

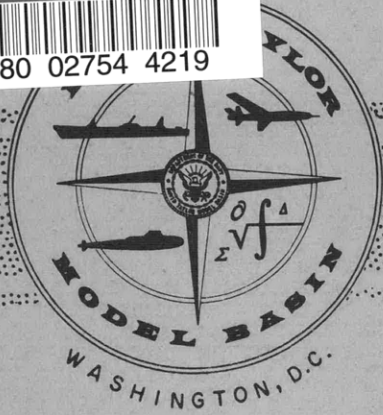
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**HYDROMECHANICS**



**AERODYNAMICS**



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**ACOUSTICS AND  
VIBRATION**

A MULTICHANNEL DIGITAL DATA  
ACQUISITION SYSTEM

by

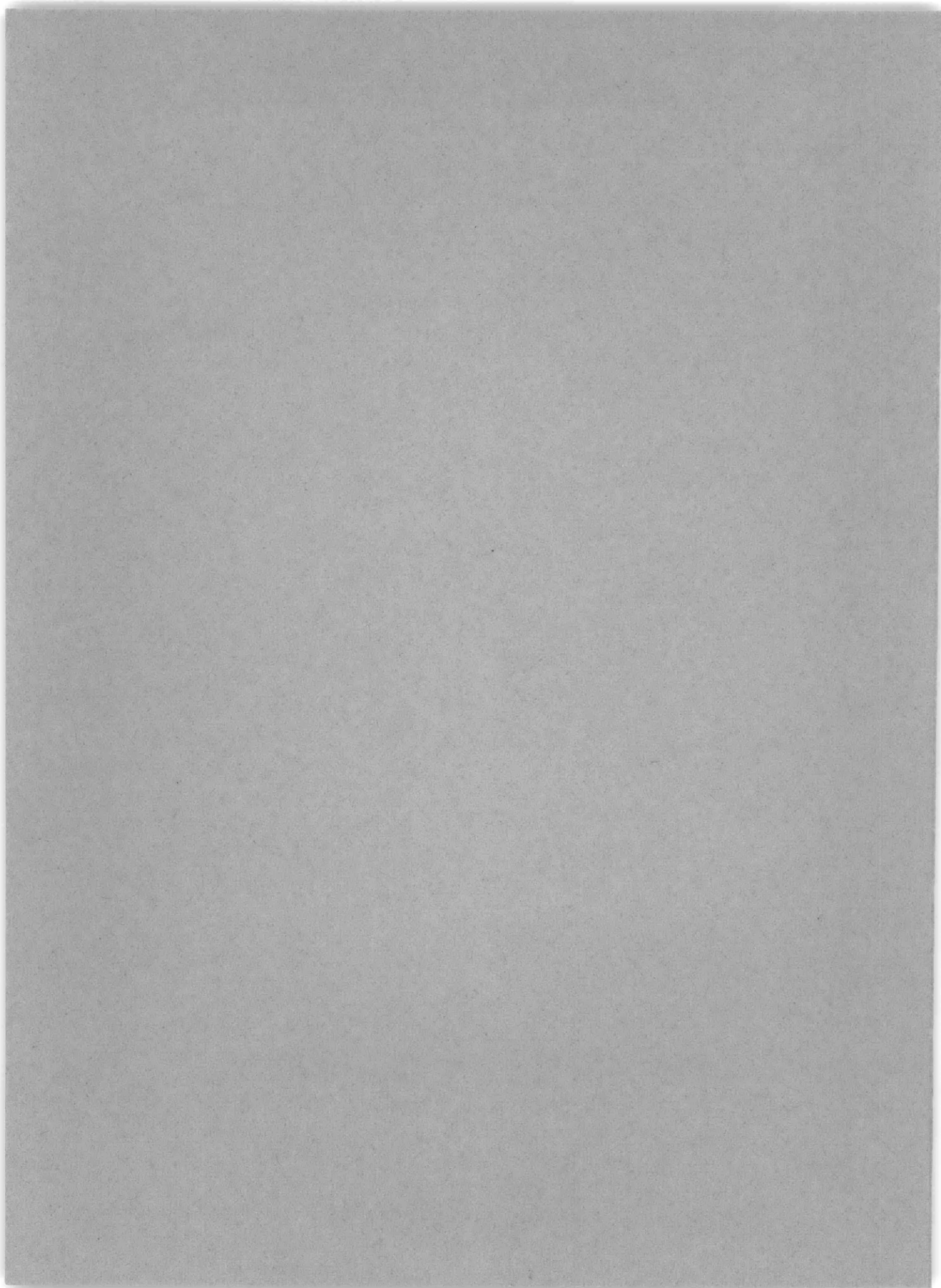
James A. Luistro



HYDROMECHANICS LABORATORY  
RESEARCH AND DEVELOPMENT REPORT

September 1964

Report 1630



**A MULTICHANNEL DIGITAL DATA  
ACQUISITION SYSTEM**

**by**

**James A. Luistro**

**September 1964**

**Report 1630  
SS 600-000  
Task 1703**

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## ABSTRACT

A digital data acquisition system (DIDAS) is discussed with emphasis on its concepts and capabilities. Any arbitrary combination of 43 inputs made up of 36 analog inputs, 6 digital inputs, and 1 events pulse input may be sampled at rates up to 6000 samples per second, digitized where necessary, and recorded on magnetic tape. These output digital tapes are suitable for direct entry into an IBM 7090 or similar digital computer. Since the primary function of DIDAS is to sample, digitize, and record analog data, the system is considered a 36-channel system, and it is with this principal consideration that the operational and performance characteristics are described herein.

## INTRODUCTION

With the development of electronic components and digital computers it has become possible to design a digital data acquisition system that will accommodate large quantities of analog data, digitize the data at the test site, insert a limited amount of programming for computer use, and store the digitized data on magnetic tape for reduction and analysis with a high-speed digital computer. If there are sufficient programming potentialities built into the system, only a limited amount of input data are needed when the magnetic tapes are brought to the computer for processing. In some cases the computer may be part of the system, and the data reduction may be completed at the test site.

When the Bureau of Ships<sup>1</sup> requested the David Taylor Model Basin to investigate the unsteady loads on hydrofoils under different operating conditions, the first steps were taken to procure a suitable digital data acquisition system (DIDAS). Many of the specifications written for this system were dictated by the particular needs of the hydrofoil program. On the other hand, certain features which would enhance its usefulness for future projects were incorporated into the design.

In September 1961 a contract was awarded to Beckman Instruments, Inc., to design a system that would digitize up to 36 channels of analog input data and record it on magnetic tape in a format suitable for use with the Model Basin IBM 7090 high-speed computer.<sup>2</sup> The system was delivered to DTMB in April 1962, and final acceptance was made in October 1962. During the contract period, IBM computer programs were developed to evaluate the DIDAS acceptance test data and to prepare the hydrofoil program test data for analysis.

The purpose of this report is to explain briefly the design philosophy and the resultant system design and to provide an abbreviated operation and procedures manual. The system has a multitude of programming possibilities, but only those pertinent to the immediate use of this equipment are dealt with in any detail.

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<sup>1</sup>References are listed on page 52.

## GENERAL SYSTEM DESIGN

### SYSTEM CONCEPT

The immediate test data reduction program would involve the harmonic analysis of time-varying data from hydrofoils towed at high speeds both in calm water and in waves.

Therefore, a critical review of analog-recording techniques, ranging from pen-and-ink recording to frequency modulated (FM) magnetic tape recording, was undertaken. The results of this study indicated that utilization of these techniques would require expensive and time-consuming intermediate steps to digitize and prepare the data for entry into a digital computer for analysis. Concurrently, a study was undertaken to evaluate the economics of digitizing the data on the test site by incorporating a digital data acquisition system into the program. This type of equipment offered reliability, accuracy, relative freedom from costly down time and maintenance, minimum operational functions and personnel, and the elimination of intermediate data processing. Transcribing errors are eliminated since the data are recorded on magnetic tape for direct computer entry. In addition, there is the potential of programming the data on the test site and possible maximum utilization of facility time.

The design of DIDAS was based primarily upon the needs of the hydrofoil test program that will yield test data from a variety of primary transducers, over a frequency range from 0.05 to 100 cps. These data will be acquired under conditions that are not considered normal or ideal for systems of this type. In addition to being operated in a very high humidity with a wide seasonal temperature range, this equipment will be operated on board the TMB high-speed (50-knot) towing carriage. Because this system was to be subjected to the vibrations and accelerations associated with a mobile operation, the design requirements were more stringent than those normally required for laboratory-type installations; this mobile application imposed the additional requirements of minimum physical size and weight.

The general philosophy applied to the design was that the system, as originally supplied, would be complete in the digital logic areas. The analog area, which contains the necessary strain gage balance equipment and signal conditioning amplifiers, would be expandable with minimum cost and effort.

The original design included provisions to allow on-site identification of the data by using digital switches for the insertion of test identification information (date, depth, speed, etc.) onto the recorded data tape. Since many data errors originate in the hand logging of the data recording equipment conditions during test operations, provisions were included to automatically identify the recorded data for future sorting by the computer program. A further degree of computer programming on the test site was offered by the establishment of separate, automatically identified, recording modes of operation.

A system sequence patchboard, where either digital or analog input signals could be randomly mixed for sampling, provided flexibility of the recording order of the data. This



patchboard would allow the users of this system to vary the rate at which a particular input is sampled by systematically varying the number of times it appears in the patch program.

A time generator input, to time-tag each data sample, was not considered necessary because the rate at which the signals are sampled is controlled by a very precise clock, thus providing a stable reference time base. It was necessary, however, to reduce the magnitude ambiguity introduced during the decision period of the successive approximation type of analog to digital converter (ADC). This ambiguity is brought about by the continuing change of the input signal voltage during the time required for the ADC to complete its decision.

The use of a sample-and-hold amplifier was considered essential to reduce this ambiguity in the data samples. This amplifier, which provides a 10-microsecond sampling period, holds the instantaneous signal level at the time of cutoff so that the ADC may digitize, without ambiguity, a stable voltage during a quiet period of system operation. This sample-and-hold feature further provides a known time at which the digitized sample is taken for use in more accurately defining the phase relationship between signals.

Since a spectral analysis of the data accumulated was planned, it seemed desirable to take data samples at equally spaced intervals of time to facilitate this analysis. Therefore, because of the operational limitations of digital tape recorders to provide this capability, temporary data storage was needed while the system was operating at low sampling rates. This need was satisfied by the incorporation of a magnetic core memory to store the dynamic data serially as it was sampled regardless of the time required for recording fixed data. The unloading of these data at a constant rate and at intervals dictated by the loading rate of the memory would allow the magnetic tape recorder to operate at a constant tape speed during actual recording. The logic for the operation of the tape recorder also controls the generation of the required IBM 7090 data spacings.<sup>3</sup>

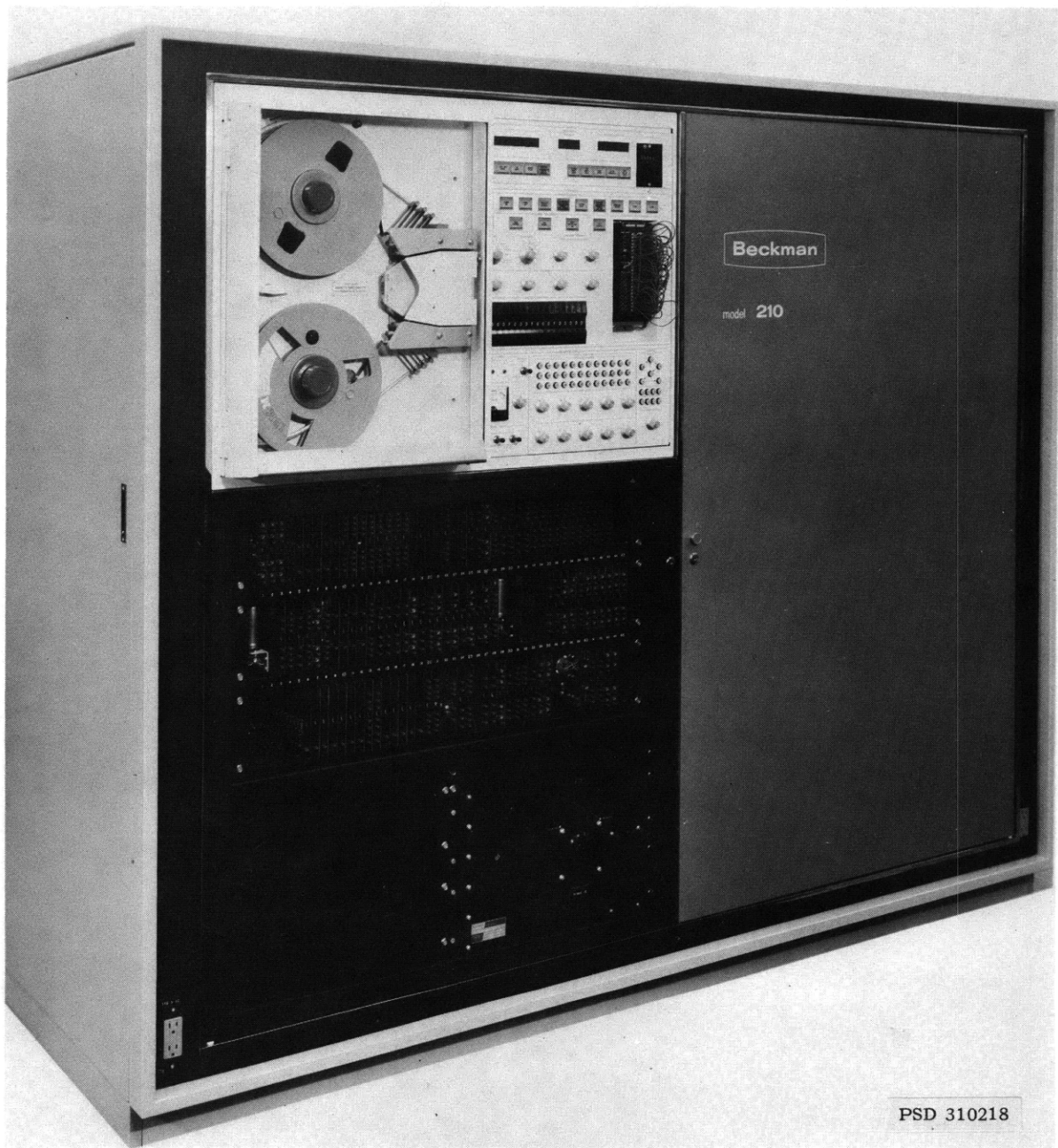
The cost of this system precluded the procurement of any playback or printout capability. However, the need to observe the character of the input signals during testing was recognized, and the design included the provision for external analog recording of these signals by monitoring the output of the signal conditioning amplifiers.

Figure 1 shows a simplified system block diagram. This diagram presents the general system concept resulting from the aforementioned considerations. Specific details and pertinent discussions of any of the various components not brought out in the body of this report may be found in Appendix A or the manufacturer's manuals.<sup>4</sup>

## SYSTEM DESCRIPTION

DIDAS is a 36-channel data system that can sample data at rates up to 6000 samples per second and digitize and record these data on magnetic tape. The inputs may be arbitrarily made up of 26 narrow band and 10 wide band analog inputs, 6 digital inputs, and 1 events counter input.





**Figure 2 – Digital Data Acquisition System**

The control panel of DIDAS is shown in Figure 4. The panel is divided into three areas: **DISPLAY**, **CONTROL**, and **MAINTENANCE**. The upper area, **DISPLAY**, is made up of the various indicators of data content, system status, and system alarms. The strip marked **DATA**, in the upper left-hand corner, contains a 5-place back projection type of digital display, in octal code, of the digitized data sample; see Reference 4 for octal conversion tables. To the right of **DATA**, a 2-digit decimal display shows the number of the **SEQUENCER POSITION** being sampled. Next, a 3-digit decimal display, **RECORD COUNTER**, indicates the number

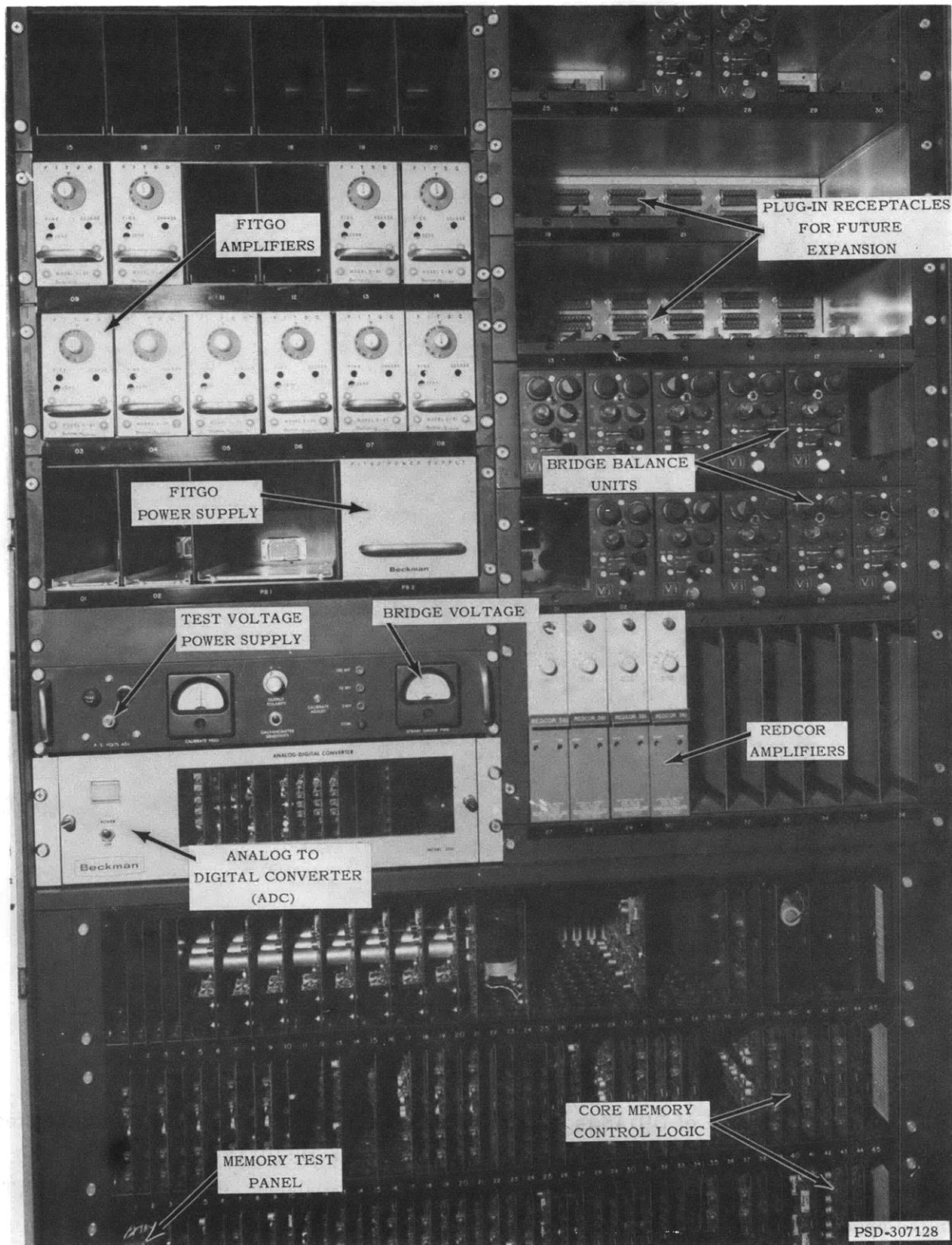


Figure 3 – DIDAS Analog Section, Showing a Portion of the Bridge-Balance Units and Signal-Conditioning Amplifiers

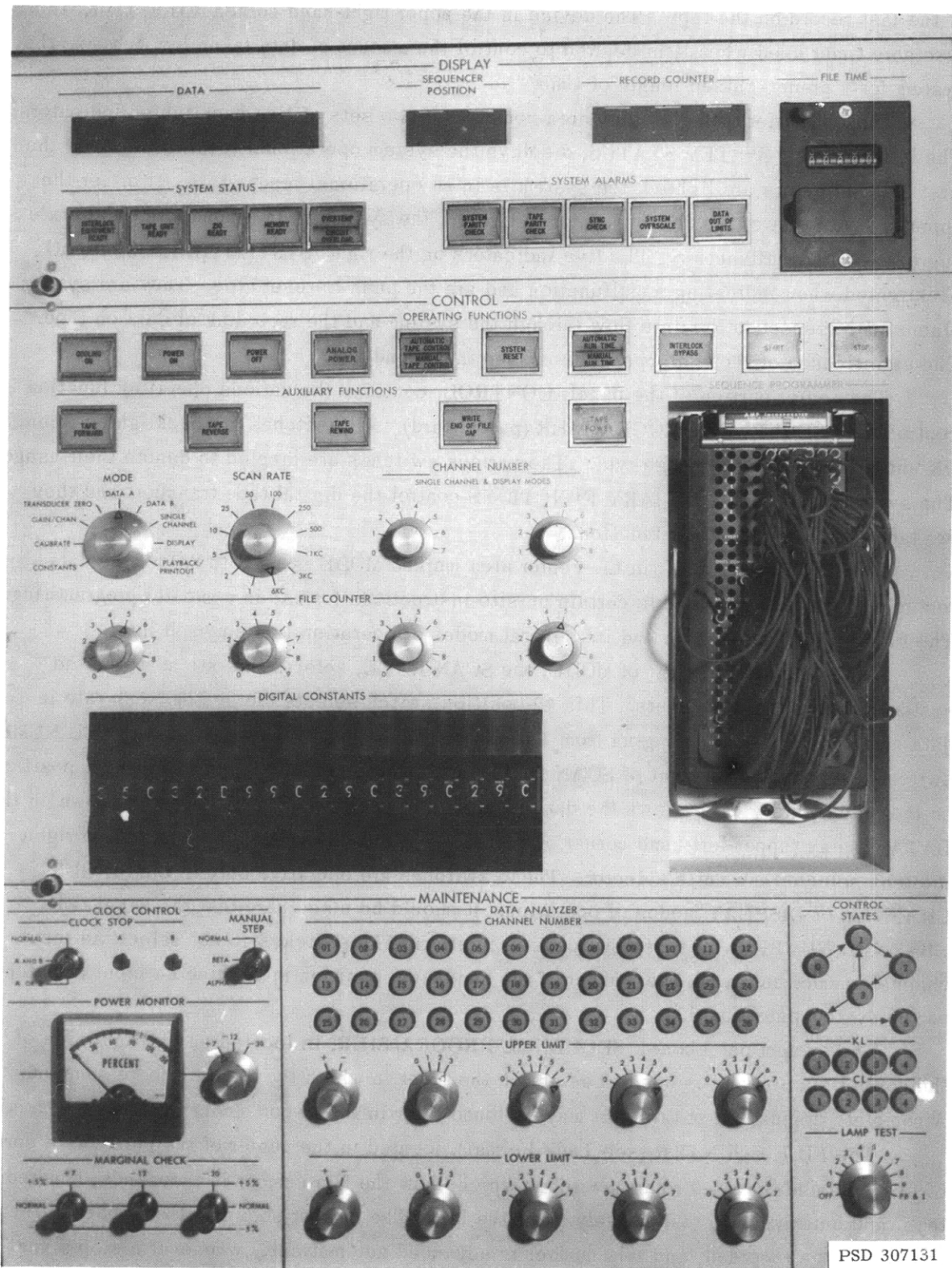


Figure 4 – Digital Data Acquisition System Control Panel

of the last record on the tape. The device in the upper right-hand corner, **FILE TIME**, is a resetable timer used when it is desired to control the amount of data taken by operating the system for a predetermined length of time.

The remainder of the display area consists of two sets of five backlighted indicators. The left-hand set, **SYSTEM STATUS**, displays the system operational readiness. When the first four indicators are lighted, the system is in an operational ready state. If either the upper or lower part of the fifth indicator is lighted, the system is in a nonoperational state due to a system malfunction. The five indicators on the right, **SYSTEM ALARMS**, are all backlighted when indicating a malfunction and are the push-to-reset type. They are system alarms with respect to the data flow through the system and the recording of data on tape. The significance of these alarms is discussed in Appendix B.

The center portion of the panel, **CONTROL**, contains the various operating function controls and **SEQUENCE PROGRAMMER** (patchboard). All switches are backlighted when ON and are the push-to-change type. The various switches are labeled to denote their usage. The switches marked **AUXILIARY FUNCTIONS** control the digital tape transport and they are labeled to indicate their function.

The switch on the left in the center area marked **MODE** is used to select the data recording format and to provide certain on-site instructions for use in computer programming. The functions of this switch and its several modes of operation is discussed later.

The switch to the right of **MODE**, the **SCAN RATE**, selects the rate at which the system samples the test inputs. This 12-position switch selects the system scan rate in data samples per second, ranging from 1 to 6000 samples per second. The **CHANNEL NUMBER** switches, located to the right of **SCAN RATE**, are used to select a single sequencer position on the patchboard. This allows the data input to that position to be recorded or shown on the **DATA** display (upper left-hand corner of Figure 4). These switches are, from left to right, the tens selector and units selector. These switches are operative only in the **SINGLE CHANNEL** or **DISPLAY** modes of operation. It should be noted here that the panel title, **CHANNEL NUMBER**, for these switches is in error. The switches do not select the input channel number but rather the number of the sequencer position into which an input is patched on the system patchboard.

The system patchboard, **SEQUENCE PROGRAMMER**, is located on the right side of the control section and is used to establish the order in which the data are to be sampled. A complete discussion of this unit may be found later in this report under System Programming.

The **FILE COUNTER** (see Tape Format), located in the center of the panel, is a series of four solenoid-operated rotary switches which show the file number in thousands, hundreds, tens, and units values, respectively, from the left. The number shown is the number of the next file to be recorded, and this number is advanced automatically whenever a stop signal is given to the system. These rotary switches may be rotated clockwise to set manually any number desired, up to 9999, when starting a test series, or may be reset to the next number of an interrupted series.

Extending across the lower left portion of the CONTROL area are 18 digital switches marked DIGITAL CONSTANTS. These are 16-position alphanumeric switches with a range of 0-9 and A-F. They may be used to insert identification data onto the data tape; see Tape Format.

The entire lower section of the control panel, MAINTENANCE, is reserved primarily for maintenance functions. The functions shown on the left and right ends are discussed in detail in the manufacturer's manuals.<sup>4</sup> The center section of this lower panel, however, contains a DATA ANALYZER which may be used during operations to monitor the various digitized input levels. The purpose and the use of this analyzer are discussed in Appendix B.

## SYSTEM PROGRAMMING

### SEQUENCE PROGRAMMER PATCHBOARD

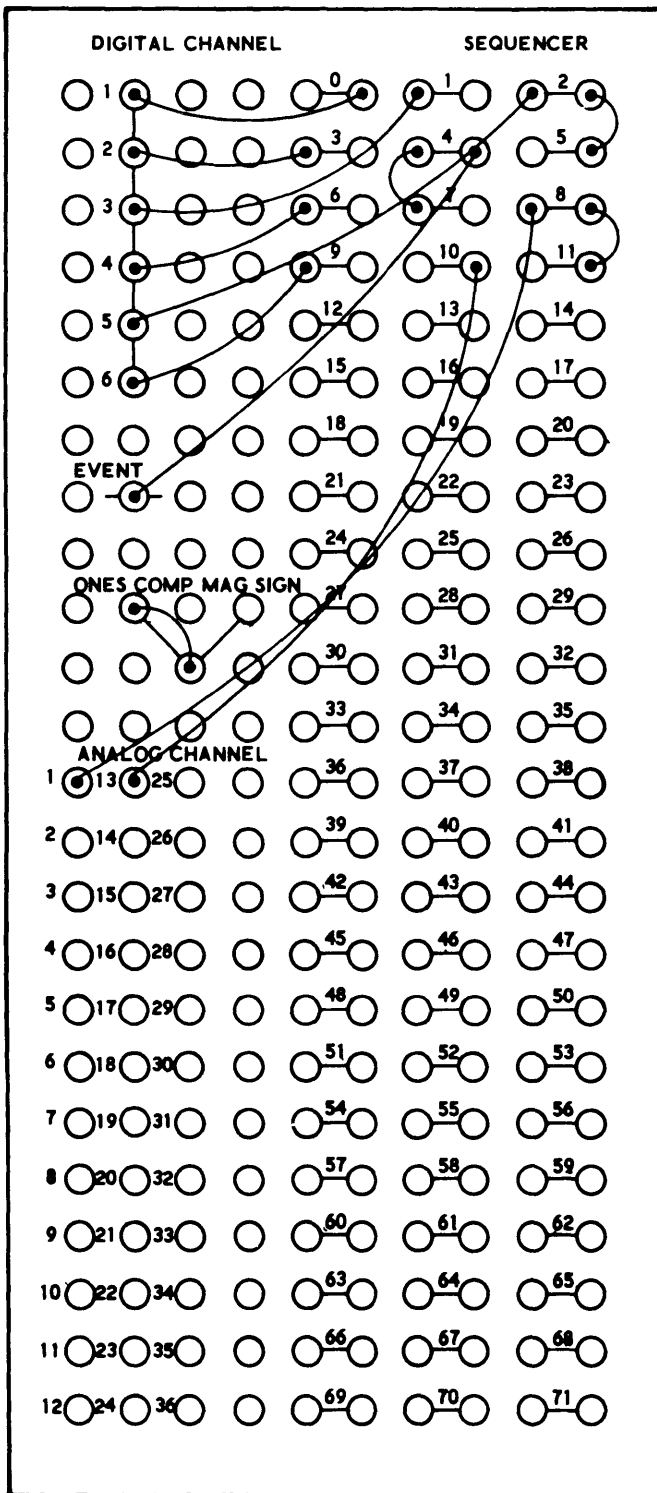
The patchboard, Figure 5, has a 72-position rectangular pattern; however, it may be more convenient to think of it as a circular pattern. This concept will allow the user of this equipment to visualize a repeating patch pattern. This is required to provide equal time spacing between data samples, which is most desirable for the recording of dynamic signals. These equally spaced samples facilitate later computer operations. However, care must be exercised in planning the patchboard wiring to ensure minimum signal distortion or loss of magnitude for time-varying inputs. Guidelines and techniques for determining optimum patchboard programming are discussed in Appendix E. The patchboard, Figure 5, shows the pin-jacks (hubs) for each input channel located along the left side of the board. The right half of the board contains hub pairs for the 72 sequencer positions. Programming is selected by installing a patchcord from each input to the desired sequencer position, then a patchcord jumper on to the next position, etc.

An arbitrary patched program is illustrated in Figure 5, and for clarity only the first twelve sequencer positions are shown programmed. There is no restriction to the number of times a channel may be programmed, but *all sequencer positions must be used*.

The method of signifying negative data is also selected at the patchboard. Either the "Magnitude-Sign" method or the "One's Complement" method<sup>3</sup> is selected by patching across the appropriate hubs, located just above the analog channel hubs on the patchboard. In the illustration, the "One's Complement" method is selected.

### TAPE FORMAT

From a survey of industry it was determined that maximum information retrieval, with the minimum use of magnetic tape and an appropriately sized magnetic core memory, could be obtained by recording the data in straight binary code.<sup>3,4</sup> The use of a 12-bit binary system, where one bit is used for sign, would provide a resolution of 1 part in 2048. The information



Sample Program

Sequence Position	Input
0	Digital Channel 1
1	Digital Channel 3
2	Digital Channel 5
3	Digital Channel 2
4	Events Channel
5	Digital Channel 5
6	Digital Channel 4
7	Events Channel
8	Analog Channel 1
9	Digital Channel 6
10	Analog Channel 13
11	Analog Channel 1

Figure 5 – DIDAS Sequencer Programmer Patchboard, Showing the Initial Patchcord Installation for a Sample Program



is recorded with packing density of 200 bits per inch, in 7 longitudinal tracks, one of which is used for parity check, on 1/2-inch magnetic tape. All of the load gaps and parity codes required by the IBM 7090 are automatically recorded.

For the sake of clarity at this point, a brief explanation of the nomenclature associated with the system digital recording seems appropriate. The nomenclature of the components of a data tape recording follows:

one bit	A magnetized portion of tape oxide in a longitudinal track, approximately 0.003 by 0.070 inch.
character	A transverse line of 7 bits (6 data bits and 1 parity bit.)
DIDAS data word	Two characters, 12 data bits plus 2 parity bits.
computer (IBM) word	Six characters, or three DIDAS data words.
a record	A serial group of 124 computer words containing 360 DIDAS data words. This subdivision of the data is primarily for computer load control only.
a file	A serial group of records continuously recorded for a single test condition such as speed, test run, depth or wave length.
parity bit	A recorded bit in the seventh or parity track which makes the sum of the bits in a character odd, or a recorded bit in a track at the end of a record which makes the sum of the bits even.

The format of a typical DIDAS record is shown in Figure 6. The first four computer words contain identification information and they are followed by 120 computer words of data. The four identification (ID) words contain fixed data representing the settings of operational controls and optional data constants from the digital switches. If parity bits are ignored the 36 data bits in each of the ID words may be identified as follows:

- 36 bits (C) – 36 external contact closures (i.e., switches)
- 16 bits (F) – file or run number
- 4 bits (S) – scan rate
- 3 bits (M) – mode identification
- 1 bit (C) – one external contact closure
- 12 bits (R) – record number
- 72 bits (K) – 18 manually set constants (4 bits each)

The rest of the record contains 120 IBM words of data or 360 DIDAS words of data. These data may have a variety of formats depending upon the character of the input data or the mode of operation. The digitized analog data (AN) appear on the tape, Figure 6, with the most significant bit (SN) of the first character indicating the sign. The remaining 11 bits of the 2-character data word are recorded in binary code. The most significant bit (A42) appears after the sign bit, and the others follow in descending order to the least significant bit (A11).



Digital inputs (DIG) are recorded on the tape as 12 bits with the most significant bit (D44) appearing in the first character. There is no assigned input coding system to a digital input, the significance of the data is dependent only upon the manner or coding in which it is presented to the system (see Appendix D), and this order or code is preserved in the recording.

The events counter data word (EVENTS), Figure 6, is a special binary coded decimal (BCD) recording. This special code utilizes 4 bits per digit for a 3-digit number (999), where the first 4 bits (E44, E42, E41, and E34) of the first character are the 8-4-2-1 code assigned to the most significant digit of the recorded number. The last 2 bits (E32 and E31) in this character are the 8-4 parts of the code for the next least significant digit, and the first 2 bits (E24 and E22) of the next character are the 2-1 parts of the BCD code for that digit. The remaining 4 bits (E21, E14, E12, and E11) of the second character are the BCD code for the least significant digit.

There is a special mode of operation (see Modes of Operation) in which data words identify the sequence of patching of the amplifiers and the gain of each channel. The gain channel data word (GAIN CHAN) appears only in the gain/channel mode of operation and uses the 4-2-1 bits of a BCD code for the signal conditioning amplifier attenuator setting (gain) code in the first character. The 8-bit (G8) is reserved for identification of either a digital input or the events counter input. The second character of this data word is a 6-bit binary presentation of the amplifier address (channel number) and is recorded as all zeros for either a digital input or the events counter input.

## MODES OF OPERATION

To facilitate the reduction of data, DIDAS has seven recording modes of operation. The display and playback/printout modes are primarily for system monitoring. The manner in which these modes should be used, to be compatible with the data-sorting program, is explained in Appendix C. The titles assigned to the several modes of operation for this system are indicative of the intended use, and the selection of the mode is made on the system control panel, Figure 4, by using the MODE switch. This switch automatically supplies a specific code number to be recorded in the fourth character of the second ID word on the data tape, (M4, M2 and M1). The mode codes associated with the seven recording modes of operation are listed in Table 1. In all modes of operation, two or more complete 124-word records are recorded, and the sampling of the input data continues after a stop signal until a full record of data is stored in the memory and is recorded. After recording this last record of data, the system logic automatically generates and records the end-of-file gap and mark.<sup>3</sup>

**TABLE 1**  
**Mode Codes**

Mode of Operation	Mode Code
Constants Only	3
Calibrate	2
Gain/Channel	6
Transducer Zero	1
Data A	5
Data B	7
Single-Channel Record	4
Single-Channel Display	none
Playback/Printout	none

A description of the several modes of operation follows:

### **Constants Only**

The purpose of this mode of operation is to provide a separate file for data identification by utilizing the 18 digital constants switches on the system control panel. The data portion of the file contains input information that is ignored in subsequent analyses. In this mode of operation the format of a file consists of two records; each record contains the appropriate mode code in the second ID word. The file is terminated by an end-of-file gap and mark.

### **Calibrate**

This mode of operation provides test-site programming for electrical calibrations of the various input circuits; see Appendix C for use of this data. The format of the data in this file is identical to the constants only file, and the appropriate mode identification is recorded in the second ID word.

### **Gain/Channel**

This mode of operation simplifies the computer sorting program card input requirements by supplying on tape the exact order and identification of the data input as it appears in the tape format, plus the signal conditioning amplifier gain setting for use in subsequent data computations. This file contains two records of data. A discussion of this mode of operation and its use by the computer sorting program will be found in Appendix C.

This mode of operation may also be used as a final check of the system patchboard wiring order and the amplifier gain settings. This is accomplished visually by operating the

system at a low scan rate and by observing the DATA display and the SEQUENCE POSITION display on the system control panel. There will be shown on the DATA display in the thousands and hundreds positions a 2-digit code designating the gain settings of the amplifier and in the tens and units positions a 2-digit octal display of the amplifier position being sampled. See Table 2 for a complete listing of these numbers.

### **Transducer Zero**

The purpose of this mode of operation is to provide a separately identified recording of transducer zero input levels for computer adjustment of the data; see Appendix C. In this mode, the data file contains only two records of the system inputs and has appropriate mode identification.

### **Data A and Data B**

These two modes of operation are identical in format except for the mode code numbers. In these two modes the data files are initiated by the start button and are terminated either by a manual system stop or automatically after the duration of a preset file time, which is continuously variable from 1 to 99999 seconds and is repeatable within 1 percent. These data files may contain an arbitrary number of complete records of input data, where each record contains 4 ID words, 5 scans of all 72 sequence positions (120 IBM words), and the end-of-record gap. An end-of-file gap and mark are automatically recorded on the data tape after the last record in a file.

### **Single-Channel Record**

The purpose of this mode of operation is to provide, on the test site, a convenient and rapid means of increasing the frequency resolution of a particular input to the maximum frequency response of the associated input signal conditioning amplifier.

The selection of the input to be recorded in this mode is accomplished by using the CHANNEL NUMBER switches on the control panel; see Figure 4. These two switches are tens and units selectors, left and right, respectively. Although these switches select the sequence position into which a particular input is patched, it should be noted that *the channel number of the input amplifier selected must be dialed on the DIGITAL CONSTANTS switches 17 and 18 and is used by the computer sorting program.*

In this mode, the system samples a single channel continuously and displays the digitized value on the system control panel DATA display as samples are stored in the magnetic core memory for recording in the same tape format as that described under Data A or B modes. The displayed digital value is updated after each sample is taken.

## Single-Channel Display

In this mode of operation, the system functions as in the single-channel record mode, but does not record data on magnetic tape. This mode is used primarily for system maintenance and alignment. While in this mode, all connections to and from the tape recorder are disconnected.

## Playback/Printout

This is not an active mode of operation and is offered only for later system expansion. Should this mode be selected, no damage to the system will result but the data recorded will not have an identifying mode code. The lack of a mode code would prevent the use of the computer sorting program and would, in fact, stop the computer.

## CONNECTIONS TO SYSTEM

Figure 7 is a view of the right endbell in which the input connectors of the system are located. The grounding node structure is located at the top of the endbell and the main input connector panel is located directly below it. The uppermost section of the connector panel contains the 36 amplifier output (monitor) connectors. The next section below that contains the 36 thermocouple input connectors. Below that is the strain-gage section, also containing 36 input connectors. The six digital input connectors are located on the bottom panel. The events input connector and the large connector for the external contact closures are located to the right of the main connector panel.

The wiring between transducers and the system inputs has considerable influence upon the "front end" accuracy of the system. Proper shielding and grounding is necessary to avoid errors due to common-mode voltages or other extraneous noise sources. For the installation of connectors that handle thermocouple data, all solder connections must be made with low-thermal solder (70 percent cadmium, 30 percent tin). The strain-gage input connectors use gold-plated taper pin connections and no soldering is required. The amplifier output connectors allow monitoring of the FITGO and REDCOR amplifier outputs by any type of analog measuring device (oscilloscope, oscillograph, strip chart recorder, etc.), where the device used must have an input impedance of at least 10,000 ohms. A detailed discussion of the wiring for all the system inputs can be found in Appendix D.

## SYSTEM RESPONSES

The digital data acquisition system was received at the Model Basin on 3 April 1962. After installation and checkout by the Beckman Instrument Company representative, preparations were made for the final evaluation and acceptance tests. These tests were conducted

from 15 April to 23 October 1962. During this period, tests were performed to determine the system overall accuracy and the frequency response of both the wide-band and the narrow-band amplifiers, with and without low-pass filters. Further tests were conducted to determine the phase shift across these amplifiers with and without filters, and noise levels were determined with common-mode voltages superimposed upon a constant-amplitude, variable-frequency input signal. During this period other vital components which were considered to be sources of noise or drift were checked to determine their noise contribution or compliance with the specifications. Unless specifically discussed, all components were within specified limits.

## FREQUENCY

The frequency response of both FITGO and REDCOR amplifiers was measured both with and without the plug-in, 50-cycle, low-pass filters. The results are shown as Figure 8 for the REDCOR amplifier and Figure 9 for the FITGO amplifiers. The curves shown are representative of all amplifier and filter combinations. None of the data vary more than  $\pm 0.5$  percent from the averaged curves shown.

The REDCOR amplifiers, without filter, are flat to 20 cps and are down only 1 percent at 110 cps. The use of a 50-cycle, low-pass, post filter with the REDCOR amplifier is not generally recommended because of the degradation of the frequency response characteristics as seen in Figure 8. These amplifiers are not sensitive to input transducer impedance variations of up to 1500 ohms.

The FITGO amplifier, without a pre-filter, has a frequency response which is

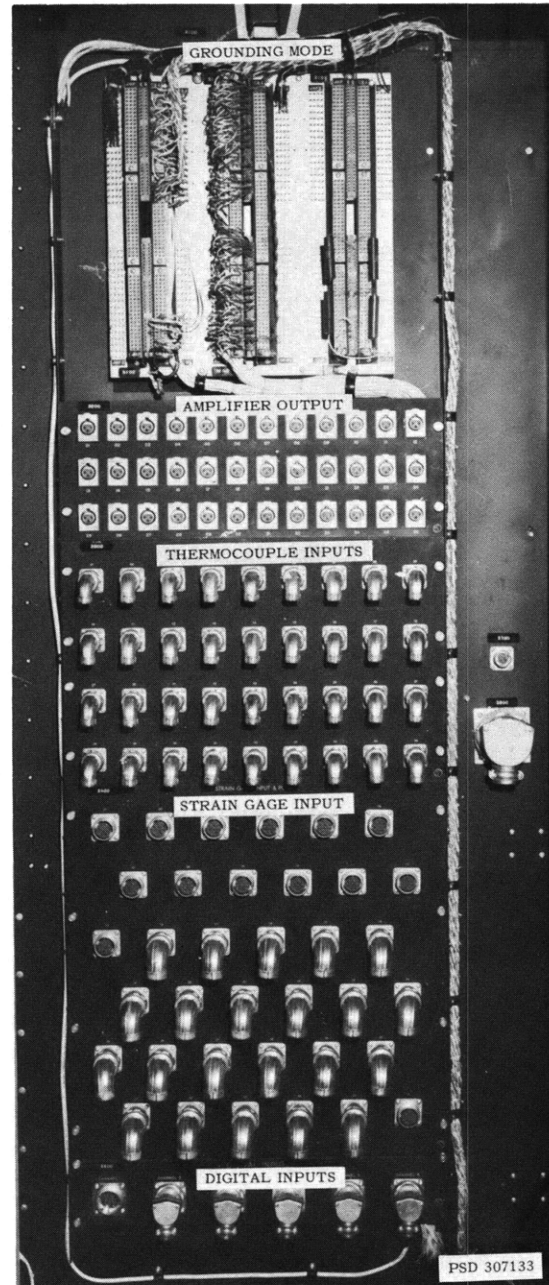


Figure 7 – Input Connector Panel, Right-Hand Endbell

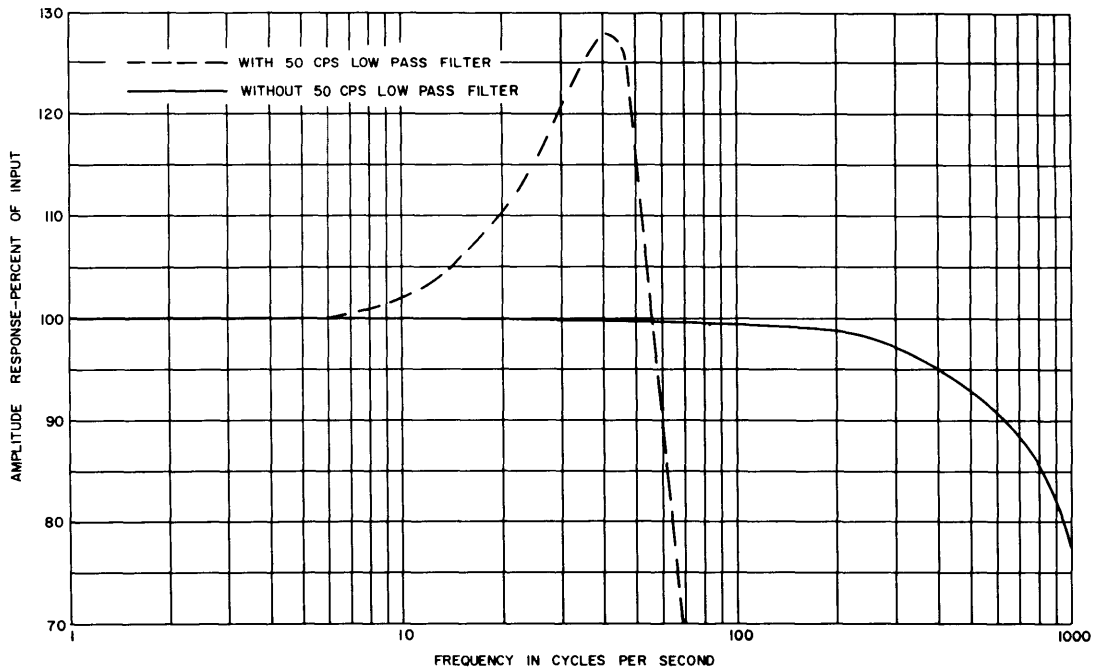


Figure 8 – REDCOR Amplifier Frequency Response, with and without 50-Cycle, Low-Pass Post Filter Installed

down 1 percent at approximately 10 cps because of the limited amplifier slew rate of 316 volts per second. However, the frequency response of this amplifier may be increased by utilizing the characteristics of a passive prefilter network. The typical response of a 50-cycle, low-pass filter can be seen in Figure 8 as a post filter with the REDCOR amplifier where the filter characteristics predominate. Figure 9 shows the effect of filter impedance matching upon the frequency response of the FITGO amplifier at various signal levels. The effects of improper input impedance matching are shown in Figure 9a for low input impedance and in Figure 9c for high input impedance. These prefilters have a replaceable resistor,  $R_F$ , which when added to the input transducer impedance,  $R_p$ , should total 1600 ohms to obtain the best amplifier frequency response characteristics. The 1600-ohm input impedance match produces a system with a frequency response which is flat within  $\pm 1$  percent out to 17 cycles for an output signal level of 80 percent of full scale or 4 volts. It should be noted here that upon approaching the slew rate of the amplifier, the output signal starts to degenerate from a sinusoid to a triangular wave form.

## PHASE SHIFT

The system phase shift was checked for all FITGO and REDCOR amplifiers using a constant-amplitude, variable-frequency input and was found to be consistent for each kind of amplifier, with a characteristic increase due to the addition of a 50-cycle, low-pass filter as noted. Figure 10 shows the average phase shift to be expected using a REDCOR amplifier



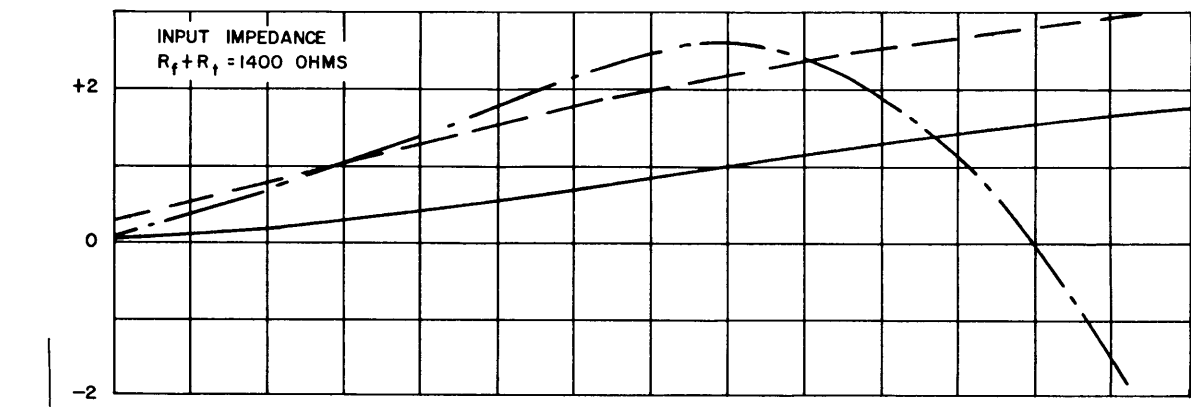


Figure 9a

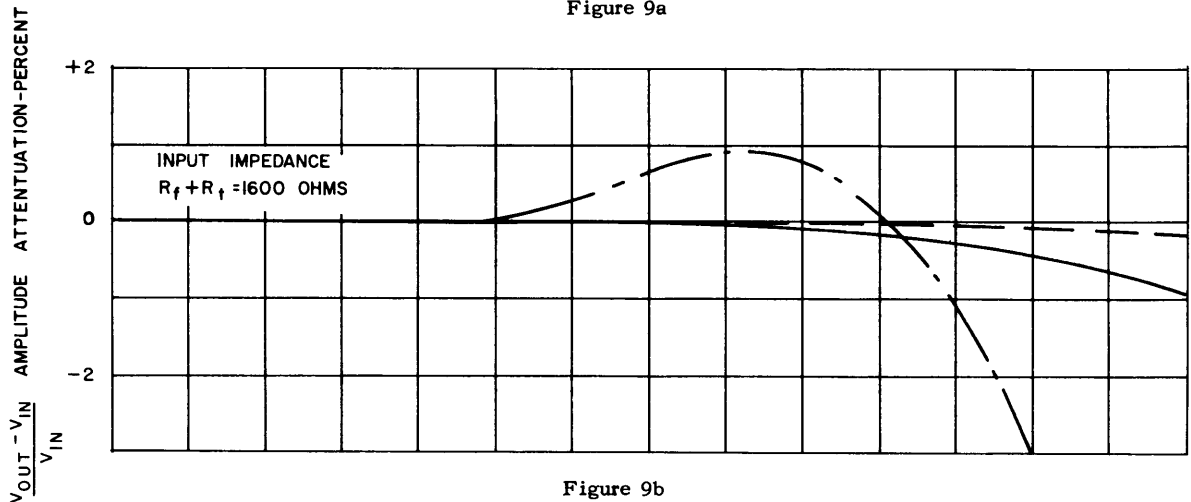


Figure 9b

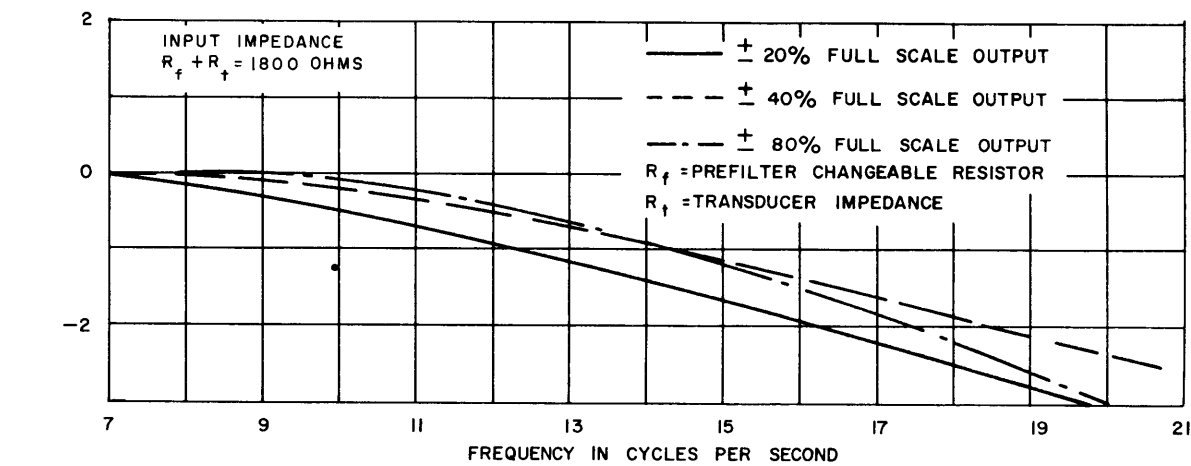


Figure 9c

Figure 9 – FITGO Amplifier Frequency Response as a Function of Input Impedance Matching

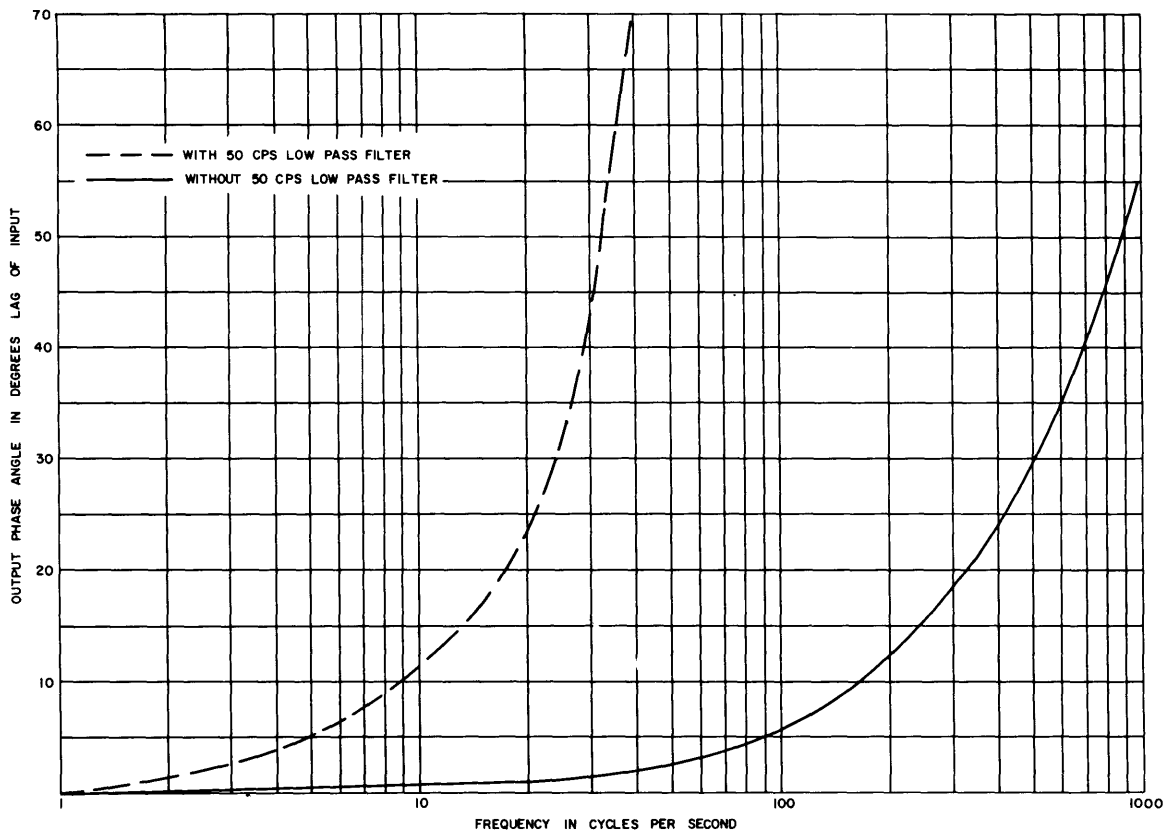


Figure 10 – Phase Shift for the REDCOR Amplifiers, with and without Post Filters Installed

and Figure 11 shows the phase shift for a typical FITGO amplifier. The data as shown are considered to be no more accurate than  $\pm 1$  percent at any frequency.

## ACCURACY

The test results for system accuracy encompassed a check on stability, drift, and noise simultaneously. There was the requirement for a very accurate, stable and drift-free voltage source for the tests, and it was decided to evaluate the system internal test voltage power supply for this purpose. A check of the 2 millivolt power supply against a standard cell, using a K-3 potentiometer and galvanometer, showed it to vary from 0.0020010 volts to 0.0019965 volts over a period of 12 hours, with readings being taken hourly.

Tests were conducted for 40 hours, with a cycle of 16 hours ON and 8 hours OFF. The specification was that the total errors from any source over this period could not exceed 0.1 percent of all readings taken.

During the test period, only the REDCOR amplifiers were reset to zero at the beginning of each day. For 8 hours a common-mode voltage of 6 volts dc and 2 volts ac was

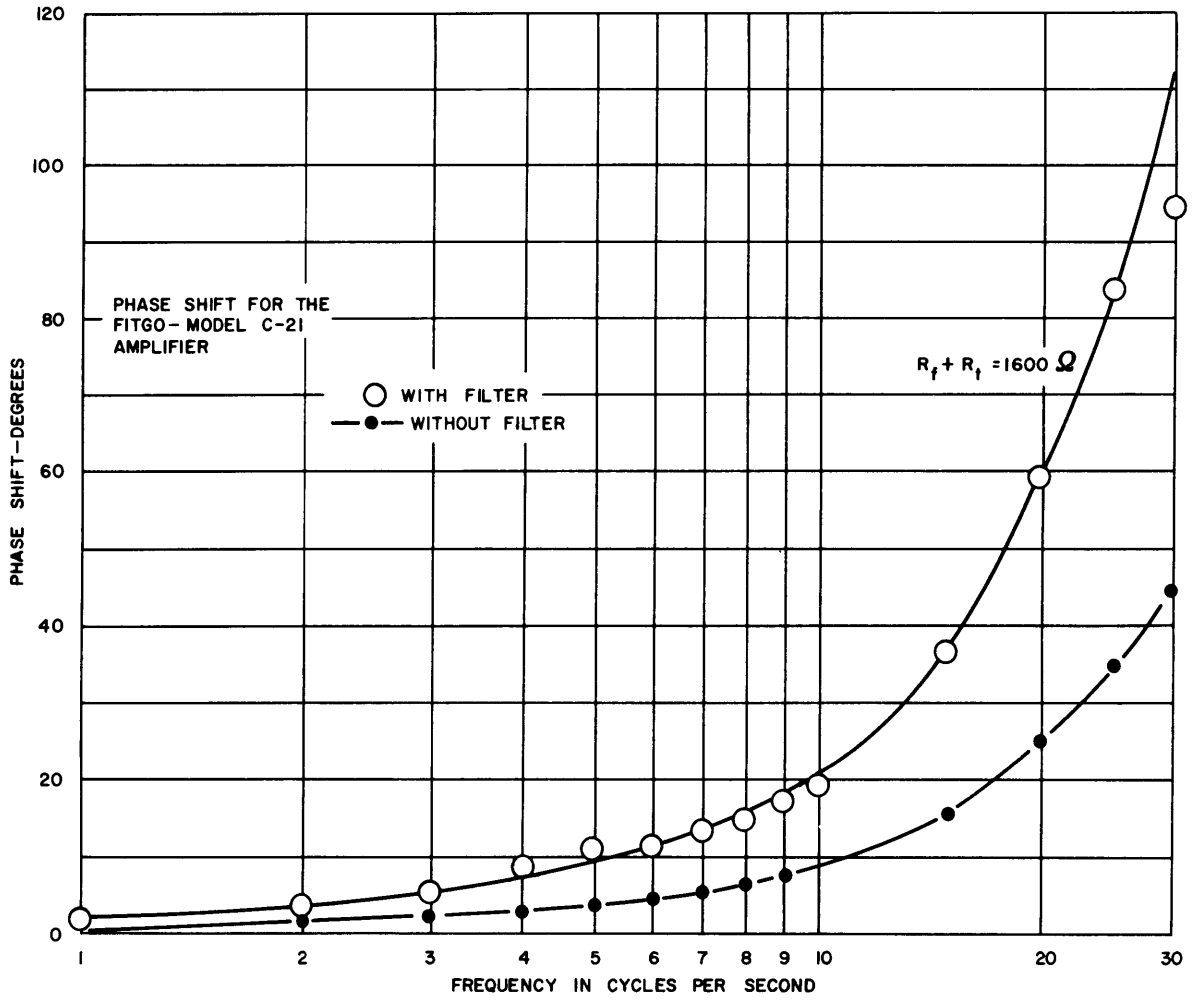


Figure 11 - Phase Shift for the FITGO Amplifiers, with and without Prefilters

superimposed on all the amplifier inputs across a 1000-ohm resistor. The system main power voltage was lowered 10 percent several times during an 8-hour period of approximately 10 minutes at a time.

The maximum system sensitivity is 2.5 microvolts of input per count at the output. A deviation from the absolute digitized value of the input of  $\pm 8$  counts, or  $\pm 20$  microvolts, was allowed, and a histogram program was used on the IBM 7090 to evaluate the test data. The results of this evaluation indicate that over the 40-hour test period only 0.02 percent of the data points taken exceeded the specified tolerance or contained parity errors.

## ACKNOWLEDGMENTS

The author is indebted to many persons for their advice, assistance, and moral support during the various phases of procurement and testing of DIDAS.

In particular he would like to acknowledge the contributions made by Messrs. W.E. Smith, G.J. Kliegel, and D.A. Jewell during the procurement phase. Also, Mr. F.E. Frillman's invaluable assistance and thoroughness which ensured precise testing and evaluation of DIDAS.

Last, but not least, the author is deeply indebted to Messrs. T.J. Langan, Arthur Reid, Jon Patton, H.S. Haller, and John Pattison for the development of the basic sorting program and the multitude of special diagnostic programs necessary during the final acceptance tests of DIDAS.

## APPENDIX A

### SYSTEM COMPONENT DESCRIPTIONS

#### BRIDGE-BALANCE UNITS

The original system has 12 bridge-balance units to accept input signals from strain-gage bridges. The basic system is completely wired for the addition, by insertion, of 24 additional plug-in bridge-balance units. The individual bridge-balance units, Figures 3 and 12, contains a signal-routing switch, a power supply for strain gage excitation, a balance potentiometer for use with strain-gage bridges, a switch for selecting one of three millivolt levels of d-c test voltages, and a selector switch for a shunt calibration resistor to be used for strain-gage calibrations. A description of the bridge-balance-unit components follows.

#### Strain-Gage Power Supply

An individual, isolated power supply for each strain-gage input is contained in each bridge-balance unit. The specifications for the strain-gage power supply are as follows:

Output voltage, continuously variable from 0 to 15 volts dc (SPAN control).

Current range, 0 to 200 milliamps.

Ripple, with line variations from 95 to 135 volts, is 0.03 millivolt rms maximum.

Noise to ground, measured when supplying a 350-ohm bridge, is 1 microvolt peak-to-peak maximum. Leakage resistance is at least 10,000 megohms. Output impedance is less than 0.1 ohm. Temperature stability is better than 0.005 percent per degree F.

Ambient temperature, allowable range, is from +40 to +120 degrees F.

The balance control (BAL) Figure 12, is used to obtain electrical zero of the strain-gage bridge output, and this balance circuit is capable of correcting a 2.5 percent unbalance in a 60-ohm bridge. To correct for greater unbalance or to provide more offset, the value of a fixed internal resistor may be changed to fit the requirements of the particular bridge being used.<sup>4</sup> Wiring for a strain-gage input is discussed in detail in Appendix D.

#### Monitor Switch

The bridge-balance unit also contains a monitor switch (MON), which connects each unit, in turn, to a common panel meter for reading the level of bridge excitation voltage being supplied to the bridge; see Figure 3.

### Signal-Routing Switch

The switch located below the BAL control is used for routing signals to the amplifiers: strain-gage inputs (SG), thermocouple input (TC), test voltage inputs (TEST) or a short circuit input (OFF position).

### Test Voltage Selector Switch

When the routing switch is on TEST, the test voltage selector switch (TEST MV) allows selection of a 2 MV, 10 MV, or 100 MV test voltage (upper scale) from a common bus network, having an output impedance not exceeding 1 ohm. A master switch is located on the test voltage power supply for reversing the polarity of this test voltage on the test bus; it will not affect the accuracy of the test voltage, which is accurate to within  $\pm 1 \times 10^{-6}$  volts. When the routing switch is on SG, the TEST MV switch allows selection of either calibration resistor  $R_1$  or  $R_2$  (lower scale).

### Strain-Gage Calibration Circuitry

Use of the strain-gage calibration switch (SG CAL) allows the insertion of the shunt calibration resistor into either the high (+) or the low (-) arm of the strain-gage bridge. The resistor  $R_1$  produces a bridge unbalance of 80 percent of full scale when the amplifier gain is set to 10 millivolts full scale, and the bridge has 120-ohm strain gages in four active arms with 10-volt excitation. For applications where specific calibration values are desired, an additional plug-in receptacle is provided adjacent to  $R_1$ . This provides for the selection of an alternate resistor  $R_2$  to be plugged in to this receptacle and used to give the system greater flexibility. The resistor plug-in board is located in the rear of the DIDAS cabinet within an area of constant temperature, free from heat and air currents.

## SIGNAL-CONDITIONING AMPLIFIERS

The signal-conditioning amplifiers are narrow-band and wide-band high-gain amplifiers, shown in Figures 13 and 14 respectively. They have attenuator (gain) switch settings for inputs of 5, 10, 25, 50, 100, 250, and 500 millivolts, each of which will give a full-scale output of 5 volts. Each amplifier attenuator setting is digitally coded, and each amplifier plug-in position has a digital address that is recorded with the attenuator code. See Table 2 for the octal code displayed on the control panel in the DATA display and recorded on tape in the Gain/Channel mode of operation.

Common-mode (60 cps) rejection requirements for both types of amplifiers are as follows: A  $\pm 6$ -volt, d-c voltage with respect to chassis ground, a 1-volt, peak-to-peak, 60-cycle, a-c voltage with respect to chassis ground, or the two voltages in combination, appearing on the input signal, will not affect the overall accuracy of the system by more

**TABLE 2**  
**Octal Display Coding for Gain/Channel Mode**

Amplifier Position Address	Amplifier Gain Switch Positions						
	500	250	100	50	25	10	5
1	0401	1001	1401	2001	2401	3001	3401
2	0402	2	2	2	2	2	2
3	3	3	3	3	3	3	3
4	4	4	4	4	4	4	4
5	5	5	5	5	5	5	5
6	6	6	6	6	6	6	6
7	7	7	7	7	7	7	7
8	0410	1010	1410	2010	2410	3010	3410
9	1	1	1	1	1	1	1
10	2	2	2	2	2	2	2
11	3	3	3	3	3	3	3
12	4	4	4	4	4	4	4
13	5	5	5	5	5	5	5
14	6	6	6	6	6	6	6
15	7	7	7	7	7	7	7
16	0420	1020	1420	2020	2420	3020	3420
17	1	1	1	1	1	1	1
18	2	2	2	2	2	2	2
19	3	3	3	3	3	3	3
20	4	4	4	4	4	4	4
21	5	5	5	5	5	5	5
22	6	6	6	6	6	6	6
23	7	7	7	7	7	7	7
24	0430	1030	1430	2030	2430	3030	3430
25	1	1	1	1	1	1	1
26	2	2	2	2	2	2	2
27	3	3	3	3	3	3	3
28	4	4	4	4	4	4	4
29	5	5	5	5	5	5	5
30	6	6	6	6	6	6	6
31	7	7	7	7	7	7	7
32	0440	1040	1440	2040	2440	3040	3440
33	1	1	1	1	1	1	1
34	2	2	2	2	2	2	2
35	3	3	3	3	3	3	3
36	4	4	4	4	4	4	4

Note: Digital Channel or Events Counter = 4000

Example

gain setting    amplifier address

than  $\pm 2$  counts. These common-mode specifications prevail when the series impedance of the transducer plus cable is 1000 ohms or less, regardless of the distribution of series-source impedance. The amplifiers meet the preceding common-mode specifications when one side of the output is connected to chassis ground.

Each amplifier output is furnished with a standard 3-pin connector suitable for attachment of an oscilloscope or oscillograph for monitoring the analog signal. System accuracy is not affected by connection at this point of a passive, properly grounded, external load of not less than 10,000 ohms. This connector may also be used to insert voltage signals higher than 0.5 volt directly into the system for digitizing. However, operation in this manner requires the removal of the associated d-c amplifier from the chassis. Signals of up to 5 volts (maximum) may be accomodated in this manner.

### **Narrow-Band FITGO**

The system has 26 plug-in receptacles for the narrow-band amplifiers and 2 plug-in receptacles for driver amplifier power supplies. Thirteen of the amplifier receptacles are connected to each power supply receptacle. Amplifiers 1 and 3 through 14 are supplied from power supply position 1; amplifiers 2 and 15 through 26 are supplied from power supply position 2. In the initial system only 1 power supply is provided to power the 10 amplifiers supplied. The FITGO amplifiers have the following specifications:

Gain	$\pm 10$ to $\pm 1000$
Input impedance	1600 ohms ( $R_F + R_t$ ; see Frequency Response)
Output impedance	Less than 5 ohms dc to 1 megacycle
Output voltage	0 to $\pm 5$ volts
Output current	0 to $\pm 100$ milliamperes
Power requirements	115 volts, 60 cps, to power supply
Drift	2 microvolts + 0.02 percent of full scale + 0.03 percent of reading
Temperature operating range	0 to 37° C
Manufacturer	Beckman Instruments, Inc.

### **Wide-Band REDCOR**

The system contains 10 plug-in receptacles for wide-band amplifiers. The wide-band amplifiers have the following operating specifications:

Gain	$\pm 10$ to $\pm 1000$
Input impedance	100 megohms minimum at dc
Output impedance	Less than 5 ohms dc to 1 megacycle
Output voltage	0 to $\pm 5$ volts



Output current	0 to $\pm 100$ milliamperes
Power requirements	115 volts, 60 cps, to power supply
Drift	$\pm (10 + \frac{300}{\text{gain setting}})$ microvolts
Temperature operating range	0 to 50° C
Manufacturer	<b>Redcor Development Corporation</b>

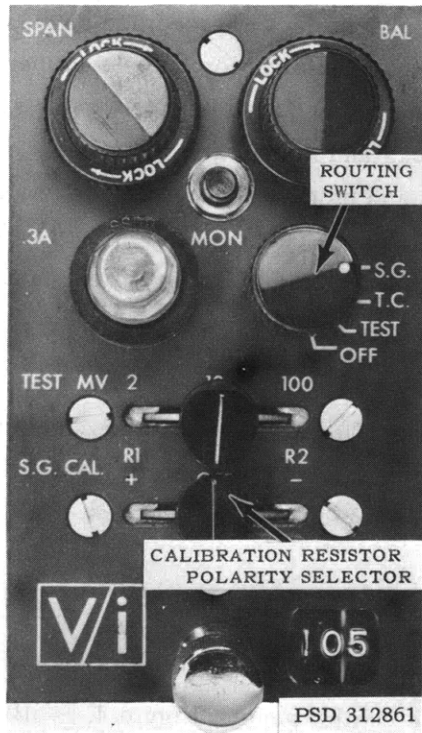


Figure 12 - Bridge-Balance Control Unit



Figure 14 - Wide-Band REDCOR Amplifier

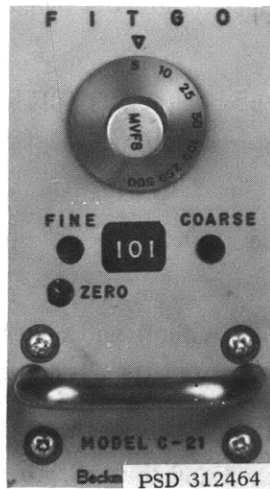


Figure 13 - Narrow-Band FITGO Amplifier

## APPENDIX B

### OPERATION INSTRUCTIONS

There are a number of preliminary operations required in turning on the system and in checking the operation of its various components. These procedures must be carefully followed to ensure proper operation of the system. Before actual test data are recorded on magnetic tape, it is necessary to record several files of introductory information. To be properly interpreted by the sorting program, this information must be acquired in a particular sequence. Finally, the use and interpretation of the system checks and alarms are discussed.

It should be noted here that these instructions and procedures are provided as a refresher checkout list only. Although these instructions are correct, they are not meant to be a substitute for actual training or for the more detailed manufacturer-supplied manuals.<sup>4</sup>

#### PREOPERATING PROCEDURES

Prior to setting controls for the desired conditions for a test run, three checking functions are performed to verify that the system control circuitry is operating properly: the power-on check, the-tape-loading procedure, and the prerun check.

##### Power-On Check

1. Check a-c circuit-breakers in left endbell; see Figure 15. All breakers should be on.
2. Observe that the POWER OFF indicator on the control panel, Figure 4, is illuminated. Operate POWER ON switch and observe that (a) the POWER ON indicator lights, and the POWER OFF indicator turns off; (b) the blower and air conditioner are on by sensing air flow at circuit cards; (c) the Roton fans are operating by sensing air flow out of empty amplifier slots; and (d) the power light on the ADC, Figure 3, is on.
3. Check the system digital power supply voltages by use of the POWER MONITOR switch and associated meter on the control panel. The meter should stay within the white area on the scale for all power supplies.
4. Operate LAMP TEST switch and observe that all indicator lamps are operating in sequence, i.e., all zeros, all 1's, etc.
5. Actuate the OVERTEMP simulation switch in the left endbell and observe that the OVERTEMP indicator lights on the control panel and the OVERTEMP alarm is sounded.
6. Trip any one of the d-c breakers on the left endbell and observe that the CIRCUIT OVERLOAD indicator on the front panel becomes illuminated and that all power is off.
7. Restore d-c breaker to ON position and observe that power is on.

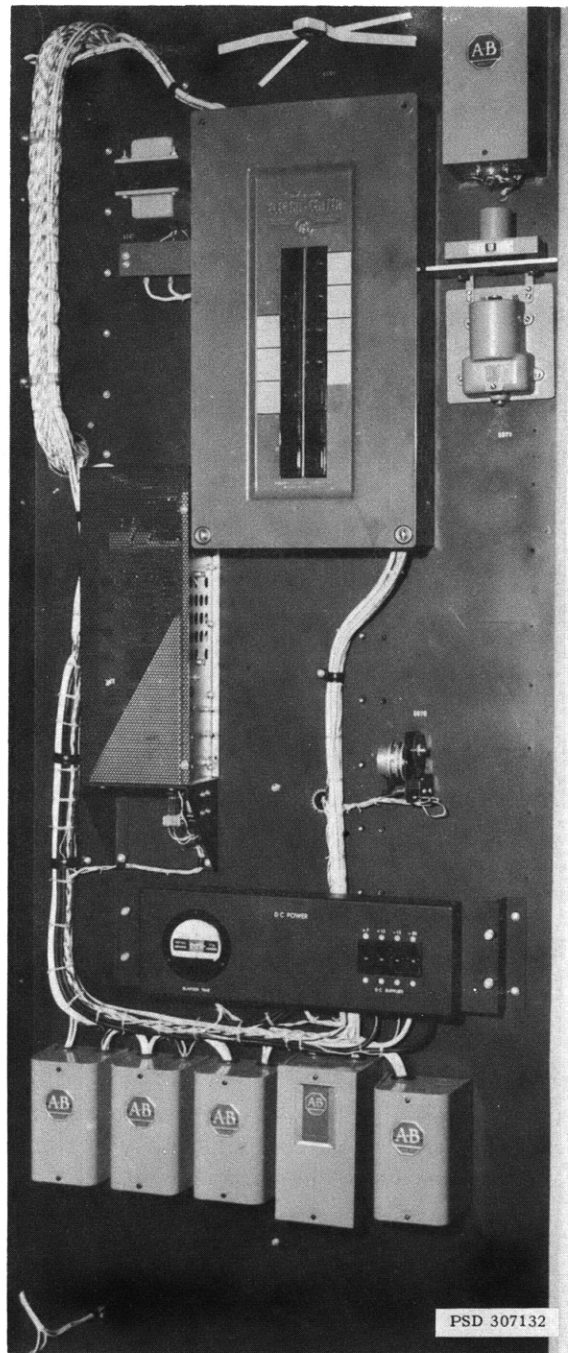


Figure 15 – Left-Hand Endbell, Showing  
A-C Circuit Breakers

8. Actuate **SYSTEM RESET** and position **TAPE POWER** switch to on (lighted). Observe that the tape handler capstan drive is in motion.

### **Tape-Loading Procedure**

1. Place tape load lever (on front of the tape handler) in a position such that the tension arms are positioned toward the vacuum buffer assembly.
2. Place tape handler a-c breaker (in left endbell) in the **OFF** position.
3. Actuate **SYSTEM RESET** and place **TAPE AUTOMATIC/MANUAL** control to **MANUAL**.
4. Place a test reel of tape on upper reel hub and thread tape by the directions in the **Potter Tape Handler Manual**.<sup>4</sup>
5. Place tape handler a-c breaker to **ON** and depress **TAPE POWER** switch on the control panel. Observe that the upper and lower tension arms become centered at the midpoint of their total range.
6. Position the upper and lower tape sensors so that the nylon tips are in contact with the tape surface.
7. Actuate **TAPE FORWARD** control for 2 or 3 seconds.
8. Actuate **SYSTEM RESET**.
9. Actuate **TAPE REWIND** control and observe that the tape is fed to the upper reel and that tape motion continues until the load point is reached. After sensing the load point, tape will stop. Repeat steps 7, 8, and 9 twice to clean the tape.
10. Turn **MODE** selector switch to **DATA A**.
11. Actuate **SYSTEM RESET** and place **TAPE AUTOMATIC/MANUAL** control to **AUTOMATIC** and observe that the tape handler jogs in the forward direction. The tape handler is now in a ready condition; this condition is indicated by the **TAPE UNIT READY** indicator on the system status display of the control panel.

**NOTE:** The precaution of placing the tape unit a-c power breaker to **OFF** during the loading operation is taken to prevent the possibility of turning the tape drive on when the tape load lever is returned to the normal position. It is mandatory that the **MODE** switch not be in **DISPLAY** when performing step 11.

### **Prerun Check**

The purpose of this check is to provide the operator with a means to verify that the control circuitry of **DIDAS** is functional prior to a test run.

1. Operate **POWER ON** control.
2. Actuate **SYSTEM RESET** switch.

3. Close interlock equipment ready circuit, if it is not being used for remote start, (by interconnecting pins 46 and 48 in Connector 3600, Figures 7 and 19) and observe that the INTERLOCK EQUIPMENT READY status indicator is illuminated.

4. Place tape unit to ready condition by following Tape Loading Procedure. Observe that TAPE UNIT READY status indicator is illuminated.

5. If MEMORY READY light is not lighted, place system memory in a ready condition by operating the rotary selector switch on the memory test board (see Figure 3, extreme lower left corner) to NORMAL.

6. Place the INTERLOCK BYPASS control in the inactive position (indicator light off).

7. Place RUN TIME AUTOMATIC/MANUAL control to AUTOMATIC.

8. Set FILE TIME counter for a run of 100 seconds.

NOTE: Prior to setting the FILE TIME counter, actuate the file time counter red reset button. The preset time setting is accomplished by opening the cover and pushing to the left the white nylon wheels, turning the units, tens, etc., wheels in sequence until the desired number of seconds (100) is set.

9. Place all CLOCK CONTROL switches to NORMAL.

10. Actuate SYSTEM RESET control and observe that the 210 READY status indicator is illuminated.

11. Starting with the units control of FILE COUNTER, place each of the four file indicators to 0. Set SCAN RATE to 1.

12. Place MODE selector to DATA A.

13. Select by the sequencer position selector, an input to the programmer patchboard which is known.

14. Actuate system START and observe that the START indicator is illuminated and the FILE TIME counter begins incrementing at a 1 count per second rate. Also observe that the SEQUENCER POSITION indicator cycles from 0 through 71.

15. After observing a number of complete sequencer cycles, actuate the system STOP control and wait for the RECORD COUNTER to increment. This action will take place approximately 360 seconds after START. Observe that when the RECORD COUNTER increments after the 360-second delay, the STOP indicator becomes illuminated and the RECORD COUNTER indicates a reading of 001, the FILE TIME counter stops incrementing and the SEQUENCER POSITION indicator stops advancing. Further observe that the FILE COUNTER now reads 0001.

16. Actuate SYSTEM RESET and observe that the 210 READY indicator does not light. Place SCAN RATE switch to 3 KC.

17. Actuate SYSTEM RESET.

18. Actuate FILE TIME counter reset and observe that the 210 READY indicator becomes illuminated.

19. Actuate system START control and observe that the associated indicator becomes illuminated and that the tape handler is in start-stop operation. Also observe that the FILE TIME counter is incrementing at the rate of 1 count per second. The system will run for approximately 100 seconds, and then the system STOP indicator will light and a record number of  $833 \pm 8$  counts is displayed.

20. Actuate SYSTEM RESET and FILE TIME reset. Observe that the 210 READY indicator is on. Place the SCAN RATE selector to 6 KC and actuate SYSTEM RESET, actuate system START and observe that the tape handler is running continuously and that the FILE TIME counter is incrementing at the rate of 1 count per second. The system will now run for an approximate time of 100 seconds, and then the STOP indicator will light and the tape handler motion will stop. A record number of  $666 \pm 16$  counts will be displayed on the RECORD COUNTER display. It should be noted here that although the actual record count is 1666, there is displayed a 666 since this is only a 3-digit recording and display.

21. Actuate SYSTEM RESET.

22. Place MODE select switch to GAIN/CHANNEL.

23. Actuate SYSTEM RESET. Place RUN TIME AUTOMATIC/MANUAL control to MANUAL. Actuate FILE TIME reset (red button).

24. Actuate SYSTEM RESET.

25. Actuate system START. Observe that the START indicator lights and that the tape handler jogs once and a record count of 002 is displayed. Also observe that the FILE COUNTER increments once.

26. Place MODE select switch to SINGLE CHANNEL.

27. Actuate SYSTEM RESET.

28. Actuate system START and observe that the START indicator lights and the SEQUENCER POSITION DISPLAY advances to the selected sequencer position number. Also observe that the known data input for the channel associated with the selected sequencer position is displayed by the DATA display. Also observe that the tape handler is recording continuously. Operating under these conditions, the CHANNEL NUMBER selector switches may be rotated to any sequencer position and the data for that channel displayed by the DATA display indicator.

29. Actuate system STOP.

30. Actuate SYSTEM RESET. Place the MODE selector switch to DISPLAY.

31. Actuate SYSTEM RESET.

32. Actuate system **START** and observe that the **SEQUENCE POSITION DISPLAY** advances to the selected sequencer position and that the proper data is displayed. Observe that the tape handler is not in motion in this mode. After having completed all of the foregoing procedures and making the specified observations, the **DIDAS** is ready for a test run as far as the major control circuits are concerned.

## **RUNNING OPERATIONS**

After accomplishing all the prerun checks, replace the test tape with a degaussed tape and set the controls for the test run by following the tape format requirements prescribed in Appendix C. The sequence of operations are as follows:

1. With tape control in **MANUAL**, depress **TAPE FORWARD** and hold for approximately 3 seconds before releasing.

2. Depress **TAPE REWIND** and release.

3. With the **MODE** selector switch in **DATA A** position, depress tape control switch to **AUTOMATIC** and observe tape handler jog. If this does not happen, repeat steps 1, 2, and 3, checking to ensure that the **MODE** selector is not on **DISPLAY**.

4. Set **FILE COUNTER** selector switches to the number desired.

5. Set **MODE** selector to **GAIN/CHANNEL**.

6. Actuate **SYSTEM RESET**. Set **SCAN RATE** desired.

7. Set **AUTOMATIC/MANUAL RUN TIME** as desired and depress red **FILE TIME** reset button before setting desired time.

8. Set all signal-conditioning amplifiers to gain settings required for the subsequent electrical calibrations.

9. Insert system patchboard, wired as required for the test.

10. Actuate **SYSTEM RESET**, set **DIGITAL CONSTANTS** switches as desired. Observe 210 **READY** is lighted.

11. Depress system **START**. Observe that the tape handler jogs twice, the system **RECORD COUNTER** registers 2, and the **FILE COUNTER** advances by 1 count.

12. Actuate **SYSTEM RESET**. Place **MODE** selector to **CALIBRATE**.

13. Set all bridge balance unit routing switches to strain gage or test voltage as appropriate to the input. For strain gages set selector switch to  $R_1$  and set polarity selector, immediately below, to positive. For test voltages select the input level desired of either 2, 10, or 100 millivolts. Set the **TEST VOLTAGE POLARITY** (located on test voltage power supply above **ADC**) switch to positive.

14. Actuate **SYSTEM RESET**.

15. Actuate system START. Observe that the tape handler jogs twice, the RECORD COUNTER registers 2, and the FILE COUNTER number increments.
16. Actuate SYSTEM RESET, actuate system START to record the second positive calibrate file.
17. Change polarity of all calibration inputs from positive to negative.
18. Actuate SYSTEM RESET, actuate system START. Repeat step 18 twice so that a total of three negative calibrate files are recorded.
19. Set all bridge balance unit routing selectors to strain gage or thermocouple, set all calibration inputs switches to center (off) position.
20. Set MODE selector to TRANSDUCER ZERO mode.
21. Actuate SYSTEM RESET, actuate system START.
22. Change all signal conditioning amplifier gain switches to the levels to be used during subsequent testing. Change MODE to GAIN/CHANNEL.
23. Actuate SYSTEM RESET, actuate system START.
24. Set MODE selector to DATA A, DATA B, or SINGLE CHANNEL record, as desired. It should be noted that if SINGLE CHANNEL record is used that the amplifier number should be inserted as the 17th and 18th digital constant switch setting.

### **Patchboard Changes**

If after starting a tape it is found that a smaller number of the original inputs are needed, then a new patchboard may be inserted with a new arrangement of the inputs; see Appendix C. Record a GAIN/CHANNEL file and proceed with the tests. If, however, new inputs are added, a complete set of introductory files is required.

### **SYSTEM ALARMS**

The DIDAS has built in self-checking features which constantly certify that the data are being recorded on the tape correctly. There are several checks performed on each data sample and upon the total data as recorded on the tape. Should an error be detected at any stage of the data path by these checking features, an alarm indicator on the system CONTROL panel, Figure 4, is lighted.

The following discussion of these system alarms will indicate the significance of the particular alarm and the corrective measures to be taken upon activation of the alarm.

#### **System Parity Check**

The parity for a particular data sample is determined and is attached to the data sample as the data flow from the input register to the memory; see Figure 1. As the data



flow out of the memory to the tape write circuits, a new determination of parity is made and is assigned to the data. If there is a variance with the parity bit present with the data, the SYSTEM PARITY CHECK alarm is lighted and the proper parity is assigned to the data. This alarm will remain lighted until depressed to reset the logic.

This alarm alerts the operator that the magnitude of the data is incorrect. The recorded data on the tape will have the proper parity and will not cause any problems on the computer. It is recommended that the operator note the record number in which the alarm became lighted, so as to assist in the interpretation of the data. After noting the alarm the operator should reset the alarm logic. Should this alarm continue to be activated in successive files, the operator should secure operations and call for qualified maintenance personnel to make repairs.

### **Sync Check**

The DIDAS contains a self-checking capability to ensure that the proper bookkeeping or routing of the data has occurred during storage in the magnetic core memory. The memory collects data in the time order in which it was taken, holding it until one record (360 data samples) is contained. At that time the data are transferred to the magnetic tape recorder.

The self-checking feature that is employed in the core memory is called a tag-bit. This tag-bit is attached to the 360th data sample, in a separate eighth track, upon entry to the memory. As the data are unloaded from the memory, a count is kept and, as the 360th data sample emerges, a check is made to see that the sample contains the tag-bit. Should this tag-bit not be present DIDAS continues to operate, but the SYNC CHECK alarm light is lighted. This alarm indicates to the operator that the data are not in the proper order on the tape. Since this is an impossible condition for the computer to handle, the file in which this occurs should be terminated and a new file should be initiated.

Should the SYNC CHECK alarm light continue to become lighted upon initiation of a subsequent file, secure operation of DIDAS and notify the maintenance group.

### **Tape Parity**

The data recorded on the DIDAS output magnetic tape are checked after being recorded on the tape to determine the required parity. After determining what parity the data character should carry, this computed parity is checked against the parity bit recorded with the data. Should this newly determined parity not coincide with the previously determined parity that is recorded, the TAPE PARITY CHECK alarm is lighted and will remain lighted until depressed to reset the checking logic.

The indication of a tape parity error indicates that a bit of the information has been lost in the recording process or that there has been a "tape drop out." The tape drop out is caused by a mechanical defect in the magnetic oxide base of the recording tape. In either instance, the computer cannot handle these data.

In the event of a tape parity error indication, terminate the file in progress, make a notation on the tape log sheet, and initiate a new file. Should the tape parity alarm become lighted in subsequent files, stop operations and call for qualified maintenance personnel assistance.

### **System Overscale**

All digitized analog data are checked immediately after digitization to determine whether or not these data have exceeded the range of the ADC. This limit is  $\pm 2047$  decimal or  $\pm 3777$  octal. Should the digitized sample exceed these values the SYSTEM OVERSCALE alarm is lighted and will remain lighted until depressed to reset the logic.

The significance of this alarm to the operator is that, although the data are good, at some point in the file the data are clipped off at the extreme magnitudes. This would in most circumstances indicate that a gain change is required on one or more of the signal conditioning amplifiers.

There is no need to terminate a file in which this alarm becomes lighted. However, if sufficient test time is available, it is recommended that the operator terminate the file, make the indicated gain change, take a GAIN/CHANNEL file, and then record the test data using the proper settings.

### **Data Out of Limits**

This alarm alerts the operator that the magnitude of a data sample has gone outside of the limits arbitrarily set by the dials in the MAINTENANCE area of the CONTROL panel. The lamp remains lighted until the indicator is depressed to reset the system logic. The function of this alarm is controlled by the DATA ANALYZER which is discussed next.

## **SYSTEM ANALYZER**

The DATA ANALYZER provides the ability to check analog accuracy of the system. Voltages entered into the system are amplified, digitized, and compared with known preset digital values. The digital value, at which the system is checked, may be computed from the known amplification factors and set on the DATA ANALYZER control panel. This comparison is made before data are stored in the memory or recorded on tape. Values, which are outside of the upper and lower limits set on the analyzer panel, light the DATA OUT-OF-LIMITS indicator on the CONTROL panel and also light a lamp on the analyzer panel which indicates which input amplifier has exceeded the limits. It should be noted here that the limits are established using the same number system (octal) as that employed in the DATA display.

During the DIDAS sampling operation the DATA ANALYZER permits the operator to monitor the output level of the analog signals only as the data are digitized. Safe positive

and negative levels for the digitized signal are set on the bank of dials on the CONTROL panel. If any digitized input is outside of either of the preset limits, the appropriate channel numbers in the DATA ANALYZER bank of lamps and the DATA OUT-OF-LIMITS alarm light. Before the next run the operator may reset the gain on the amplifiers which are in danger of overloading and may continue to test after making a new GAIN/CHANNEL file. If the SYSTEM OVERSCALE alarm is also actuated, it indicates that one or more of the data samples have also exceeded the limits of the system.

## APPENDIX C

### COMPUTER SORTING PROGRAM

There is a general purpose sorting program available for unfolding the interlaced data tape output of DIDAS. This is identified in the Applied Mathematics Laboratory program file as problem number 1-840-234-01 titled "Hydroelastic Problems."

The sorting program requires that the DIDAS output tape have a prescribed introductory group of files, which are used by the computer to determine the order in which the recorded inputs are interlaced. This introductory series of files also provides the computer with those data necessary to compute dimensionalizing constants. These constants are computed from data (by card input) from previous physical calibrations relating to the presently recorded electrical calibrations. These constants are stored in the computer for subsequent use and are stored along with the assembled data from each input on the output tapes resulting from this sorting process. The sorting program also produces a quick-look summary printout for all inputs. The printout for each file contains a dimensionalized summary for each input, using the related dimensionalizing constant previously computed and stored.

#### DIDAS TAPE FORMAT

There is the requirement for the DIDAS tape to be prepared in a particular manner for use on the computer with the sorting program. This refers to the kind of files and number of particular kinds of files rather than the type of data contained in the separate files. The data content of the various files and the manner in which it is recorded in the data records is dealt with in detail under System Programming.

The data tape must contain these specific data files, recorded in these particular modes of operation in exactly the following order:

File No.	File Data Mode	
0	Gain/Channel	
1	Calibrate No. 1	} (Positive electrical calibration inputs)
2	Calibrate No. 2	
3	Calibrate No. 3	} (Negative electrical calibration inputs)
4	Calibrate No. 4	
5	Calibrate No. 5	
6	Transducer Zero	
7	Gain/Channel	
8	Data A, Data B, or Single Channel Record, etc.	

The sorting program derives, from the first file of GAIN/CHANNEL, the locations of an input (or sorting information) in the interlaced data records. The computer also determines, from this first file, the gain setting for each amplifier in the form of a coded multiplier; see Table 2. This amplifier gain multiplier is used to adjust all dimensionalizing constants to a selected data sensitivity, which is considered to be the most sensitive gain setting for the signal conditioning amplifiers. Therefore, it is necessary that every data file, where there have been gain changes, must be preceded by a new GAIN/CHANNEL file to ensure proper adjustment of the data. Failure to do this will not impair operation of the computer, but will result in incorrect dimensional data on the quick-look printout and storage of an incorrect dimensionalizing constant on the program output tape.

## SORTING PROGRAM CAPABILITIES

As indicated previously the sorting program performs certain computations to determine the dimensionalizing multiplier. This multiplier, however, is the product of a secondary multiplier and the amplifier gain code multiplier. It should be noted at this point that this part of the program has been generalized to allow for the computation of both a positive calibration slope and a separate negative calibration slope.

The computation of the secondary multiplier  $V_1$  is as follows:

$$V_1 = \frac{V_{1b} C}{(V_{1a} - Z)G_1} \quad [1]$$

where  $V_{1b}$  is the number of counts per appropriate positive or negative electrical calibration step, as obtained from separate calibrations;

$V_{1a}$  is the number of counts per electrical calibration step, from file no. 2 for positive and file no. 4 for negative values;

$C$  is the number of dimensional units (pounds, feet, etc.) per count, with appropriate polarity as obtained from separate calibrations;

$G_1$  is the amplifier gain code multiplier, from file no. 0; and

$Z$  is the average zero offset in counts from file no. 6.

This computation requires that data from previous equipment calibrations be supplied to the Applied Mathematics Laboratory at the time a DIDAS tape is submitted for sorting. Cards are prepared which contain the following information for each transducer or thermocouple input.

1. The amplifier number where the transducer is connected.
2. The positive and negative voltage steps  $V_{1b}$  used in the calibration (in counts per voltage step, at the highest gain setting, 5 millivolts full scale).
3. The calibration constants  $C$  in dimensional units (lb, ft, etc.) per count at the highest gain setting.

Technically, if a particular input transducer is always connected to the same input channel, then for the duration of this test series no new cards will be required, regardless of the order in which these inputs are patched or sampled. It should be noted here that in Equation [1] both  $V_{1b}$  and  $C$  are at the same data sensitivity, which is the maximum gain of the system (5 millivolts full scale). For example, during a previous physical calibration of an input transducer to the system the slope  $C$  of the calibration curve was determined and is known in pounds per count. It is assumed that only the linear portion of this transducer response will be used during testing and that the electrical calibration  $V_{1b}$ , resulting from either a test voltage or shunt resistor ( $R_1$ ), falls on the curve in the linear region. If the amplifier gain setting at the time of calibration had been 10 millivolts full scale, then before the correct values of  $C$  and  $V_{1b}$  can be entered into the sorting program, they must be multiplied by a factor of 2. The program will then compute  $V_1$  using the 5 millivolt full-scale gain setting as the reference.

The value of  $V_1$  for the positive and negative calibration steps are then stored in the 7090 memory until another GAIN/CHANNEL file is detected, at which time the corrected dimensionalizing constants  $P_c$  are determined. These constants are defined as

$$P_c := V_1 G_2 \quad [2]$$

where  $V_1$  is Equation [1] and

$G_2$  is amplifier gain code, from file no. 7 or the new GAIN/CHANNEL file.

The values of  $P_c$  are stored for use by the program in the 7090 and on the output tape. The values of  $P_c$  do not change until another G/C file occurs on the DIDAS tape, at which time new values of  $P_c$  are computed and stored. It bears repeating here that if, after the start of a tape it is found necessary to reduce the number of original inputs for any reason, any new patchboard order containing any number of the original inputs requires only a new G/C file and the sorting program will proceed uninterrupted. For example if channel numbers 0, 1, 2, 3, 4, 7, 9, 11, 31, 32, 33, and 34 are used initially the new reduced order could be 31, 11, 32, 33, 7, and 0. The values of  $V_1$  do not change until another set of eight files, similar to those required at the beginning of the tape, is recorded and this may be done at any time. Whenever this eight-file series appears, new  $V_1$  and  $P_c$  values are computed at that time and are used with all subsequent data.

### Quick-Look Printout

The sorting program also provides a quick-look summary of the data contained in a file on the DIDAS tape, a sample printout of a Data A mode is shown in Figure 16. The program decodes the DIDAS tape ID words and from them prints the first three lines of the file printout. On the third line, the last group of 18 alphanumeric characters are the decoded 3rd and 4th ID word presented in the same order as the digital constants switches were set on the DIDAS at the time of recording.

DATA MODE 5 FILE NO. 1164

FIRST RECORD NO. OF MODE 5 = 1

SCAN RATE 11 ID. WORD 1.3.4 412011040241 543703126400 042114150026

ID. WORDS 3.4 BIFOCAD00111300016

PHASE ANALYSIS VALID ONLY IF AMP. ARE EQUALLY SPACED

FIRST MAX. LOC. FOR AMPLIFIER NO. 0 = 18
FIRST MAX. LOC. CAN NOT BE DETERMINED FOR AMPLIFIER NO. 15
FIRST MAX. LOC. FOR AMPLIFIER NO. 16 = 3
FIRST MAX. LOC. CAN NOT BE DETERMINED FOR AMPLIFIER NO. 17
FIRST MAX. LOC. FOR AMPLIFIER NO. 18 = 1467
FIRST MAX. LOC. CAN NOT BE DETERMINED FOR AMPLIFIER NO. 19

TRANSCENDENTAL STATE AT RECORD NO. 39

100 RECORDS SET NO. 1

AMPLIFIER NO. AVERAGE VALUES OF 20 RECORDS TOTAL AVG.
0 737 735 732 741 0 736
15 -0 -0 -0 -0 0 -0
16 -819 -819 -819 -819 0 -819
17 -1 -1 -1 -1 0 -1
18 -818 -818 -818 -818 0 -818
19 -821 -821 -821 -821 0 -821

100 RECORDS SET NO. 1

AMPLIFIER NO. MINIMUM VALUES OF 20 RECORDS AVG. MIN.
0 -409 -409 -409 -408 0 -408
15 -1 -1 -1 -1 0 -1
16 -821 -821 -821 -821 0 -821
17 -2 -2 -2 -2 0 -2
18 -820 -820 -820 -820 0 -820
19 -823 -823 -823 -823 0 -823

100 RECORDS SET NO. 1

AMPLIFIER NO. MAXIMUM VALUES OF 20 RECORDS AVG. MAX.
0 1945 1944 1945 1944 0 1944
15 0 0 0 0 0 0
16 -818 -818 -818 -818 0 -818
17 -1 -1 -1 -1 0 -1
18 -817 -817 -817 -817 0 -817
19 -821 -821 -821 -821 0 -821

COMPUTED FROM 100 RECORDS

AMP. NO. MAX. -MIN. (MAX. - MIN.)/2
0 2352 1176
15 1 0
16 3 1
17 1 0
18 3 1
19 2 1

END OF MODE 5

AMPLIFIER NO. AVG. MAX. MIN. (MAX.-MIN.) (MAX.-MIN.)/2
0 736 1944 -408 2352 1176
15 -0 -0 -1 1 0
16 -819 -818 -821 3 1
17 -1 -1 -2 1 0
18 -818 -817 -820 3 1
19 -821 -821 -823 2 1

VALUES MULTIPLIED BY PC+ OR PC-

0 -0.23787974E 01 -0.62831280E 01 0.24878048E 01 -0.76018093E 01 -0.38009046E 01
15 -0. -0. -0.81712697E-03 -0.81486311E-03 -0.
16 0.99878047E 00 0.99756096E 00 0.10012195E 01 0.36612155E-02 0.12204052E-02
17 -0.89206065E-03 -0.89206065E-03 -0.17841212E-02 -0.89285714E-03 -0.
18 0.99902297E 00 0.99780167E 00 0.10014655E 01 0.36674816E-02 0.12224939E-02
19 0.99854051E 00 0.99854051E 00 0.10009730E 01 0.24366472E-02 0.12183236E-02

Figure 16 - Sample of the Sorting Program Quick-Look Printout

The program loads 100 record sets of data into the computer memory from the DIDAS tape and then handles these data in 20-record subsets, searching each subset to collect all data from a single input. It should be noted here that the program will not handle data in less than 20-record increments. For example, should a file contain 30 records, only the first 20 will be used by the program. Care should be taken in planning the scan rate and file time to minimize the amount of data to be dropped out by the program.

The first two subsets of 40 records from a DIDAS file are used to provide the data termed Phase Analysis on the printout, Figure 16. The first maximum location indicated on the printout is the number of data samples from the file start to the data sample containing the 80 percent point of the positive half amplitude for that input. This phase determination is valid only for equally spaced inputs.

The next statement printed, "Transcendental State," indicates that the external switch closure C37 was activated in record number 39. It should be noted here that this information indicates that C37 could have been activated at any time after the start of recording the previous record number 38. DIDAS only interrogates the fixed data inputs for the first four identification words immediately after the memory has been loaded with a record of data and just prior to its being recorded on the tape.

The next set of data shown on the printout is the average value for each of five 20-record subsets and the average of those five values for each input, "total average," thus providing a 100-record average d-c signal level. The minima and maxima shown on the printout are those single absolute values occurring in the 20-record subset, and the average is taken of these five numbers. This provides an estimate only of the peak-to-peak value for the signals contained in each subset.

The difference of the average maximum and minimum values is computed from the 100-record set and is recorded. This gives the average peak-to-peak value of the data. Half of this difference is the average d-c offset for the signal extremes. At the end of the file printout the averages, obtained for the 100-record sets, are dimensionalized using the calibration multiplier  $P_c$  and are printed.

## **SORTING PROGRAM OUTPUT TAPE FORMAT**

The sorting program produces at least two and possibly three high density tapes (500 bits per inch) from the original DIDAS tape, depending on the modes of operation used on the DIDAS while recording initially. These output tapes are produced after the program has rearranged the inputs into an ascending order from 0 to 36 and has translated each data point into a FORTRAN word to facilitate subsequent computations. It should be noted here that all digital inputs and the events counter are grouped by the computer as amplifier 0.

The two output tapes always produced are a first tape containing the first, third, etc. inputs as they appear in the rearranged order and a second tape containing the second, fourth,



etc. inputs from Data A and Data B modes of operation. There may be a third output tape produced containing all Single Channel Record files, if this mode of operation is used.

The IBM 7090 output tapes contain separate files for each input from a 20-record subset of DIDAS data. These files consist of an 11-word record which is followed by a series of 100-word records. There are as many 100-word records as are required to accommodate the data points for a single input from a 20-record subset on the DIDAS tape. For example, if an input appears twice on the system patchboard, there will be two 100-word records on the output tape for that input per 20-record set. This shows that for each appearance of an input on the patchboard there will be a 100-word record on the sorting program output tape. If the DIDAS data file contains more than 20 records of data, the program will completely process the first 20-record subset, storing in series, each input file on the output tapes in the order in which the inputs appear, before sorting and transferring the next 20-record set of data to the output tape. The first 11-word record of each output tape file contains the following data in the order shown:

1. The file number, corresponding to the file number of the DIDAS tape original file from which the data was taken.
2. The amplifier number, corresponding to the input amplifier number as used on the DIDAS tape.
3. The number of words of data readings following in the unfolded data file.
4. The scan rate code, the rate at which the data were taken.
5. The number of sequence positions or samples taken between connections of an amplifier, if it is equal and constant; if not a zero is put here.
6.  $P_C$  positive.
7.  $P_C$  negative.
8. First ID word (stored as one IBM word exactly as it appears on input tape).
9. Third ID word (stored as one IBM word exactly as it appears on input tape).
10. Fourth ID word (stored as one IBM word exactly as it appears on input tape).
11. The initial offset to the first data point for this input from the first data point of the file, in number of data samples.

An example of a typical 11-word record follows: If amplifiers 1, 3, 5, 7, 8, and 9 are used on the DIDAS file No. 867, and it contains 46 records then the even output tape will contain files for each amplifier in this order 3, 7, 9, 3, 7, 9, and the odd output tape will contain the files for each amplifier in this order 1, 5, 8, 1, 5, 8. Each of these files will have stored as the first word, the DIDAS file No. 867. A sample of the 11-word record preceding one of these files is as follows:

1. File No.	867
2. Amplifier No.	7
3. No. Readings	1200
4. Scan Rate	12
5. No. Between	6
6. $P_C$ Positive	831
7. $P_C$ Negative	825
8. First ID	
9. Third ID	
10. Fourth ID	
11. Offset	3

## **APPENDIX D**

### **SYSTEM INPUT WIRING**

The techniques recommended for the cable connections between DIDAS and the test transducers or signal source are very important to the overall system accuracy. These cables can be a source of error due primarily to noise insertion to the primary signals. This noise source usually appears as induced common mode voltages due to improper grounding or shielding techniques. Each type of input has its associated cabling techniques, which are discussed under the appropriate types of inputs.

#### **THERMOCOUPLE OR VOLTAGE INPUTS**

When connecting thermocouple or voltage inputs to the system, Figure 17, observe the following rules:

1. Use only high-quality, two-conductor, twisted, shielded cables and make all solder connections with low thermal solder (70 percent cadium, 30 percent tin).
2. Ground the shield at the thermocouple or voltage source to provide a return path to system ground. (This path need not be an extremely low-resistance connection; an earth ground is usually adequate).
3. Connect one side of the thermocouple to ground with the cable shield. No other ground connections should be made.

#### **STRAIN GAGE INPUTS.**

The strain gage input connectors, Figure 17, use gold-plated taper pin connections; however, solder may be used. If solder is used when connecting strain gage inputs to the system, observe rules 1 and 3 as for the thermocouple inputs. It is important to ground both the strain gage and the cable shield at the strain gage location. The strain gage must be grounded at the minus power connections and not at one of the differential output connections. Failure to ground in this manner will result in increased noise and a loss in system accuracy. See Figure 18 for wiring schematics for the two most commonly used bridge configurations.

#### **MULTIPLE CONNECTIONS**

In the event that a single transducer or external test voltage is to be connected to more than one channel, a separate cable must be run from the input of each channel to the transducer. The use of jumper cables at the system input for the purpose of connecting a number of channels to one source is not recommended.

## DIGITAL INPUTS

Fifteen-pin AN type connectors are used for the digital inputs to the system, Figure 19. Twelve of the pins (1 through 12) of each connector are for the binary input information where Pin 1 = D 11 and Pin 12 = D 44 as shown on Figure 6. Pin 13 is connected to system ground and Pin 15 has -12 volts dc connected there for use by external equipment.

## CONTACT CLOSURES

The contact-closure information is brought in on a 50-pin connector in Figure 19. The information is assigned to Pins 1 through 37 which correspond to the C1 through C37 data entered into the fixed-data portion of the record. Pins 38 through 44 are not used. Pins 45, 47, 48, 49, and 50 are strapped together and connected to -12 volts. External switches must be supplied to connect C1 through C37 to the -12 volts necessary to enable the bit for recording on tape. If C37 is to be used as an index for the recorded data, it is mandatory that the switch remain closed until one or more records of data are actually recorded on the tape. This is particularly important at the slower scan rates. Pin 46 is the external equipment interlock which must be closed to receive the INTERLOCK EQUIPMENT READY indication on the control panel, which is required for a 210 READY light. This INTERLOCK EQUIPMENT READY may be used as a remote start if prior to closure of the switch all other requirements for running have been met.

## EVENTS INPUT

Pins B and C of the 3-pin events input connector (3700), Figure 19, are strapped together and are grounded. Pin A receives the high side of the input, which can be any timing reference signal (such as a tachometer) at a frequency not exceeding 100,000 cps. The events counter, within the system, requires pulses of -12 volts.

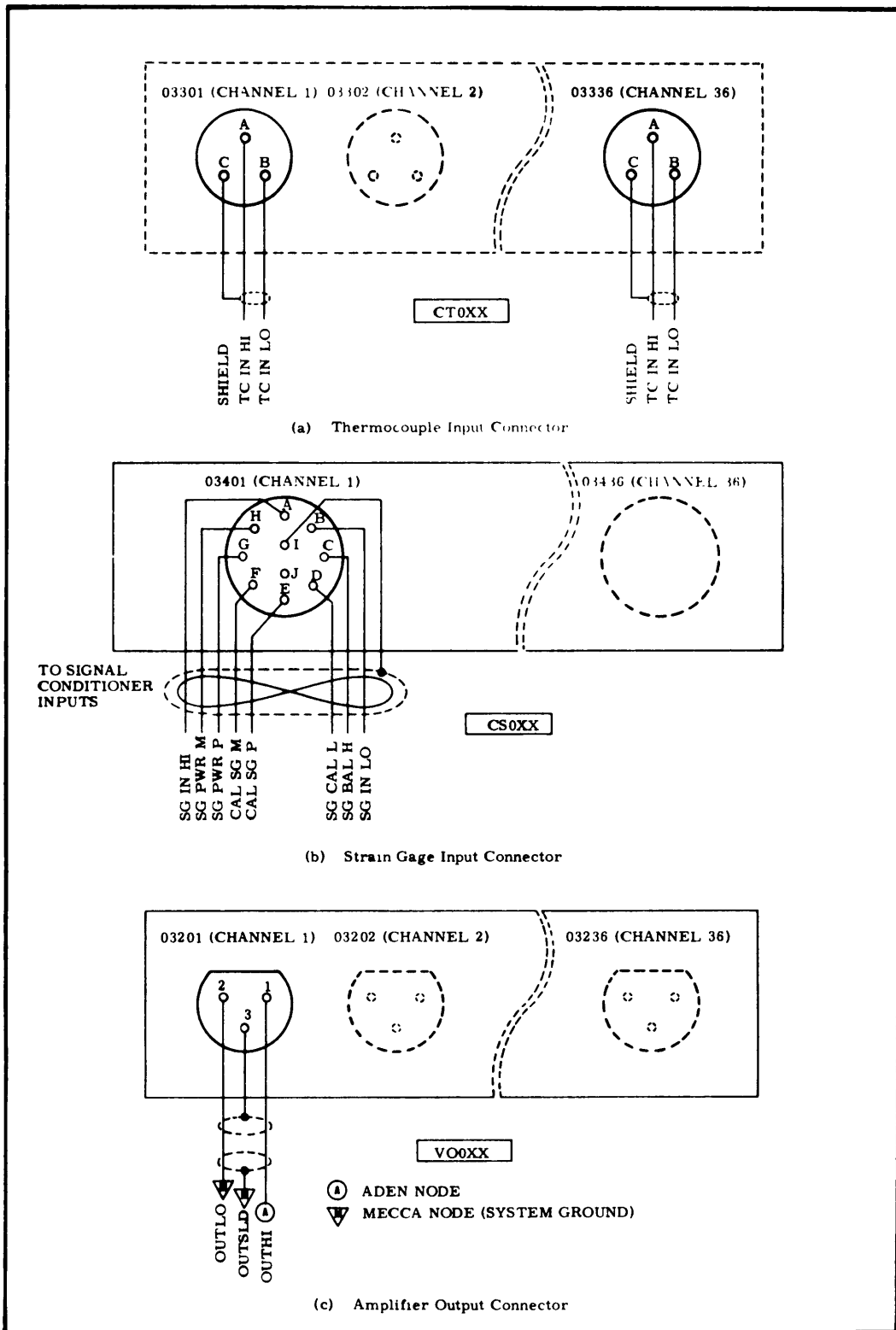
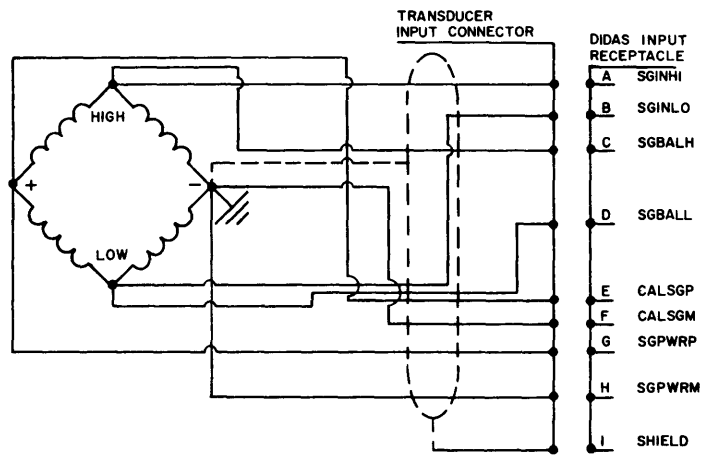
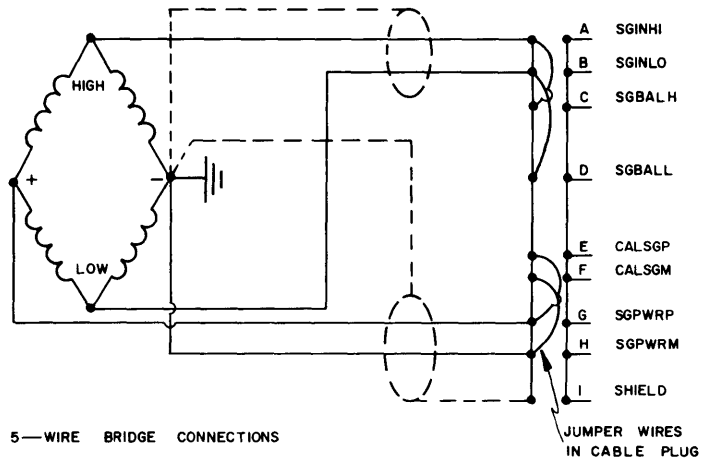


Figure 17 – Analog Input Connectors,  
Showing Terminal Connections



8—WIRE BRIDGE CONNECTIONS



5—WIRE BRIDGE CONNECTIONS

JUMPER WIRES  
IN CABLE PLUG

Figure 18 – Bridge Connections, Showing  
Jumpers Required for 5-Wire  
Operation

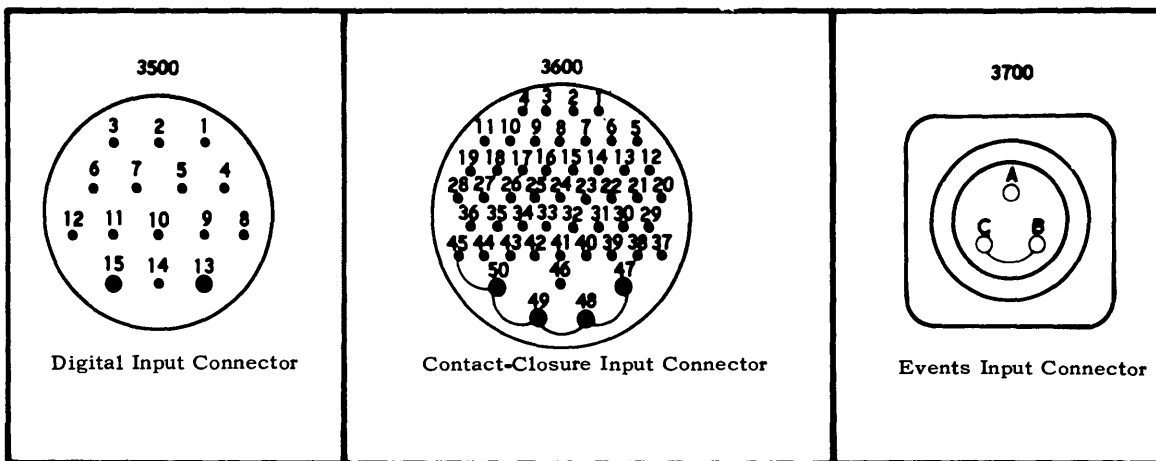


Figure 19 – Digital Input Connectors

## APPENDIX E

### PATCHBOARD PROGRAMMING

The system has a maximum recording rate (scan rate) of 6000 data words per second and is further subdivided to provide a maximum flexibility over a wide range of input conditions. The resolution of a dynamic input without "aliasing" of frequencies or loss of amplitude is of primary importance. Therefore care must be used in selecting the sampling rates for the various inputs. Whereas the use of statistical theory<sup>5</sup> indicates that 3 samples per period of a pure sinusoidal wave are sufficient to reconstruct the wave, it can be shown that in practice, with complex wave forms, 10 samples per period of this wave will ensure 98.5 percent amplitude recovery of the fundamental and will reduce "aliasing" of the higher harmonics. The more samples taken per cycle of the wave form being measured means an increasing accuracy in the analysis of the wave. Since some of the inputs to be sampled in the first use of this system will contain randomly spaced transients due to the onset of cavitation, etc., a conservative criteria of 20 samples per cycle of the highest frequency of interest has been established to allow the detection of these transients and to ensure maximum data recovery.

#### SYSTEM FREQUENCY RESPONSE

When determining the system frequency response for a number of inputs (which repeat at equal intervals on the patchboard), the relationship among system scan rate, the number of samples per cycle of the highest frequency of interest, and the number of inputs to be sampled can be expressed as follows:

$$\text{System Frequency Response} = \frac{\text{System Scan Rate}}{(\text{No. of Samples per Cycle}) (\text{No. of Inputs})}$$

The relationship expressed by this equation is the condition considered to be encountered most often in the use of this system; therefore, the frequency response has been plotted for the most significant of these conditions in Figure 20, by using the criteria that 20 samples per cycle of the highest frequency are desired. From Figure 20, a system scan rate can be determined which will yield a particular system frequency response for an equally spaced number of inputs. For example, with 6 inputs of the system, it is desired to resolve frequencies as high as 10 cps; Figure 20 shows that a scan rate of 1200 samples per second is required. Because the system does not have continuous selection of scan rate and 1200 samples per second is not available, the next higher fixed scan rate of 3000 is usually recommended. It should be noted at this point that the use of a scan rate of 1000 might be adequate in some cases and would result in fewer samples per cycle. If transients are likely to occur in the input, the higher scan rate is recommended to increase the probability of recovering these transients from the sampled data.

Figure 20 may be utilized further in the planning of a test program to determine the amount of data to be obtained per unit of recording time at the various scan rates. If automatic control of data quantity is desired and the rate at which the data are taken is known, a fixed quantity of data per data file may be chosen by selecting a file time duration for use in computer load programming. This is accomplished by using the upper abscissa scale and the curve for 18 inputs. For example, if a scan rate of 1000 samples per second is used, data will be accumulated at the rate of 2.8 records per second. Then by preselecting an automatic time duration of 20 seconds, the files of data taken will contain 56 ( $\pm 1$ ) records of data. A further aid in planning a test program is provided by Table 3, where the quantity of tape per unit of running time is shown, also the maximum running time for a 2400-ft roll of tape.

**TABLE 3**  
Allowable Tape Running Time for Various Scan Rates

Scan Rate	Record Rate	Tape Use Rate	Run Time (2400 ft)	Scan Rate Code
1	10 /hr	3.75 ft/hr	640 hr	1
2	20 /hr	7.5 ft/hr	320 hr	2
5	50 /hr	18.75 ft/hr	128 hr	3
10	100 /hr	37.50 ft/hr	64 hr	4
25	250 /hr	93.75 ft/hr	25.6 hr	5
50	500 /hr	187.5 ft/hr	12.8 hr	6
100	1000 /hr	375 ft/hr	6.4 hr	7
250	2500 /hr	937.5 ft/hr	2.56 hr	8
500	5000 /hr	1875 ft/hr	1.28 hr	9
1000	166.6/min	62.5 ft/min	38.4 min	10
3000	500 /min	187.5 ft/min	12.8 min	11
6000	1000 /min	375 ft/min	6.4 min	12

### SINGLE INPUT FREQUENCY RESPONSE

Some applications of the system may require that specific inputs have a frequency-determined patch program, whereas other inputs do not because of their static or quasi-static characteristics. The frequency response of a single input may be established by using the following equation:

$$\text{Single Input Frequency Response} = \frac{(\text{System Scan Rate}) (\text{No. of Times Patched})}{72 (\text{No. of Samples per Cycles Required})}$$



For example, if a single input is patched 12 times and a scan rate of 1000 is planned, and 20 samples per cycle of the highest frequency is considered necessary, then this equation shows that frequencies of up to 8.3 cps may be recorded with a loss of amplitude not to exceed 1 percent.

Operations of this nature require careful planning to ensure a proper interlace of the various inputs having a frequency-determined patch program.

Once a proper interlace for these inputs is established, the remaining patchboard positions are utilized for those quasi-static inputs which require only occasional sampling.

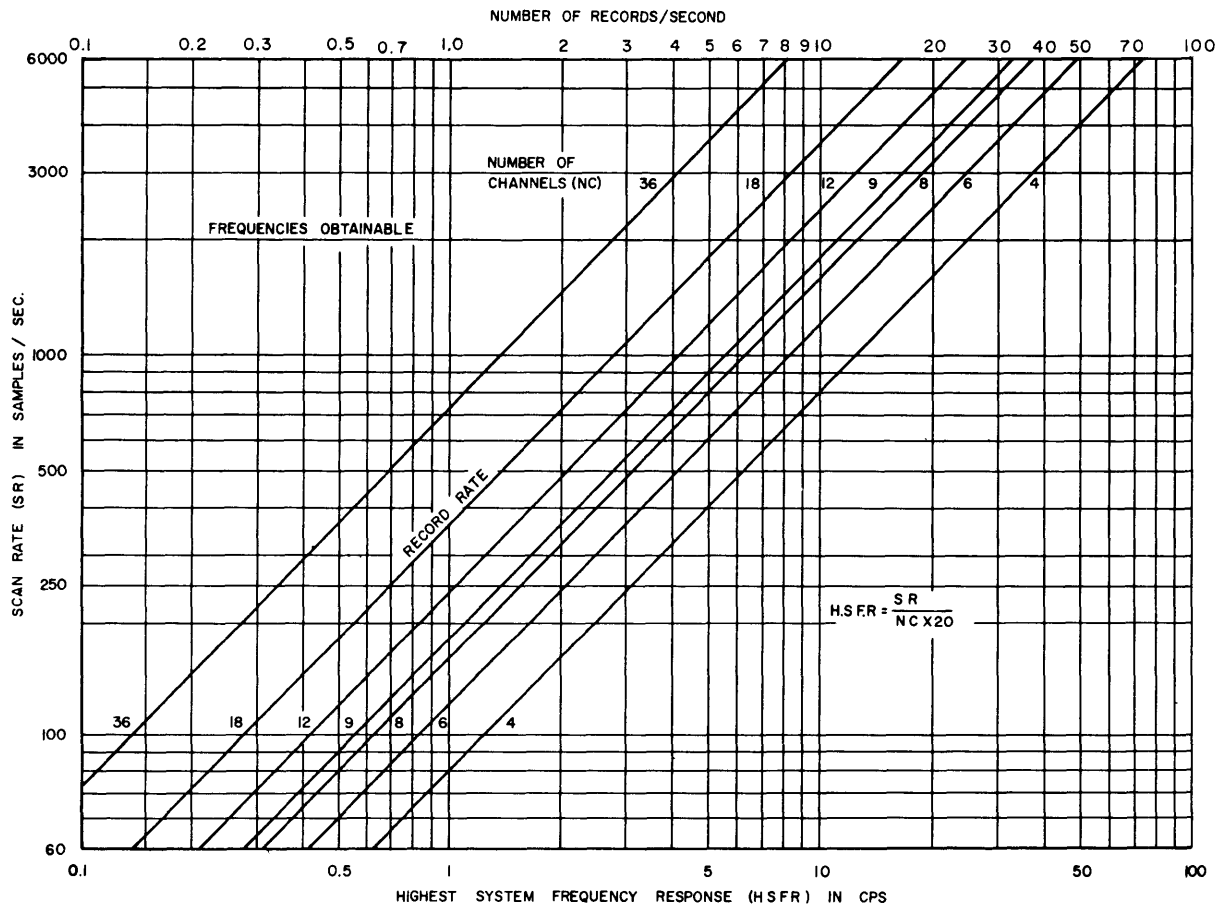


Figure 20 – System Frequency Response as a Function of Sampling Rate, and Recording Rate as a Function of Scan Rate



## REFERENCES

1. Bureau of Ships letter to Commanding Officer and Director, DATMOBAS SF0130201 Serial 420-255 of Oct 1960.
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