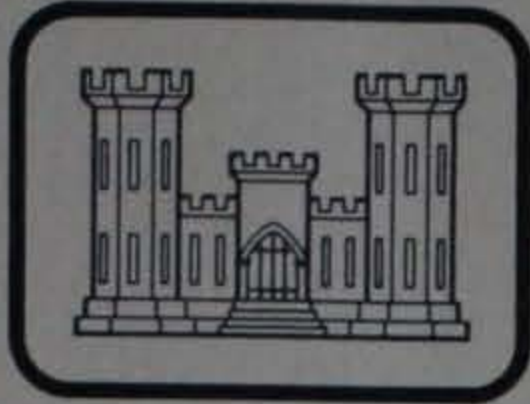MISCELLANEOUS PAPER HL-79-6

RECENT AUTOMATION CHANGES IN MODEL VELOCITY ANALYSES AND DATA ACQUISITION BY MINIATURE PRICE METERS

by

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1. On cover of report, change last two lines to read:

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Data processing	

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

Recent automation of acquisition and analysis of velocity data collected by Price meters is presented in this report. Recent improvements to the fiber optic elements for the Price meter and development of electronic/binary counting circuits are discussed. A general description of a portable digital recording system and detailed documentation of its operating procedures are presented. In addition, documentation is provided for (a) the format of the output magnetic

(Continued)

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20. ABSTRACT (Continued).

tape generated by the portable digital recording system, and (b) computer (H635) programs for reading and demultiplexing data on magnetic tape, editing and scaling velocity data, and reducing velocity data to a standard format for use in analysis programs and technical reports.

PREFACE

The automation changes in model velocity acquisition and analysis, which are documented by this report, were performed in support of the hydraulic model investigation of Little River Inlet, South Carolina, which was authorized by the U. S. Army Engineer District, Charleston. ~~office~~, Chief of Engineers, Civil Works This report was published under the ~~Civil Works Research Work Unit on~~ Research Unit on model Sensor Development ~~Model Sensor Development~~.

The study was conducted in the Hydraulics Laboratory of the U. S. Army Engineer Waterways Experiment Station (WES) during the period July 1974 to July 1975 under the direction of Mr. H. B. Simmons, Chief of the Hydraulics Laboratory, and Dr. R. W. Whalin, Chief of the Wave Dynamics Division (WDD) and under the general supervision of Mr. C. E. Chatham, Chief of the Harbor Wave Action Branch (HWAB).

The work was performed by Dr. D. L. Durham, Messrs. K. A. Turner, and C. W. Coe of HWAB, and Messrs. H. C. Greer and J. L. Pickens of the Instrumentation Services Division (ISD). This report was prepared by Dr. Durham (WDD) and Messrs. Greer (ISD) and Turner (WDD).

Directors of WES during the conduct of this work and the preparation and publication of this report were COL G. H. Hilt, CE, and COL John L. Cannon, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI)
UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
Fahrenheit degrees	5/9	Celsius degrees or Kelvins*
feet	0.3048	metres
feet per second	0.3048	metres per second
inches	2.54	centimetres

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* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: C = (5/9)(F - 32). To obtain Kelvin (K) readings, use: K = (5/9)(F - 32) + 273.15.

RECENT AUTOMATION CHANGES IN MODEL VELOCITY ANALYSES
AND DATA ACQUISITION BY MINIATURE PRICE METERS

PART I: INTRODUCTION

Model Automation Efforts

1. Since 1974, considerable effort has been expended by personnel of the U. S. Army Engineer Waterways Experiment Station (WES), Wave Dynamics Division (WDD) of the Hydraulics Laboratory, and the Operations Branch of the Instrumentation Services Division (ISD) in automating data acquisition, data analyses, and model controls for physical hydraulic wave models of harbors and tidal inlets. Basically these efforts have been devoted to:

    a. Design and development of automated systems for acquisition of model data (wave and tidal heights, temperature, and water level) and for model controls (wave and tide generators).

    b. Automation of data reduction and analyses.

2. There are presently three automated systems for hydraulic models in the Hydraulics Laboratory. One system[1] developed several years ago services the New York Harbor model in the Estuaries Division of the Hydraulics Laboratory. The other two systems,[2,3,4] are operational on various wave models in WDD. These automated systems have been given the title "Automated Data Acquisition and Control System" (whose acronym is ADACS) and have two primary functions: (a) automated acquisition of wave data in a format (magnetic tape or disc) compatible with computer reduction and analyses, and (b) automated control of sensor calibrations and of the wave and tide generators. The system configuration of ADACS consists of the following subsystems:

    a. Digital data recording and controls.

    b. Analog recorders and channel selection circuits.

    c. Sensors and interfacing equipment.

    d. Wave or tide generators and control equipment.

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3. The digital data recording and control subsystem is basically a minicomputer with the appropriate characteristics and peripheral devices. The analog subsystem is basically a backup for the first subsystem. Details of these two subsystems are presented in References 2 and 3.

4. The sensor subsystem includes the following major components:

a. Fifty wave-height sensors and stands.

b. Fifty channels of signal conditioning equipment.

c. Forty-eight channels of tidal height information using one pressure cell and a scanivalue arrangement.

d. Water and air temperature sensors.

e. Power supplies.

f. Manual and automatic calibration equipment.

5. The last subsystem, wave and tide generators and control, is not completely implemented in the present configuration of both ADACS. Upon completion, the wave generators will utilize electrohydraulic actuators for driving a wave board instead of mechanically gear-driven wave boards. The displacement of the electrohydraulic actuators will be programmed by a varying analog voltage generated by ADACS. Thus, the period and amplitude of the actuator displacement and, in turn, the generated wave will be controlled automatically.[5] Presently, Start/Stop controls are available for mechanical wave generators; however, controls for wave periods and amplitude must be set manually. For control of tide generators, ADACS provides a harmonic analog voltage, which is composed of a specified number of tidal harmonic components (amplitude and frequency), to an electrohydraulic assemblage[6] controlling the water level in a tide model.

6. With advances to the above sophisticated procedures for model controls and data acquisition/analyses, the need for improvements in model transducers and sensors has become more evident. In an attempt to improve model sensors used in wave and tidal inlet models, personnel of WDD and ISD began a sensor evaluation and development program. Initially, wave and tide elevation sensors are being scrutinized. The results of these studies are to be published in future reports. In

addition to the above wave and tidal height sensors and automated ef-
forts, preliminary efforts were initiated to provide better transducers
and to automate procedures presently used to acquire model velocity
data. Two types of electromagnetic current meters that provide low
threshold velocities and direction of flow in physical hydraulic models
are being evaluated as to designs, model applications, and ADACS inter-
face. Until new velocity sensors with the desired characteristics can
be provided, the manual procedures of acquiring model velocity data by
miniature Price meters and of analyzing those data are in drastic need
of improvement.

Purpose of Report

7. The purpose of this report is to document recent automation
changes to past procedures of acquiring and analyzing model velocity
data by miniature Price meters.[7] The concept of these meters emitting
electric pulses as the cups pass a fiber optics element was implemented
several years ago on Masonboro Inlet Model Study.[6] The sensors on that
model were interrogated directly by an ADACS. Price meters in various
forms have been used for many years by the Hydraulics Laboratory to
collect velocity data in physical hydraulic models. In fact, various
types of these sensors are manufactured at WES. It is not the intent
of this report to document specifically the miniature Price meters.
However, this report documents:

a. Recent improvements to the fiber optic elements and the
   counting circuits.

b. The description of a portable digital recording system and
   its operational procedures.

c. Reduction and analyses of the collected data to a standard
   format presently used for technical reports.

PART II: TIDAL CURRENT RECORDING SYSTEM

General

8. The recording system (Figures 1 and 2) is designed to detect water currents in hydraulic tidal models and to record the raw data on a digital magnetic tape in a computer-compatible format.

9. At the present time, the best water current transducer available for use is a cup-driven Price meter; however, much work is being done to find a more suitable meter for automatic data acquisition and for better accuracy.

10. In general, pulses generated by the Price meter are counted by an electronic counter in a digital format for a preset interval of time and recorded by a digital magnetic tape recorder. The information recorded on the magnetic tape is synchronized with prototype time so that parameters recorded on other recorders can be compared in the time domain.

Transducer

11. The transducer (Figures 3 and 4) for this system is a Price-type current meter modified to detect small water currents as low as 0.05 fps* in tidal models. For maximum sensitivity and minimum impedance to tidal currents, the diameter of the cone wheel is limited to 0.06 ft, the 0.04-ft-diam cones are constructed from plastic, and the axle of the cone wheel is supported with jewel bearings.

12. The transducer was further modified** by painting a white spot in the black field so that fiber optics could be used to sense the revolutions per minute of the cup used. In operation, a light is directed through a fiber optic element toward the white dots on the

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* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 3.
** D. H. Terrell, Physicist, Dynamics Branch, Instrumentation Service Division, U. S. Army Engineer Waterways Experiment Station.
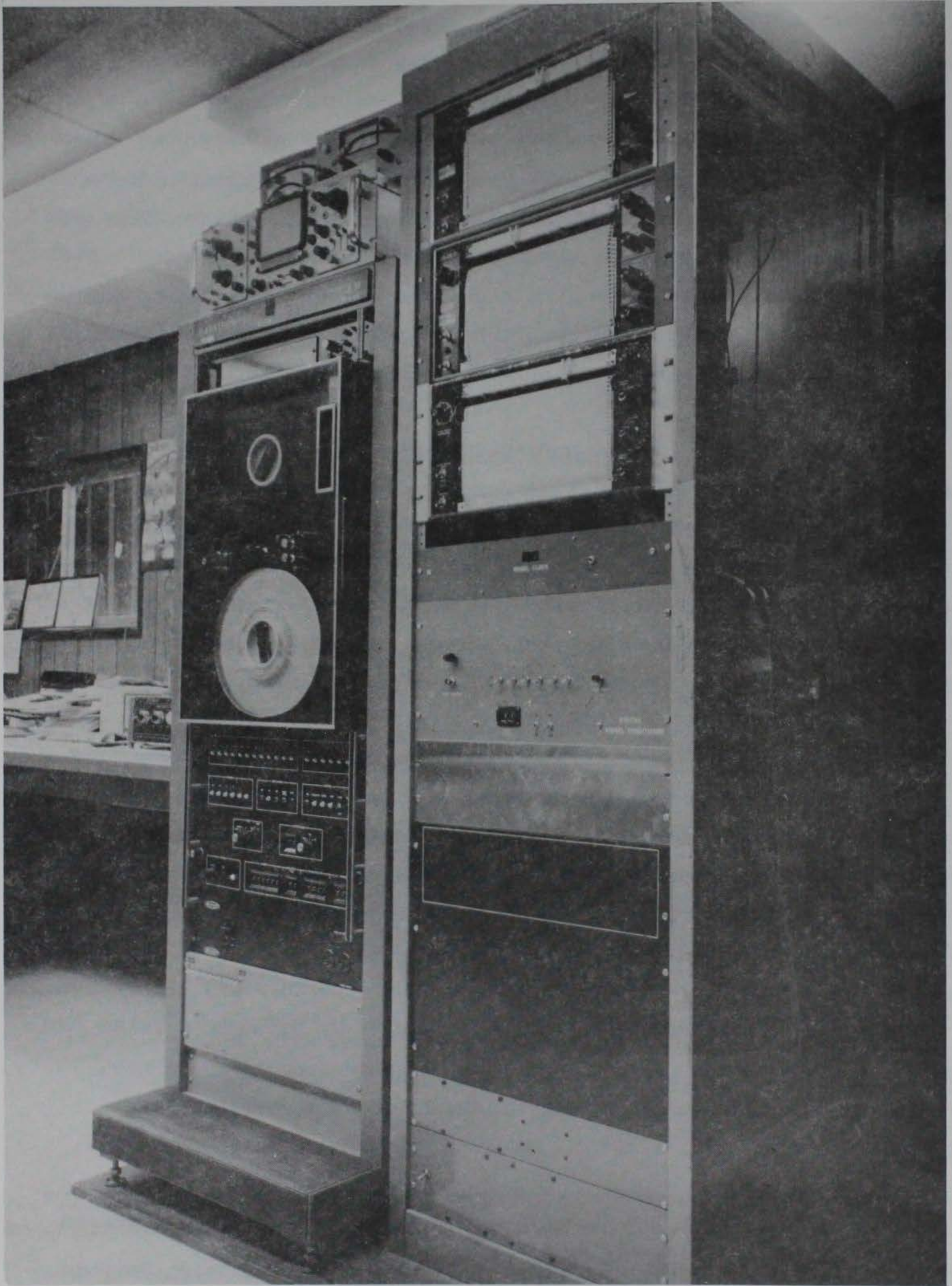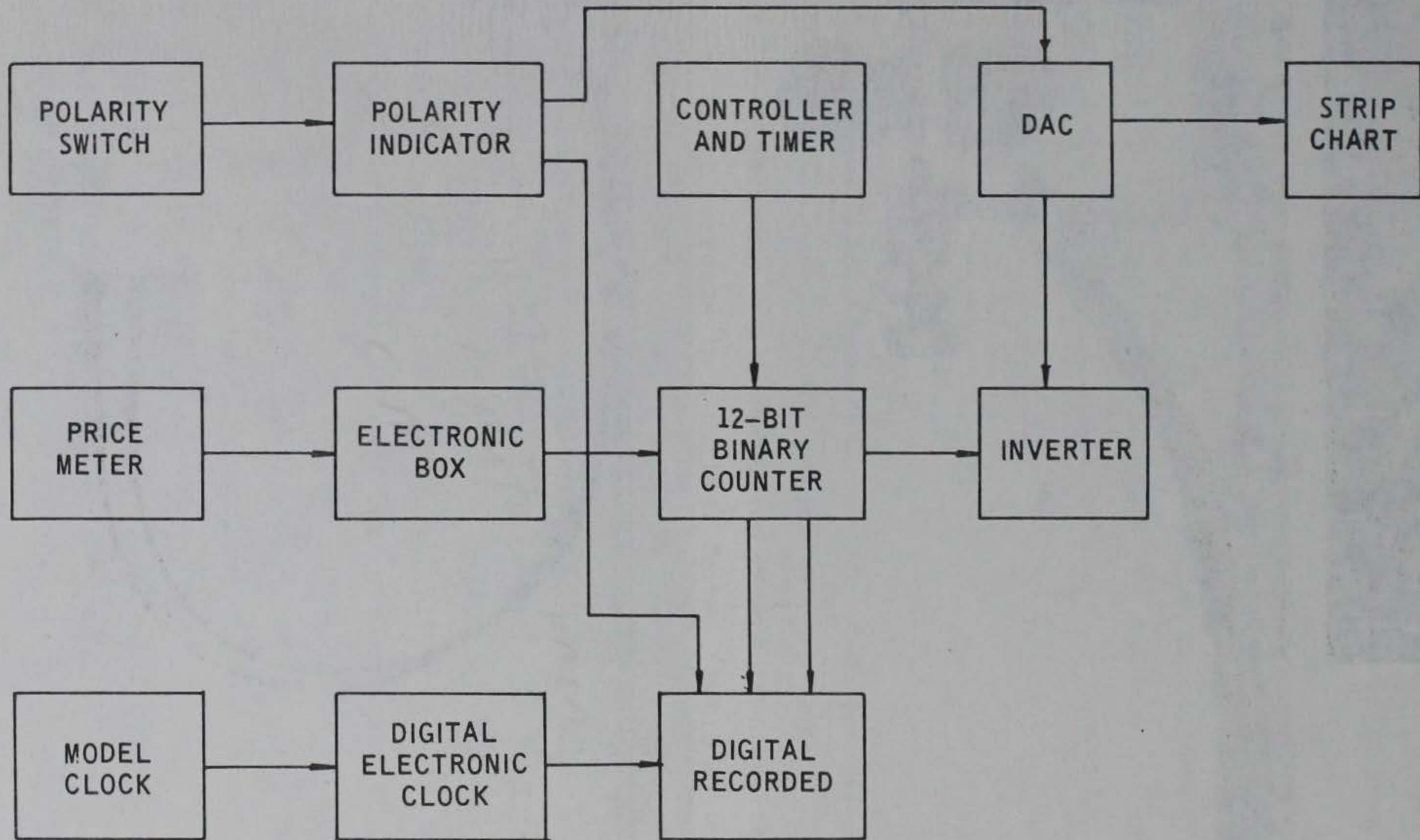
Figure 1. Data Acquisition System

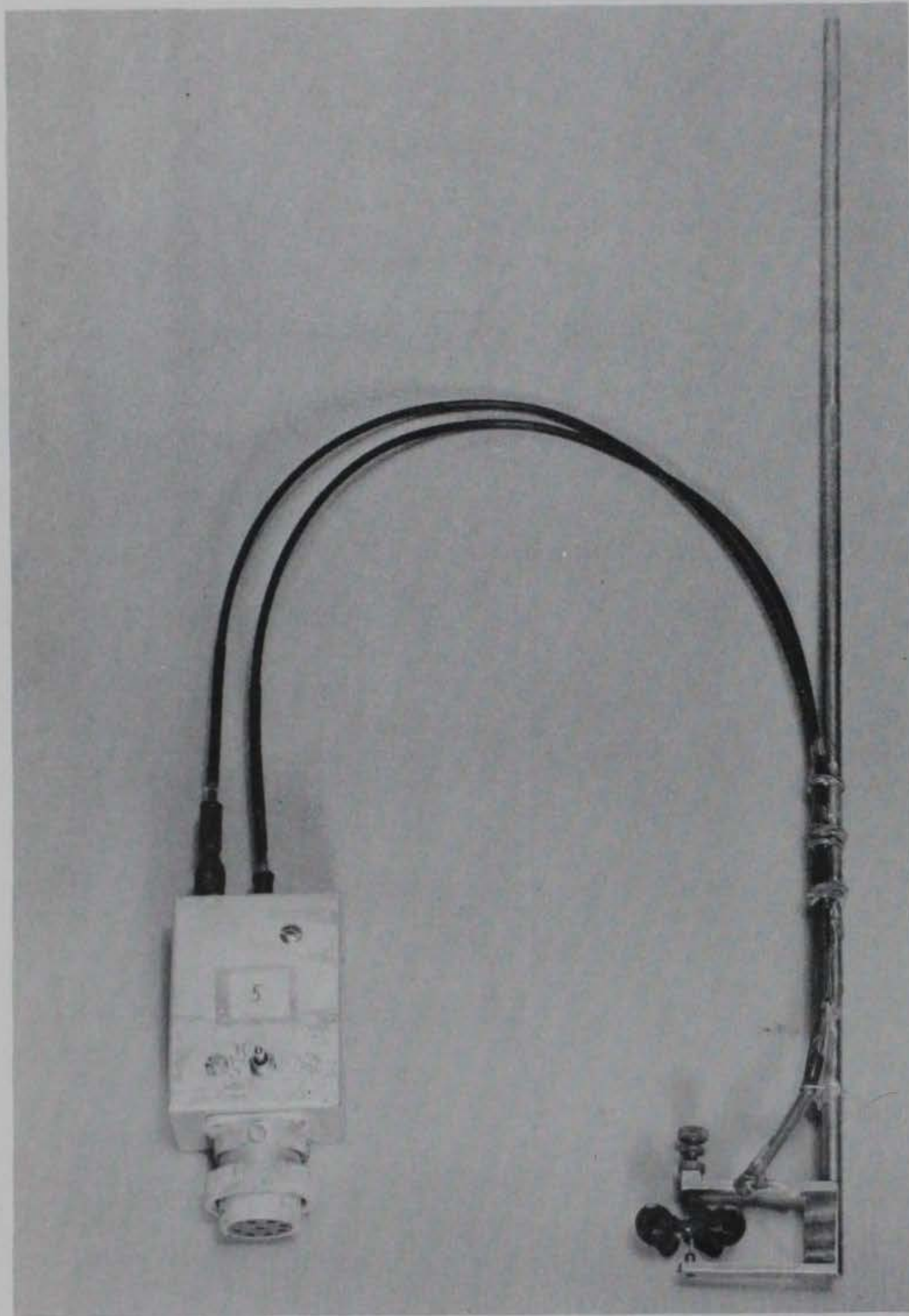Figure 2. Flow chart for Automated Velocity Recording System

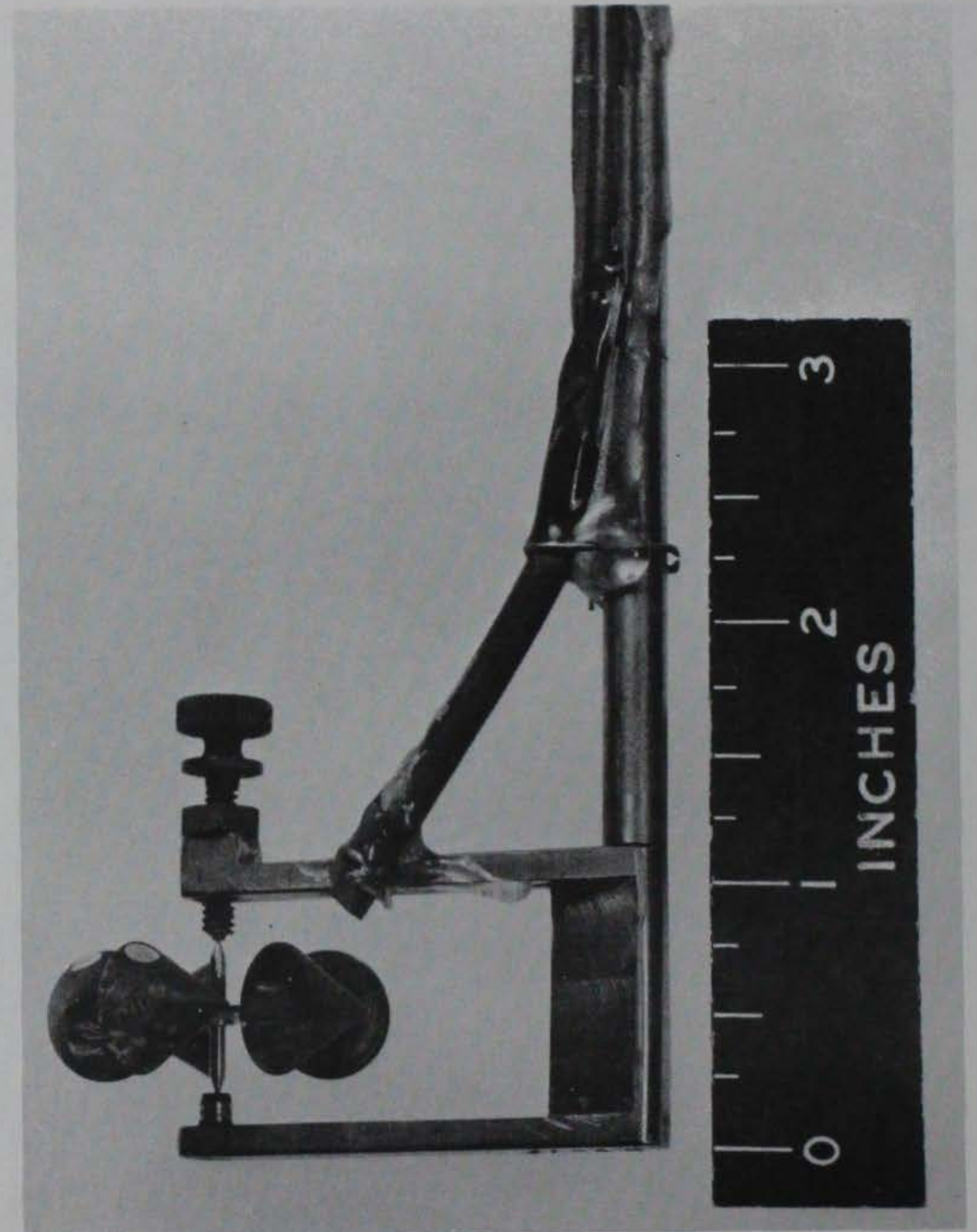Figure 3. Modified Price meter with
photoelectric circuitry

Figure 4. Modified Price meter with
fiber optics

cones. As the cone wheel rotates, light is reflected from the white spots to form a pulse train where the number of pulses per second is proportional to the water current. This pulse train is directed through a return fiber optic to a photo cell which converts light energy to electrical energy.

13. The Price meter is a unidirectional device and it is necessary for it to be rotated 180 degrees when the tidal current changes from ebb to flood and flood to ebb. The time of rotation is decided by a technician experienced in tidal model technology. At the time of rotation, a polarity switch located near the electronics box is thrown by the technician to properly polarize the data being recorded.

Counting Circuit

14. The current meter produces an output of pulses per second which are proportional to water current in feet per second. An electronic counter, totalizing over a specified period of time, can be used to measure the tidal currents in a digital format (Table 1) which can readily be recorded on a computer-compatible magnetic tape.

15. The pulses from the Price meter are received at the input of the counter (Figures 5 and 6), conditioned to be compatible with TTL logic, and counted in a 12-bit unipolar natural binary format for a predetermined time interval.

16. The counting circuit employs three integrated circuits 7493N, ripple-through binary counters. The 12-bit binary output of this counter is connected to the inputs of three integrated-circuit-quad latches (registers), 7475N, where the data are stored to be strobed and recorded by the digital recorder. The counters and registers are synchronized with a timing-control circuit (Figures 7 and 8) that updates the binary count registers and then resets the counters. The time required to store data and reset the counters, and for the counters to resume their counting is negligible; therefore no pulses or data are lost. The interval during which the counter totalizes the input pulses from the Price meter can be set with thumbwheel switches for any time
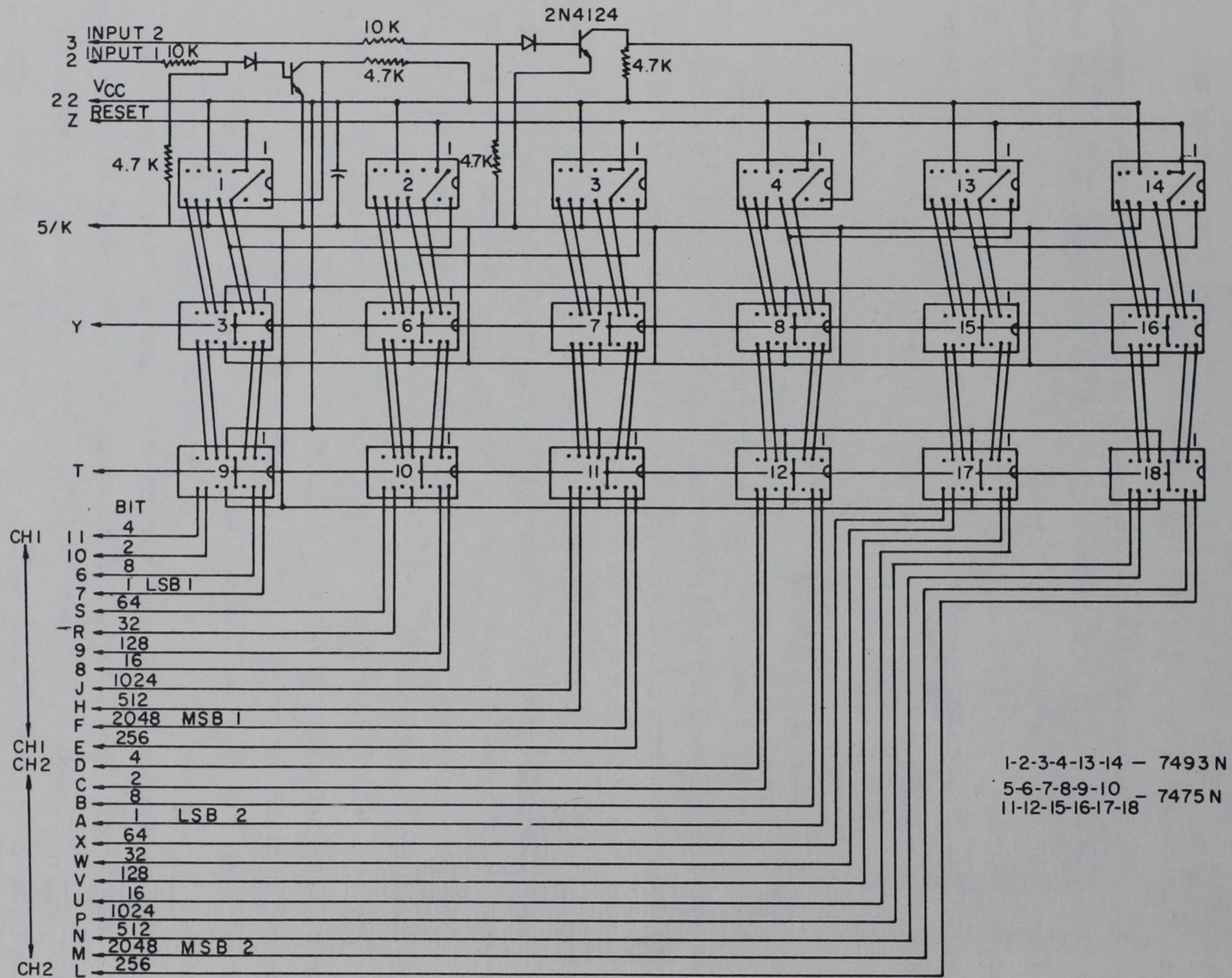
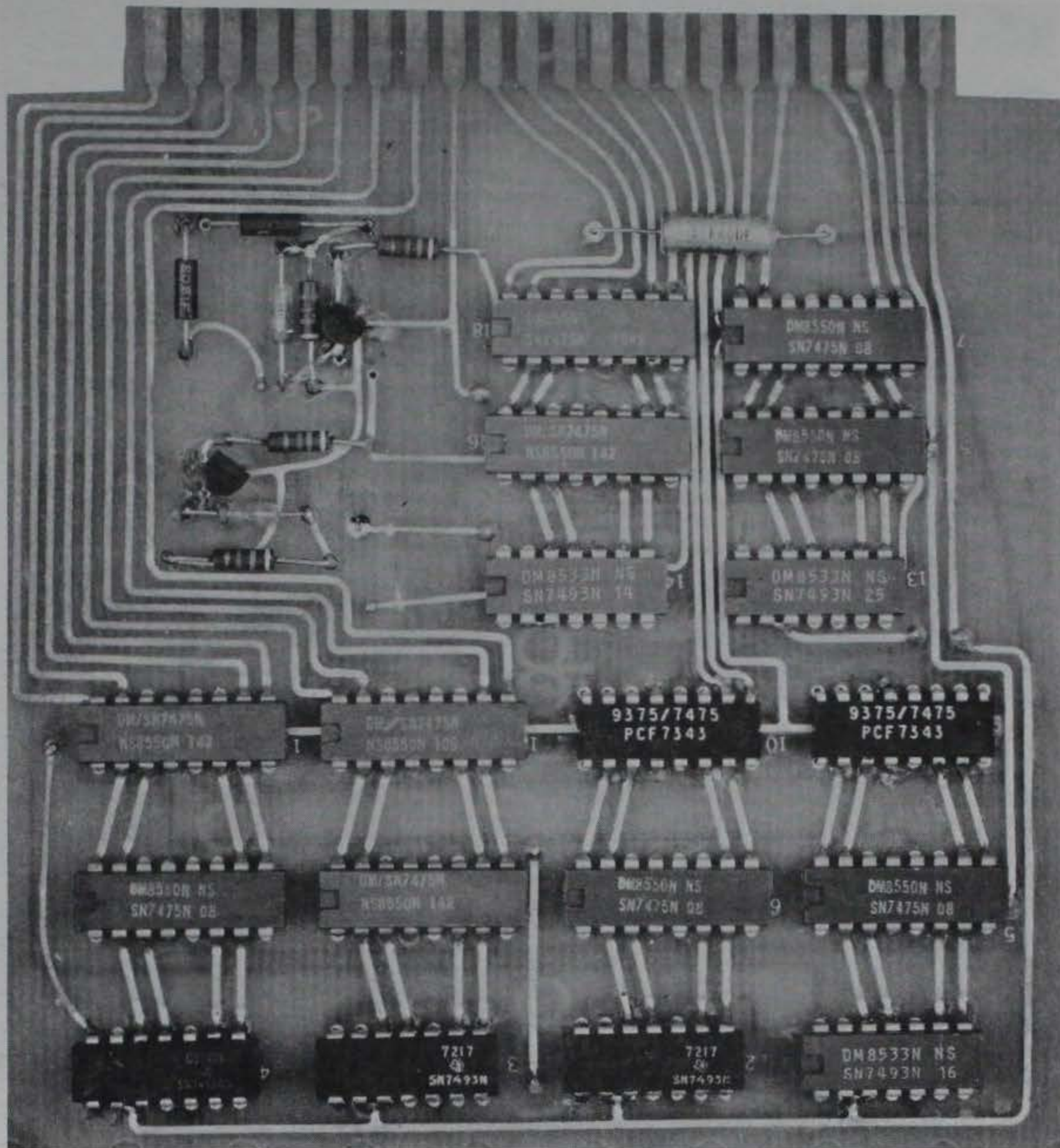Figure 5. Schematic of binary counter

Figure 6. Printed circuit board of binary counter

duration from 1 to 99 sec. Since the registers update at the end of
each time interval (1 to 99 sec), the possibility of the digital re-
corder acquiring data while the registers are updating is avoided by
the insertion of a second register between the first register and the
recorder. This second register updates with the first register, except
when the digital recorder is acquiring data. During this period of time
the second register is inhibited. The digital recorder updates its
registers in nanoseconds so this inhibit time is minimal.

Digital to Analog Converter (DAC)

17. The output of the counter card is coupled through inverters to

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Figure 7. Schematic of controller and timer
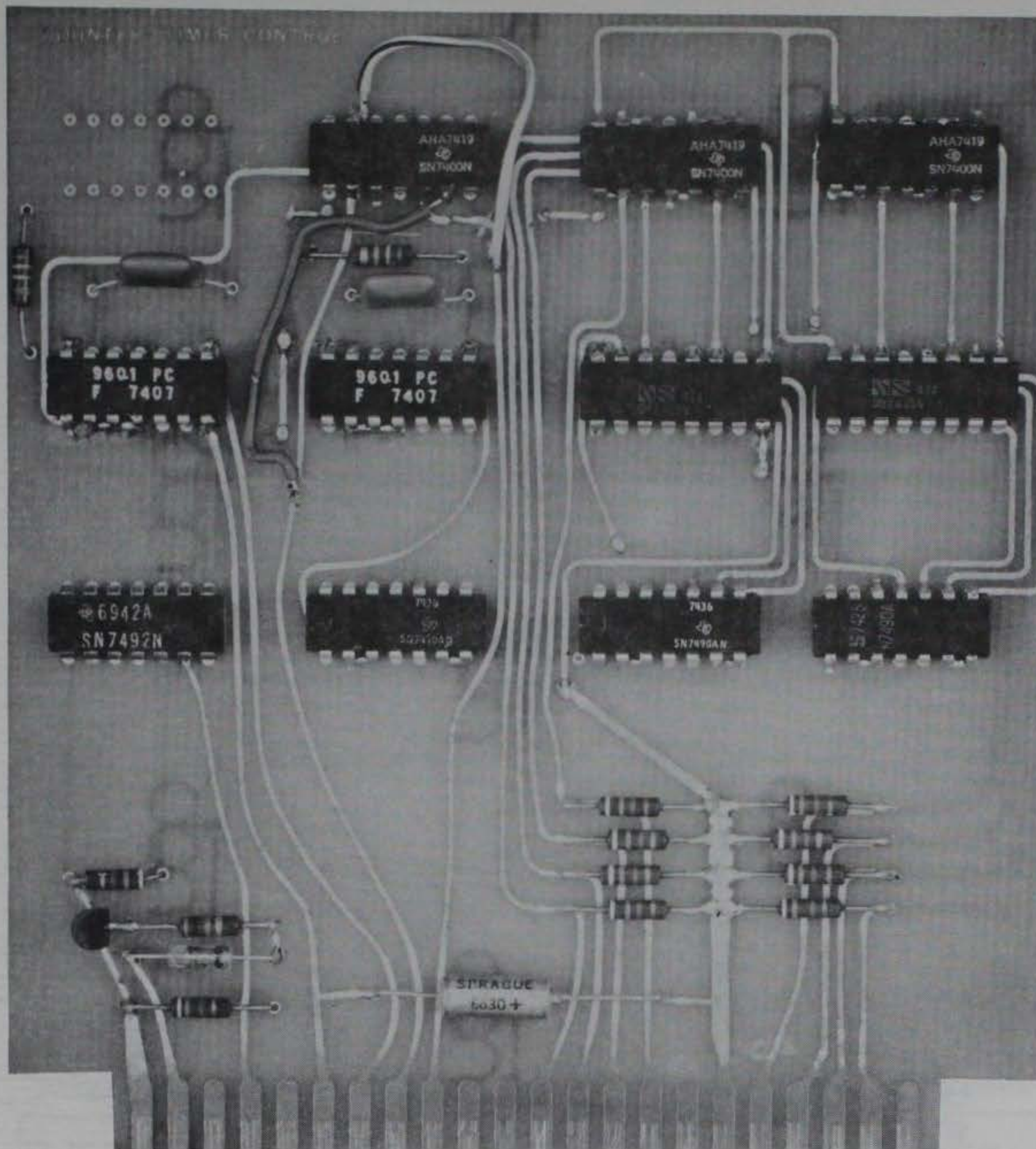
Figure 8. Printed circuit board of controller and timer

a commercial DAC manufactured by Analog Devices that has 12-bit resolution and one-half least significant bit accuracy. Detailed specifications are presented in Appendix A. The output of the DAC is coupled to a strip-chart recorder through double-pole, double-throw relay contacts wired in a normal-reverse fashion (Figures 9 and 10). This relay is controlled by the polarity indicator (Figures 11 and 12) which is a set-reset flip-flop used to arrest contact bounce of the polarity switch. The polarity of the analog signal is controlled by this relay, which is controlled by the polarity switch located near the Price meter.

Digital Recorder

18. The recording system (Figure 1) used in this system is a
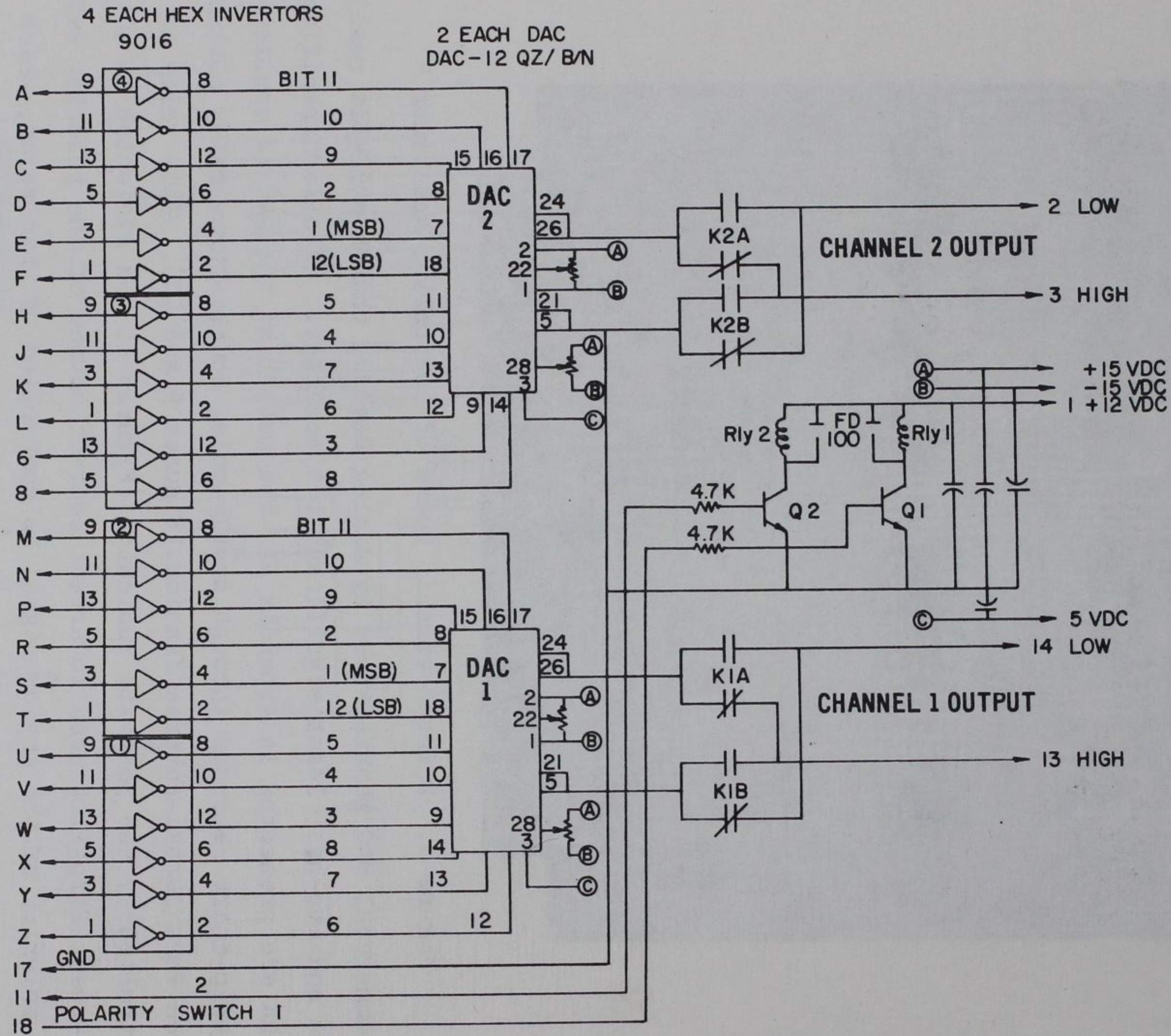
Figure 9. Schematic of digital to analog converter

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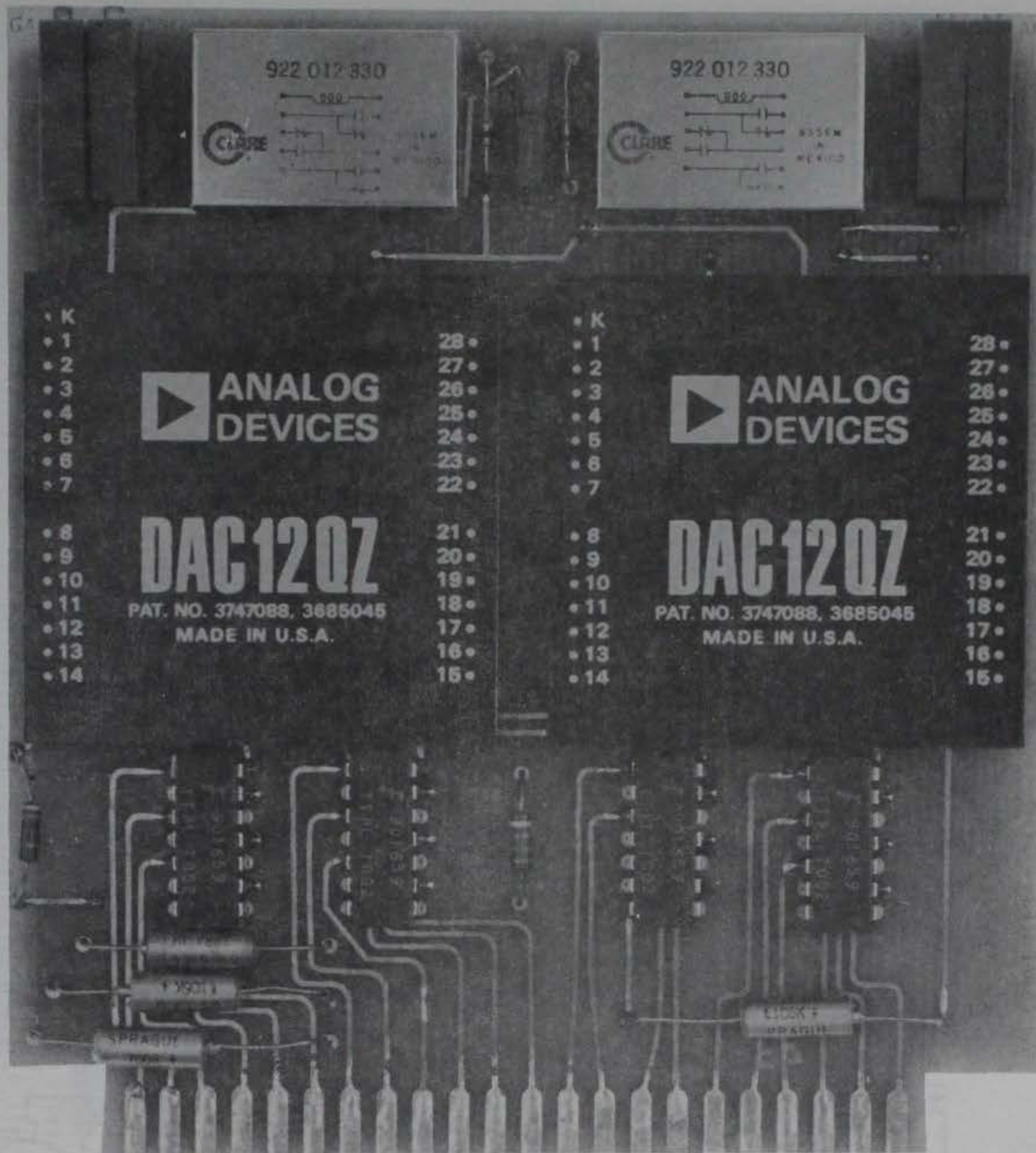
Figure 10. Printed circuit board of digital
to analog converter

Datatron Model 1500-131. Detailed specifications of this system are
presented in Appendix B. The system is basically a hard-wired, 7-track,
12-bit binary, incremental write recorder capable of writing 1000 char-
acters per second. The system has thumbwheel switches that control the
interval between scans (01 sec to 99 hr), scans per record (000-9999),
records per file (00-99), and the last channel (00-31) to be scanned.
In addition to these control functions, six uncommitted BCD characters
appear in the record header. The multiplexer sequentially scans channels
00 to the last channel selected with the thumbwheel switch (up to 18
channels). The recorder writes a tape in an IBM compatible format as
described in PART III of this report.
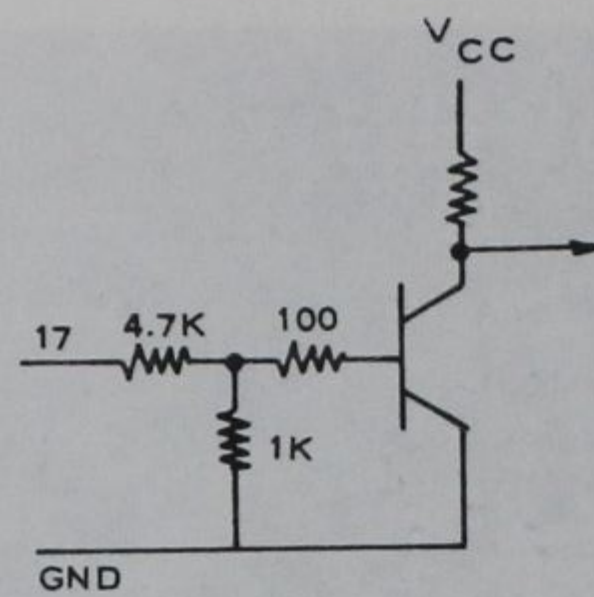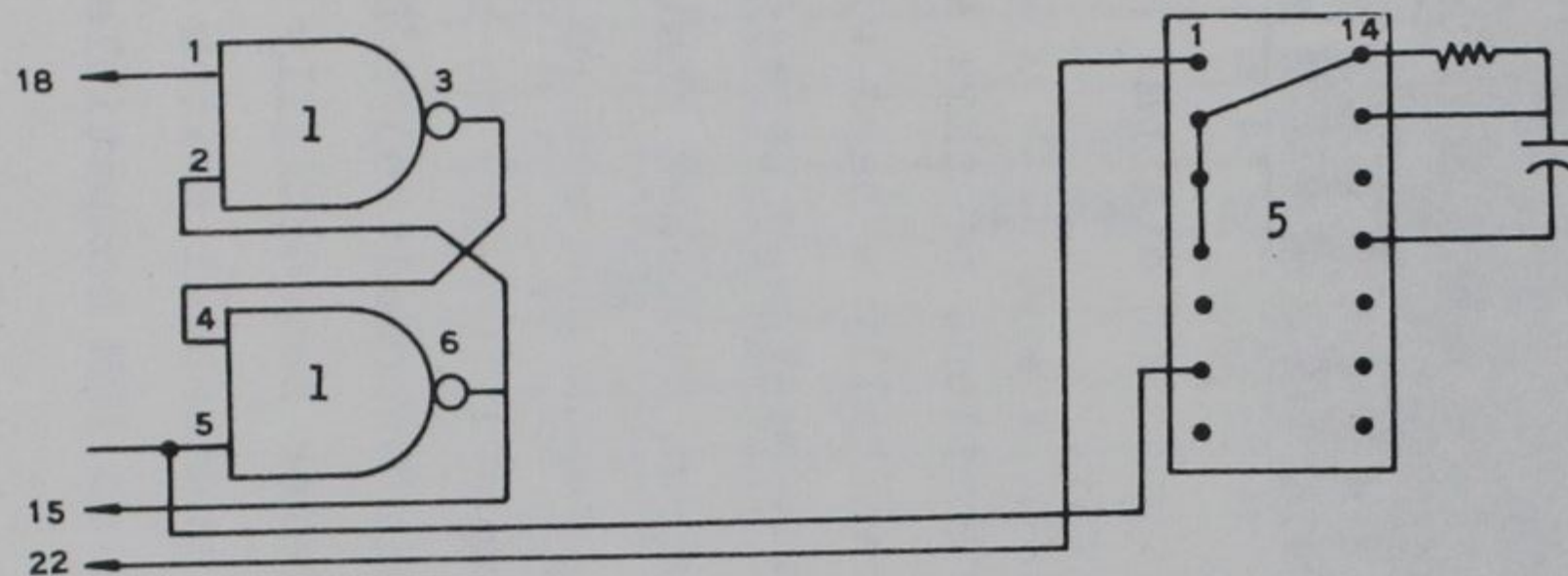
17
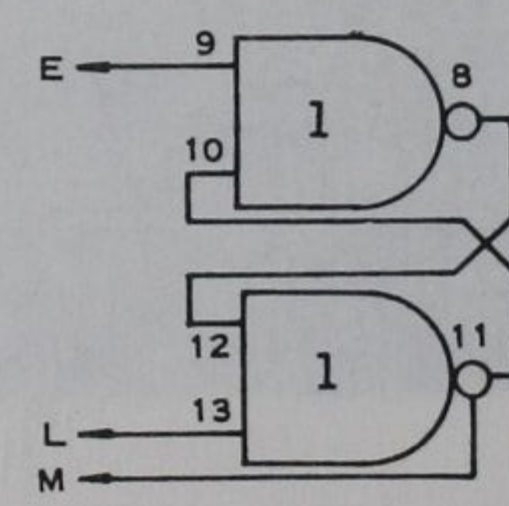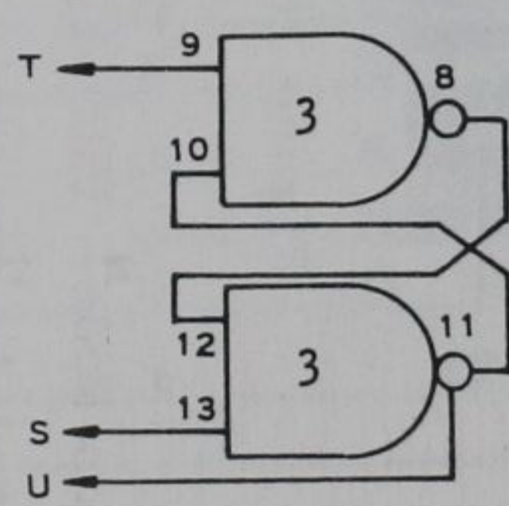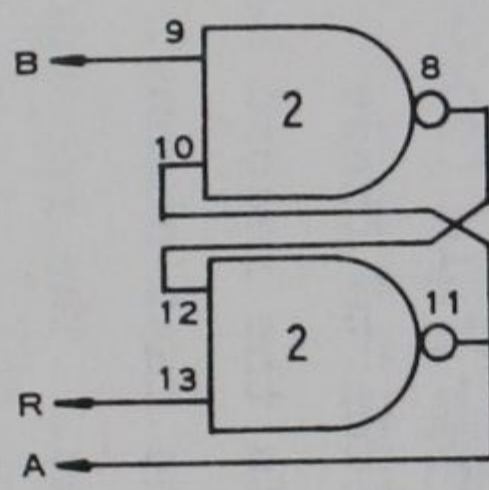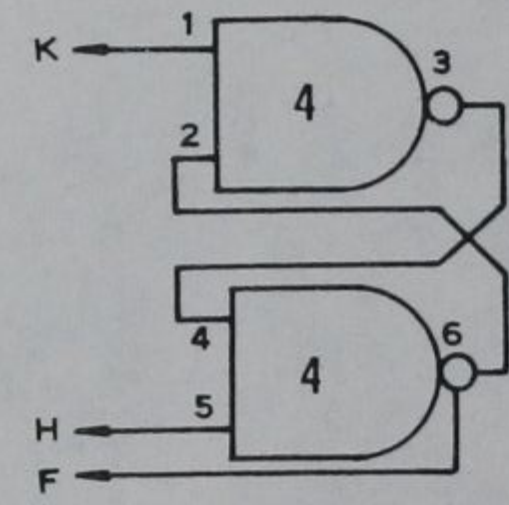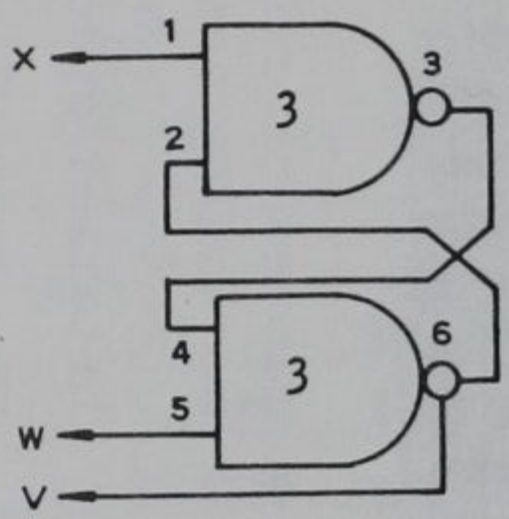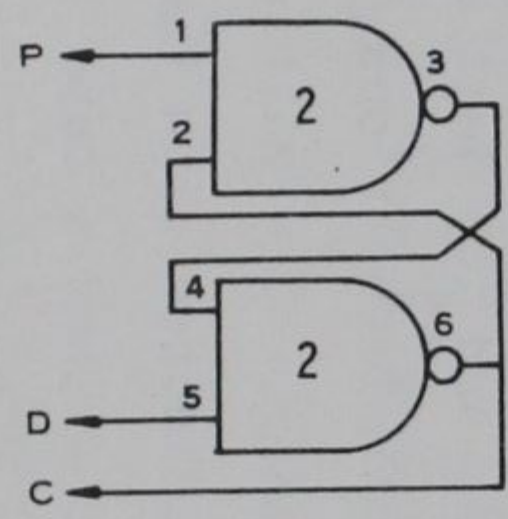
Figure 11. Schematic of polarity indicator
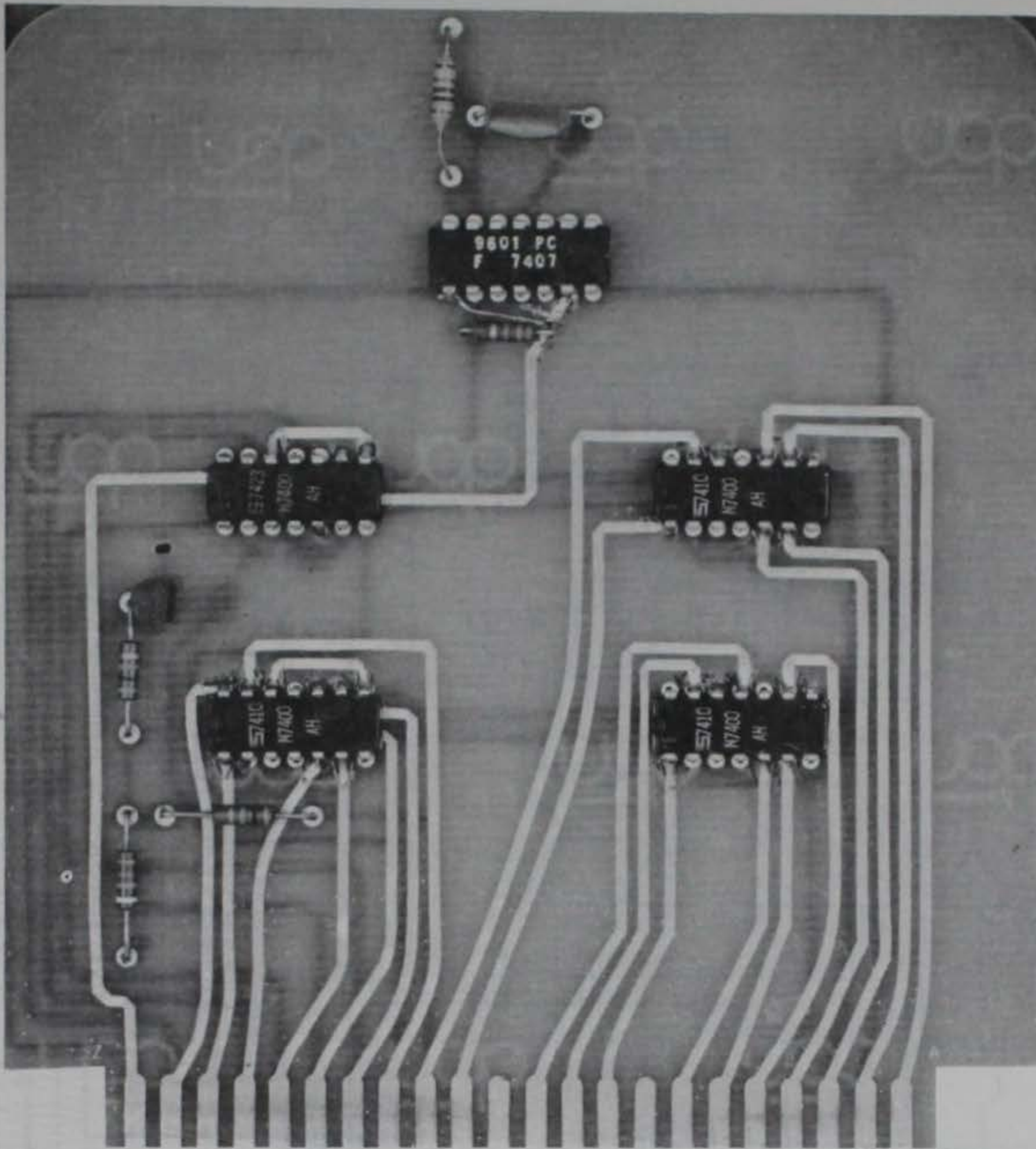
Figure 12.   Printed circuit board of polarity indicator

Digital Electronic Clock

19.   The purpose of the digital electronic clock (Figure 13) is to
transfer the prototype time from the model clock to the computer compati-
ble magnetic tape so that tidal elevations and/or other parameters
recorded on other recorders can be time-synchronized with the water
current measurements.   The clock is constructed from integrated circuits,
counts pulses from the model clock occurring at 30-min intervals (proto-
type), and keeps time from 00.0 to 12.0 hr (prototype).   The clock also
serves as a local readout of prototype time.   The coding and the loca-
tion of the BCD bits are shown in Table 2.
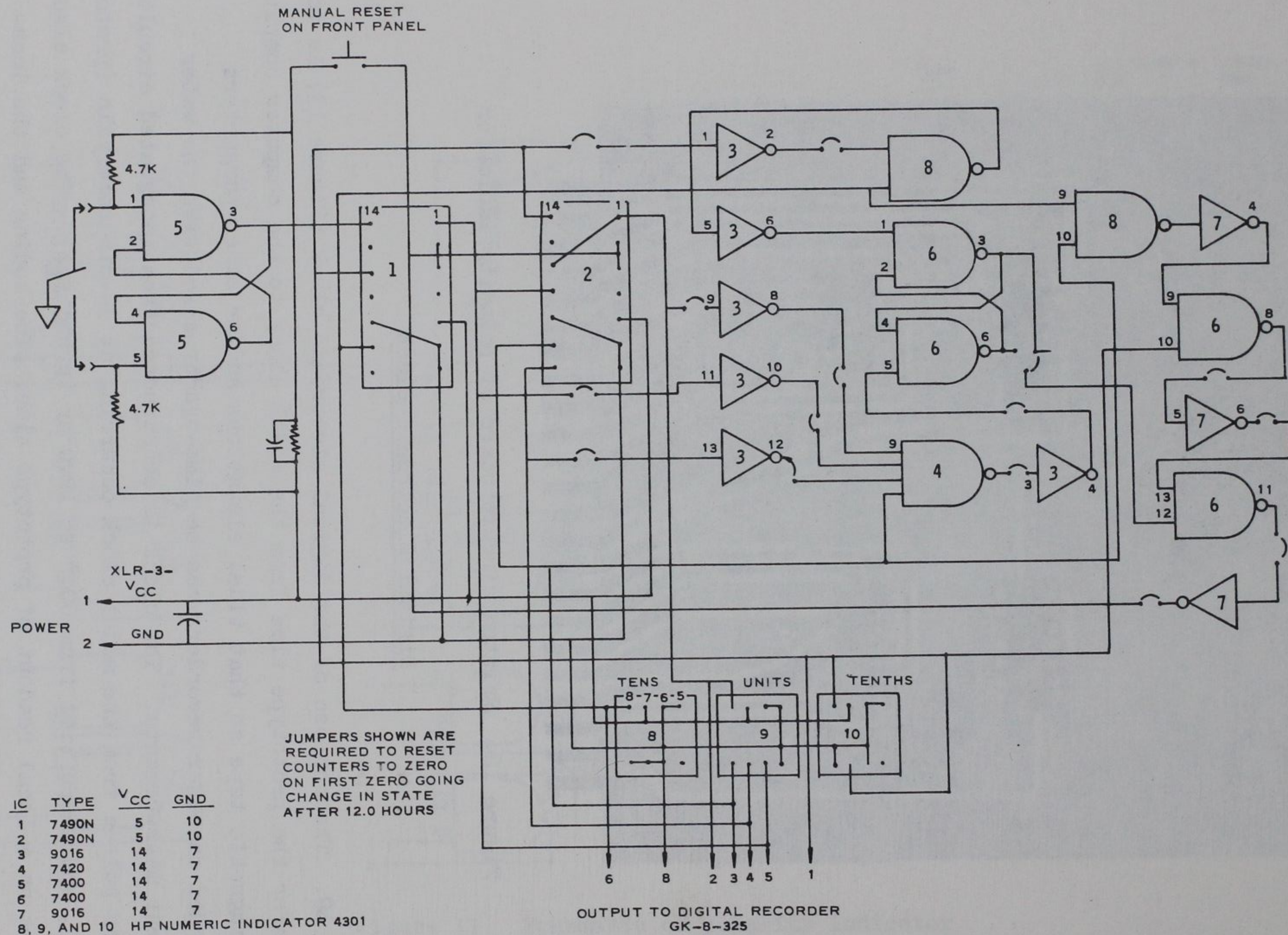
Figure 13. Schematic of digital electronic clock

Operational Procedures

20. <u>Data coupler controls and indicators.</u>*

Control or Indicator	Function
<u>POWER-ON</u> switch	Applies primary power to Datacoupler
<u>MODE</u> switch	INTVL – Causes selected number of input channels to be scanned repeatedly; interval between each scan is determined by <u>INTER-VALOMETER</u> switch positions.
	SINGLE – Causes selected number of input channels to be scanned once each time <u>Start/Stop</u> switch is set to START. Settings of <u>INTERVALOMETER</u> switches have no effect.
	TEST 1 – Allows operator to record data, one character at a time, to compare contents of Datacoupler with recorded information. One character is recorded when <u>STEP</u> switch is pressed; following character is recorded when switch is released. Binary data contained in Datacoupler is that which appears at inputs when operator steps from header to data portion of format.
	TEST 2 – No recording occurs. Datacoupler continuously displays binary data appearing at each input channel. Before input data can be displayed, operator must use <u>STEP</u> pushbutton to advance through header position of format; <u>STEP</u> switch is also used to switch from one input channel to next.
<u>STEP</u> pushbutton	Serves as manual advance control during TEST 1 and TEST 2 modes.
<u>INTERVALOMETER</u> thumbwheel and rotary switches	Establish interval between scans during INTVL mode.

(Continued)

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* From "Model 1500-131 Data Recording Instruction Manual" (unpublished manual), Datatron, Inc., Santa Anna, Calif.

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Control or Indicator	Function
HEADER thumbwheel	Establish Constants, Channel, and Year portion of tape header format; see Figure 14, page 29.
RECORDS/FILE thumbwheel switches	Determine number of records contained in each file.
SCANS/RECORD thumbwheel switches	Define number of scans contained in each record.
LAST CHANNEL thumbwheel switches	Regulate length of each scan during INTVL and SINGLE modes; switch settings; determine last input channel to be scanned.
CONTROL - START/STOP switch	Start position initiates Datacoupler operation during selected mode.
CONTROL - RESET pushbutton	Serves as master reset - clears all Datacoupler logic.
TAPE STATUS - RESET pushbutton	Resets PARITY ERROR lamp.
CONTROL - RUN lamp	Lights when Datacoupler is operating.
CONTROL - CONSTANTS lamp	Lights during "constants" portion of tape header.
CONTROL - HEADER lamp	Lights during header portion of tape format.
CONTROL - SCAN lamp	Lights when input data are being scanned.
CHANNEL DATA lamps	Each lamp lights when logic "1" appears in appropriate binary input bit position.
DATA OUTPUT lamps	Each lamp lights when logic "1" appears in appropriate output bit position. Lamps correspond to tracks on magnetic tape.
CHANNEL NUMBER Lamps	Lighted lamps indicate input channel currently being scanned; channel number is indicated in BCD.
TAPE STATUS - RDY lamp	Lights when recorder is ready to record data.

(Continued)

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Control or Indicator	Function

TAPE STATUS - EOT lamp   Lights when end of tape is detected by recorder.

TAPE STATUS - BRT lamp   Lights when broken tape is detected by recorder.

TAPE STATUS - PARITY ERROR lamp   Lights when echo parity error is detected by recorder.

21. Operational procedure steps are as follows:

    a. The tape is threaded in the tape recorder as shown directly above the power switch.

    b. Set the Start/Stop switch on the tape recorder control panel to Stop.

    c. Set both the power switches on the current meter counters to the On position.

    d. The control readout, located near the middle-right side of the digital tape recorder controller, defines the portion of the format that is presented in the control data readout. All of the machine constants, header, and data channels can be monitored at the control data readout by manually stepping through the format. The format is sequential and does not have a random access capability. All machine constants, header, and data should be checked to ascertain that the system is correctly adjusted.

    e. On the tape recorder control panel, set the mode switch to Test 2. This allows the operator to single-step the multiplexer through the whole format to examine all the header and data inputs without recording them on magnetic tape. As the input registers of the digital tape recorder are manually stepped, the channel number readout lamps located on the left side of the front panel indicate the channel addressed. The first channel is 00, indicated by all lamps being extinguished. This is the first channel monitored when the scan light is illuminated in the control readout. The channel addressed can be determined by adding the numbers associated with the illuminated lamps. Reference to the test specification sheet, supplied by the project engineer, should be made to ensure that proper machine and header constants are entered in the machine.

    f. The digital electronic clock is synchronized by resetting to zero when the model clock is at 12.5 hr.

    g. To check the counters for proper operation, the following adjustments must be performed:

(1) Connect a square-wave generator to the CAL input on the rear panel of the digital electronic counters of the system. The amplitude of the square wave should be set for +12 volts to simulate an input signal from the Price meter.

(2) Adjust the square-wave generator for the proper period (T) using an electronic counter. Then set the RUN/CAL switch to CAL and observe the binary coded count at the lamps located on the front panel of the controller of the digital tape recorder in the control data read-out section. To determine the count, the numbers associated with the illuminated lamps must be added. As an example, with the interval set at one, a 60 pps signal is applied to the system by the square-wave generator. The control data lamps should appear 000000111100 where the "0"s indicate extinguished lamps and the "1"s represent illuminated lamps.

(3) Inputs from the Price meters can be monitored with a scope at the front panel monitor test point. This test point is switchable to each channel. The amplitude of these input should be approximately +10 v.

(4) Set all counter RUN/CAL switches to the RUN position.

h. After all indicators, switch settings, polarities, and amplitudes of calibration are found to be correct, set the totalizing time for the digital counters to the specified time constant (nominally 10 sec), the mode switch on the digital tape recorder controller to INTERVALOMETER, reset the tape status and control, and set the Start/Stop to Start. The above operation will start the recording system and it will automatically record as programmed with the last channel's data appearing in the control data readout between samples. The totalizing time of the counters should be set for one-half the time which the INTERVALOMETER on the digital tape recorder controller is set.

i. The strip chart recorders should be set up as follows:

(1) Chart drive off.

(2) Turn power switch to the On position.

(3) Center white and blue pens with zero control on recorder module.

(4) Set CAL/RUN switch on digital counter to CAL position for desired channel.

(5) Adjust the square-wave generator to desired frequency (pulse rate).

(6) Set the totalizing interval INTERVALOMETER as specified by the project engineer.

(7) Disconnect the square-wave generator from the counter input, this results in zero input to the strip chart recorder.

(8) Rezero strip chart recorder if necessary.

(9) Connect the square-wave generator to counter input and adjust coarse and fine gain on strip chart for correct amplitude.

(10) Repeat steps 8 and 9 as needed.

(11) Return RUN/CAL switch to RUN and repeat.

(12) When all channels are calibrated for proper deflection, set all polarity switches for proper direction and, if necessary, rezero strip chart pins.

(13) Set specified chart speed and turn on chart drive switch.

(14) After paper begins to move, disconnect square-wave generator and return all RUN/CAL switches to CAL position. This is zero on all channels. Reconnect the square-wave generator; all pens should deflect in the same direction and the same amplitude. This is the strip chart calibration step.

(15) Disconnect the square-wave generator and all pens should return to the original zero line.

(16) This concludes the calibration of the strip chart recorder.

(17) Return all RUN/CAL switches to RUN.

(18) Strip chart is now set up and ready to record data.

This concludes the "set up"/calibration procedure, the system should now be prepared to record water current data.

22. The digital recording system has no end of test features which will automatically cease operation of the system; therefore it is necessary to follow certain procedures to ensure that the recording format is not altered. The hydraulic model test shall always be at least one complete file in length. After the number of files for a test is decided, the operation of the system can very easily be halted by placing the Start/Stop switch in the Stop position during the last record of the previous test but prior to the end of file gap generation. The Start time of the test should be noted and the time interval

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corresponding to end of the last record for a particular file of interest can be determined. For example,

$$\text{Records/file} = 3$$
$$\text{Scans/Record} = 20$$
INTERVALOMETER setting (seconds between scans) = 3

therefore, 20 Scans/Record × 3 sec/scan = 6 sec/rec. The end of the second record will have come after 120 sec. Shortly thereafter the Start/Stop control switch should be placed in the Stop position in order to cease the test after the recording of this file. This will cause an orderly cessation of the digital recording system in the proper format.

23. The Datatron Model 1500-131 digital recording system can be modified to automatically cease data acquisition at the end of any file. This capability can be obtained by inserting the end of file (EOF) mark pulse into a BCD counter-magnitude comparator-thumbwheel switch combination. The amplitude comparator would be preset with the thumbwheel switch to the next to the last file of interest. After the BCD counter has counted the number of files preset in the comparator, the comparator will generate a pulse which will cause the recording system to enter the Stop mode. This function is done by placing a NAND gate between the Stop switch and the logic elements which it controls. One input to the NAND gate would be the Stop switch and the other input would originate at the magnitude comparator; therefore a change in either input will generate a Stop command that will cease operation at the preselected time. This modification is proposed as a future addition to the present system.

PART III: TIDAL VELOCITY DATA ANALYSES

Outline of Procedures

24. In this part of the report, the format for the original data
tape as created by the recording system (PART II) is described in detail
and the procedures of reducing, scaling, editing, and analyzing the
original data with sample outputs are presented. The final output of
the analyses is interpolated velocity values at selected intervals of an
averaged tidal cycle. These data are output on punched cards and are
input to an existing tidal data plotting program (WES program number
RONEIS/TIDAL). The tidal velocity plots from this existing program are
presently accepted as standard form of reduced data for technical re-
ports. Although the existing program with minor modifications could
have been incorporated as another activity to the computer analyses pre-
sented in this report, a separate computer run of the existing program
with card input is chosen. This choice is based on:

a. The familiarity of most model engineers with card input to
the existing tidal plotting program.

b. Need to review the velocity data and preliminary plots
before final plotting for technical reports.

c. Much of the prototype tidal velocity data is provided to
WES on cards and is easily utilized in this form by the
existing tidal plotting program.

25. A concise outline of the data analyses and output is as
follows:

a. Preprocessor.

(1) Read original velocity data tape.

(2) Demultiplex and scale data.

(3) Store resultant data on permanent data tape.

(4) Output to printer.

b. Data Processor.

(1) Read permanent data tape.

(2) Analyze data and output.

(a) Edit data and print.

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(b) Plot edited data:

Original points - 0

Edited points - X

Spline fit.

(c) Average two cycles of data and print.

(d) Plot average values and spline fit.

(e) Interpolate 0.5-hr values.

(f) Print interpolated values and punch cards.

Original Tape of Tidal Velocity

26. Each magnetic tape recorded during a tidal current test con-
tains model time data (first channel plus blank second channel) and
model tidal velocity data from a specified number (5) of Price current
meters. Each file, which is physically one model run, consists of four
records. The first record is a 16-character binary coded decimal (BCD)
header of recording equipment constants followed by three records con-
taining data. Each of these one tidal cycle records has an initial 16-
character BCD header of identification information and 61 scans at 19-
sec intervals of data from seven measurement channels. The data values
are recorded in 12-bit binary data words and are sequentially multiplexed
in two characters per data word.

27. The actual number of records per file, scans per record, and
channels per scan may vary during system checks and changes in measuring
equipment or from model to model. All records are made in ODD parity.
The tape format is shown in Table 3, and in greater detail in Figure 14.
The characters shown in the bit spaces are for convenient identification
only; the actual "markings" are the absence or presence of a magnetized
spot.

28. File header (BCD).

a. File header (BCD) has items 1-3 set by manual switches.

(1) Recorder mode code (L), usually "0."

(a) 0 = INTVL - Causes selected number of input chan-
nels to be scanned repeatedly; interval between

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FIRST RECORD   LAST RECORD

CONSTANTS   HEADER   FIRST SCAN   FIRST SCAN   SPACE   LRC   IRG.   HEADER   FIRST SCAN   LAST SCAN   SPACE   LRC   EOF GAP   EOF   SPACE   LRC

TRACK	MODE	INTERVAL	SCANS/RECORD	REC/FILE	END PNT	SPACE	LRC	IRG.	MODEL RUN NO.	PLAN NO.	YEAR	DAY	HOUR	MIN	SEC	SPACE	CH1 CH2	CHN	CH1	CHN	LRC		HEADER	CH1	CHN CH1	CHN	LRC	EOF	SPACE LRC
C	P P P P	P P P P	P P P P	P	L				P P P P	P P P P	P P	P P	P P	P P	P P P		P P P P—P P	P P—P P	L				P P——P P P P—P P P P—P P					O O
B	O O O O	O O O O	O O O O	O	L				O O O O	O O O O	O O	O O	O O	O O	O O O		B_mB B_mB—B_mB	B_mB—B_mB	L				O O——O O B_mB—B_mB B_mB—B_mB					O O
A	O O O O	O O O O	O O O O	O	L				O O O O	O O O O	O O	O O	O O	O O	O O O		B B B B—B B	B B—B B	L				O O——O O B B—B B B B—B B					
8	L I I I	G G G G	R R E E	L					K K K C	Y Y D D	D H	H M	M S	S		B B B B—B B	B B—B B	L				K K——S S B B—B B B B—B B					1 1
4	L I I I	G G G G	R R E E	L					K K K C	Y Y D D	D H	H M	M S	S		B B B B—B B	B B—B B	L				K K——S S B B—B B B B—B B					1 1
2	L I I I	G G G G	R R E E	L					K K K C	Y Y D D	D H	H M	M S	S		B B B B—B B	B B—B B	L				K K——S S B B—B B B B—B B					1 1
1	L I I I	G G G G	R R E E	L					K K K C	Y Y D D	D H	H M	M S	S		B B$_L$B B$_L$—B B$_L$	B B$_L$—B B$_L$	L				K K——S S B B$_L$—B B$_L$ B B$_L$—B B$_L$					1 1

NOTES

1. ONLY DATA IS IN BINARY FORM (12 BITS): HEADER, CONSTANT AND TIME CHARACTERS ARE BCD.

2. ODD PARITY IS MAINTAINED BY TRACK C.

3. CONSTANTS APPEAR ONLY AT BEGINNING OF EACH FILE.

4. HEADER APPEARS ONLY AT BEGINNING OF EACH RECORD.

LEGEND

L	MODE CHARACTER
I	INTERVAL CHARACTER
G	SCAN/RECORD
R	RECORDS/FILE
E	LAST CHANNEL
K	MODEL RUN NO.
C	MODEL PLAN NO.
Y	YEAR (HEADER SWITCHES)
D	DAY OF YEAR
H	HOUR
M	MINUTE
S	SECOND
B_m	MOST SIGNIFICANT BIT
B	BINARY BIT
B_L	LEAST SIGNIFICANT BIT
SP	3 CHARACTER SPACES 0.072"
LRC	LONGITUDINAL REDUNDANCY CHECK
IRG	INTERRECORD GAP 0.75"
EOF	END OF FILE MARK
P	PARITY

Figure 14. Magnetic tape data format

each scan is determined by INTERVALOMETER switch positions.

(b) 1 = SINGLE - Causes selected number of input channels to be scanned once each time Start/Stop switch is set to Start. Settings of INTERVALOMETER switches have no effect.

(c) 2 = TEST 1 - Allows operator to record data, one character at a time, to compare contents of Datacoupler with recorded information. One character is recorded when STEP switch is pressed; following character is recorded when switch is released. Binary data contained in Datacoupler is that which appears at inputs when operator steps from header to data portion of format.

(d) 3 = TEST 2 - No recording occurs. Datacoupler continuously displays binary data appearing at each input channel. Before input data can be displayed, operator must use STEP pushbutton to advance through header portion of format; STEP switch also is used to switch from one input channel to next.

(2) Interval (III), specifies model sampling interval.

(a) First space - time scale, usually "0."

0 = seconds

1 = minutes

2 = hours

(b) Second space - ten characters, is 1.

(c) Third space - units character, is 9.

(3) Scans per record (GGGG) is 0061.

(4) Data records per file (RR) is 02.

(5) Last channel in scan (EE) is 06.

(6) Three character spaces (---) to fill out header character to a multiple of four.

(7) Parity check (P,L), built into system for monitoring equipment performance by checking ODD parity both across the tape (P) and longitudinally (L).

b. Record header (BDC) has items 1-3 set by manual switches and items d-g controlled by digital clock.

(1) Model run number (KKK), varies from "001" to "999."

(2) Model plan number (c), base plan is "0" with other model plans numbered sequentially from "1" to "9."

(3) Year (YY).

(4) Julian Day (DDD), varies from "001" to "365."

(5) Hour (HH), varies from "00" to "23."

(6) Minute (MM), varies from "00" to "59."

(7) Second (SS), varies from "00" to "59."

(8) One space (-), to fill out header character spaces to a multiple of four.

c. Data scans (12-bit binary) are composed of velocity values from each channel recorded sequentially usually with "channel n" equal "channel 7." (Note that data channels 1-7 are recorded in sequence on tape channels 00-06.)

(1) Most significant bit (B_M).

(2) Binary bit (B).

(3) Least significant bit (B_L).

(4) Equivalent values of bits representing decimal values of instrument output counts:

$$2048 = B_M \qquad B = 32$$
$$1024 = B \qquad B = 16$$
$$512 = B \qquad B = 8$$
$$256 = B \qquad B = 4$$
$$128 = B \qquad B = 2$$
$$64 = B \qquad B_L = 1$$

The total count for each data value can vary between 0 and 4095.

(5) The last data scan of each record is followed by three character spaces (---) and a longitudinal parity check (L), as described above for the file header.

d. End of file is identified by a 3.75-in. end-of-file gap, an end-of-file mark (1), three character spaces (---), and a longitudinal parity check (L).

Preprocessor

29. The preprocessor computer program is a multipurpose program designed to read from magnetic tape and convert to G635 system binary data whose number of bytes per word differs from G635 computer. In addition, the preprocessor scales and outputs the resultant data. For the

tidal model option, the preprocessor reads the original data tape and uses card input to control data manipulation and to select options, then it demultiplexes the data, scales to prototype units, and stores resultant data in a file on a permanent data tape for use by the data processor. These data also are output to the printer.

Procedures for the processor

30. The preprocessor reads the data tape, makes use of card input to ensure that the correct data are read, demultiplexes the data, scales the data to engineering units, stores the data on disc, edits the data to remove obvious data errors, and finally stores the resultant data on a disc or tape file for later use by a data processor. The preprocessor consists of the following routines:

> MAIN - Driver routine; reads card input and exercises the various options as specified.

Subroutines

> TRANSLATR - Breaks out the packed data words into machine words for natural binary, two's-complement binary n-bit data ($n \leq 36$), or special binary format for Price current meters.

> FHDRCK - Checks the data read from the file header against card input.

> RHDRCK - Checks the data read from the record header to ascertain the time and channels calibrated; also has option to check the time against the requested Start time or check the model test number against the requested model test number.

> BRMTREDT - Checks the barometric pressure for the record and returns the average barometric pressure for the record to be used in scaling.

> SCALDATA - Scales the wave data, velocity data, and temperature data according to input parameters:

> (1) Equation for submerged pressure transducers

$$n = A*K + B$$

> A = Linear scale factor (input AARRAY)

> B = BARRAY + REL-APAVG where BARRAY is input intercept ARRAY and REL is input relative elevation ARRAY.

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(2) Equation for all other sensors

$$n = A*K + B$$

        A = As above

        B = BARRAY + OFFSET where BARRAY is same as above
            and OFFSET is input OFFSET for a desired trans-
            lation of data.

STORDATA - Stores the data for future use in one of the following
        manners:

        (1) Record by record as read and scaled to disc,

        (2) After editing calls DSKTAP to store data on tape,
        or

        (3) Record by record as read and scaled to tape.

EDITDATA - After all records have been read and stored on disc,
        edit data is called to edit out any spikes and to re-
        construct short sequences of lost data using subroutine
        datafill.

DSKTAP - Transfers data from disc to tape and creates a tape
        file header.

STATS - Used to calculate mean and variance of a data set.

DATAFILL - Reconstructs missing data according to NEDIT option
        (1-tide only, 2-tide and waves) by performing a least-
        squares linear fit of the tide and superimposing the
        residual wave data from before and after the data gap.

LSQFIT - Least-squares polynomial fitting routine.

SMOOTH - A "feathering-in" procedure for reconstructed data
        sequences.

PRICE - Special subroutine for converting data from model Price
        velocity meters.

MTIME - Special subroutine for converting time on model to
        machine data.

Preprocessor input

31. The card inputs including formats and parameter definitions
for the preprocessor program are presented below.

CARD 1 NCH - # of channels recorded

(16I5) NSOR - # of scans per record

       NRPF - # of data records per file

       NNBWPFH - # of n-bit data words per file header

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NFCK - # of checks to be made on file header info

NNBWPRH - # of n-bit data words per record header

NRCK - # of checks to be made on record header info

NCHU - # of channels of data actually to be preprocessed

NEDIT - Editing option: 0-no editing; 1-tide only; 2-tide and waves

NSAV - Data save option: 0-no save; 1-save edited or original data

NREC - 3 of records actually to be preprocessed per file

NBPDW - I (# of bits per data word): or + = Special format keyed on NBAGTP

$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ + = Natural binary;
$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ - complemented

IST∅1 - ∅ if counters start at ∅1, 1 if counters start at 1

CARD 2   IDEVIN - Logical device # of input

(16I5)   IDEVOT - Logical device # of output

ISAV - Logical device # of save file

ISCR - Logical device # of scratch file

CARD 3   (ISTIM(I),I=1,5) - Requested start time (yr day hr min sec) or flag for tidal model test consisting of (neg. starting run no., final run no., blank, blank, blank).

MXNBP - Maximum number of bad data points acceptable for correction

ICKTIM - = ∅, if time is used to key on
$\qquad\qquad$ ≠, if time is merely information

CARD(S) 4 (ISC(I),I=1,NCG) - 1,DO;0,Do not use data for channel I

(16I5)

CARD(S) 5 (NGAGTYP(I),I=1,NCH) - 0, designates channel recorded no data

$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ 1, submerged pressure transducer

$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ 2, surface-piercing resistance gage

$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ 3, barometer

$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ 4, velocity (Price meter)

$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ 5, temperature

$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ 6, special time

$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ 7, Marsh-McBirney velocity

NOTE To mix complemented and any other code is undefined special

format data, set NBPDW + and prefix the codes here by - so that a com-
plementing routine will be called.

CARD(S) 6   (AARRAY(I) I=1,NCH) - Linear scaling factor for each chan-
(8f10.5)   nel I for converting binary counts to
                                    engineering units (= 0.1 for NGAGTYP =
                                    6)

CARD(S) 7   (BARRAY(I),I = 1,NCH) - Intercept for each channel I corre-
(8f10.5)   sponding to zero binary counts (= 0.0
                                    for NGAGTYP = 6)

CARD(S) 8   (REL(I),I=1,NCH) - Relative elevation of each channel I
(8f10.5)   (Referenced to a known datum plane)
                                    (= 0.0 for NGAGTYP = 6)

CARD(S) 9   (OFFSET(I),I=1,NCH) - Offset value for each channel I as
(8f10.5)   applicable (= 0.0 for NGAGTYP = 6)

CARD(S) 10   (IFCK(I),I=1,NFCK) - Parameter description for each file
                                    header check

                            CKNCHB - # of channels

                            CKNSPR - # of scans per record

                            CKNRPF - # of data records per file

                            CKDELT - Integer sampling interval

                            CKNCBB - No check made

                            CKSPPL - Special check with ICKF(I)

CARD(S) 10A (ICKF(I),I=1,NFCK) - Integer data values to check for
(16I5)   CKSPCL parameter

CARD(S) 11   (IRCK(I),I=1,NRCK) - Parameter description for each record
(13A6,ZX)   header check

                            CKCALB - Calibration or off-line of channel

                            CKYRBB - Year

                            CKDAYB - Day

                            CKHRBB - Hour

                            CKMINB - Minute

                            CKSECB - Second

                             CKNOB - No check

                            CKSPCL - Special check with ICKR(I)

CARD(S) 11A (ICKR(I),I=1,NRCK) - Integer data values to check for
(16I5)   CKSPCL parameter

CARD 12 (LABGAG(I),I=1,NCH) - Gage labels

(20A4)

CARD 13 DELT - Sampling interval (seconds)

(8f10.5) DEVMAX - Maximum acceptable first-difference criterion

CARD 14 FHFMT - Format according to which file header info is decoded

(A80)

CARD 15 RHFMT - Format according to which record header info is decoded

(A80)

CARD 16 MDLTTL - Model title

(A50)

Preprocessor outputs

32. The outputs of the preprocessors are a data file on a speci-
fied permanent data tape, printed model data, and other pertinent infor-
mation. The magnetic tape file consists of a BCD file header and N
records of demultiplexed, scaled binary data. A schematic of the tape
format for this permanent data tape is Table 4. In addition to the
permanent data tape, the printed output of model information and data
values are scaled velocity values (fps) in prototype units. These scaled
values depend on each Price meter calibration coefficient (linear
scaling factors and intercepts) used to scale the binary count data of
each channel. An example of model parameter information and prototype
velocity data for one channel may be found in Appendix C.

Data Processor

33. The data processor reads the permanent data tape, which is
created by the preprocessor, and obtains data for one channel at a time.
Data for each channel are edited to remove inconsistencies at each zero
velocity crossing for the entire tidal model run. Both unedited and
edited data are printed as output. An option is included to plot the
unedited data, edited data, and a spline fit of the edited data for each
channel if desired. Starting at prototype time zero during the first
cycle of the model, the following two tidal velocity cycles are averaged.
The resulting cycle of averaged data is printed as output and also may

be plotted with a spline fit if desired. Finally, data values are inter-
polated using a spline routine at half-hour intervals from zero to 12 hr.
These interpolated data are printed as output and also punched on cards
in a format compatible as input to the tidal data plotting program (WES
program number ROHEIS/TIDAL) by L. L. Daggett.

Data processor input

34. Cards inputs including formats and parameter definitions for
the processor program are presented below.

CARD 1   IOPT(I),I=,NCH - Options for each channel
(16I5)

                    0 - Channel was not used
                    1 - Channel used but no plots desired
                    2 - Plot only unaveraged data
                    3 - Plot only averaged data
                    4 - Plot both unaveraged and averaged data

CARD 2   JFLAG - Negative run number of model run to begin tidal velocity
(16I5)   analyses.

         JFND - Number of final run to be analyzed.

NOTE - This card can be the same card used for card #3 of input to the
       preprocessor. If computer run is independent of preprocessor,
       run number must be pos

CARD 3   MDLTTL - Model title
(A50)   Centered in field

Data processor edit

35. The Price current meter is an unidirectional device. To
distinguish flood and ebb tidal currents in a navigation channel, the
recording system has a switch to set a sign for each current meter. For
flood tidal currents the sign is positive. For ebb tidal currents the
sign is negative. Due to the unidirectional characteristics of the
Price meter, the meter must be rotated 180° at slack water, and the sign
bit changed. This procedure induces some error into the velocity data
near slack water. This error is associated with the time chosen by the
model operator to rotate the current meters. Since slack water does not
occur simultaneously at all velocity stations in the tide model, the

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correct time to rotate each current meter is difficult to determine.
Estimates of this time for each velocity station will be in error. Thus,
magnitude and direction errors will exist near slack water. The data
processor edit routine checks velocity data for zero values and sign
changes. When either of these occurs, the routine takes the previous
data point and assumes it to be good. The routine then skips a predeter-
mined number of points and assumes that the resultant point is also good.
Using these two good points, the equation for a straight line through
these two points is determined. Values to replace bad data values are
calculated using this equation. The number of points skipped at slack
water is determined by MXNBP (maximum number of bad points) in the first
parameter statement in the data processor. The actual number of points
skipped and replaced by calculated values is one less than MXNBP.

Data processor output

36. Printed output for the data processor consists of velocity and
model time information with unedited, edited, averaged, and interpolated
data. This information is printed in the same format as in the prepro-
cessor output and also includes linear scaling factors and intercepts.

37. Data from channel 1 are the model clock times not edited. Data
for all other channels are edited at each zero crossing by inserting a
straight line to replace bad data points. Polynomial coefficients of
the straight line, $AX + B$, for each zero crossing are printed where X
is the sequence number of the bad point. Unedited and edited data values
are printed for each cycle. If desired, a plot of this information may
be produced for each channel. Plotted parts are keyed as follows:

<blockquote>
Unedited data points - (1)

Edited data points - X

Spline fit of data
</blockquote>

Examples of printed output and plots are presented in Appendix D.

38. Average data values obtained by averaging two cycles starting
with the scan number corresponding to the first zero reading on the
model clock are calculated and printed by the processor. This output
includes model clock time, prototype time calculated from scan number,
and averaged data values. The optional plot of this information shows

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averaged values noted by X and a spline fit through these points.
Examples of this output are presented in Appendix D.

39. Previous procedures of collecting model velocity data with miniature Price meters have been improved and updated by:

a. Using digital counters to accumulate over a selectable sampling interval the number of electric pulses received through fiber optic techniques from the rotation of the cups of the Price meter.

b. Implementing a portable digital recorder to record the above digital output on 7-track magnetic tape.

c. Using a digital to analog converter to provide analog output for visual inspection of velocity data by model operator.

d. Developing computer programs for reducing, editing, and analyzing the recorded velocity data.

At the option of the user, the final form of the analyzed data can be output on cards for compatibility with past procedures (WES Program No. ROHEIS/TIDAL) of preparing tidal velocity plots for technical reports.

40. Efforts described in this report have provided tidal inlet model studies of WDD with an automated procedure of collecting, editing, analyzing, and formally documenting tidal velocity data. This procedure does not require the direct use of an ADACS, and the sensors and recording system are sufficiently portable to be moved from one model to another. Although this system of collecting tidal velocity is automated, the limitations (e.g. velocity resolution, high threshold velocity, nonlinear response at low velocities, and unidirectional response) of the Price meter are still present and must be carefully considered during data interpretation. Improvements in model transducers for monitoring velocities are certainly desirable, and other methods of measuring velocities in physical models must be pursued fully and evaluated in the near future to keep pace with other automated advances in hydraulic modeling techniques.

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Table 1

Counter Binary Code for Price Meter

Truth Table	MSB											LSB
+ Full scale (flood)	1	1	1	1	1	1	1	1	1	1	1	1
+ Full scale -1	1	1	1	1	1	1	1	1	1	1	1	0
Zero +1	1	0	0	0	0	0	0	0	0	0	0	1
Zero	0	0	0	0	0	0	0	0	0	0	0	0
Zero -1	0	0	0	0	0	0	0	0	0	0	0	1
- Full scale -1	0	1	1	1	1	1	1	1	1	1	1	0
- Full scale (ebb)	0	1	1	1	1	1	1	1	1	1	1	1

Table 2

Electronic Model Clock Binary Codes
for Digital Recording

	Location on Digital Recorder	
Bit	Hours	BCD Weights
12	Tens	1
11	Units	8
10	Units	4
9	Units	2
8	Units	1
7	Always	0
6	Always	0
5	Always	0
4	Fraction	8
3	Fraction	4
2	Fraction	2
1	Fraction	1

Truth Table, BCD Weights

	Fraction				Units				Tens
Count	1	2	3	4	8	9	10	11	12
0	0	0	0	0	0	0	0	0	0
1	1	0	0	0	1	0	0	0	1
2	0	1	0	0	0	1	0	0	
3	1	1	0	0	1	1	0	0	
4	0	0	1	0	0	0	1	0	
5	1	0	1	0	1	0	1	0	
6	0	1	1	0	0	1	1	0	
7	1	1	1	0	1	1	1	0	
8	0	0	0	1	0	0	0	1	
9	1	0	0	1	1	0	0	1	

Table 3

Original Data Tape Format

Record 1   — File Header:

     1. Recorder mode code.

     2. Sampling interval.

     3. # of scans per record. (NSCANS)

     4. # of records per file. (NRECS)

     5. Last channel in scan.

     6. Three character spaces.

     7. Parity check.

Record 2 — NRECS — Data records

     1. Record header.

         a. Run number.

         b. Model Plan number.

         c. Year.

         d. Julian day.

         e. Hour.

         f. Minute.

         g. Second.

         h. Space.

     2. Data Scans (1-NSCANS)

         a. First scan for first channel.

         b. First scan for last channel.

         c. Last scan for first channel.

         d. Last scan for last channel.

End of File

Table 4

Preprocessor Output: Permanent Data Format

Record 1   - File Header:

1. Run number (IRUN).

2. Plan number (IPLAN).

3. Sampling interval (DELT).

4. # of scans per cycle (NSPR).

5. # of records preprocessed per file (NREC).

6. Starting time of model run (year, day, hour, minute, second).

7. ISC(I), I=1, NCH from input card #4.

8. Scale factor for each channel.

9. Intercept for each channel.

Records 2-N - Demultiplexed data with data values per record and records per channel.

            - End of file.

APPENDIX A: DIGITAL TO ANALOG CONVERTER SPECIFICATIONS

ANALOG DEVICES

Low Cost General Purpose Digital to Analog Converter

DAC-12QZ

FEATURES
Low Cost: $47 (100+)
12 Bit Resolution
½LSB Linearity
±30ppm/°C TC
20ppm/% Power Supply Rejection
Programmable Output Ranges
Small Size — 2" x 2" x 0.4"

GENERAL DESCRIPTION
The DAC-12QZ is a low-cost/high performance 12-bit digital-to-analog converter designed for general purpose OEM applications. The completely self-contained module includes weighted resistor networks, monolithic µDAC current switches, temperature compensated reference and an externally programmable output amplifier. Performance specifications include ½LSB linearity error, 5µsec settling time for full scale conversion, 30ppm/°C temperature coefficient and 20ppm/% power supply rejection.

µDAC DESIGN
This outstanding cost/performance ratio has been achieved by utilizing the popular AD550 µDAC current switches as "secret ingredients". The use of monolithic quad current switches offers close inherent matching of switch characteristics and excellent temperature tracking as well as reasonably fast conversion speed. A hybrid resistor assembly of matched precision resistors and a thick film network is used in conjunction with the µDAC switches. Resistors provided include not only the weighting resistors but also the inter-quad attenuators, amplifier feedback resistors, etc. to assure close temperature tracking.

INPUT CODING
The internal µDAC switches of the binary and BCD models are driven directly by complementary input codes without need of a strobe. The complementary codes for each model are:

MODEL	-F.S.	Zero	+F.S.
DAC-12QZ/BIN		1111 1111 1111	0000 0000 0000
	1111 1111 1111	0111 1111 1111	0000 0000 0000
DAC-12QZ/BCD		1111 1111 1111	0110 0110 0110
	1111 1111 1111	1010 1111 1111	0110 0110 0110

OUTPUT PROGRAMMING
The scale factor is programmed by connecting external jumpers between module pins. With either model, the user can select any one of five output ranges, including bipolar outputs. The choices are:

Unipolar	0 to +5V, 0 to +10V
Bipolar	±2.5V, ±5V, ±10V

The external jumpers at the module pins determine the output amplifier feedback resistance, allowing use of one 5k resistor, or both, either in series to provide 10k, or parallel to provide 2.5k. Offset of exactly one-half full scale for bipolar applications is provided by connecting another jumper to the summing junction of the output amplifier. To maintain constant load on the reference zener, the bipolar offset output should be grounded when using the module in a unipolar mode.

BLOCK DIAGRAM
DAC-12QZ
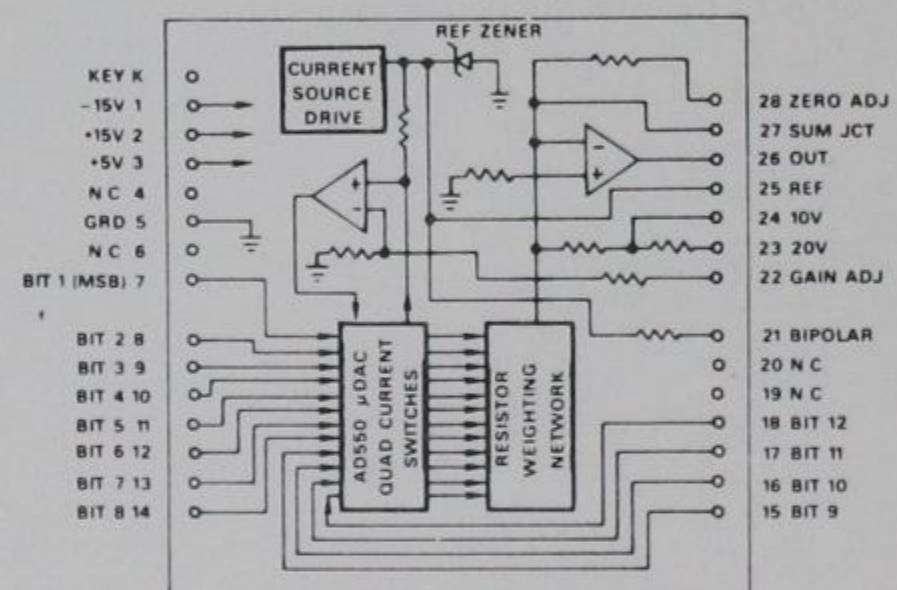
NOTE: PINS SHOWN AS HAVING NO CONNECTIONS IN C I ARE DELETED

SPECIFICATIONS (typical @ +25°C and rated supply voltages, unless otherwise noted)

RESOLUTION	12 Bits
DIGITAL INPUTS	TTL Compatible
'0' E <+0.8V	@ -1.6mA
'1' +2V<E<+6V	@ +0.1mA (open input equivalent to digital '1')
INPUT CODES	
Unipolar	Complementary Binary
	Complementary BCD
Bipolar	Complementary Offset Binary
	Complementary Offset BCD
OUTPUT RANGES	0 to +5V @ 10mA
	0 to +10V @ 5mA
(User Programmable)	±2.5V, ±5V @ 10mA
	±10V @ 5mA
OUTPUT IMPEDANCE	0.02Ω
CONVERSION SPEED	5µsec to 0.01% (for 10V step)
Slewing Rate	20V/µsec
LINEARITY ERROR	±½LSB
TEMPERATURE COEFFICIENT	
Gain	±30ppm/°C of Reading, max
Zero	±50µV/°C (Unipolar), max
	±100µV/°C (Bipolar), max
Differential Linearity	±10ppm/°C F.S., max
TEMPERATURE RANGE	
Operating	0 to +70°C
Storage	-55°C to +125°C
POWER REQUIREMENTS	+15V ±5% @ 25mA
	-15V ±5% @ 30mA
	+5V ±10% @ 35mA
POWER SUPPLY SENSITIVITY	
Gain	±20ppm/% } ±15V only;
Zero	±5ppm/% } tracking supplies
ADJUSTMENTS (USER PROVIDED)[1]	
Gain (20k, 20 turn pot)	±0.3% F.S.
Zero (20k, 20 turn pot)	±30mV
OUTLINE DIMENSIONS	2" x 2" x 0.400"
PRICES	
(1-9)	$79
(10-24)	$59
(25-99)	$49
(100+)	$47

[1] A mounting board complete with trim pots and supplied with mating connector is available at extra cost. Order Part No. 4516. Price $40.

Pin Socket — 2-330808-8, 25 required — $.20 each.

Specifications subject to change without notice.

ORDERING GUIDE:

Model DAC-12QZ/XXX

— BIN

— BCD

OUTLINE DIMENSIONS (In Inches) AND PIN CONNECTIONS
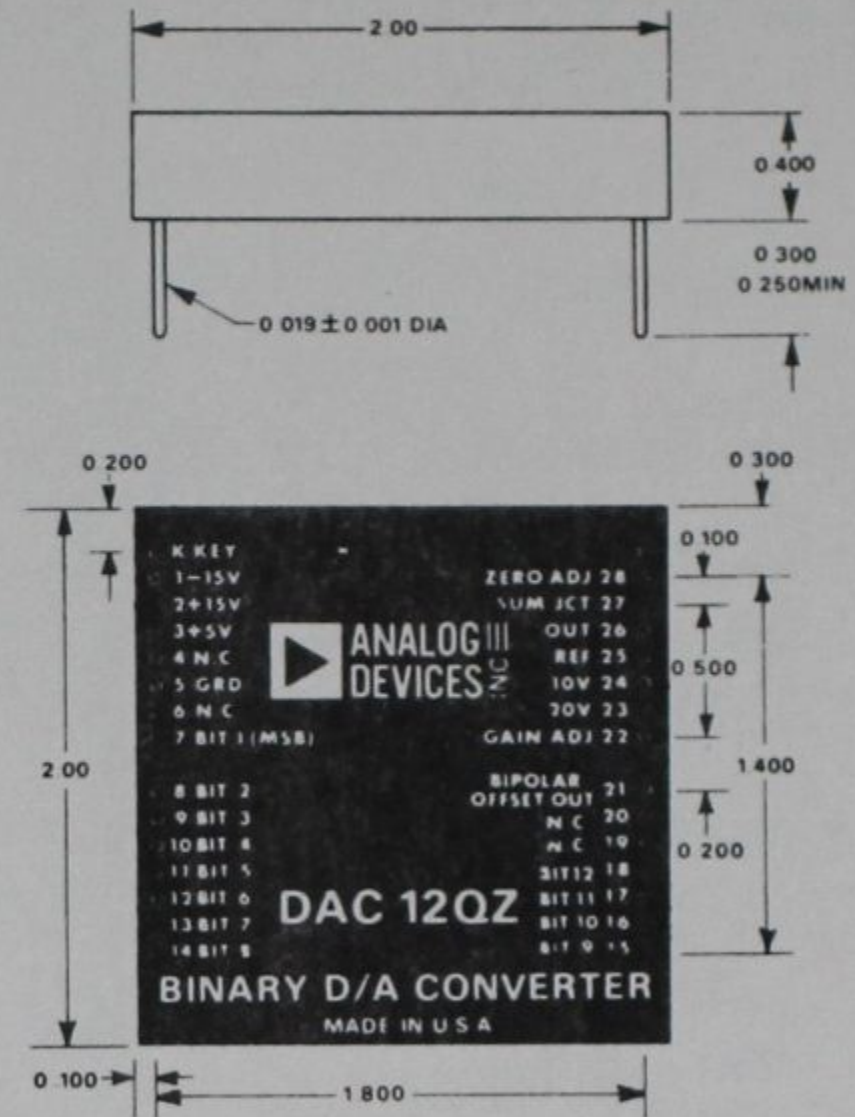
TOP VIEW

POTENTIOMETER CONNECTIONS

ZERO	GAIN
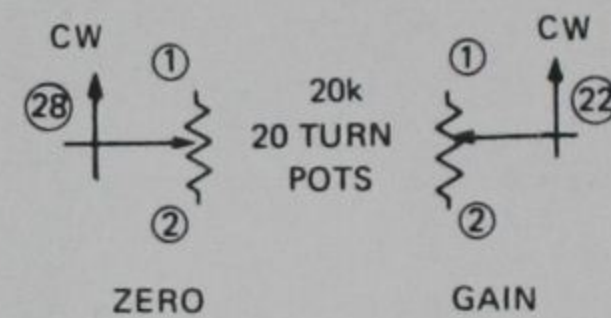
OUTPUT PROGRAMMING

Output Range	External Pin Connections		
±2.5V	21, 23, & 27	24 & 26	
±5V	21 & 27	24 & 26	
±10V	21 & 27	23 & 26	
+5V	23 & 27	24 & 26	21 & 5
+10V	24 & 26	21 & 5	

Connect pins as indicated for selected output.
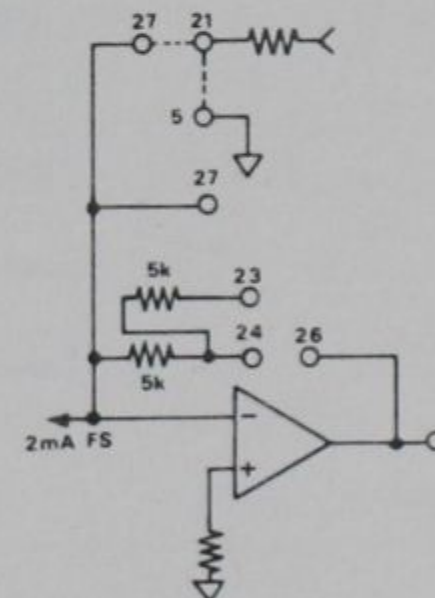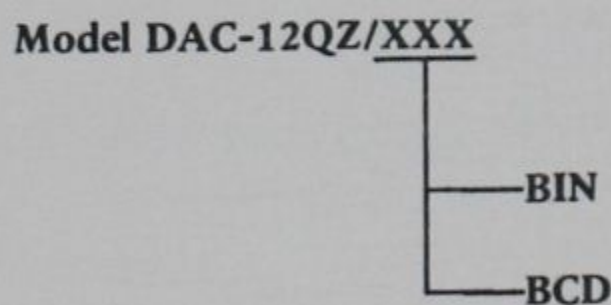
Figure 1. Output Amplifier

APPENDIX B: DETAILS OF DIGITAL RECORDING SYSTEM

Table B1

System Specifications

Item	Specification
System	
Primary power	115 ± 10 percent, VAC, 60-400 Hz, single phase
Environment	Temperature: 0°C to 50°C Humidity: 10-90 percent (noncondensing)
Dimensions	Height: 64.5 in. Width: 23 in. Depth: 30 in.
Datacoupler	
Data inputs	Format: 12-bit binary Amplitude: logic 1 = +5 VDC logic 0 = 0 VDC Number of channels: 18 (wired for 32 to allow future expansion)
Modes	Four operating modes
INTERVALOMETER	Interval between scans is switch-selected as follows: Time increments: seconds, minutes, hours Multiplier range: 00 to 99
Scan length	From 1 to 18 channels (expandable to 32). Scan always begins with channel 0. Last channel to be included in scan is switch-selected
INTVL pulse output	Appears at connector J220 Frequency: Determined by INTERVALOMETER switch settings. Pulse occurs at beginning of interval Pulse width: Approximately 10 µsec Amplitude: 0 to +5 VDC; positive true
INH1, 2, and 3 pulse outputs	Appear at connectors J221 thru J223; all three out- puts are identical. INH pulse appears while Data- coupler storage registers are being loaded with input data. Pulse width: Approximately 40 µsec Amplitude: 0 to +5 VDC; positive true
Digital Clock	Refer to Model 3350-203 Instruction Manual
Magnetic Tape Recorder	Refer to Cipher Model 100 Instruction Manual

From Datatron, Inc.

Data Input Connector Pin Assignments

First Channel			Second Channel	
Pin	Binary Bit		Pin	Binary Bit
20	1		12	1
19	GND		11	GND
22	2		14	2
21	GND		13	GND
44	4		28	4
43	GND		27	GND
46	8		30	8
45	GND		29	GND
48	16		32	16
47	GND		31	GND
50	32		34	32
49	GND		33.	GND
24	64		16	64
23	GND		15	GND
26	128		18	128
25	GND		17	GND
52	256		36	256
51	GND		35	GND
54	512		38	512
53	GND		37	GND
56	1024		40	1024
55	GND		39	GND
58	2048		42	2048
57	GND		41	GND

From Datatron, Inc.

APPENDIX C: SAMPLES OF PREPROCESSOR OUTPUT

LITTLE RIVER MODEL

VELOCITY TAPE READ AND DATA SCALE

MODEL PLAN NUMBER -   0

RUN NUMBER -   1

SAMPLING INTERVAL - 19.00 SECONDS

NUMBER OF DATA SAMPLES PER CYCLE = 61

NUMBER OF RECORDS PER RUN - 8

STARTING TIME OF RUN -

YEAR	DAY	HOUR	MIN	SEC
75	97	14	52	51

DATA CHANNELS -		LINEAR SCALING FACTOR	INTERCEPT
1	USED	0.10000	0.
2	NOT USED	0.	0.
3	USED	0.06448	0.13723
4	USED	0.06066	0.12785
5	USED	0.06088	0.18166
6	USED	0.05632	0.16840
7	USED	0.06370	0.13068
8	NOT USED	0.	0.

```
0.782 1.233 1.491 1.685 1.878 1.878 1.943 1.878 1.814 1.814 1.620 1.556 1.556 1.427 1.298 1.362 1.362 1.298 1.169 1.104
0.911-0.911-0.847 0.   -0.460-0.331-0.653-0.911-0.975-1.104-0.975-1.427-1.298-1.556-1.620-1.491-1.620-1.685-1.749-1.878
-2.072-2.265-2.459-2.394-2.523-2.652-2.523-2.652-2.523-2.459-2.394-2.007-1.749-1.491-1.233-0.975-0.782-0.589-0.331 0.
-0.524
0.782 1.298 1.556 1.749 1.943 1.620 1.685 1.685 1.556 1.233 1.298 1.362 1.104 1.169 1.104 1.233 1.298 1.362 1.169 1.104
0.782 0.589 0.395-0.266-0.653-0.331-0.589-0.782-1.104-1.104-1.233-1.427-1.491-1.556-1.427-1.556-1.556-1.685-1.685-1.878
-2.007-2.201-2.394-2.459-2.523-2.394-2.459-2.394-2.459-2.265-2.136-2.007-1.685-1.298-1.040-0.975-0.718-0.460-0.331 0.331
0.653
1.104 1.233 1.362 1.749 1.814 1.749 1.814 1.685 1.427 1.298 1.233 1.233 1.040 0.975 1.104 1.233 1.233 1.233 1.104 1.040
0.718 0.653-0.911-0.460-0.266-0.524-0.718-0.847-1.040-1.104-1.169-1.169-1.362-1.427-1.427-1.427-1.556-1.685-1.749-1.878
-2.007-2.201-2.265-2.330-2.459-2.459-2.523-2.459-2.459-2.330-2.007-1.878-1.620-1.362-1.104-0.911-0.460-0.395-0.202 0.266
0.718
```

APPENDIX D: SAMPLES OF PROCESSOR OUTPUT

LITTLE RIVER MODEL

VELOCITY DATA EDIT AND ANALYSIS

MODEL PLAN NUMBER -   0

RUN NUMBER -   1

SAMPLING INTERVAL - 19.00 SECONDS

NUMBER OF DATA SAMPLES PER CYCLE - 61

NUMBER OF RECORDS PER RUN - 8

STARTING TIME OF RUN -

YEAR	DAY	HOUR	MIN	SEC
75	97	14	52	51

DATA CHANNELS -			LINEAR SCALING FACTOR	INTERCEPT
1	USED		0,10000	0,
2	NOT USED		0,	0,
3	USED		0,06448	0,13723
4	USED		0,06066	0,12785
5	USED		0,06088	0,18166
6	USED		0,05632	0,16840
7	USED		0,06370	0,13068
8	NOT USED		0,	0,

LITTLE RIVER MODEL

PLAN NO. 0   RUN NO. 1

CHANNEL NO. 1

MODEL CLOCK

```
 3.000  3.000  3.500  3.500  3.500  4.000  4.000  4.500  4.500  5.000  5.000  5.000  5.500  5.500  6.000  6.000  6.000  6.500  6.500  7.000
 7.000  7.000  7.500  7.500  8.000  8.000  8.000  8.500  8.500  9.000  9.000  9.500  9.500  9.50010.00010.00010.50010.50010.50011.000
11.00011.50011.50011.50012.00012.000 0.    0.     0.500  0.500  0.500  1.000  1.000  1.500  1.500  1.500  2.000  2.000  2.500  2.500
 3.000
 3.000  3.000  3.500  3.500  4.000  4.000  4.000  4.500  4.500  5.000  5.000  5.000  5.500  5.500  6.000  6.000  6.500  6.500  6.500  7.000
 7.000  7.500  7.500  7.500  8.000  8.000  8.500  8.500  8.500  9.000  9.000  9.500  9.500  9.50010.00010.00010.50010.50011.00011.000
11.00011.50011.50012.00012.00012.000 0.    0.     0.500  0.500  1.000  1.000  1.000  1.500  1.500  2.000  2.000  2.000  2.500  2.500
 3.000
 3.000  3.000  3.500  3.500  4.000  4.000  4.500  4.500  4.500  5.000  5.000  5.500  5.500  5.500  6.000  6.000  6.500  6.500  6.500  7.000
 7.000  7.500  7.500  8.000  8.000  8.000  8.500  8.500  9.000  9.000  9.000  9.500  9.50010.00010.00010.00010.00010.50010.50011.00011.000
11.00011.50011.50012.00012.000 0.    0.     0.     0.500  0.500  1.000  1.000  1.000  1.500  1.500  2.000  2.000  2.500  2.500  2.500
 3.000
```

POLYNOMIAL COEFFICIENTS FOR A*X + B   A = -0.24833   B = 6.12596

POLYNOMIAL COEFFICIENTS FOR A*X + B   A = 0.37729   B = -22.59090

POLYNOMIAL COEFFICIENTS FOR A*X + B   A = -0.23544   B = 20.17177

POLYNOMIAL COEFFICIENTS FOR A*X + B   A = 0.33860   B = -40.96315

POLYNOMIAL COEFFICIENTS FOR A*X + B   A = -0.27412   B = 40.12693

DATA NOT EDITED
0.782 1.233 1.491 1.685 1.878 1.878 1.943 1.878 1.814 1.814 1.620 1.556 1.556 1.427 1.298 1.362 1.362 1.298 1.169 1.104
0.911-0.911-0.847 0.   -0.460-0.331-0.853-0.911-0.975-1.104-0.975-1.427-1.298-1.556-1.620-1.491-1.620-1.685-1.749-1.878
-2.072-2.265-2.499-2.394-2.523-2.652-2.523-2.652-2.523-2.459-2.394-2.007-1.749-1.491-1.233-0.975-0.782-0.589-0.331 0.
-0.524

DATA EDITED
0.782 1.233 1.491 1.685 1.878 1.878 1.943 1.878 1.814 1.814 1.620 1.556 1.556 1.427 1.298 1.362 1.362 1.298 1.169 1.104
0.911 0.663 0.414 0.166-0.082-0.331-0.853-0.911-0.975-1.104-0.975-1.427-1.298-1.556-1.620-1.491-1.620-1.685-1.749-1.878
-2.072-2.265-2.499-2.394-2.523-2.652-2.523-2.652-2.523-2.459-2.394-2.007-1.749-1.491-1.233-0.975-0.782-0.589-0.331 0.047
0.424

DATA NOT EDITED
0.782 1.298 1.556 1.749 1.943 1.620 1.685 1.685 1.556 1.233 1.298 1.362 1.104 1.169 1.104 1.233 1.298 1.362 1.169 1.104
0.782 0.589 0.395-0.266-0.653-0.331-0.589-0.782-1.104-1.104-1.233-1.427-1.491-1.556-1.427-1.556-1.556-1.685-1.685-1.878
-2.007-2.201-2.394-2.459-2.523-2.394-2.459-2.394-2.459-2.265-2.136-2.007-1.685-1.298-1.040-0.975-0.718-0.460-0.331 0.331
0.653

DATA EDITED
0.801 1.178 1.556 1.749 1.943 1.620 1.685 1.685 1.556 1.233 1.298 1.362 1.104 1.169 1.104 1.233 1.298 1.362 1.169 1.104
0.782 0.589 0.395 0.160-0.076-0.311-0.547-0.782-1.104-1.104-1.233-1.427-1.491-1.556-1.427-1.556-1.556-1.685-1.685-1.878
-2.007-2.201-2.394-2.459-2.523-2.394-2.459-2.394-2.459-2.265-2.136-2.007-1.685-1.298-1.040-0.975-0.718-0.460-0.331 0.008
0.347

DATA NOT EDITED
1.104 1.233 1.362 1.749 1.814 1.749 1.814 1.685 1.427 1.298 1.233 1.233 1.040 0.975 1.104 1.233 1.233 1.233 1.104 1.040
0.718 0.653-0.911-0.460-0.266-0.524-0.718-0.847-1.040-1.104-1.169-1.169-1.362-1.427-1.427-1.427-1.556-1.685-1.749-1.878
-2.007-2.201-2.265-2.330-2.459-2.459-2.523-2.459-2.459-2.330-2.007-1.878-1.620-1.362-1.104-0.911-0.460-0.395-0.202 0.266
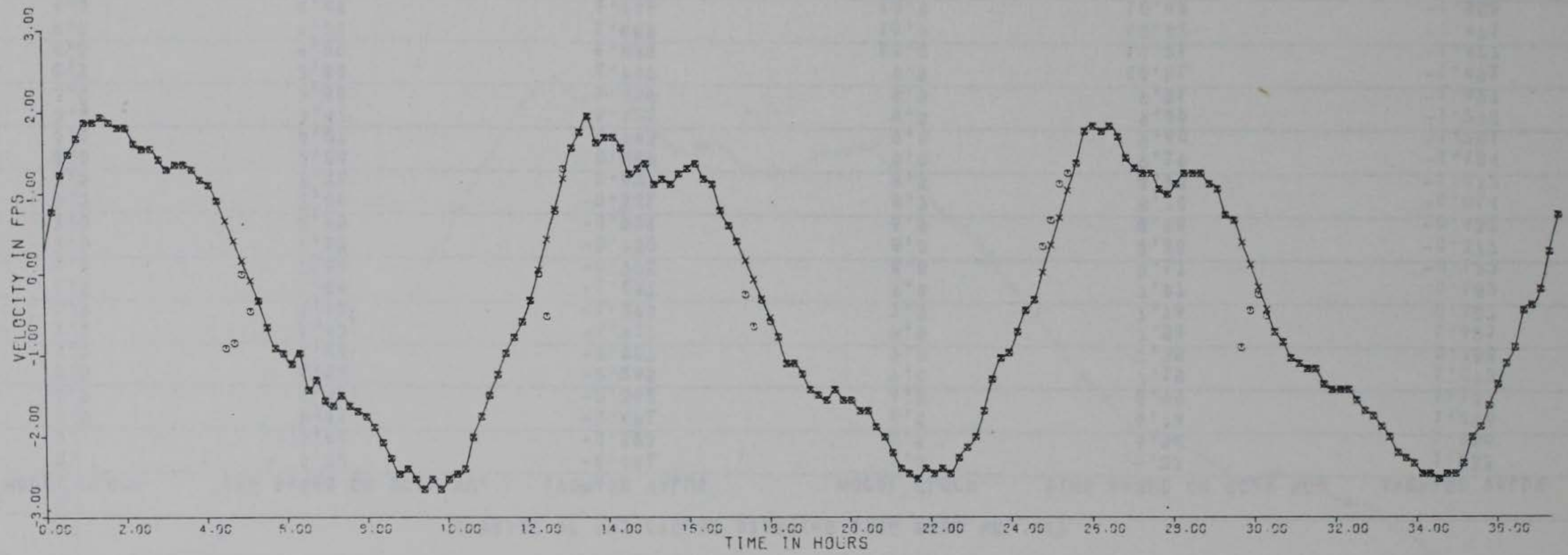0.718

DATA EDITED
0.685 1.024 1.362 1.749 1.814 1.749 1.814 1.685 1.427 1.298 1.233 1.233 1.040 0.975 1.104 1.233 1.233 1.233 1.104 1.040
0.718 0.653 0.379 0.105-0.169-0.443-0.718-0.847-1.040-1.104-1.169-1.169-1.362-1.427-1.427-1.427-1.556-1.685-1.749-1.878
-2.007-2.201-2.265-2.330-2.459-2.459-2.523-2.459-2.459-2.330-2.007-1.878-1.620-1.362-1.104-0.911-0.460-0.395-0.202 0.266
0.718

LITTLE RIVER MODEL
CHANNEL NO. 3

LITTLE RIVER MODEL
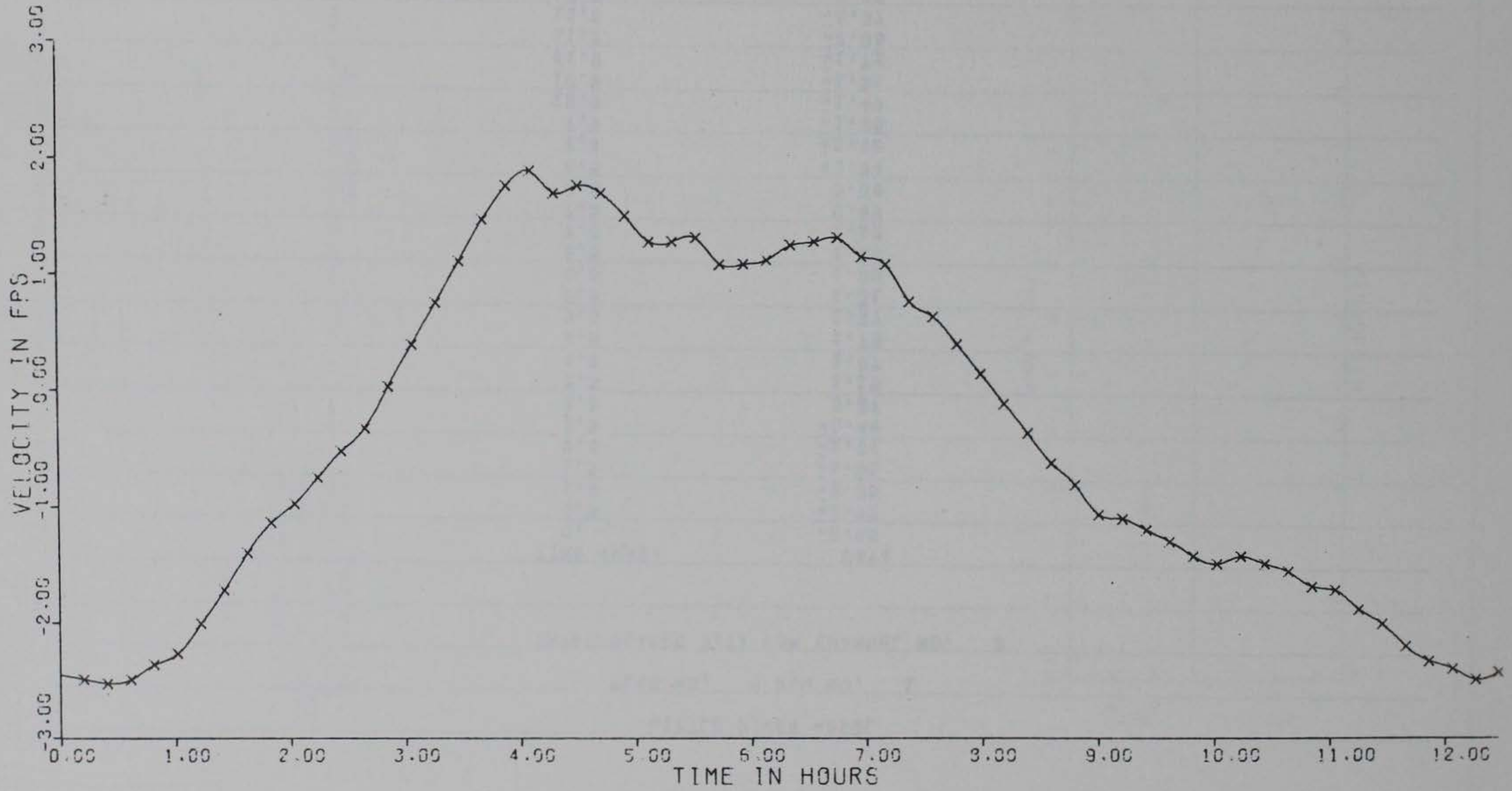
PLAN NO. 0   RUN NO. 1

CHANNEL NO. 3

AVERAGE OF TWO CYCLES STARTING WITH SCAN NO. 47

MODEL CLOCK	TIME BASED ON SCAN NO.	AVERAGE VALUE	MODEL CLOCK	TIME BASED ON SCAN NO.	AVERAGE VALUE
0.	0.20	-2.491	6.0	6.33	1.233
0.	0.41	-2.523	6.5	6.54	1.266
0.5	0.61	-2.491	6.5	6.74	1.298
0.5	0.82	-2.362	6.5	6.95	1.137
0.5	1.02	-2.265	7.0	7.15	1.072
1.0	1.23	-2.007	7.0	7.35	0.750
1.0	1.43	-1.717	7.5	7.56	0.621
1.5	1.63	-1.395	7.5	7.76	0.387
1.5	1.84	-1.137	7.5	7.97	0.132
1.5	2.04	-0.975	8.0	8.17	-0.123
2.0	2.25	-0.750	8.0	8.38	-0.377
2.0	2.45	-0.524	8.5	8.58	-0.632
2.5	2.66	-0.331	8.5	8.78	-0.814
2.5	2.86	0.027	8.5	8.99	-1.072
3.0	3.06	0.385	9.0	9.19	-1.104
3.0	3.27	0.743	9.0	9.40	-1.201
3.0	3.47	1.101	9.5	9.60	-1.298
3.5	3.68	1.459	9.5	9.81	-1.427
3.5	3.88	1.749	9.5	10.01	-1.491
4.0	4.09	1.878	10.0	10.21	-1.427
4.0	4.29	1.685	10.0	10.42	-1.491
4.0	4.49	1.749	10.5	10.62	-1.556
4.5	4.70	1.685	10.5	10.83	-1.685
4.5	4.90	1.491	11.0	11.03	-1.717
5.0	5.11	1.266	11.0	11.24	-1.878
5.0	5.31	1.266	11.0	11.44	-2.007
5.0	5.52	1.298	11.5	11.65	-2.201
5.5	5.72	1.072	11.5	11.85	-2.330
5.5	5.92	1.072	12.0	12.05	-2.394
6.0	6.13	1.104	12.0	12.26	-2.491
			12.0	12.46	-2.426

LITTLE RIVER MODEL

PLAN NO. 0 RUN NO. 1

INTERPOLATED DATA FOR CHANNEL NO. 3

TIME (HRS)	DATA
0.	-2.45
0.5	-2.52
1.0	-2.28
1.5	-1.61
2.0	-1.01
2.5	-0.48
3.0	0.27
3.5	1.15
4.0	1.87
4.5	1.75
5.0	1.37
5.5	1.31
6.0	1.08
6.5	1.26
7.0	1.12
7.5	0.65
8.0	0.09
8.5	-0.54
9.0	-1.08
9.5	-1.25
10.0	-1.49
10.5	-1.51
11.0	-1.71
11.5	-2.06
12.0	-2.37
12.5	-2.45

MID-DEPTH

VELOCITY IN FPS

TIME IN HOURS
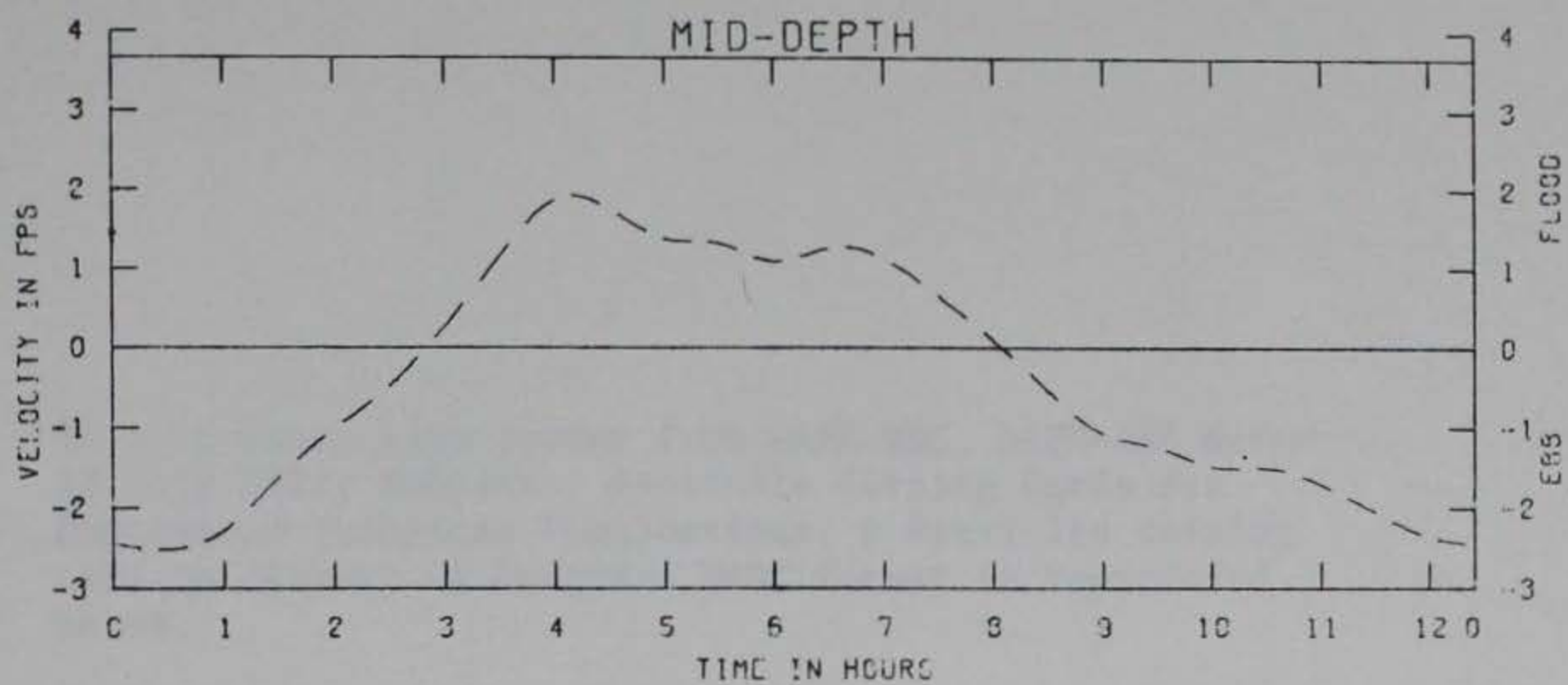
TEST CONDITIONS
TRIAL RUN FOR ANALYSIS PROGRAM DEVELOPMENT

LITTLE RIVER INLET MODEL
VELOCITY DATA ANALYSIS

TRIAL RUN TO CHECK
VELOCITY ANALYSIS

LEGEND

MODEL ─ ─ ─

STATION
03