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Digital-to-Analogue Converter

(Punched Tape to X-Y Plotter)

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Introduction

This digital-to-analogue converter is part of a system that converts punched tape digital data to analogue data in a series of points drawn by an X-Y plotter. The entire system has, in addition, a tape reader and an X-Y plotter.

The conversion is done as follows: The D/A converter commands the reader to begin reading the first point on the tape. This coded information is stored in a shift register which controls the analogue voltage source for each axis. Next, a special code on the tape commands the tape reader to stop. This command also closes relays which connect the appropriate analogue voltages to the X-Y plotter. When the plotter pen has been driven to the equilibrium position, a signal is sent which causes the pen to drop to the paper momentarily. When this occurs the tape reader is commanded to read the next set of coordinates on the tape. This procedure is repeated until all the tape information has been plotted.

This converter has been designed to plot accurately tapes that contain information other than coded numerical coordinates. If they are printed by a Flexowriter, heading information at the beginning and at other points on the tape may appear, as well as decimal points and plus-minus designation. The coordinates will appear in two separate columns.

Operators Manual

Plotting the data stored on punched paper tape requires three pieces of equipment; the digital / analogue converter, the tape reader, and the plotter. The latter two items should be plugged into the converter and all three plugged into 115 volt power receptacles. The following steps should be followed to make a successful plot.

DISCLAIMER

1. Throw the Adjust/Run switch to the Adjust position on the D/A converter. Throw the main power switch (extreme lower right) to ON. Make sure the two toggle switches immediately to the left are also on. The three panel lights should glow. The three meters should read (from left to right) approximately 14 volts, 14 volts and 55 volts. Do not attempt to adjust these voltages. Push the button marked Start.

2. Throw right hand toggle on the tape reader to ON. Leave the other switch down. The panel light should glow.

3. Throw upper right hand switch on plotter to center position. Insert graph paper, adjust to correct position, and throw upper right hand switch to left position. This causes air pump to stabilize paper. Throw Pen Control switch to left position. Push pen switch on right side to Remote.

4. Determine from the printout of the tape to be plotted the plot command signal (usually space, 110101, or carriage return, 110111). Set the toggle switches located in a row on the front panel to correspond - switch down is 1, switch up is 0.

5. If any Plus-Minus signs are coded on the tape, determine where they are located. Use the following information to set the sign switches properly.

	#1	#2
A. To read plus or minus signs in both columns when they appear in both columns	Up	Up
B. To ignore signs in either or both columns, or to read tape with no signs present	Down	Down
C. To read plus or minus signs in first column with no signs appearing in second column	Up	Down
D. To read plus or minus signs in second column with no signs appearing in first column	Down	Up

It should be noted that the D/A converter cannot read signs present in one column and ignore signs appearing in the other column.

6(a) If gain controls have been properly set, proceed to step 8. If gain controls have not been properly set and a scale tape is available, proceed to step 6(b). If gain controls have not been set, and a scale tape is not available, proceed as follows: Insert the curve tape in the reader and switch the ADJ/RUN switch to Run. Set the position and gain controls (see step 7) low enough so that the pen moves just enough to indicate maxima and minima. More gain than this is not necessary. Throw the Left Hand switch to ON, and press Start button if necessary. The tape should run completely through, plotting a curve on the X-Y recorder, and printing actual values on the Flexowriter tape. Use the curve to spot approximate locations of maxima and minima, and obtain actual locations of maxima and minima from the Flexowriter. Rerun the tape to the minima and set as discussed in step 7. Run the tape to the maxima, and set as discussed in step 7. Gains should be set so that curve values may be easily read. When this has been done, proceed to step 8.

6(b) If gain controls have not been properly set, and a scale tape is available, proceed as follows: Insert the scale tape in reader, throw Left Hand switch to ON, and press start button if necessary. The tape will feed until the first plot command is read, whereupon the tape reader will stop. To proceed to the next point, push Start button. When the ADJ/RUN switch is in the ADJ position, the machine reads one point, drives to the equilibrium position and stops. This makes it possible to adjust the gain properly as described in step 7.

7. The gain controls on the D/A converter and the pen and arm parallax controls on the plotter should be adjusted so that a plot is obtained that will be properly centered on the graph paper and utilize the entire span of the paper. The X Gain controls the pen of the plotter and the Y Gain controls the arm. Coordinates in the first column increasing with a plus sign or no sign drive the pen toward the top of the paper. Coordinates in the second column increasing with a plus sign or no sign drive the arm to the left. Full gain is obtained when the knobs are turned to a maximum counter-clockwise position and the dials read 00. In this position full scale on the paper is about 000000 to 010000 in both axes. The gain is proportional to the numbers on the dials. Position the pen with the parallax controls to the spot where the curve should begin. Adjust the gain controls approximately so the maximum values in each column will drive the plotter across the paper. To do this precisely the first time will require that these maximum values be fed into the D/A converter before the curve is plotted and the parallax and gain controls adjusted.

8. When the controls are properly set, insert curve tape in reader, throw the ADJ/RUN switch to the Run side, and push the Start button. The tape should now feed through the reader stopping only to allow the plotter pen to record a dot for each point. If the pen is driven off the paper the tape reader will stop until the pen is positioned on the paper. However, pushing the Start button will advance the tape to the next stop.

9. When the curve is completed turn the left hand switch of the reader to OFF.

10. A semi-automatic mode of operation can be performed. Throw the ADJ/Run switch to Adj and throw the Remote/Local switch on the plotter to Local. Throw

the pen control to the middle position. Alternately pressing the start button and throwing the pen control switch will cause the curve to be plotted.

Tape Format

The following are requirements that must be met in making up perforated paper tapes to be used in the digital-to analogue converter.

1. Plot command signal. This is the symbol punched in the tape that causes the tape reader to stop and causes the two coordinate voltages to be applied to the plotter. Any symbol can be used as a plot command symbol by setting the row of toggle switches on the front panel to correspond to the code of that symbol. However, the symbol used should not be one found in the data to be plotted. Usually a symbol such as space, carriage return or tab is used.

2. Heading (information punched in the tape for identification purposes when it is printed out). Any symbol may appear in heading information with the exception of the plot command symbol. If a heading appears at the beginning of the tape, it should end with a plot command signal.

3. Coordinate Representation. Each number representing a coordinate must have six digits. The most significant digit in the highest numbers in a given axis of a given curve must appear in the first position of the group. If there are not as many as six digits in the row curve data for each number representing a coordinate, zeros should be added. For instance, if the numbers in one axis range from 2 to 222, they should appear on the tape as 00200 and 222000. In the event that plus and minus signs are necessary, they must appear ahead of the number to which they refer. The first coordinate controls the pen, the second, the arm on the plotter. To obtain the maximum accuracy and precision of the system, the range of coordinate numbers should occupy as much of the first place as possible.

4. Table of commonly used symbols found on tapes with curve data:

	CODE							SYMBOL
Channel	7	6	5	4	3	2	1	
	1	0	0	0	0	0	0	0
	0	0	0	0	0	0	1	1
	0	0	0	0	0	1	0	2
	1	0	0	0	0	1	1	3
	0	0	0	0	1	0	0	4
	1	0	0	0	1	0	1	5
	0	0	0	0	1	1	0	6
	1	0	0	0	1	1	1	7
	0	0	0	1	0	0	0	8
	1	0	0	1	0	0	1	9
	0	1	0	1	0	1	0	+
	1	1	0	1	0	1	1	-
	0	1	1	1	0	1	1	Carriage Return
	1	1	1	1	0	1	0	Tab
	1	1	1	0	1	0	1	Space
	1	1	0	1	1	0	1	Decimal Point

Specifications

Input. Any mechanical punched tape reader can be used to drive the converter. It is set up to accept the standard six-line-plus-parity Flexowriter code as read by a Frieden-Commercial Controls, Inc. motorized tape reader. A special format has been evolved.

Output. Two analogue voltages, one for each plotting axis, whose magnitude and polarity are determined by the taped data. At no load the voltage range is 0 to plus or minus about two volts - from zero to 999. Loading does not affect the linearity but does lower the voltage. Output impedance is 100,000 ohms. It is required that the plotter inputs both be electrically isolated. The converter is set up to operate on Electronic Associates, Inc. Variplotter, Model 1100E, modified for use with a 17-9E keyboard unit. A further modification consists of changing the values of four resistors in the reference voltage circuit. Referring to the plotter manual schematic, R25 and R26 were changed from 16 K ohms 0.1% each to 150 K ohms 0.1%. Resistors R23, R24 changed from 11 K ohm 0.1% each to 100 K ohms 0.1%. This change increases the sensitivity of the recorder from 0.10 volt/inch to 0.020 volt/inch.

Accuracy. Three place accuracy is maintained in the converter. In order to allow scaling without degrading resolution, the converter accepts and plots 4 decimal digits for each axis. Up to six digits in each axis can be accepted; however the last two are merely stored.

Theory of Operation

The main element in the digital-to-analogue converter is a shift register, made up of flip-flops, four channels wide and 13 bits long. Referring to schematic IH-50-1-5, it will be noted that the first four channels of the tape reader are connected to the four shift register inputs. The transistor collectors on the

flip-flops which are grounded by the set condition (a hole read in the tape) in bits nine through 13 are connected to the "X" ladder network. The voltage produced between the tap on the ladder and a reference voltage of about -10 volts is a function of the stored number. The same arrangement holds for the collectors in bits four through seven connected to the "Y" ladder. The proper output voltages are not obtained until the shift register is entirely filled.

The shift pulses are generated by a cam operated contact in the tape reader that closes about 8 milliseconds before the holes are read. This closure causes the one-shot multivibrator (13Y) to flip. It is set for 30 milliseconds so that any noise from the contact, which stays closed for 25 milliseconds, will be shunted to ground. The leading edge of the one-shot pulse (positive going) is coupled to the trigger input of the one-shot (14Y) which has a period of about one millisecond. The leading edge of the available negative pulse (pin 9, 14Y) is coupled to one of the OR/inverters on 16Y. If a number to be stored is being read the pulse goes through 16Y and triggers 17Y which in turn emits a positive pulse to the shift pulse buses in the shift register (exclusive of the first bit). The trailing edge of the negative pulse available at pin 4 of 14Y is amplified by two stages in 16 Y and sent to the input flip-flops. Delaying the latter pulses allows the register shift pulse gating to be performed before the gating information has been shifted out.

The rest of the circuit performs the automatic operation based on the status of the first flip-flops in channel one through four (boards 11Y and 12Y) and the flip-flops connected to channels five and six (board 13X). The logic functions will be described in the order that they occur in plotting a tape.

Rejecting Non-numerical Data

The Flexowriter code is arranged so that numbers are represented by holes in the first four channels only. All other symbols (except letters from A to G)

involve holes in either or both channels five and six. Whenever no hole is read in channel five and/or six the negative collectors on board 13X are gated with a negative shift pulse on board 16Y and a shift pulse goes to the register. If a hole is read in five and/or six the gate does not open and no shift pulse is sent to the register.

Reading Plus and Minus Signs

When plus and minus signs are expected in both columns of data, front panel switch #S9 is thrown up and switch #S10 is thrown up. The Flexowriter code for plus is 010101 and for minus 110101, reading with channel one on the left. Except for channel one, the code is the same. The collectors that go negative on the flip-flops when a sign is read are connected to board 15Y along with a negative shift pulse. This board acts as a negative AND gate. It passes a positive going edge to the four shift pulse inputs on board 18X, which is connected as a two-bit shift register. Each bit is connected to polarizing relays K2 and K3 through Indicator Driver 18Y. A sign appearing in the first column is shifted into the register. The sign appearing in the second column is shifted into the first bit of the register and the previous sign is moved into the second bit. If a negative sign is read it energizes the polarizing relay. A positive sign leaves the relay off. Combinations of switches S9 and S10 allow the reading of signs when they appear in only one of the two columns of data.

Start Plot Operation

This operation is started by the occurrence of a positive-going signal at the output of the Or/Inverter board 16X. The inputs of this board are connected to the collectors of the transistors in the input flip-flops. A set of six front panel toggle switches select the side (set or reset) to which each line is connected. Thus the command code character can be selected. A seventh input to the Start

Plot board, which is connected as a seven-input AND gate for negative signals, is a negative-going signal generated by the end of the long one-shot pulse. This allows plenty of time for all the input flip-flops to stabilize. The output of 16Y deenergizes the tape reader clutch through the flip-flop on 17X and the indicator driver 18Y. It remains off until the flip-flop is reset. The same signal closes the output relays K1 and K5 and transfers the hold-off bias on Schmitt trigger 19Y to the unbalance voltage (negative) from the plotter. These relays are driven by 18Y also.

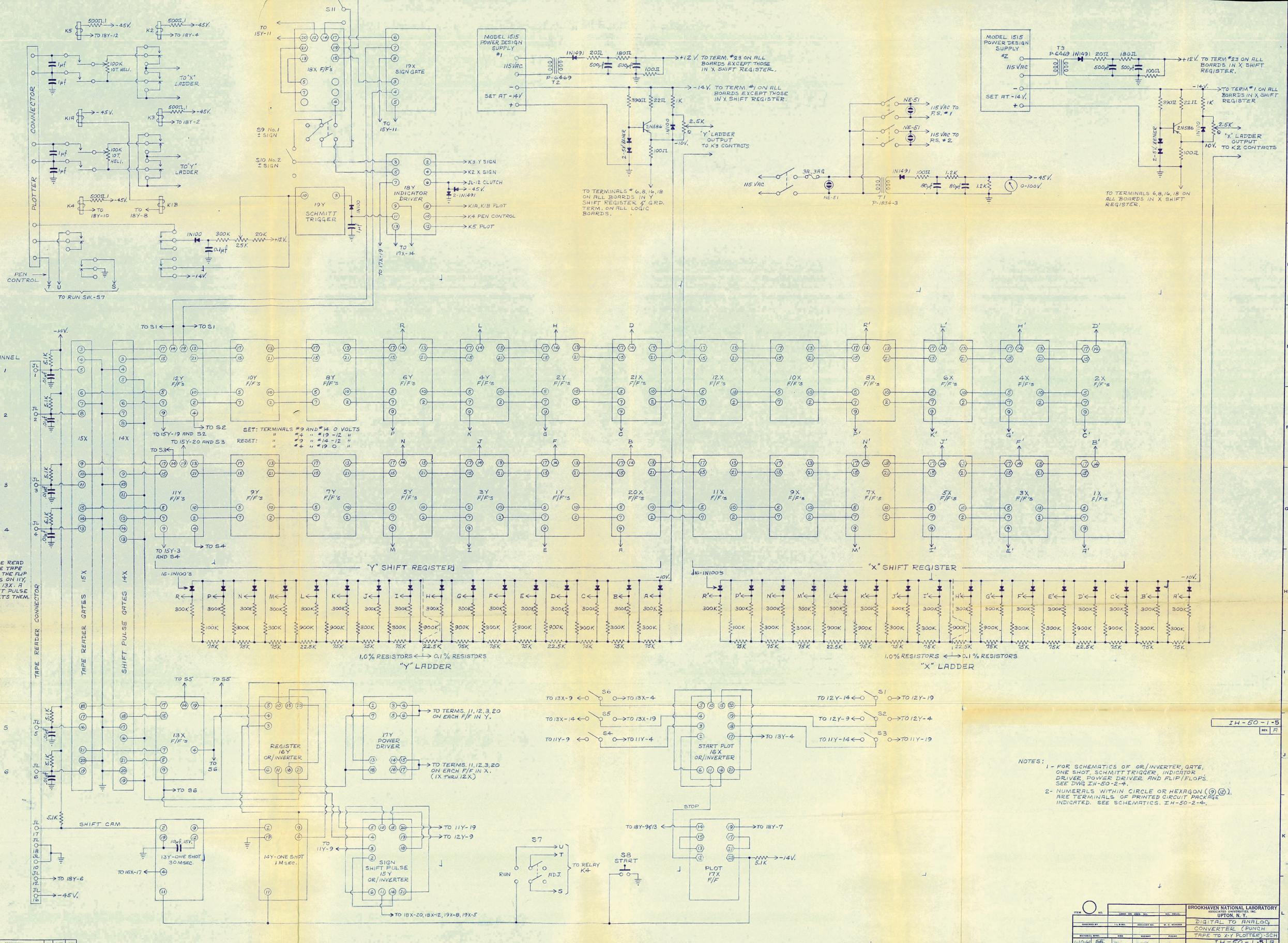
When the plotter has reached equilibrium the negative voltage appearing at terminal #10 on the Schmitt trigger by way of the emitter follower drops to a low value causing the circuit to flip. A negative-going voltage at the output energizes the pen control relay K4. This in turn energizes the pen dropping mechanism in the plotter momentarily and resets the plot flip-flop (board 17X) which in turn opens the output relays K1A and K5 and energizes the tape reader clutch. The next set of coordinates are fed into the shift register.

This operational cycle can be interrupted by throwing S7 to the Adjust position, preventing the closure of K4 from resetting flip-flop 17X. Pushing the front panel push button marked Start causes the cycle to repeat once.

Power Supplies

An unregulated power supply with a metered output provides the nominal -45 volts to operate the relays and the tape reader clutch. The boards are powered by two Power Designs Model 1515 supplies. They are set and damped at about -14 volts. To provide a stable reference voltage to which the transistor switches in the ladder network can be clamped, an emitter follower type of regulator using two five volt zener diodes for reference is used for each ladder. To compensate for the forward voltage drop across the clamp diodes in the ladder network, the reference voltage for one side of the output is made slightly more negative than the

-10 volt supply. This is done by connecting the reference side of the output to the wiper connected across a diode conducting in the forward direction. This adjustment is made by having a tape with alternate plus and minus zeroes run through the reader. At the proper setting the pen will record the same point for both.



IH-60-1-5 REV. A

NOTES:
1 - FOR SCHEMATICS OF OR/INVERTER, GATE, ONE SHOT, SCHMITT TRIGGER, INDICATOR DRIVER, POWER DRIVER AND FLIP/FLOPS. SEE DWG IH-50-2-4.
2- NUMERALS WITHIN CIRCLE OR HEXAGON ((9) (12)), ARE TERMINALS OF PRINTED CIRCUIT PACKAGE INDICATED. SEE SCHEMATICS. IH-50-2-4.

REV.	DESCRIPTION	BY	DATE	CKR

FORM NO. 161

ITEM NO.		ISSUED ON DWG. NO.		MOD. RECD.
CHECKED BY		I. L. B NO.	ACCOUNT NO.	W. O. NUMBER
MATERIAL SPEC.		SIZE	WEIGHT	FINISH
DATE 1-10-61	DRAWN BY EA	CHECKED BY	APPROVED BY	SCALE

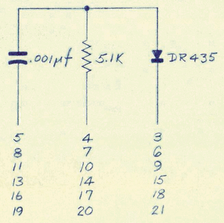
BROOKHAVEN NATIONAL LABORATORY
ASSOCIATED UNIVERSITIES, INC.
UPTON, N. Y.

DIGITAL TO ANALOG CONVERTER (PUNCH TAPE TO X-Y PLOTTER)-SCH

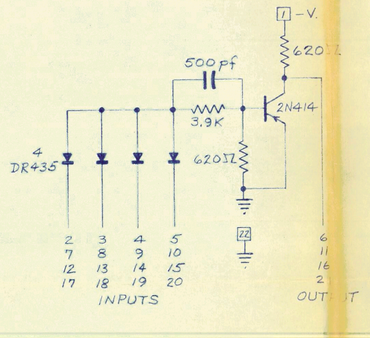
IH-60-1-5 A

DRAWING NUMBER REV.

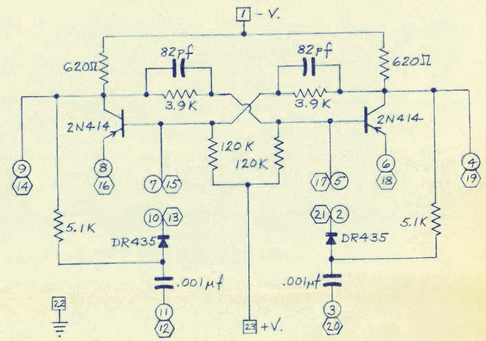
TOLERANCE — DECIMAL ± .005, FRACTIONAL ± 1/64, ANGULAR ± 30'
REFERENCE —
USED ON DWG.



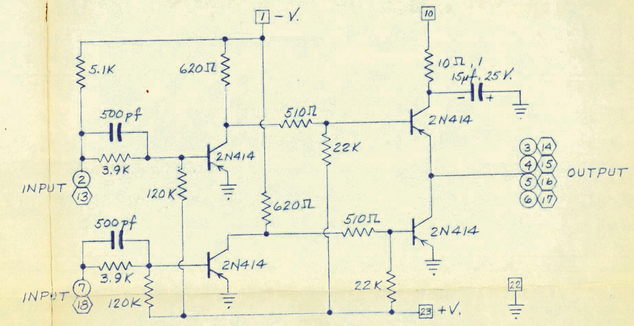
GATE
6 CIRCUITS / PACKAGE



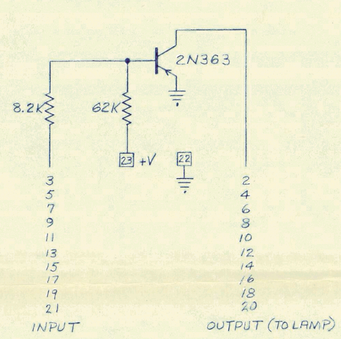
OR INVERTER
4 CIRCUITS / PACKAGE



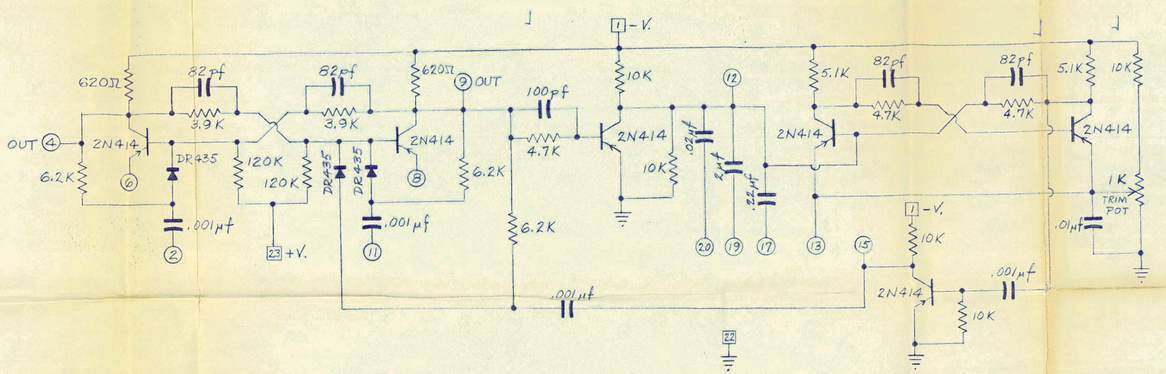
FLIP / FLOP
2 CIRCUITS / PACKAGE



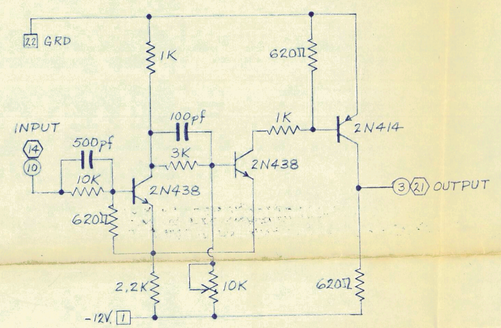
POWER DRIVER
2 CIRCUITS / PACKAGE



INDICATOR
10 CIRCUITS / PACKAGE



ONE-SHOT
1 CIRCUIT / PACKAGE



SCHMITT TRIGGER
2 CIRCUITS / PACKAGE

IH-50-2-4-A

NOTE:
1- ABOVE CIRCUIT PACKAGES MANUFACTURED BY ACF INDUSTRIES INC.
2- ○ DENOTES CIRCUIT A } IN 2 CIRCUIT
⬡ " " B } PACKAGES ONLY.
□ " COMMON TERMINAL

ACF
Circuits

MATERIAL SPEC.		SIZE	WEIGHT	FINISH
1-13-61	[illegible]	[illegible]	[illegible]	
DATE	DRAWN BY	CHECKED BY	APPROVED BY	SCALE

BROOKHAVEN NATIONAL LABORATORY
ASSOCIATED UNIVERSITIES, INC.
UPTON, N. Y.
DIGITAL TO ANALOG CONVERTER (PUNCH TAPE TO X-Y PLOTTER)-SCH
IH-50-2-4 A
DRAWING NUMBER REV.

FORM NO. 160