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D. R. Olsen
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END STATION TRIGGERS

There seems to be some confusion about the SLAC trigger system, especially from the users' (experimenters') point of view. The purpose of this note is to describe what types of triggers are available, their characteristics, and the language that is used in establishing a beam and its related triggers. Also there is a short description of two alternate methods of deriving beam synchronous triggers. These methods are especially useful when very fast, stable triggers are required.

Description of End Station System

The essence of the end station trigger system is shown in Figs. 1, 2, and 3. Figure 1 is a graphic description of the trigger system installation showing the locations of the various trigger generator chassis, the pattern signal source and the main trigger line characteristics.

Each trigger generator is supplied with an input from the main trigger line and a set of four pattern signals. These pattern signals serve to select only the desired pulses from the 360-pps main trigger line. Three of these patterns are set by a switch matrix in the Central Control Room (CCR) and the fourth is fixed and gates only the 60-pps phase-1 pulses. See Fig. 2 for an example and a description of the various pulses, and Fig. 4 for an illustration of the CCR switch matrix.

Main Trigger Line

The main trigger line contains two pulses: a positive going pulse which occurs approximately 4 microsec before the leading edge of the beam pulse (at the injector) and a negative going pulse which occurs approximately 25 microsec before the beam. Approximately is used because the actual delay between the trigger and the beam can be varied by a control in CCR over an interval of one microsec. Once the beam is set up, this trigger-to-beam interval is quite stable. Stability characteristics are given in a following section. The main trigger line is 1-5/8" air dielectric Heliax and has a propagation velocity of 0.921 c (velocity of light). This means the trigger-to-beam timing changes by about 0.08 nanosec/ft as the beam proceeds down the accelerator. Thus a trigger that precedes the beam by 4 microsec at the injector, leads the beam by 3 microsec in the end stations.

Characteristics

Rise time (2 miles) 5% - 50%	27 nanosec
Impedance	50 ohms
Temperature stability - change in electrical length	± 0.002%/°C
Amplitude at injector	400 volts

Trigger Generator

The trigger generator chassis outputs are labeled "pattern 1 pretrigger" or "pattern 2 main trigger," etc. The pattern numbers refer to a particular output point on that particular trigger generator. At present there are three generators in the end station area in the following locations: End Station A Counting House (ESA CH), Building 108 servicing the A End Station area (ESA), and Building 209 servicing the B End Station area (ESB). Each user is assigned one or more of these pattern signals. The pretrigger refers to the -25 microsec trigger. The main trigger refers to the -4 microsec trigger. The pattern triggers are the gated trigger pulses, while the buffered pattern outputs are the actual pattern signals. As an example, ESB-3 is output 3 of the End Station B trigger generator.

Characteristics

Output trigger rise time	20 nanosec
Output trigger fall time	30 nanosec
Output trigger amplitude into 50 ohms	+9 V min; +12 V max
Output trigger width	.4 microsec min; 1.0 microsec max
Output polarity	positive

Trigger Delay/Repeater

The trigger delay/repeater chassis is located in the users' equipment racks. The purpose of this chassis is to provide several outputs for each cable from the trigger generator, and to allow the user to delay a trigger by an arbitrary amount. Figure 3 shows a typical use of this chassis, and as shown there are 4 separate outputs for each input. The output stages of this unit are identical to those of the trigger generator. It is planned, however, to build an alternate output stage with a rise time of less than 5 nanosec. The present output has a rise time of 20 nanosec when terminated in 50 ohms. All inputs and outputs are transformer-coupled, and isolated from the chassis. In the present setup 2 of the 4 outputs are negative going, the other 2 are positive. If this is not desirable, the polarities may be changed by appropriate use of a soldering iron.

Characteristics

Delay stability	0.0025%/°C, Fig. 6
Minimum delay	100 nanosec
Maximum delay	10 sec
Short term delay jitter	None observed on TEK 547 scope

Model 1 Outputs

Identical to those of the trigger generator with the exception of polarity.

Model 2 Outputs

Output trigger rise time	5 nanosec
Output trigger fall time	5 nanosec
Output trigger amplitude into 50 ohms	+9 V min; +12 V max
Output trigger width	100 nanosec max

Injector Trigger Generator

Characteristics

Delay stability	0.002%/°C (passive elements)
Short-term delay jitter	None observed on TEK 547 at injector

If we assume a 20° C change for the main trigger line, a 10° C change for the injector trigger generator and the trigger delay/repeater, the maximum timing change for the entire system would be 0.085% which is less than 4 nanosec for a 4-microsec delay interval. Short term in the above context is taken to mean something less than 10 minutes. This system should, therefore, provide triggers with long-term (several hours) stabilities of better than 5 nanosec and short-term stabilities of better than 1 or 2 nanosec. This last figure is derived from the fact that jitter has not been observed on oscilloscopes that have a resolution on the order of 2 nanosec.

Beam Setup Procedure

Figure 4 is a one-picture explanation of the beam setup procedure. The upper set of boxes labeled 'Pattern,' 'Beam Definition,' and 'Trigger Matrix' is a set of two-position toggle switches located in the CCR. The lower box labeled 'Pulsed Magnet Supply Program' is a set of 3-position toggle switches located in the DAB.

As shown, each horizontal row of the upper set of boxes represents a potential beam. Probably the easiest way to explain this is by way of example. The darkened dots in Fig. 4 indicate that that particular switch is in the 'on' position. In the example, the CCR beam number 1 uses time slots 1, 3, and 5 which means it is an evenly-spaced 180-pps rep rate. The beam pulse associated with that pattern has a width of 1.6 microsec, a peak current of 10 ma and an energy of 10 BeV. The pattern is sent to End Station A Counting House trigger generator output 1 (ESA CH 1), End Station B trigger generator output 3 (ESB 3), and to the Data Assembly Building trigger generator output 1 (DAB 1). The pulse magnet triggers determine whether the beam into the 'A', 'B', or 'C' beams. This is set up on the Pulse Steering switches in the CCR and the 'Pulsed Magnet Power Supply Program' in the DAB. In the above example, it is assumed that the pulsed magnets are set such that CCR beam 1 goes to the A End Station. As is obvious from the trigger matrix, the pattern for any beam may be sent to any of the trigger generators. This allows any user to check the background noise associated with another user's beam. CCR beam 2 has one interesting feature not indicated in beam 1. Time slot 2 pattern is put into a circuit which divides that particular 60-pps rate by an integer, producing 30, 15, 1.0, 0.5, etc., pps, as desired by the user. The divider is labeled Rate P/S on Fig. 4. There is a total of six dividers, any one of which may be connected to any of the time slots. The example beam CCR 2 is set up for 1 pps, occurring in time slot 2. The priority matrix defines which CCR beam has priority for a particular time slot pattern. In the example (a bad one at that), ESA has requested any pattern (trigger) on output 1. The operator has obliged by sending him time slot 2. However, since CCR 2 has the higher priority on this time slot, ESA 1 will only receive 59 pps. The priority matrix only has meaning if the same time slot is assigned to two different CCR beams. α and β on the Pulse Steering refer to the polarity of the power supplies connected to the pulse magnets. Since this polarity is reversible, it is not possible to associate α and β with the 'A' and 'B' beams. The process of setting up the pulsed magnets is quite complicated and at present is being programmed on the DAB 925 computer.

A control which is not part of the trigger system, but nevertheless interacts with it quite strongly is the permissive pulse control which is furnished to all users. This control may inhibit the beam, either by inhibiting the injector, or by inhibiting the triggers associated with that beam. The standard procedure will be to inhibit the injector only. When the beam is inhibited, the user will still receive the pattern triggers. The standard rep rate meter furnished to the users will give the correct reading of 0 pps when the beam is inhibited, since its input requires both the pattern trigger and the permissive pulse signal to give an indication. When the injector (beam) is inhibited, the permissive pulse for that beam is shut off.

Alternate Trigger Sources

The above trigger system should be adequate for most user requirements. A possible shortcoming could be triggering for very fast beam pulses such as produced by the beam knockout system. Here the triggers must have very fast rise times and have jitter of less than 1 nanosec with respect to a part of the beam pulse. The two triggers described below are both derived from the beam itself. The first source is a toroid placed around the beam pipe. In general, this must be located in front of the beam target. Such a toroid has been built by D. Porat and has the following parameters: rise time < 1 nanosec; sensitivity 6.4 mV/mA into 50-ohm load. The problem with this is to develop a circuit which will take the various level outputs from this toroid corresponding to different beam intensities and develop a standard output trigger pulse which is stable in time and amplitude. The other basic source is to use a photomultiplier tube. The tube could be placed in the secondary beam after a sweeping magnet, for example, or near the beam target, or in general near any source of radiation. This trigger source has the advantage over the toroid of producing a large pulse regardless of the intensity of the primary beam. With this large amplitude, it is possible to develop very stable triggers.

References

TN-63-34, Functional Specifications of Trigger System, K. B. Mallory

TN-63-35, Pattern Control Generator, K. B. Mallory

TN-63-41, Main Trigger Transmission Line, K. B. Mallory

TN-64-9, Functional Description of Trigger System, K. B. Mallory

TN-65-22, Trigger Requirements for Positron Operation, K. B. Mallory

Engineering Design Reports (EDR):

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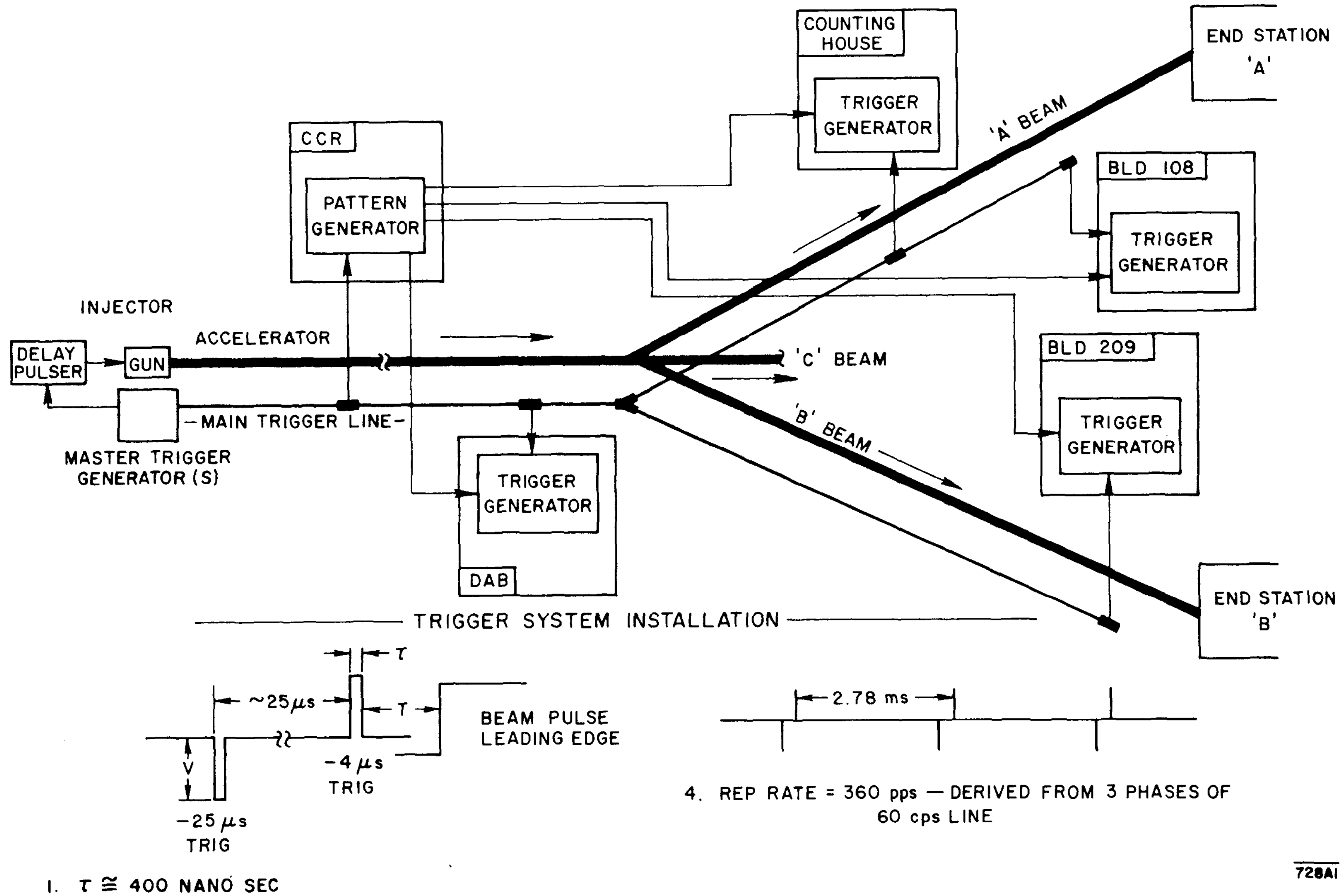
Pattern Generator, TR 136-074-RO, J. Faust, May 1965

Notes:

Trigger System Functional Description, J. Faust, April 1964

Main Trigger Transmission Line, A. Barna, November 1963

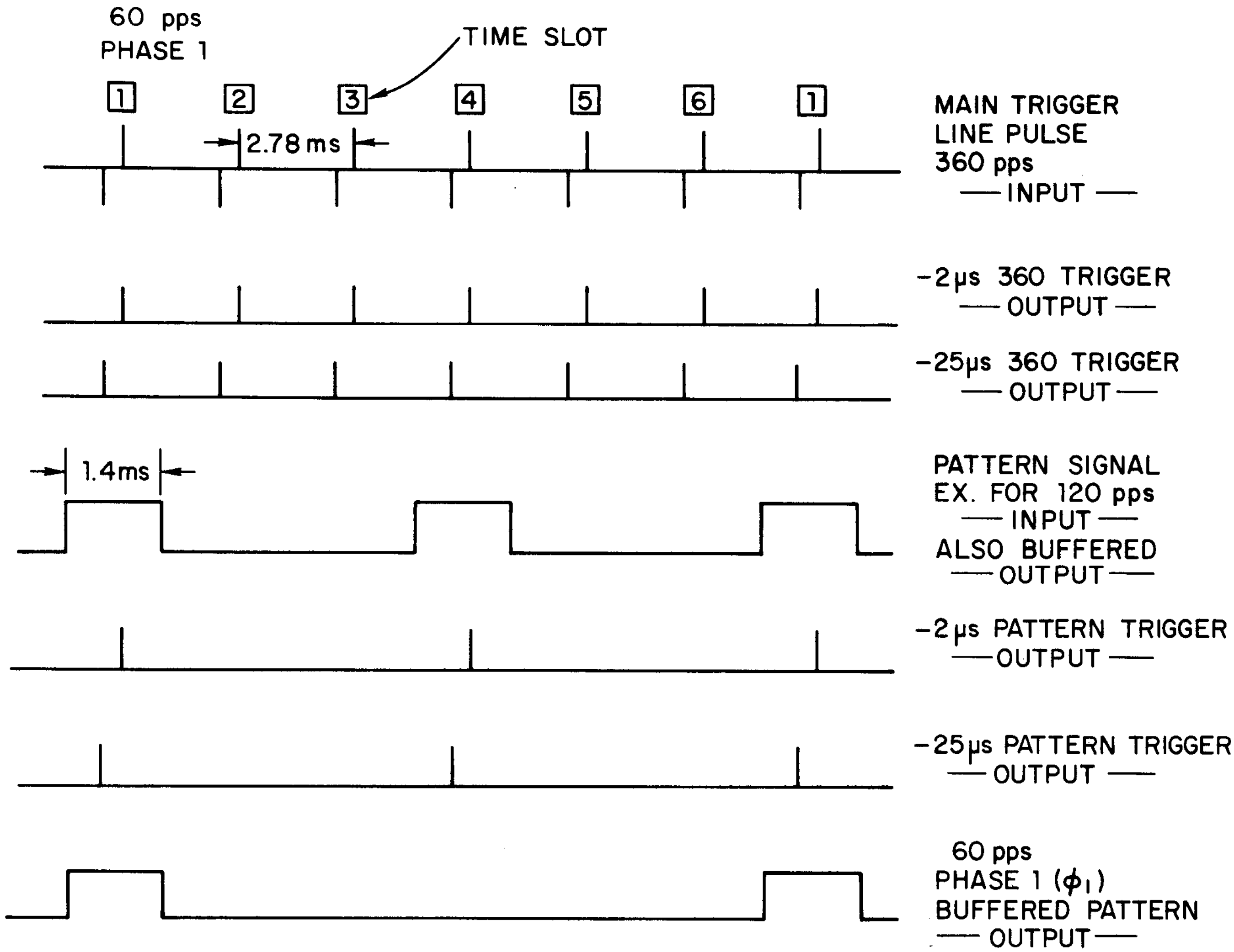
Trigger Logic, J. Harris, November 1966



1. τ ≅ 400 NANO SEC
2. T ≅ 4 μs AT INJECTOR, 3 μs AT END STATIONS
3. V ≅ 400 V ON MAIN TRIGGER LINE
   ≅ 10V INTO TRIGGER GENERATORS

TRIGGER LINE PULSE

FIG. 1 -- MAIN TRIGGER LINE SYSTEM / PULSE CHARACTERISTICS



NOTES:

1. Pattern signals 10V, 1.4 millisec
2. Trigger signals 10V, 400 nanosec
3. -2μs trigger also called main trigger
4. -25μs trigger also called pre trigger

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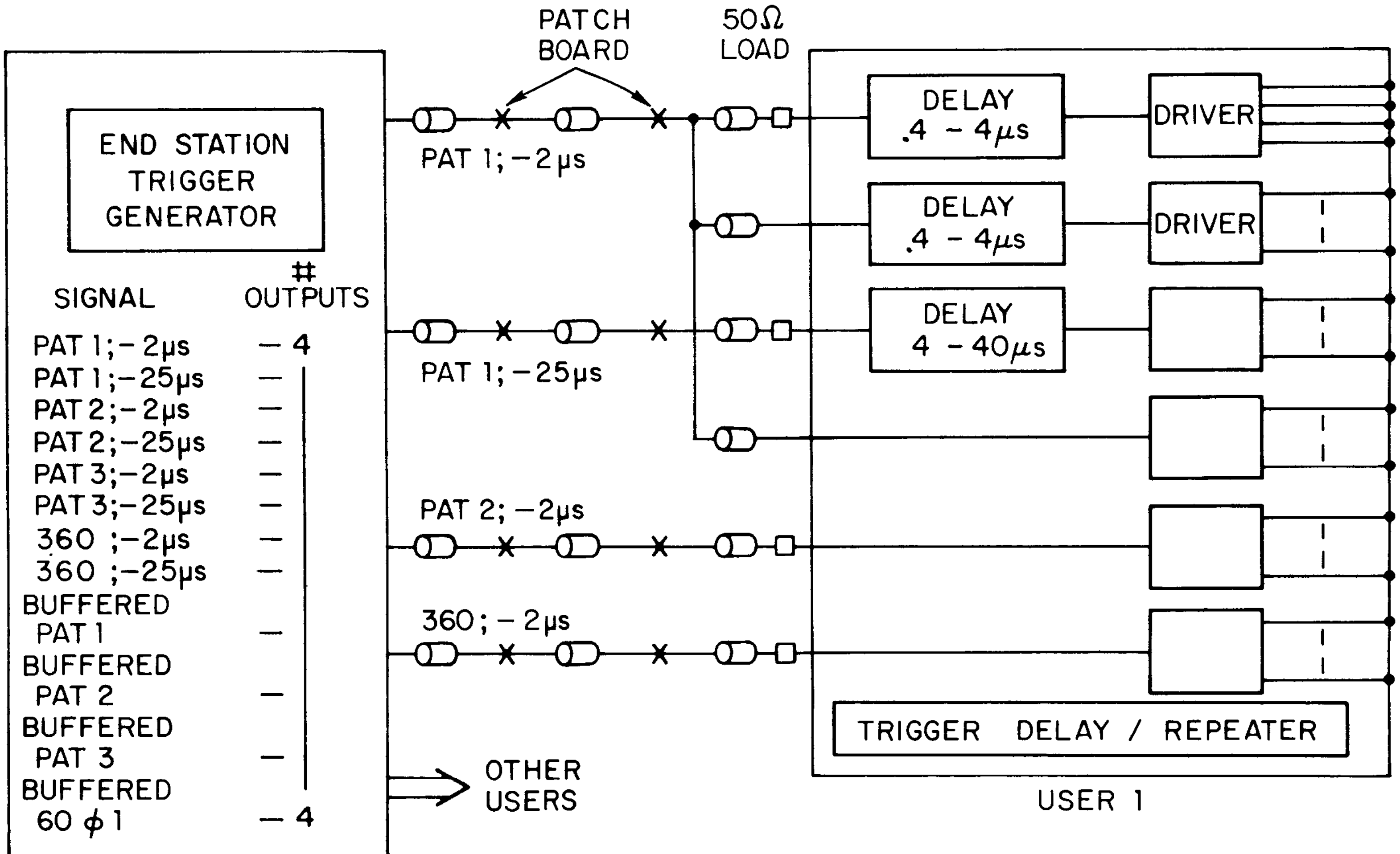
Fig. 2 - END STATION TRIGGER GENERATOR INPUT/OUTPUT SIGNALS



NOTES:

1. Delay has range of 10:1, with delay time set by a capacitor eg .4 - 4μs, 4 - 40μs etc.
2. Inputs to trig delay/repeater are high impedance (500Ω). Input lines must be terminated.

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Fig. 3 – EXAMPLE USER SETUP

MULTIPLE BEAM
PROGRAMMER VERSION I
NOV 21, 1966

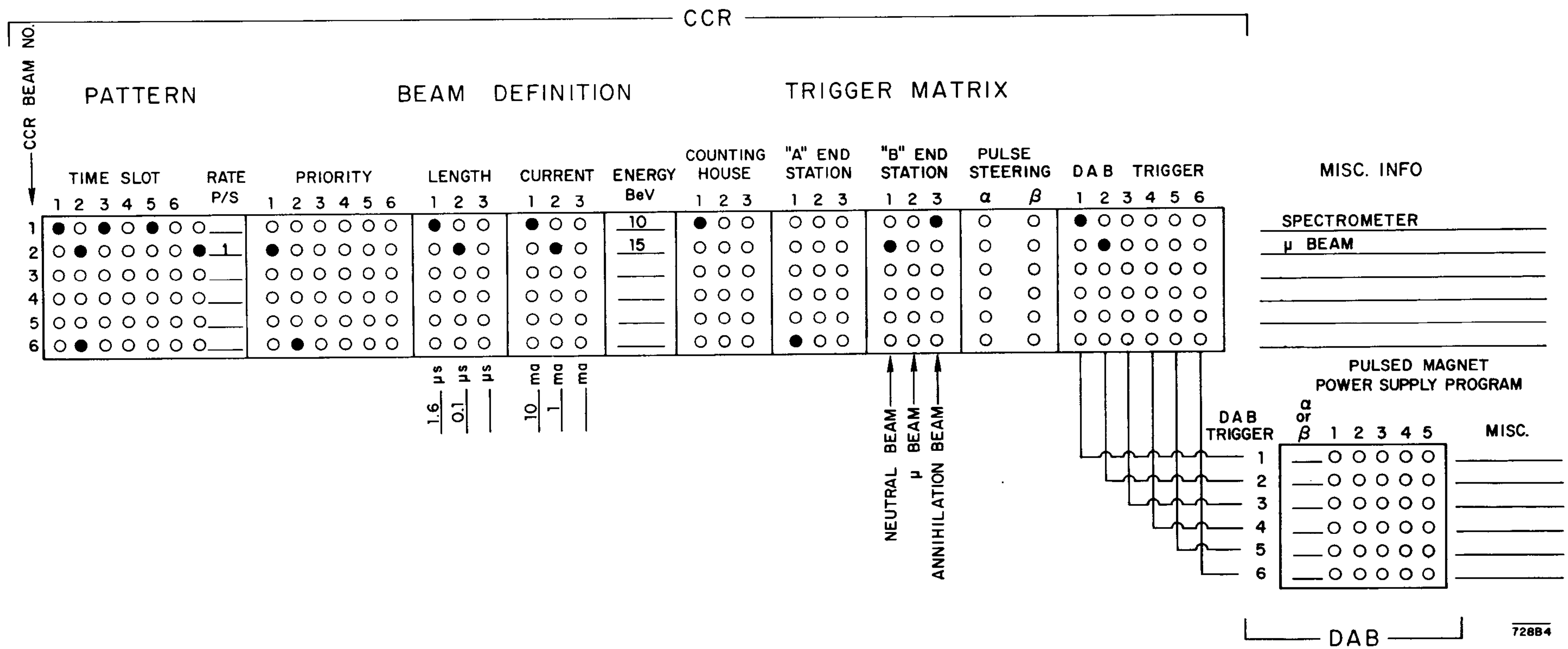

FIG. 4

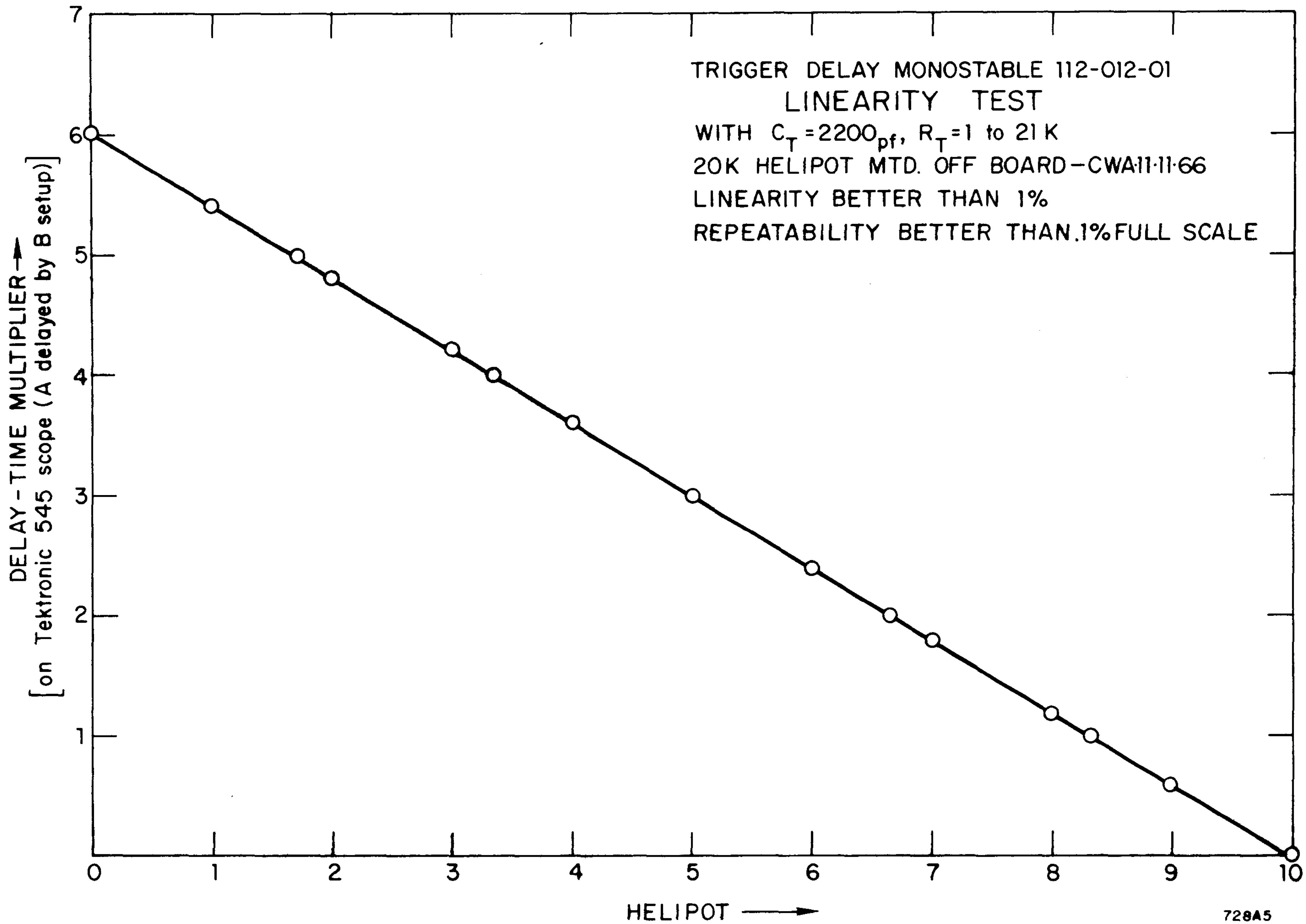
TRIGGER DELAY MONOSTABLE 112-012-01
LINEARITY TEST
WITH $C_T = 2200_{pf}$, $R_T = 1$ to 21 K
20K HELIPOT MTD. OFF BOARD—CWA 11·11·66
LINEARITY BETTER THAN 1%
REPEATABILITY BETTER THAN .1% FULL SCALE
DELAY-TIME MULTIPLIER →
[on Tektronic 545 scope (A delayed by B setup)]
HELIPOT →
0
1
2
3
4
5
6
7
8
9
10
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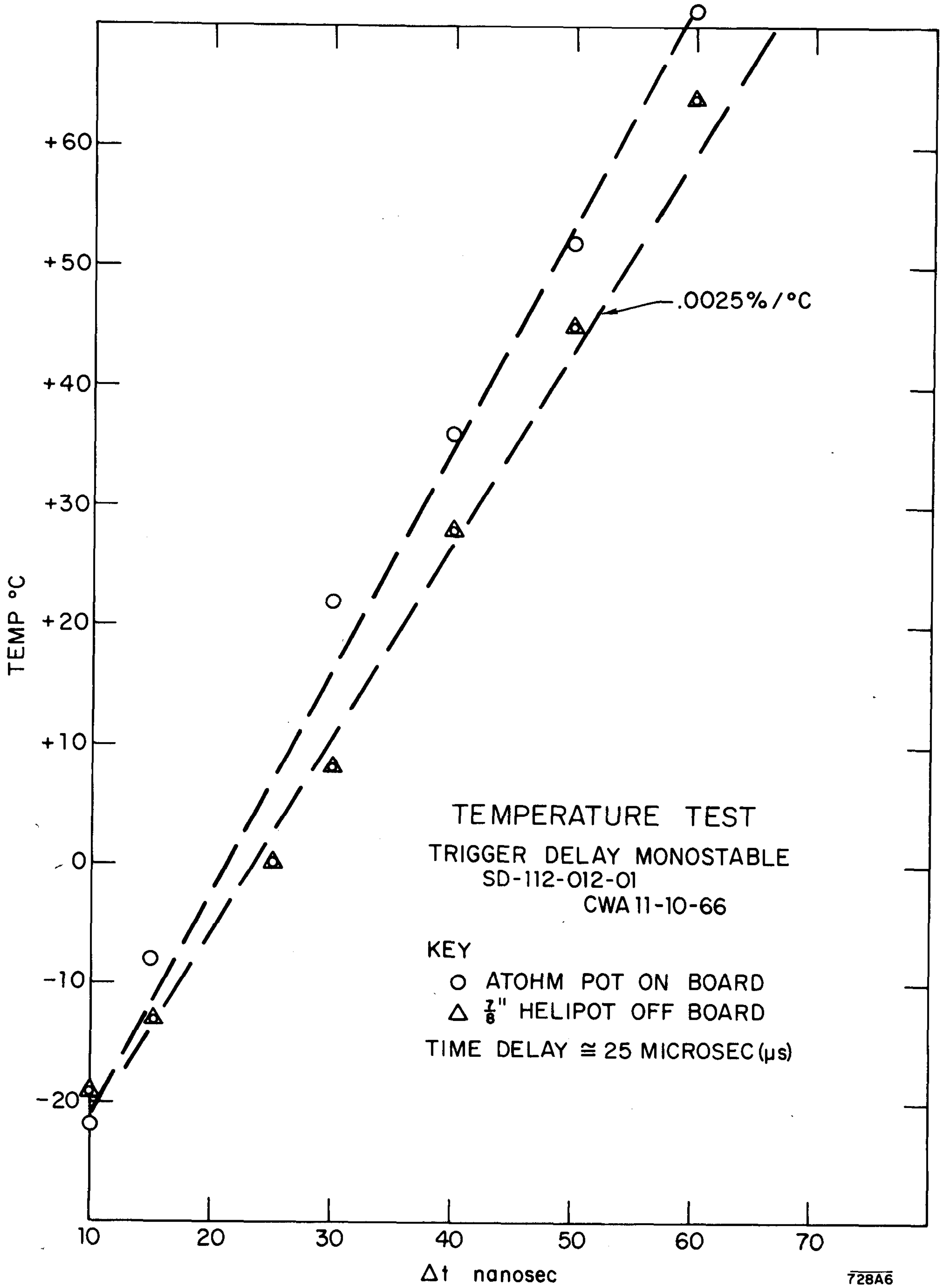
FIG. 5



TEMP °C
+60
+50
+40
+30
+20
+10
0
-10
-20
10
20
30
40
50
60
70
Δt nanosec
.0025%/°C
TEMPERATURE TEST
TRIGGER DELAY MONOSTABLE
SD-112-012-01
CWA 11-10-66
KEY
O ATOHM POT ON BOARD
Δ 7/8" HELIPOT OFF BOARD
TIME DELAY ≅ 25 MICROSEC (μs)
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FIG. 6