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A TAPE-TO-PLOTTER CONVERTER

By
R. A. Semmler
J. F. Tribby

September 1964

Laboratories for Applied Sciences
University of Chicago
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COO-712-88

INSTRUMENTS
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A TAPE-TO-PLOTTER CONVERTER

R. A. Semmler
J. F. Tribby

Report written by R. A. Semmler

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The University of Chicago
Laboratories for Applied Sciences
Chicago, Illinois 60637

FOREWORD

This report describes a tape-to-plotter converter designed and constructed to facilitate experimental work with a multichannel analyzer at the Laboratories for Applied Sciences, The University of Chicago, under Task V of AEC Contract AT(11-1)-712. This supplemental report is separated from the final report for Task V to permit a more appropriate distribution category.

The assistance of Mr. R. Pernic during the construction of the converter is acknowledged.

Respectfully submitted,

R. A. Semmler
Staff Member

J. F. Tribby
Staff Member

Approved:

Jay Burns
Director

ABSTRACT

A tape-to-plotter converter for use with punched paper tapes prepared by a Nuclear Data Model 130A multichannel analyzer is described. The converter reads 3 BCD digits from the tape and generates both linear and logarithmic analogue voltages for plotting. Relays are used for the 12 bit memory and a stepping switch is used to accomplish much of the pulse routing and logic. Circuit diagrams are included.

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1. INTRODUCTION

Anyone using a multichannel analyzer soon finds that manual plotting of data can become prohibitively time consuming and expensive. Some sort of automatic plotting equipment is essential. Although the analyzer (Nuclear Data Model 130A) used for work under this contract will generate linear and logarithmic plotting signals for use with an X-Y or strip chart recorder, only 2 digits, out of the 6 digits stored in each channel, are used to generate the plotting voltage. Also, in the linear display mode, only 2 decades of data can be displayed as a continuous curve.

In order to improve the plotting accuracy and to increase the range of the linear display, a tape-to-plotter converter has been designed and constructed. This converter reads 3 digits of data directly from paper tapes prepared by a Nuclear Data analyzer and generates both linear and logarithmic plotting signals.

2. GENERAL DESCRIPTION

Circuits for tape-to-plotter converters have been previously reported^{1, 2, 3} and are available commercially as a stock⁴ or custom⁵ item. These are generally all-electronic units and cost

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¹ J. A. Ladd and A. J. S. Davidson, "A Data Plotting System for use with Punched Paper Tape. Part I, General Description," CREL-1009 (Part I) (May 1962).

² J. A. Ladd, "A Data Plotting System for use with Punched Paper Tape. Part 2, Detailed Description," CREL-1009 (Part 2) (Sept. 1962).

³ G. N. Wall, "Digital-to-Analogue Converter (Punched Tape to X-Y Plotter)," BNL-6440 (Jan. 1962).

⁴ Dymec, 395 Page Mill Road, Palo Alto, California.

⁵ Microdyne, Inc., 411 N. Wolf Road, Wheeling, Illinois

approximately \$5000. After considering the available units, it was decided that a cheaper converter could be constructed using relays for storage and a stepping switch to perform much of the pulse routing. The final circuit is partly electronic and partly electromechanical. The speed is somewhat less than an all-electronic converter but so is the cost and the difference in speed is not great. The tape reader and the plotter are both electromechanical devices that will limit the plotting speed regardless of the capabilities of the converter. Table 1 gives a brief comparison of the plotting speed for an all-electronic and an electromechanical converter.

Table 1

Comparison of plotting speed using an electronic and an electromechanical converter.

<u>Converter</u>	<u>Read Speed</u>	<u>Read Time per Channel</u>	<u>Plotting Time</u>	<u>Total Time and Plotting Rate</u>
Electronic	60 c/s	7 cycles at 60 c/s = 117 ms	200 ms (servos on between points)	317 ms, 3.2 pt/s
Electronic	60 c/s	7 cycles at 60 c/s = 117 ms	400 ms (servos muted between points)	517 ms, 1.9 pt/s
Electro- mechanical	35 c/s	11 cycles at 35 c/s = 314 ms	200 ms (servos on between points)	514 ms, 1.9 pt/s
Electro- mechanical	35 c/s	11 cycles at 35 c/s = 314 ms	400 ms (servos muted between points)	714 ms, 1.4 pt/s

Even using a larger memory to permit reading while plotting will only increase the plotting rate to 5 points per second - the maximum plotter capability.

The converter is used in conjunction with a tape reader (Tally Model 424), X-Y plotter (Electro-Instruments Model 500), null detector (Electro Instruments Model 472), and a typewriter-to-tape

converter (Tally Model 1502) as shown in Fig. 1. The Model 1502 is used only as a convenient source of drive pulses and could be replaced by an appropriate pulse generator.

The converter is specifically designed to read tapes prepared by a Nuclear Data analyzer. These tapes contain only the counts per channel and do not contain the channel number. The general tape format is shown in Fig. 2. The counts in each channel are punched on the tape as a 6 digit number using binary coded decimals (BCD). There is a single space between the 6 digit numbers and a punch in the 8th tape level for each digit location. In the linear mode of operation, the converter will read any 3 of the 6 digits in each channel and convert this number to an analogue signal. In the logarithmic mode of operation, the first three significant digits are read regardless of location. The analogue signal generated by these 3 digits goes to a logarithmic attenuator to provide a mantissa which is then added to a separate voltage proportional to the characteristic. The sum is proportional to the logarithm of the number on the tape. With a method such as this, the logarithmic converter has to be accurate only over 1 decade, say 100 to 999, even though the input range is 6 decades.

Front panel controls are provided for the selection of the range and mode of operation as well as for such operations as clearing the memory, manually generating start pulses for single point plotting, manually generating seek-plot signals, generating calibration voltages on both the X and Y axes, advancing the X-axis counter without advancing the tape, skipping points which are not to be plotted, and limiting the Y-axis voltage to prevent excessive attempts to plot off-scale values.

Tests using specially prepared linear and exponential tapes indicate that the overall system plotting error is less than 1.0% of full

Fig. 1 Block diagram of converter and auxiliary components.

Fig. 2 Format of punched paper tape prepared by a Nuclear Data 130A Analyzer.

scale deflection. Plotting speeds (with servos muted between points) in the linear mode of operation are typically 1.2 points per second; in the logarithmic mode, 1.0 to 1.2 points per second depending on the number of significant digits. The X-axis output is 0.0 to + 280 mv; the Y-axis output is 0.0 to + 115 mv (linear) and + 1.0 to + 2.2 v (log).

A brief description of the operation in the linear mode is as follows (See Fig. 3): The "clear" button is pressed to ensure that the buffer is cleared, that the pulse generator is off and that the stepping switch is in the home position. Tape is inserted into the reader anywhere on the leader. Both X and Y calibration switches are then put in the "run" position. A "plot-complete" pulse from the null detector will initially start the 4.5 ms drive pulse generator. The drive pulses are routed by the 8th channel tape contact to the tape drive circuit only. These pulses advance the tape until the first block of digits occurs. As soon as a hole occurs in the 8th tape level indicating a digit, the pulses are routed to deck A of the stepping switch. Deck A initially sends the pulses only to the stepping motor leaving the reader positioned over the first digit. When the stepping switch reaches position 3, interrogation of the tape begins. All 6 digits will be interrogated but only 3 are connected to the buffer by the range selection switch. The 3 selected digits (12 binary bits) are stored in a 12 relay buffer. A current proportional to the stored number is generated by a weighted resistor network connected to the relay contacts. When the reader reaches the blank space between numbers, a "no-digit" condition is sensed by the 8th tape level switch just as when advancing through the leader. However, the stepping switch is now off of the home position so that the off-normal switch is closed. This routes the "no-digit" pulse not only to the tape advance circuit but also to circuits which stop the pulse generator, plot the generated voltage, and set relay K13. The pulse generator remains stopped until the plotting operation

BLOCK DIAGRAM OF MAJOR COMPONENTS IN
3-DIGIT TAPE-TO-PLOTTER CONVERTER WITH
LOG AND LINEAR OUTPUTS.

Fig. 3 Block diagram of major components in tape-to-plotter converter.

is complete. A plot-complete signal generated by the null detector restarts the pulse generator. Relay K13 routes the pulses to the stepping motor until the stepping switch is back in the home position. When the stepping switch reaches the home position, the buffer is cleared, K13 is reset (by an off-normal switch which is not indicated on Fig. 3) and the same cycle is begun for the second point. The above steps are tabulated in Table 2.

The sequence of operations in logarithmic operation is very similar. The basic difference is that when interrogation of the tape begins (stepping switch position 3), there is no connection to the stepper motor except on the output side of the reader contacts. The stepping switch thus remains in position 3 until a significant digit is detected on the tape. Once the first digit is detected, the stepping switch continues to move with each pulse as in linear operation. The actual number of steps made by the stepping switch is equal to the total number of significant digits. The position of the stepping switch when the stop-and-plot signal is generated is detected by deck G and is used to generate a signal which gives the characteristic of the desired logarithm. The mantissa is generated from the current out of the buffer by a logarithmic attenuator. The characteristic and mantissa voltages are then added to give a voltage proportional to the logarithm of the number on the tape. The above steps for log operation are tabulated in Table 3.

X-axis voltages proportional to the channel number are generated by counting the number of complete cycles of the stepping switch. Electrical contacts on the counter are connected to weighted resistors to generate a current proportional to the indicated count.

Table 2. Sequence of steps during linear operation. The cycle begins with 2 leader spaces and continues through 2 channels of data. Four digit numbers are assumed to be stored in the first 2 data channels and full scale is set at 10,000.

Pulse No.	Via	Tape advance	Step switch advance	Seek Plot Stop Oscill. Set K13	Step switch to pin No.	Read from tape	Initial and final tape position
1	no hole	x					L-L
2	"	x					L-1
3	hole, K13 reset		x		1		1-1
4	"		x		2		1-1
5	"		x		3		1-1
6	"	x	x		4	0	1-2
7	"	x	x		5	0	2-3
8	"	x	x		6	1st digit (to K1-K4)	3-4
9	"	x	x		7	2nd digit (to K5-K8)	4-5
10	"	x	x		8	3rd digit (to K9-K12)	5-6
11	"	x	x		9	4th digit (not stored)	6-B
12	no hole, off normal sw.	x		x			B-1

Point is plotted and PLOT-COMPLETE pulse restarts oscillator.

13	hole, K13 set		x		10		1-1
14	hole, K13 reset		x		1		1-1
15	"		x		2		1-1
16	"		x		3		1-1
17	"	x	x		4	0	1-2
18	"	x	x		5	0	2-3
19	"	x	x		6	1st digit (to K1-K4)	3-4
20	"	x	x		7	2nd digit (to K5-K8)	4-5
21	"	x	x		8	3rd digit (to K9-K12)	5-6
22	"	x	x		9	4th digit (not stored)	6-B
23	"	x		x			B-1

Point is plotted and PLOT-COMPLETE pulse restarts oscillator.

Table 3. Sequence of steps during logarithmic operation. The cycle begins with 2 leader spaces and continues through 2 channels of data. Four digit numbers are assumed to be stored in the first 2 data channels.

Pulse No.	Via	Tape advance	Step switch advance	Seek plot Stop Oscill. Set K13	Step switch to pin No.	Read from tape	Initial and final tape position
1	no hole	x					L-L
2	"	x					L-1
3	hole, K13 reset		x		1		1-1
4	"		x		2		1-1
5	"		x		3		1-1
6	"	x				0 (to K1-K4)	1-2
7	"	x				0 (to K1-K4)	2-3
8	"	x	x		4	1st digit (to K1-K4)	3-4
9	"	x	x		5	2nd digit (to K5-K8)	4-5
10	"	x	x		6	3rd digit (to K9-K12)	5-6
11	"	x	x		7	4th digit (not stored)	6-B
12	no hole, off normal sw.	x		x			B-1

Point is plotted and PLOT-COMPLETE pulse restarts oscillator.

13	hole, K13 set		x		8		1-1
14	"		x		9		1-1
15	"		x		10		1-1
16	hole, K13 reset		x		1		1-1
17	"		x		2		1-1
18	"		x		3		1-1
19	"	x				0 (to K1-K4)	1-2
20	"	x				0 (to K1-K4)	2-3
21	"	x	x		4	1st digit (to K1-K4)	3-4
22	"	x	x		5	2nd digit (to K5-K8)	4-5
23	"	x	x		6	3rd digit (to K9-K12)	5-6
24	"	x	x		7	4th digit (not stored)	6-B
25	no hole, off normal sw.	x		x			B-1

Point is plotted and PLOT-COMPLETE pulse restarts oscillator.

3. CIRCUIT DESCRIPTION

3.1 Stepping Switch Characteristics

Detailed circuit drawings are shown in Figs. 4-9. Before discussing the circuit in more detail, some of the characteristics of a stepping switch are described.

A stepping switch is basically a motor (solenoid) driven rotary switch. The switch rotates continuously in one direction and does not "fly-back" to the home position. The switch used here is a 7 pole, 10 position switch (see parts list). The switch does not begin to rotate when voltage is applied to the coil, rather, actuating the coil moves an armature which compresses a drive spring. The spring is not released until voltage is removed from the coil. This provides sufficient time lag to send a pulse through the switch contacts even though the same pulse activates the coil.

In addition to the switching contacts there are 2 kinds of auxiliary switches which are an integral part of the stepping switch unit: 1) interrupter switches which open (or close) for each step, 2) off-normal switches which open (or close) as the switch reaches or leaves the home position. The interrupter switch is connected to the armature so that the interrupter contacts are opened (or closed) as soon as the spring is compressed.

The switch will step when pulsed externally or will self-step using a "door bell" circuit. Self-interrupted operation is used here to ensure that the switch is in the home position at the beginning of a plot. The switch will automatically return to the home position if voltage is applied to the coil via the interrupter contacts and an off-normal switch in series. The interrupter contacts provide

Fig. 5 Pulse routing and storage circuit.

* = 0.1%, 0.4W
OTHERS 1%, 0.25 W

POLES WITHIN
DASHED LINES
ARE GANGED

Fig. 6 Y-axis circuit.

* = 0.1%, 0.4W
OTHERS = 1%, 0.25W

Fig. 7 X-axis circuit.

Fig. 8 Subassemblies in control circuit.

Fig. 9 Subassemblies in Y-axis circuit.

the "door bell" action by breaking the supply voltage each time the drive spring is compressed. The action continues until the supply voltage is permanently broken in the home position by the off-normal switch. In self-interrupted operation the stepping rate is about 60 steps per second. Voltage is supplied to the coil for about 12 ms and is interrupted for about 4 ms in each step. It is important to realize that in self-interrupted operation the field around the solenoid does not completely collapse between pulses and the voltage is reapplied before the switch has come to rest on the next contact (except, of course, for the first step which is slower than the rest). It is for this reason that the switch can be externally pulsed at only 35 steps per second unless some means of biasing or overdriving the coil is provided. When pulsed externally (with no bias and no overvoltage) the stepping switch used in this converter requires a pulse about 18 ms long. The switch leaves the original contact 5 ms after the pulse terminates, bridges the gap between contacts (if non-shorting) in 1 ms and comes to rest on the new contact in another 4 ms. The total time for one step is thus 28 ms or approximately 35 steps per second.

3.2 Pulse generator

A 50v, 4.5 ms pulse is required to properly drive a Tally 424 reader. The same pulse is used to interrogate the tape contact switches and advance the tape since the tape contact switches do not actually change until 7 ms after the pulse arrives. Properly shaped pulses were already available from a Tally Model 1502 so this unit was used as a pulse generator. The generator is turned off by applying a 50v bias to the oscillator in the pulse generator.

3.3 Tape contacts

A form C switch is provided for all reader contacts in the Tally 424. The 50v, 4.5 ms pulse is applied to the common pole of the 8th tape level to sense whether there is a digit stored in that location or not. The pulse subsequently appears on J1 at either pin A (digit) or pin D (no digit). One can not look at the digital data on the tape to detect the beginning of a block of numbers since nothing is punched for the digit "0". A "0" appears the same as leader except for the punch in the 8th tape level. When leader is positioned in the tape reader, pulses from pin D (no hole) go only through an OR gate back to the tape drive unit since the 1st off-normal switch (O.N. 1) is open.

3.4 Stepping switch

When the first block of numbers finally reaches the reader, the pulses begin coming out of pin A (hole). These pulses go to the pole of deck A in the stepping switch which determines much of the logic of the control circuit. The first pulse into deck A is routed out through pin 10 to the pulse stretcher and subsequently to the stepping switch motor (coil M). The reader remains positioned over the first digit in the block of numbers. The 4.5 ms pulse from the pulse generator is too short to drive the stepping switch directly. The pulse stretcher itself is described in the next paragraph. As the stepping switch moves from position 10 (home) to position 1, all off-normal switches close. The closure of O.N. 1 provides a path for the stop-and-plot signal which must exist when the blank space between channels is reached but not when the blank space on the leader is sensed. The closure of O.N. 2 is not involved in the control of the plotting cycle and is used only to bring the stepping switch to the home position at the beginning of the plot. The closure of O.N. 3 supplies

50v to the relays in the 12 bit buffer so that digital data can be stored as required. O.N. 3 also supplies 50v to the solenoid in the X-axis counter. The next two pulses drive the stepping switch to position 3, still leaving the reader positioned over the first digit.

In the linear mode the next pulse is routed out through pin 3 to the tape drive solenoid, the common pole of reader contacts "1", "2", "4", "8", and the stepping switch motor. If a non zero digit is detected on the tape, the pulses will be returned to the converter on pins h, c, Y, U of J1. These 4 lines from the reader contacts are connected to the poles of decks B, C, D, and E for routing to the buffer. Pulses corresponding to the 1st digit are thus delivered to position 3 of decks B through E. The next pulse will arrive with the stepping switch in position 4 and again the pulse goes to the tape drive, reader contacts "1", "2", "4", "8", and the stepping switch motor. Pulses corresponding to the second digit are delivered to position 4 of decks B through E. The subsequent digits of the tape are interrogated in a similar manner and the resulting pulses are delivered in sequence to positions 5, 6, 7, and 8 of decks B through E. The actual digits which reach the buffer will depend on the position of the range switch. The range switch connects any 3 pins of decks B through E to relays in the buffer. After all 6 digits have been interrogated, the next pulse will be delivered out of pin D (8th level, no hole) because of the blank space between channels. This pulse will advance the tape just as if there were leader in the reader, but now, in addition, O.N. 1 is closed. This permits the pulse to reach the oscillator control relay K16, and the pick coil of relay K13. Relay K16 turns the oscillator off. Relay K13 initiates a seek plot signal, removes the 50v being supplied to the solenoid in the X-axis counter, and establishes a route with pole 4 which directs any subsequent pulses directly to the stepping

switch drive circuits. After the point is plotted and a plot complete pulse from the null detector restarts the oscillator, pulses appear at pin A since the reader is positioned over the 1st digit in the next block of numbers. These pulses are routed by pole 4 of K13 directly to the stepping switch drive circuit. This is necessary to bring the stepping switch back to the home position before starting another cycle. As the stepping switch reaches position 10, all off-normal switches reopen. This clears the memory and resets relay K13. The cycle is then repeated for the second block of 6 digits.

In log operation, the "log-lin" switch opens the line to the stepping switch motor from pin 3 of deck A of the stepping switch. As the tape is interrogated and advanced, the stepping switch will remain in position 3 until a non zero digit is detected. Pulses from the first non zero digit will drive the stepping switch motor via the diode OR gate connected to the output of the reader contacts. These pulses are also routed to the buffer. In log operation, the buffer relays are always connected to pins 3, 4, and 5 of the stepping switch so that the first three significant digits, regardless of location within the block of 6 digits, will be stored.

Decks F and G of the stepping switch are used in log operation to generate an artificial 1.00 whenever 000000 appears on the tape and to count the number of significant digits. These decks are described later.

3.5 Pulse stretcher

Relay K15 is a mercury wetted relay that stretches the 4.5 ms tape drive pulse out to about 15-20 ms to drive the stepping switch. Power is supplied to the stepping switch coil through a

normally open contact of relay K15 and the interrupter contacts on the stepping switch. The 4.5 ms pulse closes relay K15 which supplies power not only to the stepping switch coil but also to the relay coil itself. The relay thus locks itself closed and remains closed as long as required to properly drive the stepping switch. The relay will not open until the interrupter contact reopens indicating that the drive spring is properly compressed. A silicon controlled rectifier could also be used for this purpose since an interrupted current will also turn such a rectifier off. The time required for a single step would also be reduced by about 1.5 ms, the operating time of the relay. The dashed resistor (300 to 1K, 10w) can be used to supply a bias to the stepper motor if desired.

3.6 Channel counter S7

The X-axis counter is a mechanical counter with electrical readout. The counter is partly advanced when power is supplied to the counter solenoid as the stepping switch leaves the home position. The count is completed when the power is interrupted by pole 2 of relay K13. This pole is opened at the same time a stop-and-plot situation occurs. This counter can also be triggered manually by switch S10 which applies 50v directly to the solenoid. The counter is cleared manually by a push button on the front of the counter. A 1-shot similar to S9 except designed for 50v could also be used to drive the X-axis counter.

3.7 Range switch S8

The range switch is a standard 12 pole, 4 position switch. The only purpose is to connect the 12 relays in the buffer to the appropriate digital output of the stepping switch. The relays can be connected to pins 3-4-5, 4-5-6, 5-6-7, or 6-7-8. In log operation, the relays are always connected to pins 3-4-5.

3.8 Buffer

The 12 relays in the buffer are 4 pole double throw wire contact relays which operate in 2.5 ms. The relays are closed using the "pick" coils by the 4.5 ms pulses from the reader switches. The relays are held closed by their own contacts using pole 1. Current limiting resistors are used in series with the "hold" coils to limit the power dissipation to 1.4 watts. The relays will store the 12 bits of information until the holding current is broken by an off-normal switch (O.N.3) on the stepping switch. Poles 2 and 3 are not used here but could be used for indicator lights if desired.

3.9 Oscillator control

Relay K16 is a bistable mercury wetted relay that provides a 50v bias to the oscillator in the pulse generator. The relay is opened (oscillator on) by the 20v, 30 ms pulse from the start 1-shot. The relay is closed (oscillator off) by a 50v, 4.5 ms stop-and-plot pulse, by the 50v bias applied through the clear switch, or by the 6v bias applied from the end-of-plot circuit.

3.10 Start 1-Shot

This one shot is a prepackaged pushbutton operated pulse generator that is modified to permit electrical triggering as well. The pulse input from the null detector (18v, 2 μ s) is connected to the base of the first (normally on) transistor as shown schematically in the figure. The output is a 20v, 30 ms pulse. The pushbutton can be used to plot single points by disconnecting the plug into P2 (plot-complete input).

3. 11 Seek Plot 1-Shot

S13 is also a pushbutton operated pulse generator that has been slightly modified. Pole 3 of relay K13 is connected in parallel with the pushbutton so that seek-plot pulses are generated by either the closure of K13 (stop-and-plot) or by a front panel pushbutton. The output to the null detector is a 15v, 2 μ s pulse.

3. 12 Deck F of stepping switch S14

Deck F is used to route the +43 reference voltages in logarithmic operation. When the stepping switch stops in position 3, which corresponds to 000000 on the tape, the reference voltage is routed to a 400K resistor to generate an artificial output equivalent to the digits 100. These digits together with the characteristic of 0 generated by deck G produce a voltage proportional to 1.00 whenever 000000 appears on the tape in logarithmic operation.

Deck G generates the characteristic in logarithmic operation. The stepping switch stops in positions 3, 4, 5, etc. when there are respectively 0, 1, 2, etc. significant digits on the tape. The resistors on deck G are inversely weighted as 1, 2, 3, 4, 5, and thus generate a current proportional to the characteristic.

3. 13 Logarithmic range switch S3

Switch S3 is used in logarithmic operation to prevent wear and tear on the plotter when there are numerous off-scale values on the tape. This switch can be set at 10^4 , 10^5 , 10^6 and will automatically generate a constant voltage corresponding to full scale whenever a number greater than full scale appears on the tape.

3.14 Y-axis DAC

Precision resistors with values appropriate to a BCD code are used to generate a current proportional to the number stored in the buffer. This current produces a plotting voltage directly in linear operation and after passing through a log diode produces the mantissa in logarithmic operation.

3.15 Logarithmic diodes

In logarithmic operation, the output of the Y-axis DAC goes to ground through 2 diodes in the forward direction. The voltage across the diodes is proportional to the logarithm of the current and is thus proportional to the mantissa of the number on the tape. One must keep in mind that in logarithmic operation all numbers such as 000001, 000010, 000100, etc. will appear as 100 in the buffer since no storage occurs until the first non-zero digit appears. The buffer will thus contain only numbers between 100 and 999 and the logarithmic diodes need be accurate only over one decade. The shunt resistor across the diodes is used to increase the accuracy of the logarithmic response of the diodes.

3.16 Sum amplifier

This amplifier is the same as that used by Nuclear Data in our multichannel analyzer^{*} to add voltages in their 2-digit converter.

3.17 Log-Lin switch S2

Besides providing the obvious function of switching the Y-output to either the sum amplifier or the Y-axis DAC, this switch also inserts a 400K resistor (which is equivalent to a value of 1.00)

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* Nuclear Data Model 130A Multichannel Analyzer, Nuclear Data Inc., Box 451, Palatine, Illinois.

into the logarithmic "zero" level calibration circuit on the Y-axis, and determines the route of the pulse from pin 3 of deck A in the stepping switch.

3.18 X-axis counter S7

This counter is basically an ordinary mechanical counter which gives a visual indication of the channel number while plotting. In addition, electrical contacts on each digit are connected to appropriately weighted resistors to generate a current proportional to the indicated count.

3.19 End-of-plot selector switch S6

Each of the 3 poles of this "Digi-switch" are independently moveable and are used to set the desired end point of the plot. Only sufficient pins were wired to provide connections at channel number 064, 128, 256, or 512 but any numbers could be connected. These connections are used to sense the presence of a voltage in the resistor network during plotting operations and are used to supply a voltage to the same resistors for X-axis calibration. The number of points available for calibration will again depend on the particular pins which have been wired.

3.20 X-axis calibration switch S5

When plotting, this switch connects the +43 reference voltage to the X-axis resistor network and connects the end-of-plot selector to an AND gate. When calibrating, the reference voltage is either isolated to generate a zero level or is applied to the resistor network via the end-of-plot selector to generate a voltage corresponding to the full scale on the X-axis.

3.21 End-of-plot AND gate

This is an ordinary diode logic AND gate which rises to

about +12 volts when all digits of the X-axis counter and the end-of-plot selector switch match.

3.22 End-of-plot driver

The output of this power driver is approximately +6.5 volts when turned on. This is sufficient to drive the bistable relay K16 to the off condition and keep it in the off condition even if a start signal is applied to the start coil of this relay.

3.23 Y-axis calibration switch S4

In linear operation, this switch generates calibration points at the zero level and at full scale. In logarithmic operation, this switch generates calibration points at the zero level (= 1.00) and at each decade line up to full scale.

4. CONSTRUCTION COMMENTS

The front panel layout diagram used in the construction is shown in Fig. 10. The wiring is not complicated but is tedious.

IBM terminal boards were used to mount the resistors and diodes in the buffer circuit. These boards use a tapered pin connector. It should be noted that tapered pins cannot be inserted into the same hole from both the front and back sides of this terminal board. Sometimes a tight connection will be obtained but sometimes the second pin will knock the first pin loose. Adjacent holes are provided and must be used. The special taper pins and crimper specified by IBM were not used. A cheaper standard pin and crimper (listed in the parts list) appeared to work quite well. Preassembled IBM jumpers were used for much of the construction in the buffer. Some of these would fit a standard installation tool while others would not. Those that would not fit were pushed into place using an "extraction tool".

Fig. 10 Layout drawing, front panel.

The seek-plot 1-shot and pushbutton were actually purchased as an integral unit. Since the interconnecting wiring must be broken to insert leads to pole 3 of K13, they should be purchased separately. The leads of the integral unit are not accessible.

5. RESULTS

Photographs of the assembled converter are shown in Figs. 11-14.

Special linear and exponential tapes were prepared to check the accuracy of the converter operation. The numerical data on these tapes is tabulated in Tables 4-5. Table 4 is an exponential function covering 6 decades in 256 channels. Table 5 is a linear function covering 6 decades in 256 channels. The values for Table 4 was computed to 4 figures and rounded to 3 figures. In the logarithmic mode of operation, the function in Table 4 should be plotted as a straight line.

Figures 15 and 16 are plots prepared by the converter from the data in Tables 4 and 5. Figures 17 and 18 are a comparison of the same data plotted by the Nuclear Data analyzer (2 digit conversion) and the tape-to-plotter converter (3 digit conversion). The first 128 channels of data were prepared by skipping alternate groups of 5 points from a linear curve. The last 128 channels is composed of an arbitrary set of peaks with the base line at 40 and 500. These figures indicate maximum rather than typical differences between a 2 digit and a 3 digit conversion. The additional detail provided by the third digit is obvious in the figures.

Table 4

Exponential function covering 6 decades in 256 channels

0	000000	947000	898000	850000	806000	763000	723000	685000
8	649000	615000	583000	552000	523000	496000	470000	445000
16	421000	399000	378000	358000	340000	322000	305000	289000
24	274000	259000	246000	233000	220000	209000	198000	187000
32	178000	168000	159000	151000	143000	136000	128000	122000
40	115000	109000	104000	098100	092900	088000	083400	079000
48	074800	070900	067200	063700	060300	057100	054100	051300
56	048600	046100	043600	041300	039200	037100	035200	033300
64	031600	029900	028300	026800	025400	024100	022800	021600
72	020500	019400	018400	017400	016500	015600	014800	014000
80	013300	012600	011900	011300	010700	010200	009620	009120
88	008640	008180	007750	007340	006960	006590	006240	005920
96	005610	005310	005030	004770	004520	004280	004050	003840
104	003640	003450	003270	003090	002930	002780	002630	002490
112	002360	002240	002120	002010	001900	001800	001710	001620
120	001530	001450	001380	001300	001240	001170	001110	001050
128	000996	000944	000894	000847	000802	000760	000720	000682
136	000646	000613	000580	000550	000521	000494	000468	000443
144	000420	000398	000377	000357	000338	000320	000304	000288
152	000272	000258	000245	000232	000220	000208	000197	000187
160	000177	000168	000159	000150	000143	000135	000128	000121
168	000115	000109	000103	000098	000093	000088	000083	000079
176	000075	000071	000067	000063	000060	000057	000054	000051
184	000048	000046	000043	000041	000039	000037	000035	000033
192	000031	000030	000028	000027	000025	000024	000023	000022
200	000020	000019	000018	000017	000016	000016	000015	000014
208	000013	000013	000012	000011	000011	000010	000010	000009
216	000009	000008	000008	000007	000007	000007	000006	000006
224	000006	000005	000005	000005	000005	000004	000004	000004
232	000004	000003	000003	000003	000003	000003	000003	000002
240	000002	000002	000002	000002	000002	000002	000002	000002
248	000002	000001	000001	000001	000001	000001	000001	000001

Table 5

Linear function covering 6 decades in 256 channels

0	000000	996000	992000	988000	984000	980000	976000	972000
8	968000	964000	960000	956000	952000	948000	944000	940000
16	936000	932000	928000	924000	920000	916000	912000	908000
24	904000	900000	896000	892000	888000	884000	880000	876000
32	872000	868000	864000	860000	856000	852000	848000	844000
40	840000	836000	832000	828000	824000	820000	816000	812000
48	808000	804000	800000	796000	792000	788000	784000	780000
56	776000	772000	768000	764000	760000	756000	752000	748000
64	744000	740000	736000	732000	728000	724000	720000	716000
72	712000	708000	704000	700000	696000	692000	688000	684000
80	680000	676000	672000	668000	664000	660000	656000	652000
88	648000	644000	640000	636000	632000	628000	624000	620000
96	616000	612000	608000	604000	600000	596000	592000	588000
104	584000	580000	576000	572000	568000	564000	560000	556000
112	552000	548000	544000	540000	536000	532000	528000	524000
120	520000	516000	512000	508000	504000	500000	496000	492000
128	488000	484000	480000	476000	472000	468000	464000	460000
136	456000	452000	448000	444000	440000	436000	432000	428000
144	424000	420000	416000	412000	408000	404000	400000	396000
152	392000	388000	384000	380000	376000	372000	368000	364000
160	360000	356000	352000	348000	344000	340000	336000	332000
168	328000	324000	320000	316000	312000	308000	304000	300000
176	296000	292000	288000	284000	280000	276000	272000	268000
184	264000	260000	256000	252000	248000	244000	240000	236000
192	232000	228000	224000	220000	216000	212000	208000	204000
200	200000	196000	192000	188000	184000	180000	176000	172000
208	168000	164000	160000	156000	152000	148000	144000	140000
216	136000	132000	128000	124000	120000	116000	112000	108000
224	104000	100000	096000	092000	088000	084000	080000	076000
232	072000	068000	064000	060000	056000	052000	048000	044000
240	040000	036000	032000	028000	024000	020000	016000	012000
248	008000	004000	000000	000000	000000	000000	000000	000000

Fig. 11 Front view of tape-to-plotter converter.

Fig. 12 Top view of tape-to-plotter converter with buffer relays tilted back for access to terminals.

Fig. 13 Bottom view of tape-to-plotter converter.

Fig. 14 Oblique view of tape-to-plotter converter.

Fig. 15 Data in Table 4 (exponential curve) plotted by the converter in the logarithmic mode.

Fig. 16 Data in Table 5 (linear curve) plotted by the converter in a linear mode.

Fig. 17 Comparison of 3 digit conversion by converter (top) and 2 digit conversion by analyzer (bottom) in linear mode.

Fig. 18 Comparison of 3 digit conversion by converter (top) and 2 digit conversion by analyzer (bottom) in logarithmic mode.

6. COST

The approximate costs of the separate circuits used here are given below to facilitate comparison with any alternate circuits. No great effort was made to reduce the cost of an individual item and quantity discounts are not assumed.

Table 6. Approximate Costs

<u>Circuit</u>	<u>Approximate Cost</u>
Pulse Routing and Storage (Fig. 5)	\$ 82.00
Control Circuit (Fig. 4)	73.00
Pulse Stretcher (Fig. 8)	15.00
Oscillator Control (Fig. 8)	22.00
Seek-plot 1-shot (Fig. 8)	11.00
Start 1-shot (Fig. 8)	22.00
Y-axis circuit (Fig. 6)	32.00
Y-axis DAC (Fig. 5)	22.00
Sum Amplifier (Fig. 9)	10.00
X-axis circuit (Fig. 7)	225.00
End-of-plot power driver (Fig. 9)	8.00
Power (Fig. 9)	32.00
Miscellaneous hardware	<u>117.00</u>
TOTAL	\$ 671.00

About half of the cost is in 3 items: wire contact relays (\$61.00), X-axis counter (\$160.00), and precision resistors (\$83.00).

The estimated parts cost for an all-electronic unit using commercially available printed circuit boards was about \$2000.00, or about 3 times the cost of the instrument described here.

7. PARTS LIST

Pulse Routing and Storage Circuit, Fig. 5.

<u>Part No.</u>	<u>Description</u>	<u>Function</u>
S8	12P4T rotary switch	Linear Range
K1-K12	Wire contact relays, IBM No. 226628	
AS1-AS3	Arc suppressors, IBM, No. 328601	
R1-R12	330, 2W	
D1-D12	IN2483	

Control Circuit, Fig. 4.

<u>Part No.</u>	<u>Description</u>	<u>Function</u>
D13-D24	IN2483	Clear
S11	2PIT (normally open, pushbutton switch, microswitch No. 2PB-11-T2	
S14	Stepping switch; Automatic Electric Type 80, 48VDC, 2 bridging levels, 5 non-bridging levels, interrupter spring 1C, off-normal spring 3A, 10 points all levels, varistor coil protection.	
R16	1K, 2W	
K13	Wire contact relay, IBM No. 226628	
AS4	Arc suppressor, IBM No. 328601	Advance X-counter
R13	330, 2W	
R14	47, 1/2 W	
C1	.05 mf, 600v	
S10	1PIT (normally open) pushbutton switch, Micro-switch 2PB-11-T2	
S7	See x-axis parts list	Seek Plot
R15	2K, 1W	
P1	Insulated banana jack	
P2	Insulated banana jack	
P5	Insulated banana jack	
P6	Insulated banana jack	Common
P7	34 pin male connector and hood, Continental Connector Corporation No. 25034-16P and 34-20 KH	
P8	34 pin female connector and hood, Continental Connector Corporation No. 25034-16S and 34-20 KH	Plot
S15	1P2T pushbutton switch, Microswitch No. 2PB-11-T2	

Y-Axis Circuit, Fig. 6.

<u>Part No.</u>	<u>Description</u>	<u>Function</u>
S4	3P8T rotary switch	Calibrate Y
S14	(See control circuit parts)	
S3	6P4T rotary switch	Y-axis limit
S2	4P2T rotary switch	Log-Lin
P3	Insulated banana jack	Y-output
D25-D26	IN461	
R17	22K, 1/2 W	
R18	400K, 0.1%, 0.4 W	
R19	40K, 0.1%, 0.4 W	
R20	40K, 0.1%, 0.4 W	
R21	50K, 0.1%, 0.4 W	
R22	66.5K, 1%, 0.25 W	
R23	100K, 1%, 0.25 W Vamister	
R24	200K, 1%, 0.25 W Vamister	
R25	100K, 1%, 0.25 W Vamister	

X-Axis Circuit, Fig. 7.

<u>Part No.</u>	<u>Description</u>	<u>Function</u>
S7	Electro mechanical counter with electrical readout, Veeder Root No. C-174404, 48VDC, manual reset	
S6	Digi-Switch No. 331F-3	End of Plot
S5	5P3T rotary switch	Calibrate X
P2	Insulated banana jack	Plot Complete
P4	Insulated banana jack	X Output
R26	50, 1%, 0.25 W	
R27-R29	95K, 1/2 W	
R30-R32	22K, 1/2 W	
D27-D32	IN457	
R33	350K	
R34	40K, 0.1%, 0.4 W	
R35	20K, 0.1%, 0.4 W	
R36	13.33K, 0.1%, 0.4 W	
R37	10K 0.1%, 0.4 W	
R38	8K, 0.1%, 0.4 W	
R39	400K, 1%, 0.25 W	
R40	200K, 1%, 0.25 W	
R41	133K, 1%, 0.25 W	
R42	100K, 1%, 0.25 W	

X-Axis Circuit, Fig. 7 Cont'd

<u>Part No.</u>	<u>Description</u>	<u>Function</u>
R43	80K, 1%, 0.25 W	
R44	66.5K, 1%, 0.25 W	
R45	57.1K, 1%, 0.25 W	
R46	50K, 0.1%, 0.4 W	
R47	44.1K, 0.1%, 0.4 W	
R48	4M, 1%, 0.25 W	
R49	2M, 1%, 0.25 W	
R50	1.33M, 1%, 0.25 W	
R51	1M, 1%, 0.25 W	
R52	800K, 1%, 0.25 W	
R53	665K, 1%, 0.25 W	
R54	571K, 1%, 0.25 W	
R55	500K, 1%, 0.25 W	
R56	444K, 1%, 0.25 W	

Y-Axis DAC, Fig. 5.

<u>Part No.</u>	<u>Description</u>	<u>Function</u>
R57	50K, 0.1%, 0.4 W	
R58	100K, 0.1%, 0.4 W	
R59	200K, 0.1%, 0.4 W	
R60	400K, 0.1%, 0.4 W	
R61	499K, 1%, 0.25 W	
R62	1M, 1%, 0.25 W	
R63	2M, 1%, 0.25 W	
R64	4M, 1%, 0.25 W	
R65	4.99M, 1%, 0.25 W	
R66	10M, 1%, 0.25 W	
R67	20M, 1%, 0.25 W	
R68	40M, 1%, 0.25 W	

Pulse Stretcher, Fig. 8.

<u>Part No.</u>	<u>Description</u>	<u>Function</u>
R69	50, 1/2 W	
R70	20K, 1/2 W	
R71	300 to 1K, 10 W (optional)	
D33-D34	IN2483	
C2	.02 mf, 600v	
K15	Mercury wetted relay, Clare No. HGS 1005	

Oscillator Control, Fig. 8.

<u>Part No.</u>	<u>Description</u>	<u>Function</u>
S12	2P1T (normally closed) pushbutton switch, Microswitch No. 2PB-11-T2	Skip
R72	10K, 1/2 W	
C3	.001 mf, 600v	
D35-D37	IN2483	
K16	Mercury wetted relay, Clare No. HGS 1085	

Seek-Plot 1-Shot, Fig. 8.

<u>Part No.</u>	<u>Description</u>	<u>Function</u>
C4	.05 mf, 100	
C5	5 mf, 100	
R73	330, 1/2 W	
S13	Pushbutton activated magnetic core pulse generator, Microswitch No. 101 ED2 (pushbutton not included)	

Start 1-Shot, Fig. 8

<u>Part No.</u>	<u>Description</u>	<u>Function</u>
R74	100K, 1/2	
C6	.0005 mf, 100	
D38-D39	IN646	
S9	Push button activated pulse generator (push button included) Microswitch 1PB 3001	

End of Plot Power Driver, Fig. 9

Q1	2N1304
Q2	2N446
Z5	1/4 M 6.8AZ5
D40	IN457
R75	5K, 1/2 w
R76	92K, 1/2 w
R77	45, 1/2 w
R78	5K, 1/2 w

Sum Amplifier, Fig. 9

Q3	2N711	
Q4	2N711	
Q5	2N446	
R79	150K, 1/2 w	
R80	470K, 1/2 w	
R81	2.2K, 1/2 w	
R82	1K, 1/2 w	
R83	750, 1/2 w	
R84	500, linear potentiometer, 1/2 w	Adjust log
C7	500 mmf	

Misc. Power Supply, Fig. 9

B1, B2	50v, battery	
B3	12v, battery	2-6 volt
F1-F3	2A fuses	
S1	5P2T rotary switch	off-on
R85	47, 1/2 w	
C8	0.1 mf	
R86	450, 2 w	

Misc. Power Supply, Fig. 9 (cont'd)

<u>Part No.</u>	<u>Description</u>	<u>Function</u>
R87	1.8K, 2 w	
R88	4K, 1 w	
R89	1.4K, 2 w	
R90	380, 0.5 w	
Z1	IN3035B	
Z1	IN3035B	
Z2	IN3024B	
Z3	1/4 M 8.2Z5	
Z4	1/4 M 4.3 AZ5	

Miscellaneous

<u>Part No.</u>	<u>Description</u>	<u>Function</u>
	2 - mounting channel, IBM #238211	
	13 - relay receptacle, IBM #159941	
	3 - terminal block, IBM #344012	
	20 - mounting clip, IBM #159944	
	5 - " " , IBM #159946	
	10 - " " , IBM #284424	
	100 - mounting screws, IBM #198363	
	20 - 1/8" brass jumper, IBM #205331	
	100 - jumper wires, 3-1/2", IBM #129243	
	25-jumper wires, 4-1/2", IBM #129244	
	25 - jumper wires, 6-1/2", IBM #129246	
	3 - dust covers, IBM #326323	
	1 - AE lube kit	
	3 - AE mounting cushions	
	1 - crimping tool, American Pamcor, #48698	
	1 - insertion tool, American Pamcor, #380306-2	
	1 - extraction tool, American Pamcor, #380305-1	
	200 - taper pins, American Pamcor, #41640	