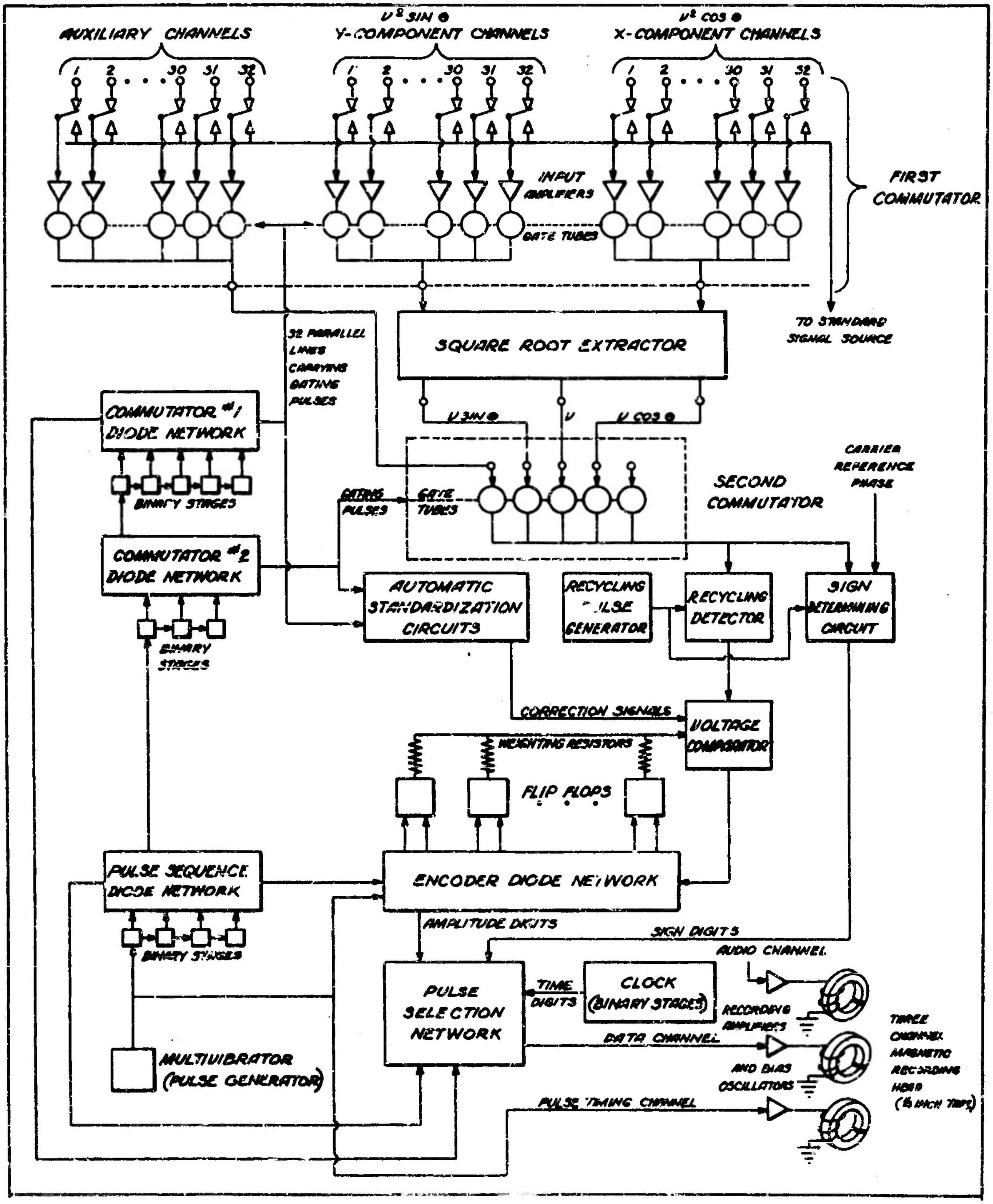

FIGURE I - BLOCK DIAGRAM OF MULTIPLE CHANNEL RECORDING SYSTEM

Two of the three channels issuing from the first commutator are combined in a "square root extractor" in such a way that both entering signals are divided by the wind velocity magnitude. The signals issuing from the extractor unit are combined with the auxiliary channels in the second commutator to produce a single channel containing seriatim samples of all of the 96 input channels plus the derived quantity V from the extractor.

As the signals issue from the second commutator, they are still in the form of rectangularly modulated carrier waves. The magnitude (rectangle height) and sign (phase of carrier) are obtained by the recycling detector and by the sign determining circuit, respectively. Fig. 2 presents the time pattern and the waveforms involved in some of the analog-to-digital conversion operations. Fig. 2-A shows the sequence of 32 commutation channels comprising a complete one-third second cycle. Each of these small sections is further split up by the second commutator as illustrated in Fig. 2-B.

The action of the recycling detector is depicted in Fig. 2-D; the dotted sine wave represents the 3000 cps carrier wave whose amplitude it is required to hold pending conversion to digital form. The voltage of the detector is reset (below zero level) by the recycling pulse; immediately thereafter, the output

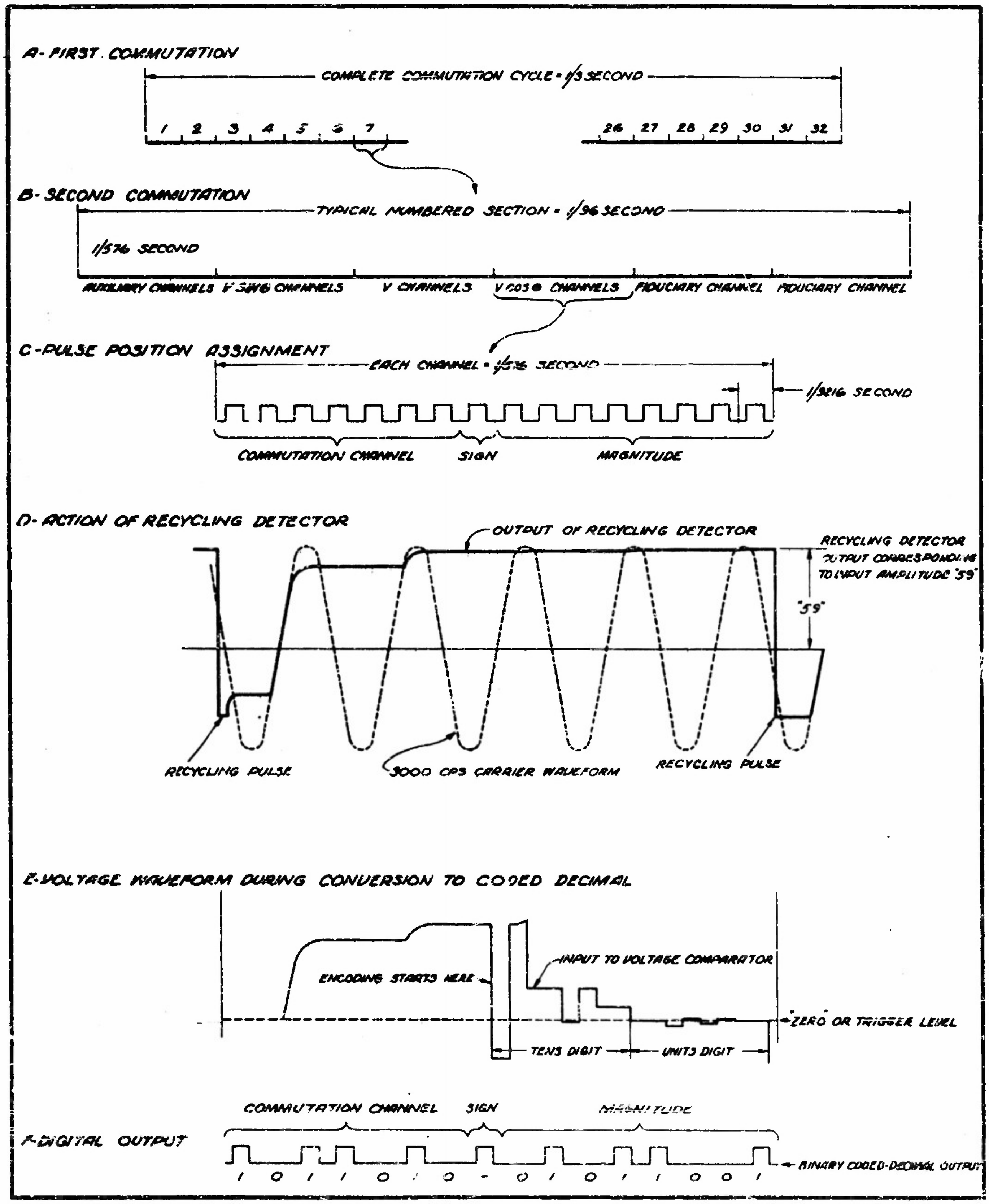

FIGURE 2 - TIMING SCHEDULES AND WAVEFORMS IN OPERATION OF MULTIPLE CHANNEL RECORDER

voltage follows the rising carrier wave upward, and the peak value is very nearly attained in three wave periods. The action of the sign determining circuit is not illustrated; it is similar to that just presented, but the magnitude is not of concern.

The conversion of the output of the recycling detector to serial pulse-coded form is achieved by a combination of circuit units which may be characterized in aggregate as a feedback coder; the principles of operation of the coder have been discussed in an earlier report (Ref. 4) and several treatments of the subject have appeared in recent literature (Refs. 5, 6). Fig. 2-E shows the "error voltage" waveform appearing at the voltage comparator throughout a coding cycle (1/576 second) consisting of sixteen pulse times. The coding operation is delayed until the ninth pulse time to allow the output of the recycling detector to converge asymptotically to the required peak of the input waveform; the first seven pulse times are alloted to the numbering of the commutation channel (see Fig. 2-F); the eighth pulse represents the sign of the number; the last eight pulses correspond to the number magnitude, here shown in binary-coded-decimal form (each decimal digit is represented by four binary pulses). The successive trial subtractions and occasional restorations (when the heavy line in Fig. 2-E falls below the trigger level) which occur in the coding process can be seen in Fig. 2-E for a hypothetical input of magnitude "59". The first four bits (binary digits) of the magnitude coding in Fig. 2-F correspond to "5", the second four to "9".

The information issuing from the encoder diode network (part of the feedback coder) and from the sign determining circuit is now entirely in binary form ("on" or "off", magnitude of voltage not of concern) and is largely in pulse-coded form. The pulse selection network performs the job of combining the pulse-coded signals from the commutation networks, from the sign circuit, from the keying pulse generator (not shown), from the timing pulse generator, from the encoder, and from the real-time clock into a meaningful sequence of pulses according to a prearranged schedule. You can't tell one pulse from another without a program; the pulse selection network establishes the program.

The magnetic recorder and playback units are designed to provide three channels on quarter-inch magnetic tape moving at approximately 7.5 inches per second during recording; rewind and playback may be performed at much higher rates. In the present equipment one magnetic tape channel is to be used for timing and keying pulses (denoting the origin or start of the commutation cycle), a second channel is used for recording the coded information, and a third is available for auxiliary uses, perhaps for occasional verbal commentary during the course of the recorded experiment. The recording bandwidth will be greater than 10 kilocycles per second. The recording time will be one hour when ten-inch tape reels are employed.

The pulses which are used to turn on and off the commutator gates and which determine the operating schedules of the entire system are derived from multivibrator clock pulses counted down in several stages by conventional binary flip-flops. The distribution of the gating pulses to the gating amplifiers is achieved by diode networks designed to execute the desired step-sequential logic. Similar networks are employed to obtain functional switching in connection with encoding and with pulse selection.

The Multiple Channel Punching System

Fig. 3 illustrates, in block outline form, a data punching system which is intended to permit the transcription of the tape-recorded pulse-coded information into punched card form at the maximum speed attainable by IBM card feed rates. The information is read from the tape by the middle magnetic reading head; the left-hand head reads the timing pulses from the tape; the right-hand head is not involved in the present operations.

The pulses read from the tape in serial form are redistributed by the distributor, a diode-type function switch, into as many as eighty parallel channels. The pulse information read during an IBM card-feed cycle is held from the instant of its arrival in the first register until punching clears the second register; at that time, the information held in the first register is shifted into the second register to await punching. The use of two successive registers obviates synchronization

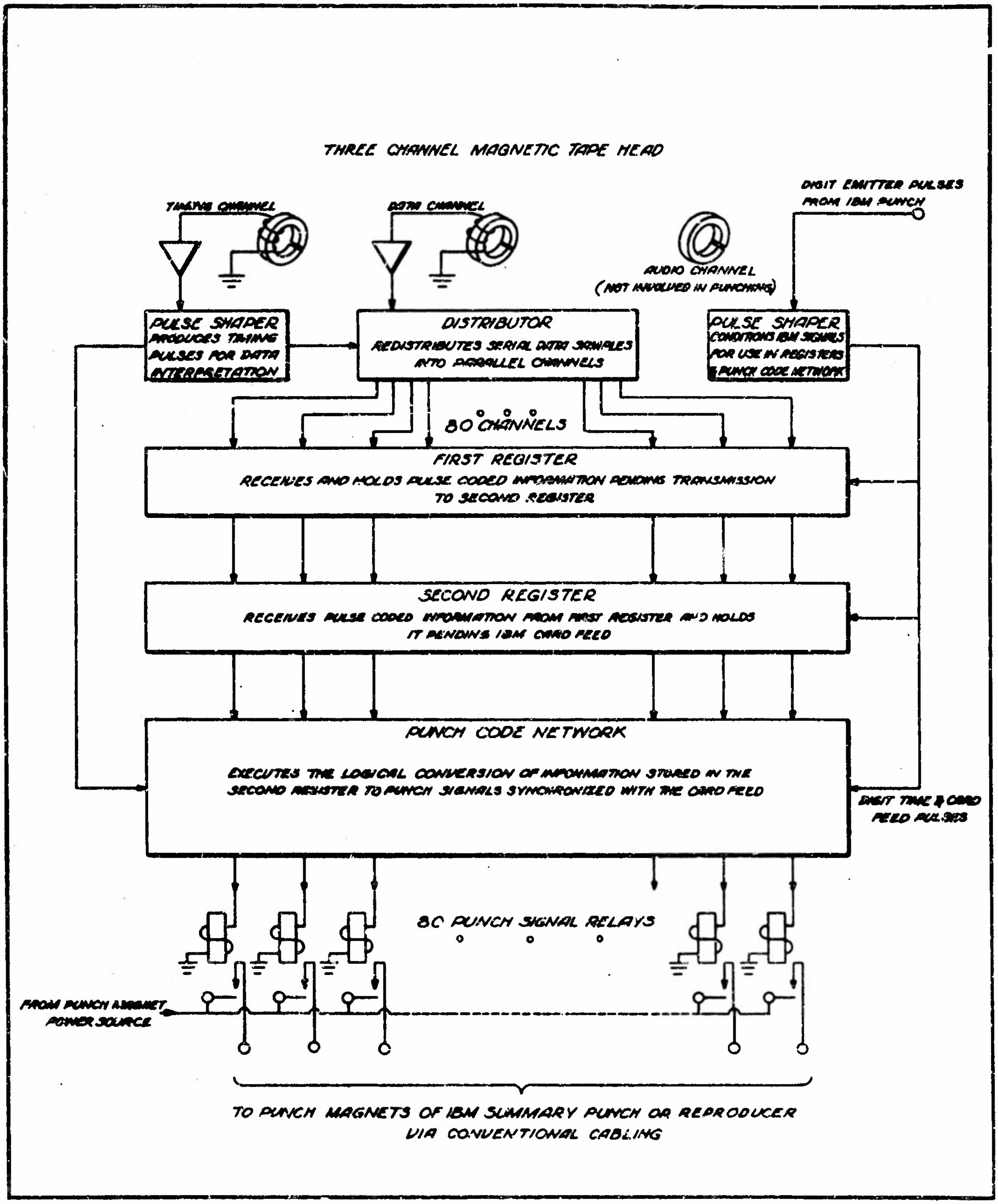

FIGURE 3-BLOCK DIAGRAM OF MULTIPLE CHANNEL TAPE READING CARD PUNCH SYSTEM

between tape motion and card feed. The <u>punch code network</u> compares the binary codes held in the second register with the position code corresponding to the instantaneous phase of the card-feed process and activates the punch signal relays at the instant the correct row of the card passes beneath the punching dies.

Fig. 3 presents the form of the punching system as it is presently conceived; further steps in the design and development process may modify the block arrangement.

Program for the Next Interval

To complete the instrumentation phase and to install this equipment at field stations in Santa Barbara. Collection of wind data should commence by the end of December or early in January of 1954.

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