MODEL TC 446

SERIAL NO. 4

INSTRUCTION MANUAL

MODEL TC 446

TENNELEC

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TABLE OF CONTENTS

Section		Pase No.
1.0	INTRODUCTION	1
	1.1 TIMING TECHNIQUES USING LINEAR SIGNALS	1
	1.2 MODEL TC 446	3
2.0	SPECIFICATIONS	5
3.0	CONTROLS AND CONNECTORS	7
	3.1 OUTPUT DELAY	7
	3.2 THRESHOLD SENSITIVITY	7
	3.3 THRESHOLD ADJUST	7
	3.4 RESET LEVEL (INTERNAL CONTROL)	7
	3.5 PULSE WIDTH (INTERNAL CONTROL)	7
	3.6 FAST OUTPUT	7
	3.7 SLOW OUTPUTS	7
4.0	OPERATION PROCEDURES	8
	4.1 FIRST TIME OPERATION	8
	4.2 GENERAL OPERATION	8
	4.3 WALK IN LINEAR AMPLIFIER SYSTEM DUE TO AMPLITUDE VARIATION	10
5.0	CIRCUIT OPERATION	11
	5.1 INPUT BUFFER	11
	5.2 BIAS CURRENT GENERATOR and FEEDBACK SWITCH	11
	5.3 DELAY AND PULSE WIDTH GENERATOR	13
	5.4 OUTPUT STAGES	13
6.0	APPLICATION	13
7.0	SERVICING	13
8.0	SHIPPING DAMAGE	13
9.0	WARRANTY	14

1.0 INTRODUCTION

1.1 TIMING TECHNIQUES USING LINEAR SIGNALS

Linear signals are used as the source of timing information in both the leading edge timing method and the crossover timing method. Measurement or determination of the time of flight of neutrons, identification of particles, and measurement of angular correlations all require accurate timing techniques; the assignment of "time of occurrance" to nuclear events is of primary importance.

In leading edge timing, a level (amplitude) sensitive discriminator, such as a Schmitt trigger, is used to detect the leading edge of a linear signal. The only requirement that must be met for the level sensitive discriminator to detect the leading edge is that the amplitude of the signal must be greater than the trigger threshold setting of the discriminator.

When the leading edge of a linear signal is used as the source of timing information, the primary concern becomes "walk," i.e. a shift in the location of a timing mark caused by sensitivity to the amplitude of the pulse that generated the mark. Therefore, the basic disadvantage of leading edge timing, particularly when RC shaped signals are used, is inconsistent timing information that is caused by variation in amplitude of the linear signals. Figure 1 illustrates the "walk" associated with the leading edge timing. Note that even though signals A and B appeared at the same time, the variation in their amplitude caused them to reach the trigger threshold A at different times. 'This difference in time, ΔT, is the walk.

The walk is reduced if the trigger threshold is lowered (Trigger Threshold B). However, the minimum level to which the threshold can be reduced is to a threshold that is just above the peak noise level of the system; reduction to this level does not totally eliminate walk. If the trigger threshold is less than the peak noise level of the system, timing errors increase.

In crossover timing, the time at which the crossover point of a doubly differentiated signal occurs is used as the source of timing information. The crossover point or zero crossing of a doubly differentiated signal is the point at which the pulse crosses the baseline (Fig. 2).

A variable hysteresis discriminator is used to detect the crossover point. The requirements that must be met for the discriminator to detect the crossover are that the amplitude of the input signal must exceed the biased threshold level ($V_{Threshold}$) of the discriminator and that the trailing edge of the input signal must fall below the reset level (OV) of the discriminator. When the amplitude of the input signal exceeds the $V_{Threshold}$ level, the discriminator is armed; it does not reset until the input signal falls below zero volts. If the amplitude Of the input signals falls below the $V_{Threshold}$ level, it is completely ignored (waveform 4, Fig. 2).

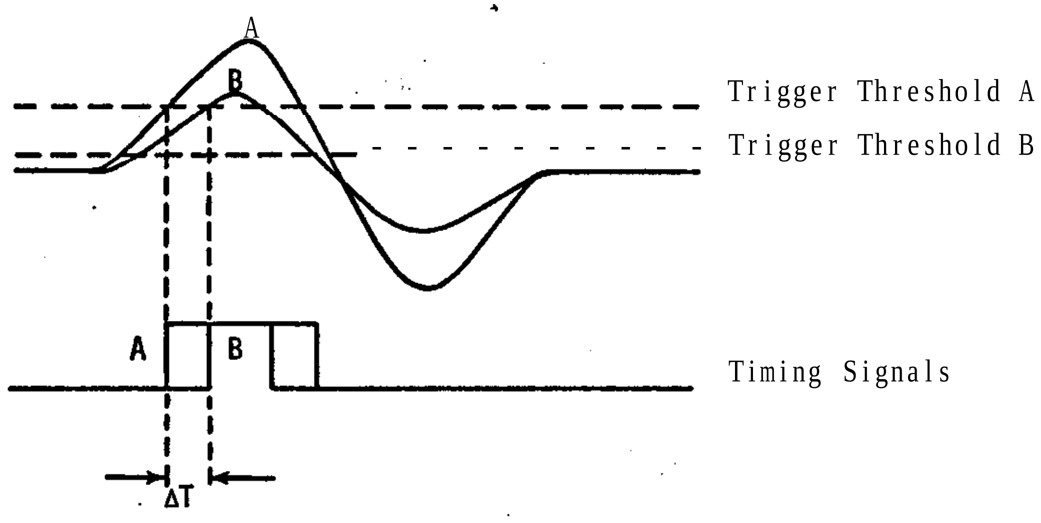


Fig. 1.

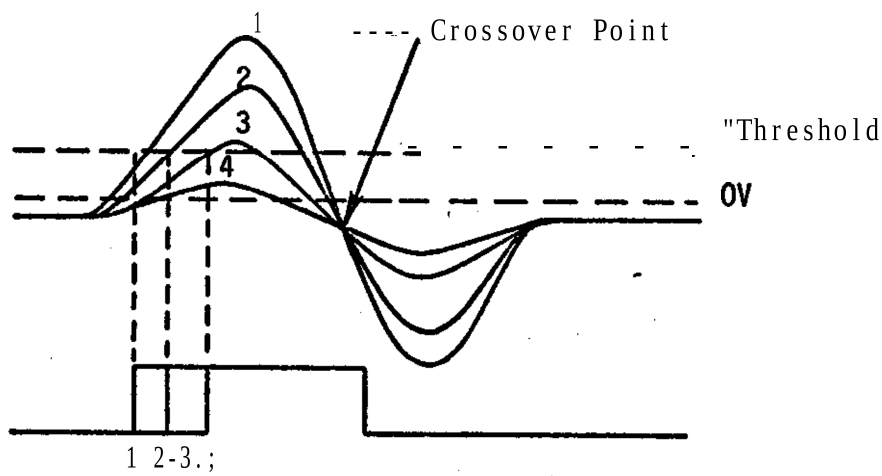


Fig. 2.

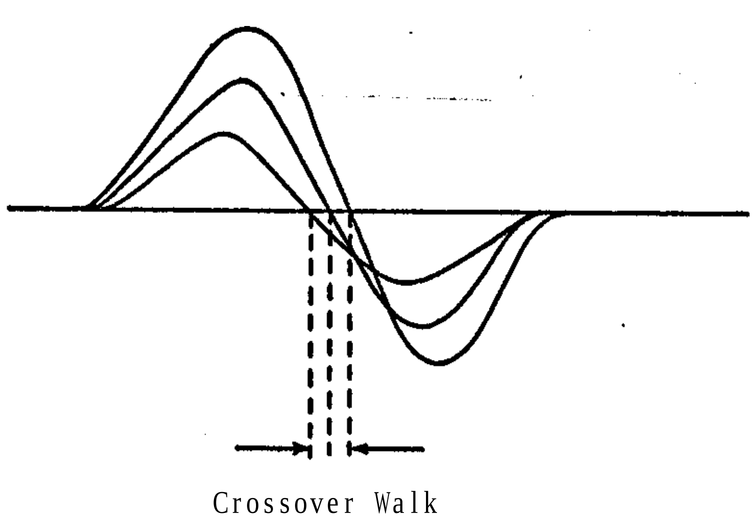


Fig. 3.

When the crossover.point of a linear signal is used as the source of timing information, the primary concern is the crossover walk of the input signal (Fig. 3). The input signal "walks" if slewing occurs in the main amplifier. Slewing is a non-constancy of pulse shape which results when-the constant rise time condition at low signal levels gives way to a constant rate-of-rise condition at high signal level (Fig. 4). If it becomes necessary to compensate for crossover walk in the input signal, the reset level of the variable hysteresis discriminator is set off zero in either direction for compensation purposes. Figure 2 illustrates a yield of zero walk with the crossover technique. See Section 4.2 for the procedure used in determination of walk associated with the input signal.

The technique of crossover timing offers the simplest approach to extracting a reasonably accurate "time-of-occurrence" from a linear signal. In doubly, differentiated RC (or active RC) signal processing the crossover time, in real time, is approximately two time constants after the detected event is presented to the system in the form of a step function of voltage or charge. For double delay-line clipping, the crossover occurs at one clipping time from the leading edge of the input step function. In both cases, the crossover represents a point midway between the initial and final values of the step function. Figure 5 illustrates the real-time delay of the crossover timing technique.

In cases where the linear signal is to be further processed as a result of its time of occurrence, proper linear delays must be added into the system. This is usually done with delay amplifiers or long lines. In either case, the delays will not exactly match the inherent delay of the crossover point. To match the linear and digital delays, a linear delay greater than the delay of the crossover:point must be chosen and the digital signal delay must be adjusted to match the linear delay.

1.2 MODEL TC 446

The Model TC 446 Crossover Pickoff is designed to provide highly accurate timing reference signals for nuclear instrumentation systems. It detects the time of the crossover point of a doubly differentiated signal emitted by a nuclear pulse amplifier and then generates a logic signal with a minimum of walk (1 nsec maximum for 10:1 range in amplitude).

The TC 446 consists of an input buffer amplifier, a variable hysteresis discriminator, a delay generator, a'pulse-width generator, and output drivers. It accepts 0 to 10V bipolar pulses (positive lobe leading). The threshold ranges of the variable hysteresis discriminator are LOW: 100mV to 1V and HIGH: 10mV to 100mV; a toggle switch and multiturn potentiometer are used to select and adjust the trigger threshold.

Front panel connectors provide access to three simultaneous outputs: negative fast (1.2V), negative slow (8V), and positive slow (8V). The delay of either of the slow outputs is variable over a range of 0.1 to 1.1 μsec by means of the OUTPUT DELAY control.

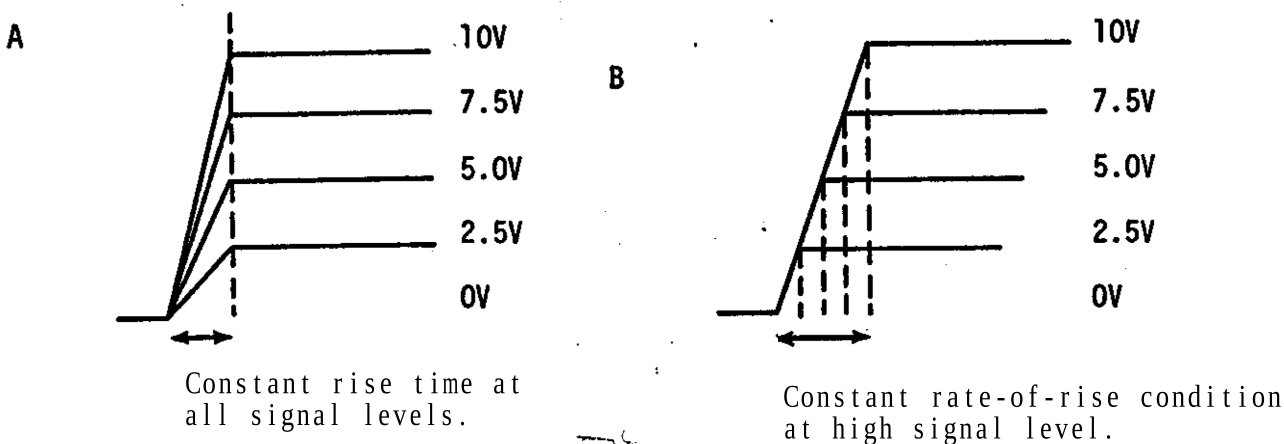

A
10V
7.5V
5.0V
2.5V
0V
Constant rise time at all signal levels.
B
10V
7.5V
5.0V
2.5V
0V
Constant rate-of-rise condition at high signal level.

Fig. 4.

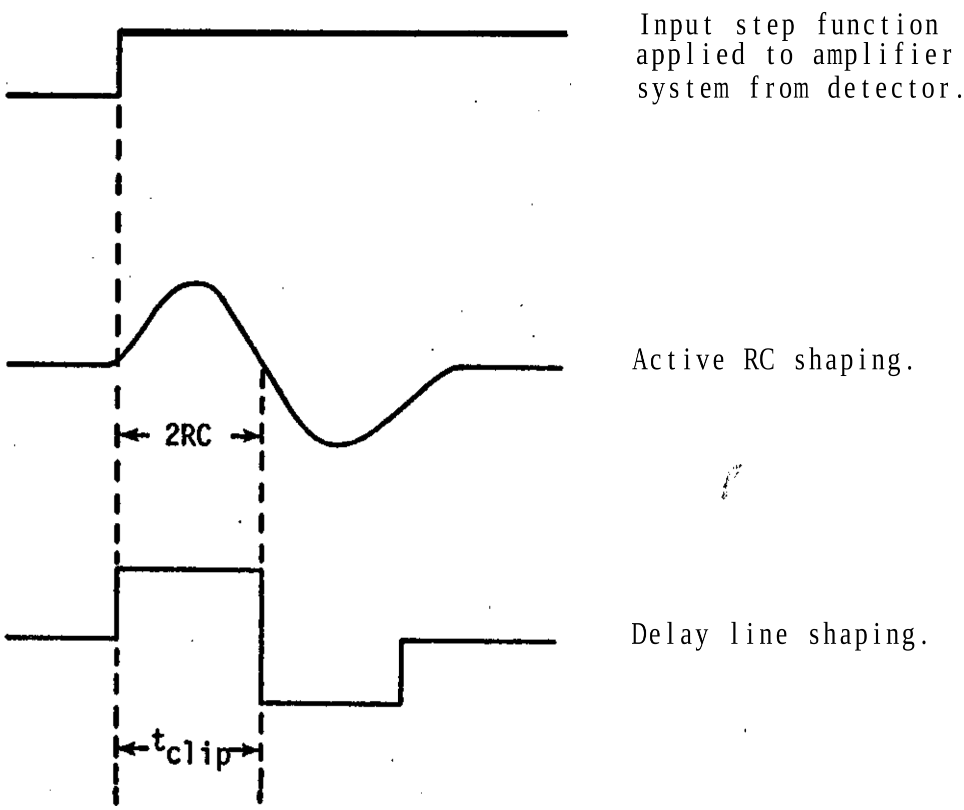
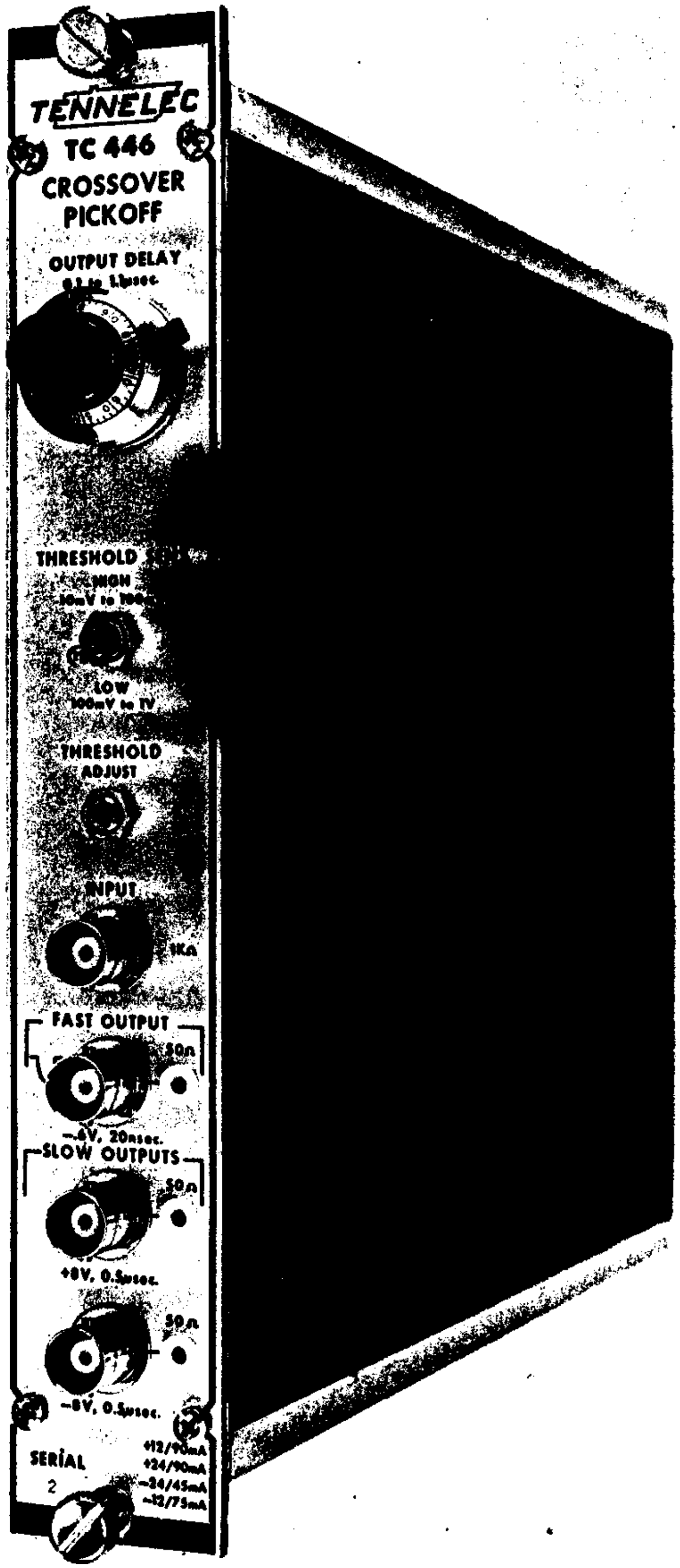

Input step function applied to amplifier system from detector.
Active RC shaping.
2RC
Delay line shaping.
t_{clip}

Fig. 5.

2.0 SPECIFICATIONS

INPUT PULSE REQUIREMENTS	
Amplitude	0 to 10V.
Shape	Bipolar.
Shaping	RC, delay line, or constant fraction.
Polarity	Positive lobe leading.
Width	Greater than 50 nsec.
INPUT IMPEDANCE	1kΩ.
THRESHOLD SENSITIVITY	High: 10mV to 100mV; Low: 100mV to 1V, front panel switch selectable.
COUNT RATE CAPABILITY	Limited by pulse shaping constants of linear amplifier.
WALK (TIME vs PULSE HEIGHT)	Logic output pulses from crossover of input signal: 1 nsec maximum for 10:1 range in amplitude variations; 10 nsec maximum for 200:1 range in amplitude variations. Determined with 0.1 μsec active RC shaping (TENNELEC TC 200 or TC 220 Linear Amplifiers).
PULSE PAIR RESOLUTION	650 nsec.maximum when set for minimum delay. (This increases as a function of increased delay time and output pulse width.)
OUTPUT DELAY	
Range	0.1 to 1.1 μsec.
Linearity	0.25%.
Accuracy	2.0%.
OUTPUT PULSE CHARACTERISTICS	
Slow	
Amplitude	8V (open circuit).
Shape	Rectangular.
Width	0.5 μsec. Internally adjustable from ~0.25 to 2.0 μsec.
Rise and Fall Times	30 nsec.
Polarity	Either; simultaneously available from separate connectors.

OUTPUT PULSE CHARACTERISTICS (Cont'd)	
Fast	
Amplitude	1.2V (open circuit).
Shape	Unlpolar.
Width	-20 nsec (FWHM).
Polarity	Negative.
Timing	Occurs simultaneously with leading edge of slow output pulses.
OUTPUT IMPEDANCE	50Ω, all terminals.
TIMING SIGNAL TEMPERATURE STABILITY	0.2 nsec/°C maximum at 100 nsec delay.
OPERATING TEMPERATURE RANGE	0° to 50°C.
CONTROLS	
Output Delay	Linear calibrated lo-turn dial (front panel).
Threshold Sensitivity	Two-position toggle switch (front panel).
Threshold Adjust	Screwdriver-adjustable multiturn potentiometer (front panel).
CONNECTORS .	
Input	BNC (UG-1094/U), front panel.
Fast Output	BNC (UG-1094/U), front panel.
Slow outputs (2)	BNC (UG-1094/U), front panel.
Power	NIM standard power connector (rear panel).
POWER REQUIREMENTS	+12V @ 90mA. +24V @ 90mA. -24V @ 45mA. -12v @ 75mA.
ACCESSORIES FURNISHED	One instruction manual.
PACKAGING	No. 1 AEC NIM standard width.
NET WEIGHT	3 lbs (1.3 kg).
SHIPPING WEIGHT	5 lbs (2.2 kg).
WARRANTY	Two years,



TENNELEC
TC 446
CROSSOVER
PICKOFF
OUTPUT DELAY
THRESHOLD
ADJUST
INPUT
FAST OUTPUT
SLOW OUTPUTS
SERIAL

3.0 CONTROLS AND CONNECTORS

3.1 OUTPUT DELAY

This linearly calibrated lo-turn control is used to vary (delay) the time at which the output logic (digital) signal is generated once the input signal arms the crossover discriminator circuit. The delay range is 0.1 to 1.1 μsec as read from the dial.

3.2 THRESHOLD SENSITIVITY

This two-position toggle switch is used to select the trigger threshold range of the variable input hysteresis discriminator of the TC 446. The ranges are LOW: 100mV to 1V and HIGH: 10mV to 100mV.

3.3 THRESHOLD ADJUST

This screwdriver-adjustable multiturn potentiometer establishes the level at which the input signal arms the crossover discriminator circuit within the trigger threshold range selected by the THRESHOLD SENSITIVITY CONTROL.

3.4 RESET LEVEL (INTERNAL CONTROL)

This screwdriver-adjustable potentiometer, located directly to the rear of the positive SLOW OUTPUT terminal, selects the amplitude level at which the crossover circuit resets; the reset level is factory set at zero. The RESET LEVEL control is used to compensate for the walk in the preceding amplifier system. See Section 1.1.

3.5 PULSE WIDTH (INTERNAL CONTROL)

This screwdriver-adjustable potentiometer, located directly to the rear of the μA711 in the upper rear corner of the printed circuit board, is used to vary the width of the SLOW OUTPUT signals from 0.25 to 2.5 μsec.

3.6 FAST OUTPUT

This BNC connector provides access to a negative, unipolar 1.2V (open circuit), -20 nsec wide (FWHM) pulse that occurs. simultaneously with the leading edge of a slow output pulse.

3.7 SLOW OUTPUTS

These BNC connectors provide access to positive or negative, rectangular 8V (open circuit), 0.5 μsec wide (internally adjustable from ~0.25 to 2.0 μsec) pulses.

4.0 OPERATION PROCEDURES

4.1 FIRST TIME OPERATION

Every instrument from TENNELEC, Inc. is thoroughly checked before it leaves the plant. However, it is possible for damage to occur during shipping, and it is advised that a few tests be run before the instrument is put into actual operation.

Visually check the Model TC 446 upon receipt for possible external damage. If it appears to be damaged, proceed according to the instructions given in the SHIPPING DAMAGE section of this manual.

It is recommended that the power supply of the bin be off when the TC 446 module is inserted.

It is preferable, but not essential, that the user become familiar with the controls of the instrument by making initial checkout tests with a pulse generator-main amplifier system instead of with a detector-preamplifier-main amplifier system as the signal source. Instruments recommended for initial operation of the TC 446 Crossover Pickoff are an oscilloscope (triggered sweep, 30 MHz or greater bandwidth), a pulse generator (square-wave or tail pulse generator such as the TENNELEC Model TC 800 Precision Pulser and Model TC 812 Pulser), a main amplifier (TC 220), a standard NIM power supply (Tennebin 2 or equivalent), and shielded cables with BNC connectors.

4.2 GENERAL OPERATION

Connect the instruments as shown in Fig. 6.

Set the controls as follows:

PULSE GENERATOR

Pulse Height	Maximum.
Decay Time Constant	Maximum.
Polarity	Positive (+).
Attenuation	None.

MAIN AMPLIFIER

Shaping	Doubly differentiated.
Time Constant	≤0.2 μsec.
Polarity	Direct.
Gain	10V plus peak amplitude.

TC 446 CROSSOVER PICKOFF

Output Delay	0.1 μsec.
Threshold Sensitivity	High.
Threshold Adjust	Full CCW.

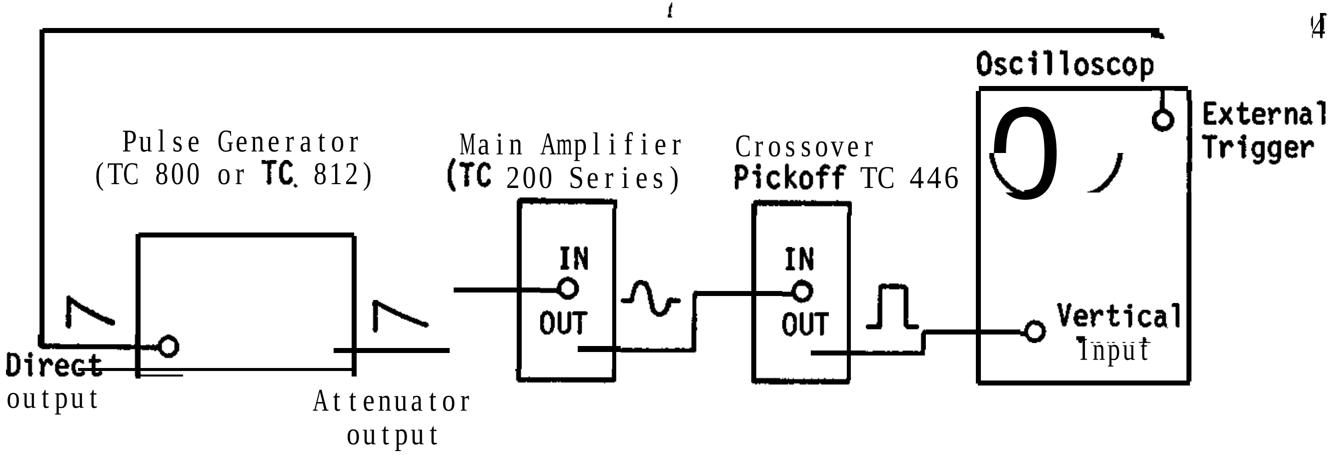

Oscilloscop
External
Trigger
Pulse Generator
(TC 800 or TC 812)
Main Amplifier
(TC 200 Series)
Crossover
Pickoff TC 446
IN
OUT
IN
OUT
Vertical
Input
Direct
output
Attenuator
output

Fig. 6.

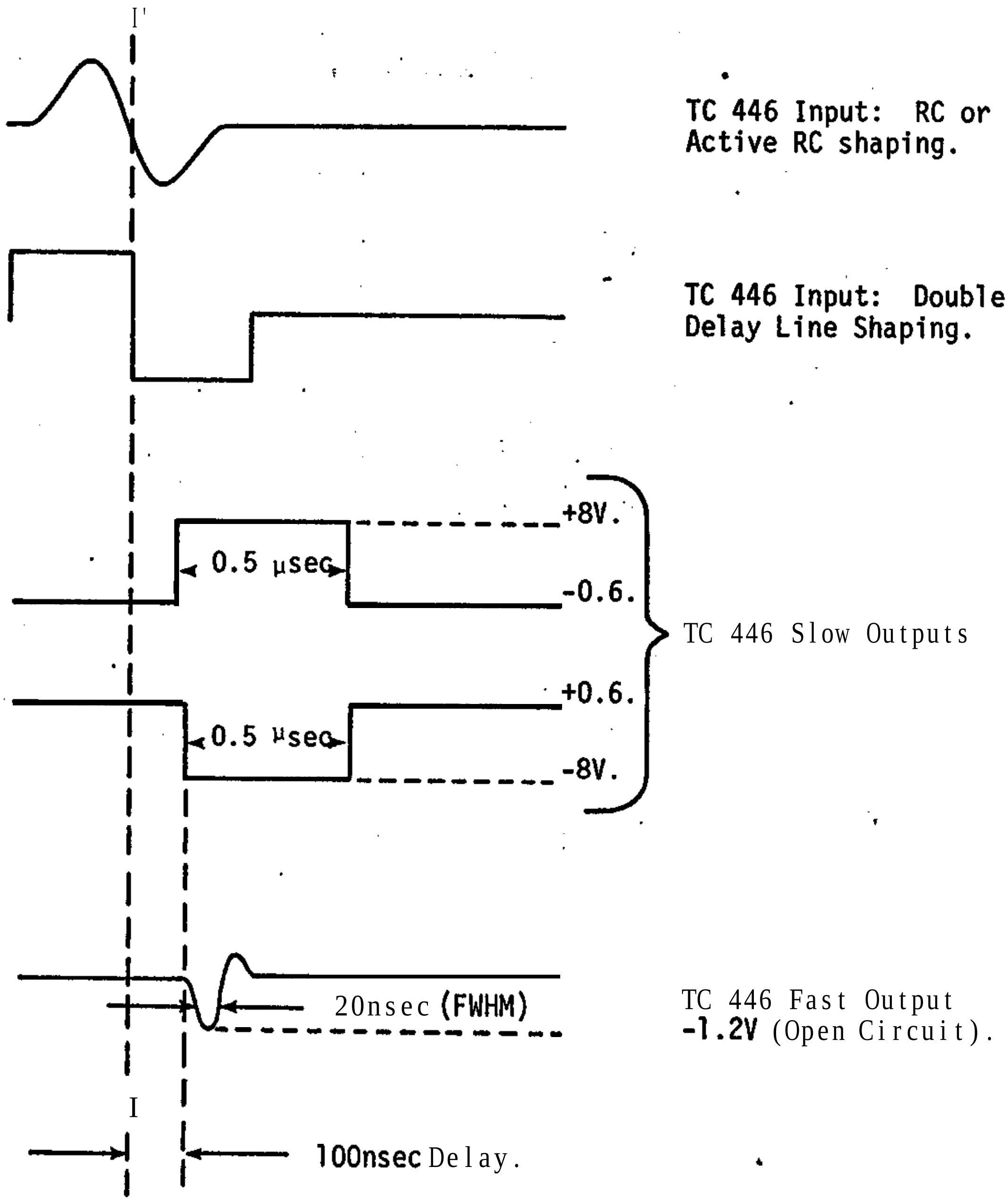

TC 446 Input: RC or
Active RC shaping.
TC 446 Input: Double
Delay Line Shaping.
+8V.
0.5 μsec
-0.6.
TC 446 Slow Outputs
+0.6.
0.5 μsec
-8V.
20nsec (FWHM)
TC 446 Fast Output
-1.2V (Open Circuit).
100nsec Delay.

Fig. 7.

GENERAL OPERATION (Cont'd)

OSCILLOSCOPE

Sweep	0.5 μsec/Div.
Vertical Sensitivity	5V/Div.
Trigger	
Mode	External.
Slope	Positive (+).

Turn the pulse generator ON and observe the positive SLOW OUTPUT of the TC 446. (If no signal appears, check the main amplifier output for a 10V, positive-lobe-leading signal.) Observe the signals at the negative SLOW OUTPUT and the negative FAST OUTPUT. Traces and time relationships similar to those shown in Fig. 7 should be seen on the screen of the oscilloscope.

Vary the OUTPUT DELAY control over'its entire range and observe the linear relationship between the dial readings and observed delay. (A dual trace oscilloscope is convenient but not necessary for this observation.) To match linear and digital delays, a linear delay greater than the delay of the crossover point (See Section 1.1) must be chosen and the logic signal delay must be adjusted by means of the OUTPUT CONTROL.

The walk characteristics of the TC 446 are depicted in Fig. 8. Walk is plotted as a function of attenuation from 10V and as a function of the reset level of the discriminator. This family of curves is useful in predicting the offset of the RESET LEVEL control required for compensation of walk that results from walk in the input signal.

4.3 WALK IN LINEAR AMPLIFIER SYSTEM DUE TO AMPLITUDE VARIATION

Instruments necessary for determination of walk associated with the amplifier-main amplifier system are the same as those listed in Section 4.1. Also needed is an attenuator box that is of the same impedance and sequence as that of the pulser.

Connect the instruments as shown in Fig. 9. Set the pulse height controls of the pulse generator* and the gain controls of the main amplifier to produce signals of full-scale output voltages. Set the attenuation factor of Attenuator No. 1 to zero and the attenuation factor of Attenuator No. 2 to 10. Monitor the output of Attenuator No. 2 (main amplifier full-scale voltage/attenuation factor of Attenuator No. 2). Alter the attenuation factors of Attenuator No. 1 and No. 2 while observing the crossover point of the output signal at Attenuator No. 2 according to the following sequence:

Attenuator No. 1	Attenuator No. 2
0	10
2	5
5	2
10	0

The deviation of the crossover point of the output signal of Attenuator No. 2 constitutes crossover walk; this crossover walk is the result of amplitude variation that occurred in the preamplifier-amplifier chain. This determination is based on the assumption that there is no variation in amplitude occurring in the attenuator box. Walk introduced by the attenuators may be measured using this same technique. Simply connect the output of Attenuator No. 1 to the input of Attenuator No. 2 and proceed as described above.

NOTE: *In this test, it is mandatory that the oscilloscope be properly set; the crossover point of the output signal of Attenuator No. 2 (prior to the addition of attenuation factors) must fall on the center of the oscilloscope gradicule. The procedure for proper setting of the oscilloscope is as follows:

1. Set the sweep speed to the value which is to be used in the observation (10 to 20 nsec).

2. Set the vertical gain so that a reasonably large slope is produced at the crossover (45° is sufficient).

3. Reduce the sweep speed to the point where the baseline of the input signal can be observed.

4. Using the VERTICAL POSITIONING control, set the baseline on the center line of the gradicule.

5. Increase the sweep speed to 10 to 20 nsec/div.

6. Set the crossover point of the observed signal at the center of the gradicule of the oscilloscope by adjusting the Horizontal CENTERING control.

5.0 CIRCUIT OPERATION

A complete circuit diagram of the TC 446 Crossover pickoff is included at the end of this manual.

5.1 INPUT BUFFER

The input buffer of the TC 446 consists of IC-1 and Q1. This stage performs the buffer function plus that of scaling. The output dynamic range is -10 nsec.

5.2 BIAS CURRENT GENERATOR and FEEDBACK SWITCH

The bias current generator consists of IC2C, C12 and Q3. The current is continuously variable from ~50 μA to 10mA over two ranges that are selected by S1, the THRESHOLD SENSITIVITY switch.

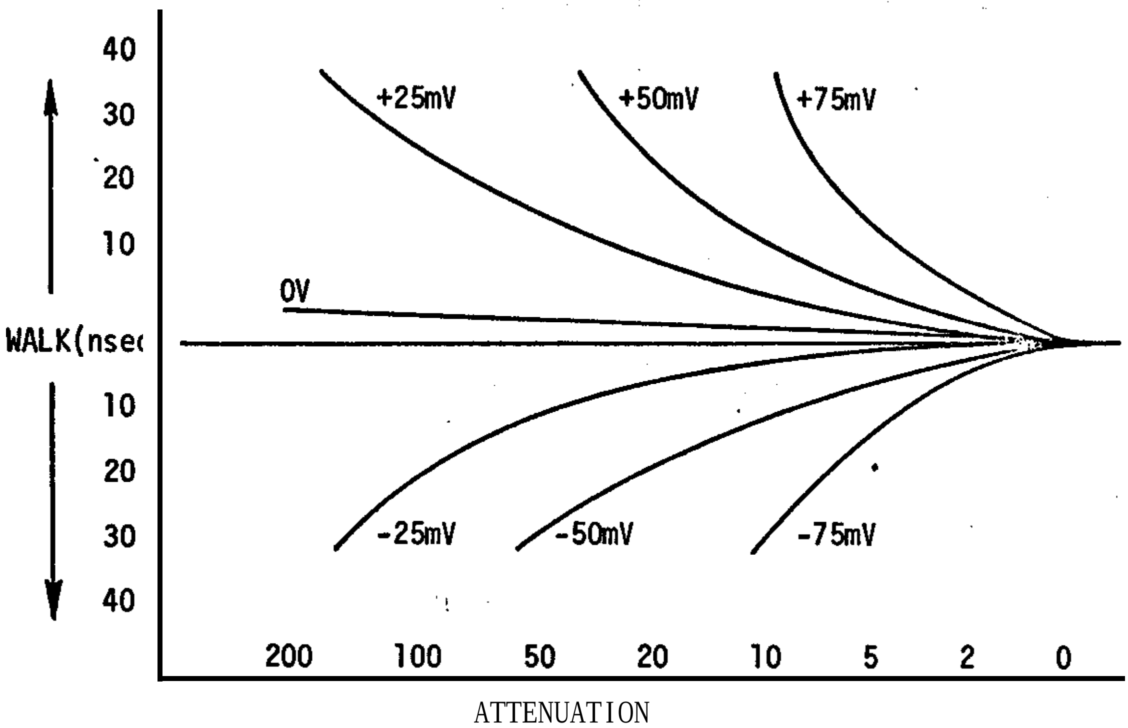

40
30
20
10
WALK(nsec
10
20
30
40
+25mV
+50mV
+75mV
0V
-25mV
-50mV
-75mV
200
100
50
20
10
5
2
0
ATTENUATION

Fig. 8.

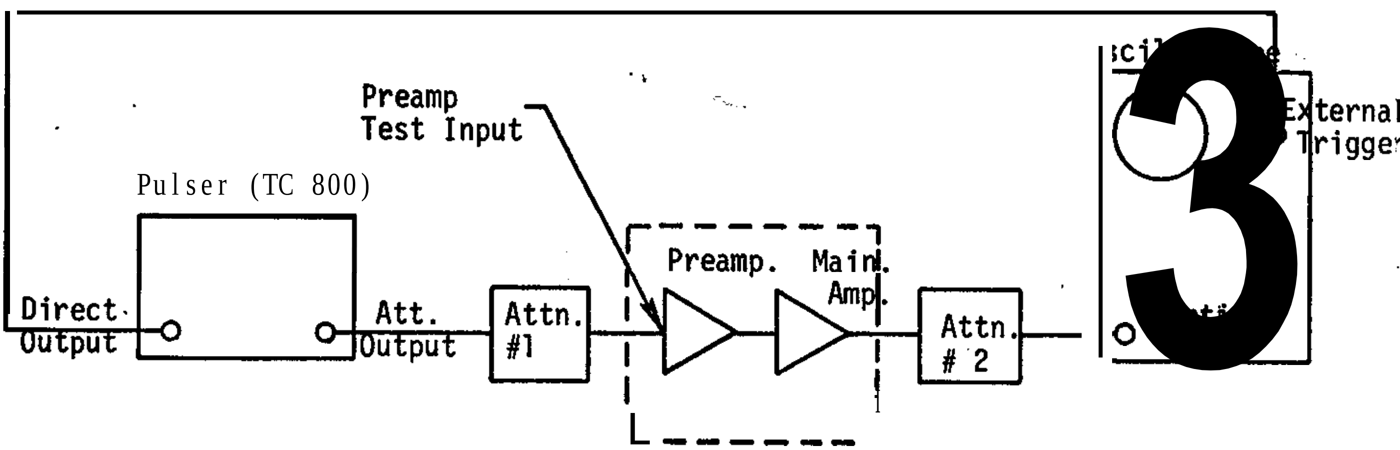

Preamp
Test Input
Pulser (TC 800)
Direct
Output
Att.
Output
Attn.
#1
Preamp.
Main.
Amp.
Attn.
2

Fig. 9.

The feedback switch consists of D5 and D14. When the input current to the discriminator (through R11) exceeds the bias current, the discriminator changes states. This action raises the anode of D14 to ~+4V which results in D5 being cut off. With D5 cut off, the bias on the discriminator becomes that set by R51; the input side of the discriminator must fall below this new bias level before it can reset to its initial state.

The rise and fall times of this discriminator are about 10 nsec.

5.3 DELAY AND PULSE WIDTH GENERATOR

The delay and pulse width generator is made up of IC4, IC5 and Q8 through Q11. The delay is generated by the application of a constant current, developed through Q9, into C26. When the linearly rising voltage exceeds the reference level seen by the comparator, IC5, a stop signal is generated; this discharges the timing capacitor, C26, and simultaneously triggers the pulse width generator (a one-shot multivibrator).

The output of the pulse width generator drives the two slow outputs and triggers the fast negative output generator.

5.4 OUTPUT STAGES

The three output stages of the TC 446 are the two slow output stages and one fast output stage. The two slow output stages consist of Q12, Q14 and 913, Q15 which-operates as saturated amplifiers and emitter-followers, respectively. 916, Q17 and D22 make up the fast output stage; the output is developed by the impulse current from C39 through Q17 and RP3.

6.0 APPLICATION

The need for logic signals within a nuclear instrumentation system arises when measurements of time at which events occur are required and when on-line computations are made. The Model TC 446 Crossover Pickoff is most useful 'in a system designed for fast/slow or fast coincidence measurements. By far the most common application of the TC 446 is to provide logic signals to the coincidence analyzer in a fast coincidence system. Figure 10 illustrates a wide dynamic range fast coincident system.

7.0 SERVICING

In the event of a component failure, replacement may be done in the field or the instrument may be returned to our plant for repair. There will be no charge for repairs that fall within the warranty.

8.0 SHIPPING DAMAGE

Upon receipt of the instrument, examine it for shipping damage. Damage claims should be filed with the carrier. The claims agent should receive a full report; a copy of the report that is sent to the claim agent should be sent to TENNELEC, Inc., P. O. Box D, Oak Ridge, Tennessee 37830. The model and serial number of the instrument must be included in the report. Any remedial action taken by TENNELEC, Inc., will be based on the information contained in this report.

9.0 WARRANTY

In connection with TENNELEC's warranty hereinafter setout, TENNELEC suggests that should a fault develop, that the customer immediately notify the TENNELEC Customer Service Manager. He may be able to prescribe repairs and to send replacement parts which will enable you to get the instrument operating sooner and at less expense than if you returned it.

Should return prove necessary, the TENNELEC Customer Service Manager must be informed either IN WRITING, BY CABLE, or BY TWX of the nature of the fault and the model number and serial number of the instrument. Pack the instrument well and ship PREPAID via Air Express to TENNELEC, Inc., 601 Oak Ridge Turnpike, Oak Ridge, Tennessee 37830. As stated in the warranty, DAMAGE IN TRANSIT DUE TO INADEQUATE PACKAGING WILL BE REPAIRED AT THE SENDER'S EXPENSE as will damage that obviously resulted from abuse or misuse of the instrument.

Quotations for the repair of such damage will be sent for your approval before repair is undertaken.

Warranty

TENNELEC, Inc. warrants that the products or components manufactured by it shall be free from defects in material or workmanship for a period of two years from the date of delivery to purchaser. If such product or component is determined to be defective by TENNELEC, its sole warranty obligation shall be limited to either replacing or repairing such defective product or component or allowing credit therefor, at TENNELEC's option. Such warranty is further conditioned upon the purchaser's giving prompt notice of any such defect and satisfactory proof thereof to TENNELEC's customer service manager; thereafter upon TENNELEC's approval, the purchaser shall return such defective product or component to TENNELEC's factory at Oak Ridge, Tennessee, all transportation charges prepaid. TENNELEC shall be responsible only for transportation charges incurred in returning such product or component to purchaser. All customs. brokerage and duty charges shall be at the expense of the purchaser. Damage in transit due to inadequate packaging will be repaired at purchaser's expense. Any repairs or replacements by the purchaser without TENNELEC's approval, any willful abuse or any evidence that the product or component was not properly used and maintain&, would automatically void this warranty.

TENNELEC makes no warranty whatsoever in respect to products or components not manufactured by it but instead the applicable warranties, if any, of the respective manufacturers thereof shall apply. Likewise fuses. batteries and input transistors in ultra low-noise amplifiers are specifically excluded from this warranty.

THIS WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSOR IMPLIED. STATUTORY OR OTHERWISE, INCLUDING WARRANTY OF MERCHANTABILITY AND FITNESS.

TENNELEC

P. O. Box D

Oak Ridge, Tenn. 37630

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TWX 810-572-1018

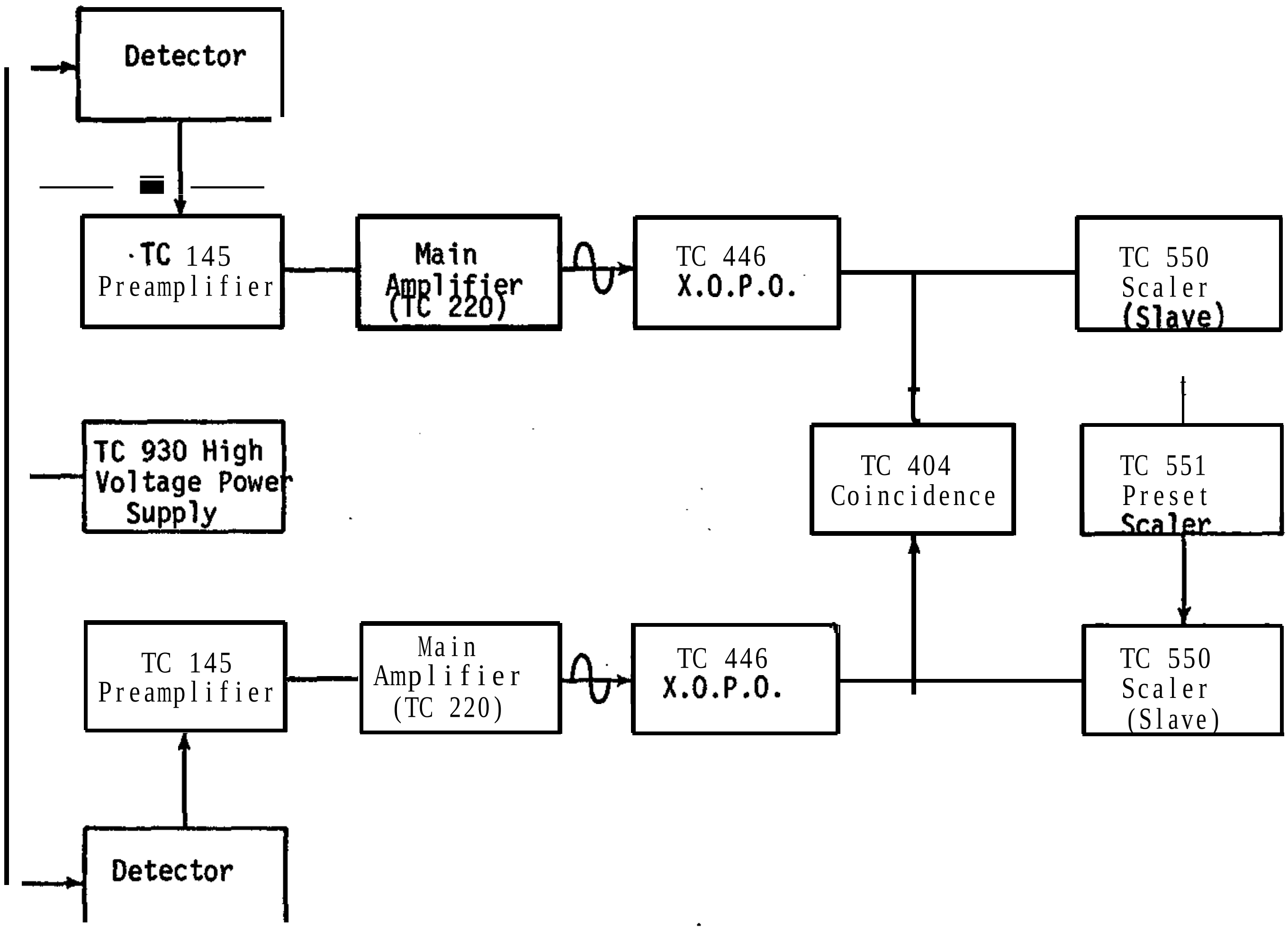
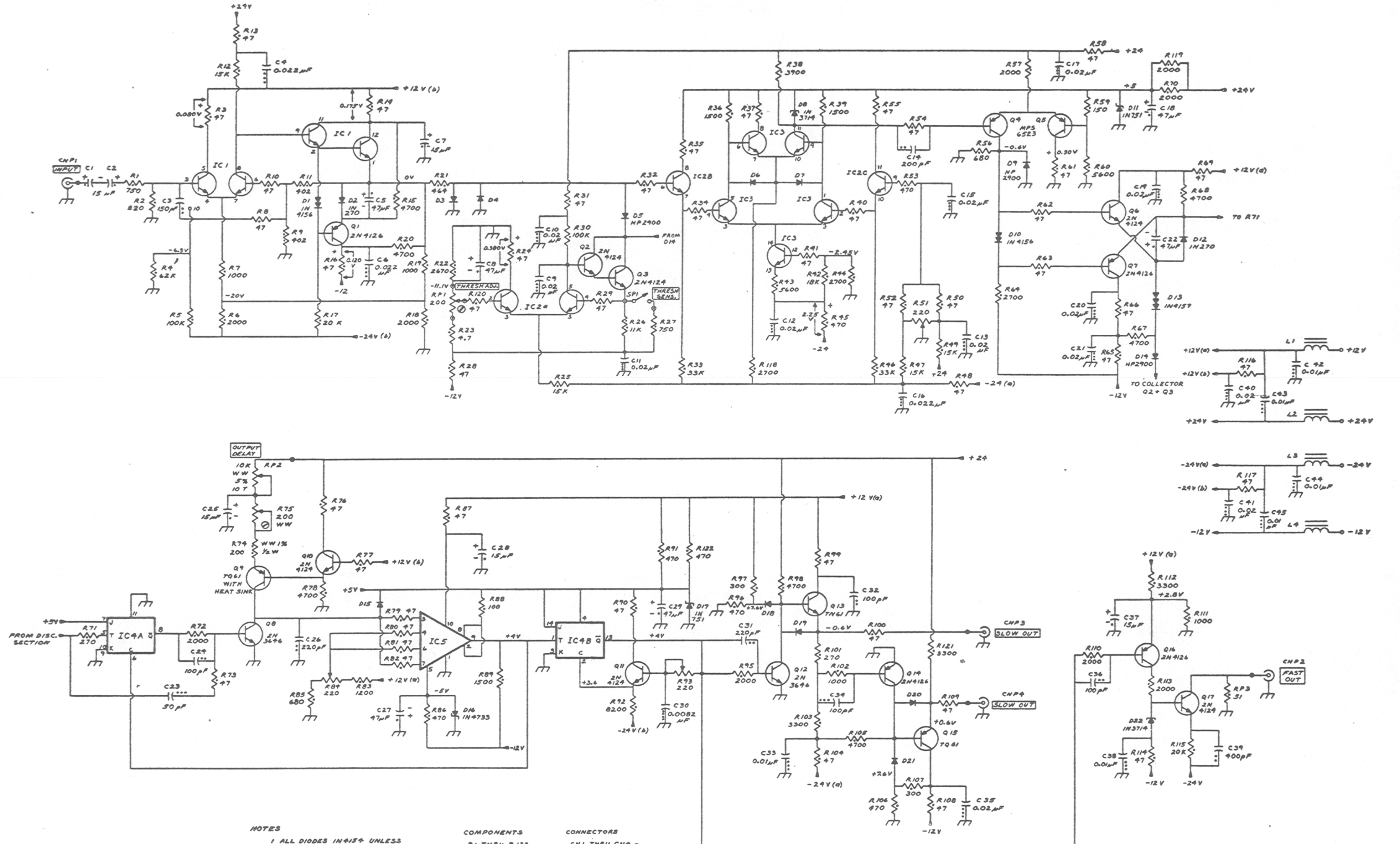

Detector
TC 145
Preamplifier
Main
Amplifier
(TC 220)
TC 446
X.O.P.O.
TC 550
Scaler
(Slave)
TC 930 High
Voltage Power
Supply
TC 404
Coincidence
TC 551
Preset
Scaler
TC 145
Preamplifier
Main
Amplifier
(TC 220)
TC 446
X.O.P.O.
TC 550
Scaler
(Slave)
Detector

Fig. 10.



NOTES

1 ALL DIODES IN4154 UNLESS OTHERWISE NOTED

2 RESISTORS NOTED AS BELOW
- • 1/4W 5% DEPOSITED CARBON
- •• 1/4W 1% METALFILM

3 CAPACITORS NOTED AS BELOW
- • TANTALUM
- •• MICA
- ••• NPO CERAMIC
- •••• MYLAR

COMPONENTS

R1 THRU R122
C1 THRU C45
D1 THRU D22
Q1 THRU Q17
L1 THRU L4
CNP1 THRU CNP4
SP1

CONNECTORS

CN1 THRU CN4 - BNC, DAGE 95712-667-6

CN5 - AMP 202515-5

INTEGRATED CIRCUITS

IC 1 - CA3018
IC 2, IC 3 - CA3046
IC 4 - SN7473N
IC 5 - MC1711C6

NO.	REVISION	DATE	BY
1	RN# 68-00	12-68	RS

TENNELEC INSTRUMENT COMPANY, Inc.

TC 446 CROSSOVER PICKOFF

CIRCUIT DIAGRAM

ERRON ANDERSON	9-14-69	EF
JACK WALKER	7-8-69	DWG. NO. TC446-1