TENNELEC

INSTRUCTION MANUAL

TC 307

INNOVATION TO MAKE IT FIRST.
RELIABILITY TO MAKE IT LAST

INSTRUCTION MANUAL

TC 307 LINEAR GATE

TC 307
TAELE OF CONTENTS

1.0 INTRODUCTION

The TENNELEC TC 307 Linear Gate is a single-width NIM designed to block OK pass a linear signal at the command of an externally-applied gating pulse. The gain is unity, noninverting.

The TC 307 is dc-coupled, allowing it to operate from dc to high count rates without baseline shift. In the normally open (N.O.) mode, it will pass 0-10V signals of either polarity (dc, unipolar, bipolar, sinewave, etc.) unless inhibited by an external gate pulse ($\geq$ +1.3V). In the normally closed (N.C.) mode, it will block signals of either polarity unless enabled by the external gate pulse ($\geq$ +1.3V). Gating time is <15 ns. The gate trigger circuit remains in its switched state for the duration of the externally-applied gate signal and recovers within 15 ns after removal of that signal, By applying a train of gate pulses, a linear dc signal may be chopped synchronously with the gate pulses.

An LED indicates the presence of output signals (pulse or dc, either polarity) larger than 0.25V.

Front-panel connectors are duplicated on the rear,

TABLE OF CONTENTS

LIST OF FIGURES

2.0 SPECIFICATIONS

GAIN	0.99 ± 0.02
INPUT	
Coupling	DC
Polarity	Either
Range	
Linear	>10V
Maximum	
DC	±24V
Pulse	±75V, 10% duty cycle
Impedance	
Below 11V	1950 ohms ± 1%
Above 11V	460 ohms
OUTPUT,	
Coupling	DC
Polarity	Same as input (noninverting)
Range	
Open Circuit	
Linear	>10V
Maximum	±12V
Terminated, in 50 ohms	
Linear	>5V
Maximum	±6V with output R set for 50 ohms ±12V with output R set for <1ohm
Impedance	
50 ohm setting	50 ohms ±1%
<1 ohm setting	<1 ohm
PEDESTAL (Input terminated in 50 ohms)	≤5mV decaying to zero in 15us
GATE SWITCHING TRANSIENTS	
Amplitude	<50 mV
Width	<20 ns full width at half max.

GATE INPUT	
Coupling	DC
Polarity	Positive
Threshold	≤ +1.3V, 1.2V typical
Maximum Input	
DC	±20V
Pulse	±75V, 10% duty cycle
Hysteresis	0.4V typical
Width	Gate signal is initiated when input exceeds the threshold level and remains on until input drops 0.4V below threshold.
Input Impedance	
Below 4V	1,000 ohms nominal
Above 4V	1,300 ohms nominal
PROPAGATION DELAY	
Linear channel	30 ns typical
Gate (0.1V overdrive)	15 ns typical
FEEDTHROUGH (Gate closed, ±10V quasi-gaussian pulse, 2 us peaking time)	≤5 mV
INTEGRAL NONLINEARITY 0 to ±10V, 1k load, quasi-gaussian input pulse, 2us peaking time	<0.05% referred to 10V full scale
RISETIME (10% - 90%) 0 to ±10V, 1k load	≤40 ns, 30 ns typical
OVERSHOOT	<2%
NOISE	
Wideband, 50 ohm input (measured with Hewlett-Packard 400 Series ac voltmeter)	200uV rms typical
Output filtered with quasi-gaussian shaping network, 2us peaking time	35uV typical

TEMPERATURE COEFFICIENT	
Gain	≤100 ppM/°C, 0° to 50°C
Zero	≤100 uV/°C, 0° to 50°C
SUPPLY VOLTAGE SENSITIVITY	
Gain change	≤0.01%/Volt
Zero shift	
+24V, -24V supplies	≤0.5 mV/Volt
+12V, -12V supplies	16 mV/Volt
SIGNAL INDICATOR LED	
Threshold	±0.25V typical

2.1 OTHER INFORMATION

POWER REQUIREMENTS	
+24V	45 mA maximum
+12V	55 mA maximum
-12v	50 mA maximum
-24V	35 mA maximum
WEIGHT	
Shipping	4.0 lbs. (1.82 kg)
Net	2.1 lbs. (0.96 kg)
DIMENSIONS	Standard single-width NIM (1.35 " x 8.714") per TID 20893 (Rev).
WARRANTY	One year
INSTRUCTION MANUAL	One provided with each instrument ordered

3.0 CONTROLS

3.1 FRONT-PANEL CONTROLS

PEDESTAL	Multiturn, screwdriver adjustable
Range	0 to ±0.25V nominal
MODE	Z-position toggle switch N.O. (normally open) and N.C. (normally closed).

3.2	CIRCUIT BOARD CONTROLS	
	N.O. ZERO	One-turn trimmer, screw-driver adjustable
	N.C. ZERO	One-turn trimmer screw-driver adjustable
	OUTPUT ZERO*	One-turn trimmer screw-driver adjustable
	TBERM BAL	One-turn trimmer screw-driver adjustable
	OUTPUT IMPEDANCE	2-position slide switch, 50 ohms and <1 ohm
3.3	REAR PANEL CONTROLS	None
4.0	CONNECTORS	
4.1	FRONT PANEL CONNECTORS	
	GATE	BNC (UG 1094/U)
	INPUT	BNC (UG 1094/U)
4.2	REAR PANEL CONNECTORS	
	GATE	BNC(UG1094/U). Parallels front-panel GATE connector
	INPUT	BNC (UG1094/U). Parallels front-panel INPUT connector
	OUTPUT	BNC (UG1094/U) Parallels front panel OUTPUT connector when OUTPUT IMPEDANCE switch is in the <1 ohm position. Front and rear panel OUTPUT connectors are isolated from each other by independent 50 ohm ±1% resistors when the OUTPUT IMPEDANCE switch is in the 50 ohm position.

*Serial numbers above 209.

5.0 FIRST TIME OPERATION

The following test is a good way for users to familiarize themselves with the operation of the TC 307. The test results given below are typical.

5.1 Instruments Required

TC 307 LINEAR GATE

RECTANGULAR PULSE GENERATOR: Adjustable amplitude, risetime 0.25us or less, output impedance 100 ohms or less.

ATTENUATOR BOX: Impedance to match pulse generator.

OSCILLOSCOPE: 5 MHz or greater bandwidth, delayed input, externally triggered sweep, dual trace.

SHAPING AMPLIFIER: Nuclear pulse amplifier with peaking time 0.25 us or greater.

TERMINATOR for the pulse generator.

COAXIAL CABLES: As needed.

NIM BIN or other power source.

Connect the system as shown in Fig. 5-1 and turn it on. Note the following:

1. The TC 307 was shipped with internal adjustments accurately set for power supply voltages within 0.1V of the nominal values of ±24V, ±12V.
2. The OUTPUT IMPEDANCE switch was set to the 50 ohm position prior to shipment.
3. The TC 307 will not be damaged by inserting or removing it from the bin with the power ON.

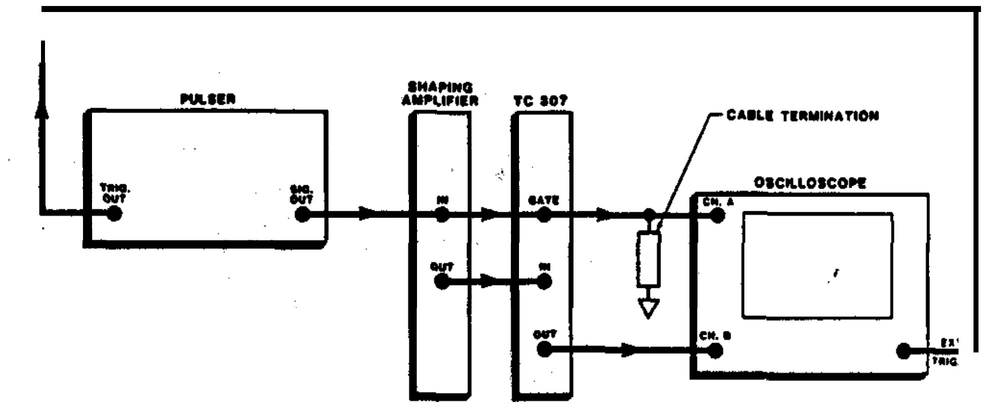

Fig. 5-1 Setup for observing operation of the TC 307

5.2 Control Settings

With the test instruments listed below, the following control settings should be made. Settings may require modification if instruments other than those listed below are used.

OSCILLOSCOPE	TEKTRONIX 475 (200 MHz B.W.
Channel A	0.5V/Div, dc coupled
Channel B	0.05V/Div, dc coupled
Sweep	0.5 us/Div
Tc 307	
MODE	N.C.
SHAPING AMPLIFIER	TBNNELEC TC 205A
Shaping Constant	0.25 us, Unipolar
Gain	
Coarse	10
Fine	X0.6
Polarity	+In, +Out
PULSE GENERATOR	TEKTRONIX 114
Period	0.5 ms
Width	2.7 us
Amplitude	0.9V or 1.5V. See text.
ATTENUATOR	X100

5.3 Waveform observations, Low-Level Signals

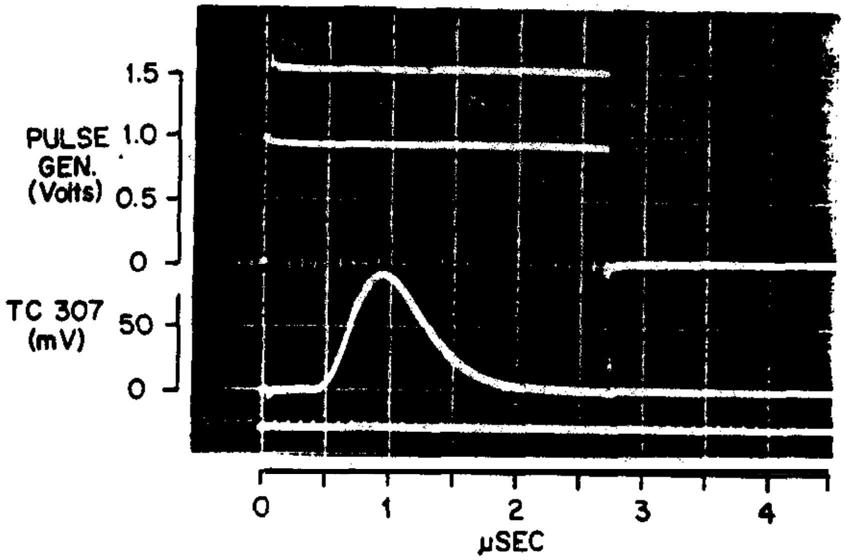

Fig. 5-2. TC 307 and gate-pulse waveforms, low-level signal.

In Fig. 5-2, a multiple exposure oscillogram is displayed of the gate-pulse generator output and TC 307 output. The gate was in the N.C. mode.

With the pulse generator output at 1.5V (top waveform), the gate is opened and transmits the 90 mV guasi-gaussian pulse from the TC 205A amplifier. Note the switching spike approximately 30 mV high at the instant of gate closure (at 2.7 us). Another smaller and narrower spike exists at the start of the pulse, but is not large enough to be visible in the. figure. The delay in the onset of the TC 205A output pulse is inherent in the TC 205A. The pedestal control was tweaked to align the baseline before and after gate closure (at 2.7 us).

With the pulse generator output reduced to 0.9V, the gate remains closed and no signal is transmitted. This is illustrated by the lowest line in the figure, which was displaced (with the oscilloscope positioning control) to distinguish it from the waveform above it. The L.E.D. should not glow under the conditions of the preceding test.

5.4 Waveform Observation, High-Level Signals

Fig. 5-3 shows the feedthrough of a 10V signal. To obtain the waveforms, reset the controls as follows (control settings other than those listed remain unchanged):

OSCILLOSCOPE Channel B	5V Div
TC 307 MODE	N.O.
ATTENUATOR	out
PULSE GENERATOR	1.0V
SHAPING AMPLIFIER Fine Gain	Adjust for 10.V output signa

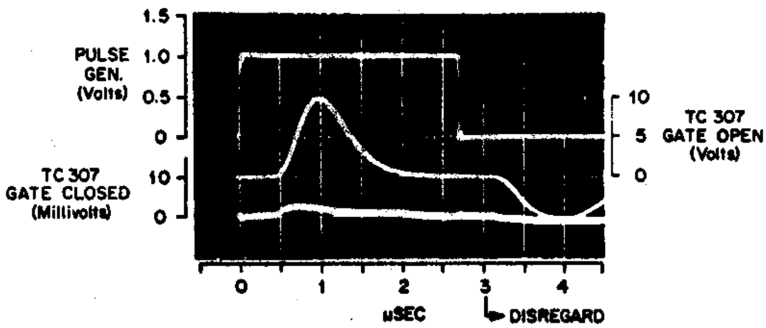

Fig. 5-3 TC 307 and gate-pulse waveforms, high-level signal.

In the figure, the center waveform (amplitude scale at the right) is that transmitted by the TC 307. The uppermost wavetorm is that of the pulse generator.

If the TC 307 MODE switch is set to N.C. and the oscilloscope sensitivity increased to 10 mV/Div, the lowest waveform results. (The oscilloscope position control was readjusted to separate the two lowest waveforms). This shows the feedthrough of the 10V pulse when the gate is closed. Note that the peak of the feedthrough signal is synchronized with that portion of the input signal which exhibits the greatest slope.

The L.E.D. should glow when the TC 307 is transmitting the 10V signal, but not when the signal transmission is blocked (gate N.C.).

The waveform to the right of the 3 us mark is a response of the amplifier to the trailing-edge pulse-generator transition and has no bearing on this test.

5.5 Waveform Observations, Switching Spikes

Disconnect the amplifier from the TC 307 and terminate its input with 50 ohms.

Change control settings as follows:

OSCILLOSCOPE	
Channel B	20 mV/Div
Sweep	0.05 us/Div
PULSE GENERATOR	
Width	0.2 us
Amplitude	1.5V
ATTENUATOR	X100

The upper waveform in Fig. 5-5 is that of the pulse generator and the lower is that of the switching spikes.

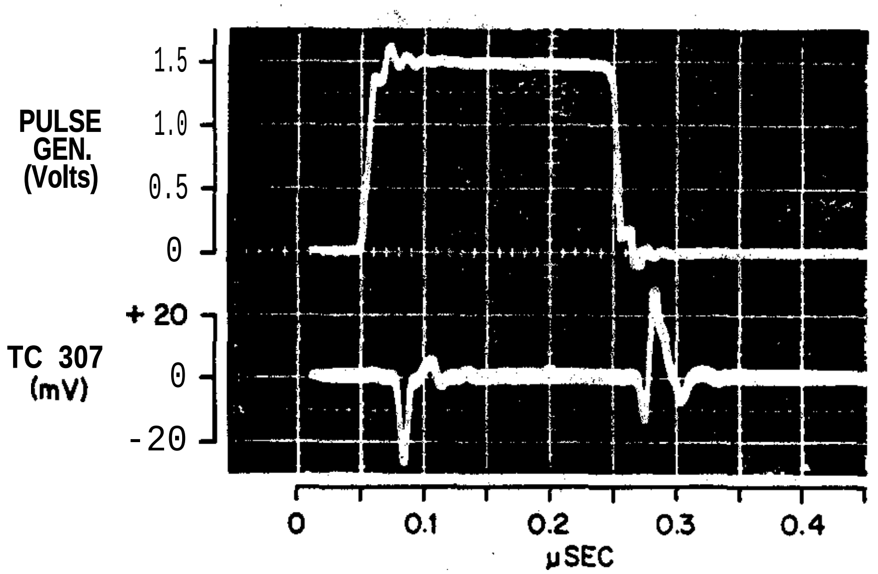

Fig. 5-5. TC 307 switching spikes.

The delay between the gate-pulse transitions and the spikes is due mainly to the propagation delay (≈30 ns) of the linear circuits in the TC 307.

In the TC 307 used for this test, the pedestal was about 2 mV high and caused a vertical shift of the baseline between the leading-edge and trailing-edge spikes. This pedestal was tuned out with the PEDESTAL control prior to making the oscillogram.

6.0 ADJUSTMENTS

6.1 PEDESTAL Control

In normallpoff operation, when a gate enabling pulse occurs, a transient baseline offset known as a ‘pedestal” may appear at the OUTPUT of the TC 307. Linear signals will ride on this pedestal, causing an error in signal height equal to the pedestal height. The pedestal may be adjusted to zero using the PEDESTAL control.

The PEDESTAL control (front panel) was intended to compensate only for the dc offset in the signal source, and for this reason, the range is only ±0.25V. Circuit modification is required for a larger range and is described in Sect. ‘8.7.

6.1.1 Pedestal Adjustment with Signal-Source Offset Control

If the signal source has an offset control, begin the adjustment by replacing the signal source with a 50-ohm terminator (connected, to the TC 307 INPUT). Connect a dc millivolt meter or a dc-coupled oscilloscope to the OUTPUT of the TC 307. With the gate signal removed (or below threshold), trim the PEDESTAL control so that no change in TC 307 output voltage occurs when the MODE switch is flipped. Note that the absolute voltage may be different from zero when this condition is attained. If this offset is excessive for the intended application, the internal offset controls must be readjusted. See (Sect. 6.2)

Remove the terminator and reconnect the signal source. Now trim its off set control as described above as if it were the PEDESTAL adjustment. (If a meter is used for this adjustment, no pulses must emerge from the signal source because they will cause an error. The use of an oscilloscope permits pulses to be present because the baseline between pulses can be observed.)

6.1.2 Pedestal Adjustment, Signal Source Offset not Adjustable

Connect a dc millivolt meter or oscilloscope to the OUTPUT of the TC 307 and connect the signal source to the INPUT. Do not gate the TC 307 and do not allow pulses to issue from the signal source. Adjust the PEDESTAL control so that no change *in* dc output level occurs when the MODE switch is flipped.

If pulses cannot be turned off from the signal source, use the oscilloscope as the dc indicator to allow observation of the baseline between pulses. If the dc offset from the signal source is large enough to be outside the range of adjustment of the PEDESTAL control (±0.25V), the range *may* be increased by *an* internal modification. See Sect. 8.7.

6.2 Internal Adjustments

The internal adjustments are one-turn screwdriver-adjustable trimmers for normally closed zero (N.C. ZERO), normally open zero (N.O. ZERO), OUTPUT ZERO* and thermal balance (THERM BAL). The trimmers are mounted on the circuit board. The left-side module cover plate must be removed for access. The adjustments can be made with the TC 307 mounted in a NIM bin if the TC 307 is inserted in the slot nearest the right side of the bin and if the modules to the left of the TC 307 are removed for access to the trimmers.

THERM BAL readjustment should never be required unless the input integrated circuit is replaced. Even then, readjustment may be unnecessary.

As in the TBERM BAL case, it is unlikely that the zero adjustments will require changes. However, an offset may result from power supply errors. The supply voltages should first be trimmed to within ±0.1V of their nominal values to confirm that TC 307 readjustment is necessary.

*Serial numbers above 209.

In addition to the TC 307 and its power source, a square-wave generator, an oscilloscope, and a 50 ohm terminator will be required.

Connect the system as shown in *Fig. 6-2.*

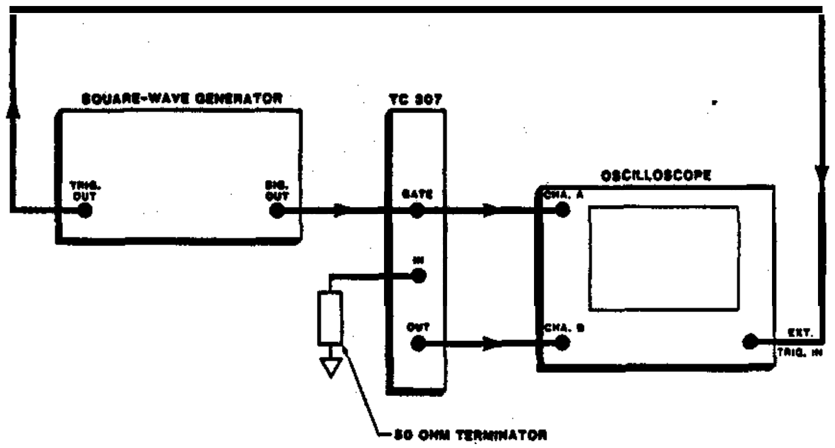

Fig. 6-2 Test setup for adjustment of TC 307 internal controls.

Set controls as follows:

OSCILLOSCOPE	
Channel A	**0.5V/Div** dc coupled
Channel B	**10 mV/Div** dc coupled
sweep	**1 ms/Div**
Vert mode	CHOP
GENERATOR	
Repetition rate	250 Hz
Amplitude	**0.9V**
Polarity	+
TC 307	
MODE	*N.C.*

Trigger the oscilloscope sweep from Channel A (the generator channel) or directly from the generator. With **Channel B** disconnected, (or its INPUT switch set to GROUND), adjust the oscilloscope positioning controls to produce the waveforms shown in Fig. 6-3.

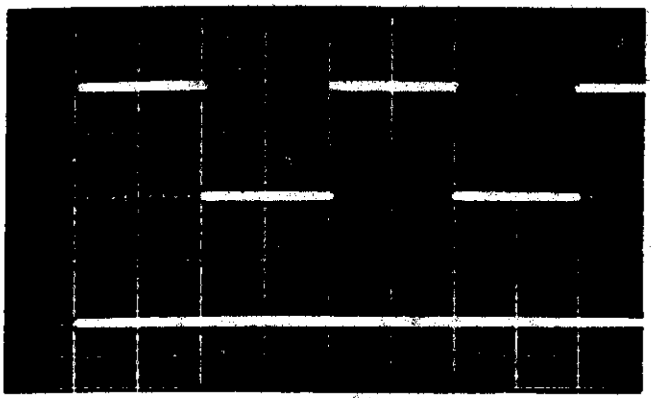

Fig. 6-3 Waveforms for TC 307 setup

Reconnect the TC 307 OUTPUT to Channel B. Adjust the N.O. ZERO and/or the OUTPUT ZERO (the two adjustments are virtually interchangeable) on the circuit board to zero output volts.

Switch the TC 307 MODE to N.O. and adjust the PEDESTAL control for zero volts output. If the control is out of range (which may occur if IC1 or IC2 are changed), alter the relative adjustments of the N.O. ZERO and OUTPUT ZERO and start over.

With the PEDESTAL and N.O. ZERO controls correctly set, the trace will not move from zero when the TC 307 MODE switch is flipped back and forth.

Increase the generator output to 1.5V, causing the TC 307 gate to operate. Adjust the N.C. ZERO trimmer so that the Channel B trace remains at zero for both half-cycles of the square wave (the MODE switch setting is immaterial).

Next, adjust the THERM BAL trimmer so that the positive and negative transients at the square-wave transitions are symmetrical. See Fig. 6-4. Note that changing the setting of the THERM BAL trimmer will move the TC 307 baseline. After adjustingthetrimmer for symmetrical transients, readjust the N.O. and N.C. ZEROs. This completes the alignment.

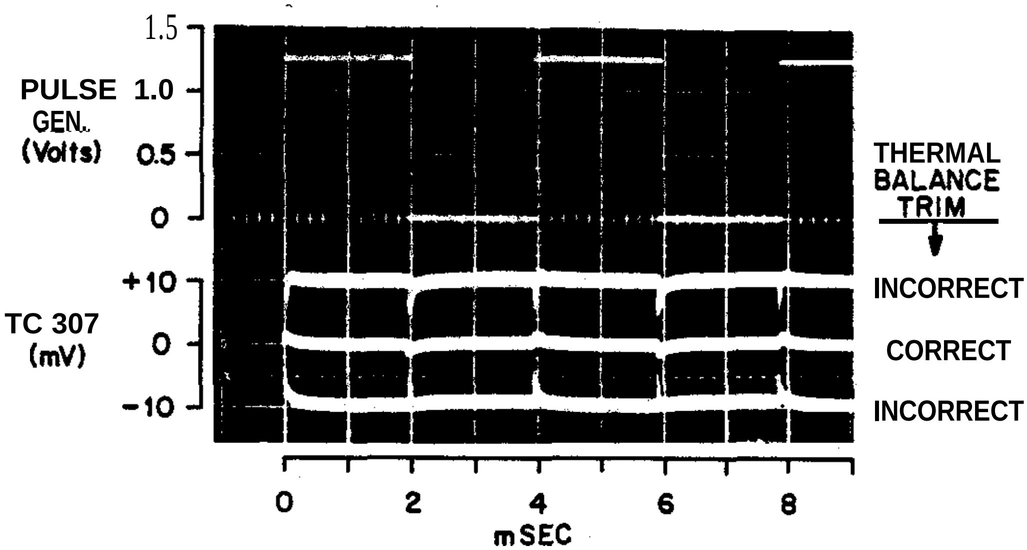

Fig. 6-4 THERM BAL trimmer adjustment

7.0 CIRCUIT OPERATION

A circuit diagram is at the end of this manual. The circuit is divided into four sections: Input Stage, Gate Switch, Output Stage, and Counting Monitor.

7.1. Input Stage

The input group is built around an integrated dual differential array (IC1a and IC1b). Depending on the state of the gate switch and the gate signal applied to pins 3 and 11 (Test Points 17 and 18) of IC1, one or the other half of the array will be conducting and will constitute the active input stage for the remainder of the inverting operational amplifier Q1 through Q5. In the absence of gate signal, IC1a is normally conducting. The INPUT signal is routed through the MODE switch either to IC1a (N.O. position) or IC1b (N.C. position).

The input resistor is R1 plus R5 or R6, depending on the position of the MODE switch. R8 and R9 limit the loop gain of the input group for stability against oscillation.

The PEDESTAL bias is derived from RO and is injected through R2 into the junction between R1 and R5(R6). -The diode network D1-D4 limits the input signal to prevent any of the linear stages from saturating.

The THERM BAL control is used to set the operating voltage on the input IC transistors. Adjustable offset voltages are injected into the bases of these same transistors.

R1, R5 (R6), and R10 (R11) determine the gain of the input group. The gain is precisely 0.49 referred to a signal source with a 50 ohm internal resistance.

Q1, Q2, and Q4 are gigahertz transistors.

7.2 Gate Switch

This stage is a Schmitt trigger. The loading on Q6 and Q7 was designed to give a symmetrical output such that the average voltage at pins 4 and 12 of IC1 does not change when the gate is triggered. This symmetry minimizes gate transients. The switching voltage at pins 4 and 12 is set by R58 and is just large enough to cause complete current switching between IC1a and IC1b. D23-D26 limit the switching voltage of Q6-Q7 and also speeds up the' transition.

D20-D22 protect Q6-Q7 from excessive input voltage.

7.3 Output Stage

This is an inverting op amp built around IC2. D9, D10, and D13 limit the base currents to Q12 and Q13 when the output is short circuited.

IC3 and IC4 are 15V regulators which limit at 100 mA minimum; 200 mA typical. With the OUTPUT IMPEDANCE switch in the 50 ohm position,, rated maximum output will be obtained if one of the two outputs is loaded with 50 ohms and may or may not be obtained if both outputs are loaded, depending on the saturation level of IC3 or IC4. If the switch is in the <1 OHM position and either of the outputs is loaded with 50 ohms, a maximum signal level of 5V can be obtained, and the maximum may be 10V depending on the saturation level of IC3 or IC4.

7.4 Counting Monitor

This circuit consists of a pair of comparators IC5a and IC5b connected as a univibrator. IC5a responds to positive polarity signals and IC5b to negative. R92 and R94 set the threshold of IC5a, and D15 and D16 set the threshold of IC56. C52 and R95 determine the recovery time (≈1 ms) after triggering. Q13 and Q14 are normally nonconducting. When IC5 is in the triggered state, Q13 and Q14 turn on, illuminating the LED D19. R103 and C56 constitute a saturating differentiator. For low count rates, the current into the LED is high so that the presence of a single pulse is visible. As the pulse rate increases, the average current drops off to maintain approximately constant LED illumination. C54 is a filter to prevent LED pulse current from appearing in the output signal;

8.0 OPERATING NOTES

6.1 Gate Control

The gate will remain in a switched state for the duration of a greater-than-1.3V gate signal. The duration and time of occurence of the gate signal can be controlled by a Delay and Gate Generator, such as a TENNELEC TC 410A (0.1 to 110 us range for both delay and duration).

a.2 Output Impedance

The output impedance may be set to 50 ohms ±1% or to less than 1 ohm by a slide switch which is mounted on the circuit board. The switch is in the 50 ohm position when shipped. Unless there is a particular need for the <1 ohm output impedance, it is recommended that the switch be kept in the 50 ohm position.

8.3 <1 ohm Operation

In the <1 ohm switch position, output loads on the TC 307 of lk produce at most a 0.1% drop in signal height. However, except for very short connecting cables, cable termination probably will be required to avoid ringing. Critical cable lengths, unless terminated, may cause oscillation.

If the cable is terminated in 50 ohms, a 10V output signal will require the output stage to feed 200 mA into the termination. Because the voltage regulators which supply the output stage are guaranteed for a saturation level of only 100 mA, not all TC 307s will furnish a 10V signal into a 50 ohm load, (However, the TC 307 will not be damaged by such operations).

a.4 50-ohm Operation

In the 50 ohm position,, a 50 ohm ±1% resistor is interposed between the output stage and the front panel OUTPUT connector, and a separate 50 ohm ±1% resistor is interposed between the output stage and the rear panel connector. The two output connectors are effectively isolated. from each other by the low common resistance of the output amplifier.

In the. 50 ohm position, cable termination should not be required for output cable lengths up to or greater than 100 feet, and then only if *signal* risetime is less than approximately 0.2 usec. Termination will halve the signal height.

With an internal impedance of 50 ohms, lk loading will cause signal attenuation of 5%. If two instruments with the same input resistance are driven from a TC 307, signal loss can be halved by driving one from the front-panel output connector and the other from the rear, but this arrangement usually is unnecessary.

If the output is loaded with 50 ohms (terminated cable in the 50-ohm output impedance setting), the signal will be halved. Linearity will not be affected up to 5V output in this instance if only one output connector is loaded, but if both connectors are loaded with 50 ohms, the unit may not be able to drive the outputs to full voltage.

8.5 Placement in a System

The usual placement of a linear gate in a pulse height measurement system is between the output of the shaping amplifier ‘and the following pulse height discriminator or multichannel analyzer. In situations where there is a high background of unwanted pulses and the desired Pulses are of relatively low rate and are time correlated with the gating signal, it is tempting to place the gate between the preamplifier and shaping amplifier (keeping the gate in the normally closed mode) in an attempt to reduce pileup in the shaping amplifier. This is not a recommended arrangement for the following reasons:

1. Preamplifiers usually have a decay time which is many times that of the pulse width existing in the shaping amplifier. The result is that even at moderate count rates, the preamplifier output rarely has an opportunity to fully recover between pulses. If the gate is opened for a desired pulse, the instantaneous preamplifier output voltage will constitute a pedestal which is superimposed on the desired pulse. This pedestal will vary in amplitude and polarity from instant to instant, making for a very noisy measurement.

2. To avoid the preceding problem, the user may be tempted to reduce the decay time of the preamplifier, in effect placing the system's first differentiator there. This arrangement is undesirable for these reasons:

2a. Moving the first differentiator to the preamplifier can quadruple the system noise level.

2b. Superimposed on the preceding noise will be an added component which results from a gating operation in the part of the system which precedes the low pass portion of the shaping network.

2c. The equivalent input noise of the TC 307 is 3X to 7X greater than that of the usual shaping amplifier. This does not affect the system performance when the gate follows the main amplifier, but it may if the gate precedes it.

2d. The dc output stability of preamplifiers is poor. A changing dc level will result in a changing pedestal in the gate, further adding to the measured noise level.

6.6 AC vs DC Coupling

A linear gate should never be ac coupled (capacitively coupled) to an amplifier because baseline shifts directly proportional to the count rate will occur. Any change in baseline will appear in the gate as a pedestal.

If the output of the gate is ac coupled to a following instrument, a baseline shift proportional to count rate also will occur unless the following instrument contains a baseline restorer.

0.7 Increasing the Range of the PEDESTAL Control

The range of the PEDESTAL control can be approximately doubled (from ±0.25V to ±0.5V) by shunting R2 with a 20-kilohm resistor. For a further increase in range, the 50k PEDESTAL control should be replaced with a 10k, 2-watt unit and R2 further reduced. If R2 is reduced to 2 kilohms, the range will be increased to ±3V. However, this change will also reduce the gain of the TC 307 to a value which varies from 0.92 with the control at its midrange setting to 0.84 with the control at one of its end settings.

9.0 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 that report should be sent to TENNELEC, Inc., P.O. Box 2560, Oak Ridge, Tennessee 37830-2560. The model number 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.

10.0 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.

11.0 WARRANTY

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