Gating Adapter for Type O Plug-In

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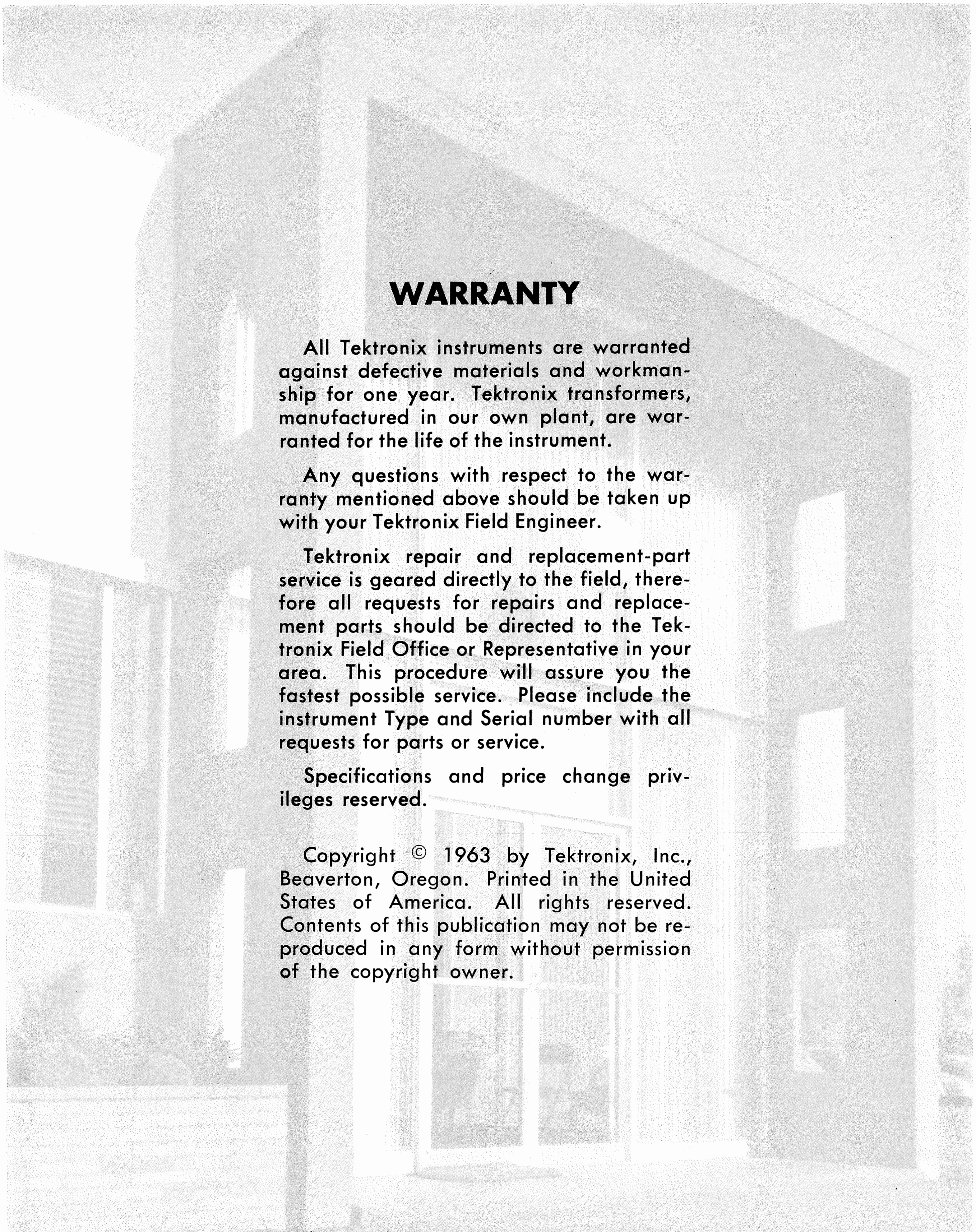
070-395 563



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Gating Adapter for the Type O Plug-In Unit

General

When the Gating Adapter is plugged into the 'B' Operational Amplifier of a Type O Plug-In Unit, an electronic switch is formed that is used to gate "on" and gate "off" the 'A' Operational Amplifier. A repetitive signal applied to amplifier 'A' will then be amplified, integrated, or differentiated only during the "on" time. There will be no signal at the 'A' output during the "off" time.

The Gating Adapter is of great value during integration operations. Except with signals which have a net integral of zero, true integration is impossible without gating since the integral of a repetitive signal would accumulate to a voltage value beyond the range of the Type O Unit. The Gating Adapter, however, permits integration for a selected time and then resets the integrator to zero. This cycle repeats with each oscilloscope sweep.

The 'A' amplifier is gated "on" by applying repetitive positive-going pulses of about 20 volts amplitude to the Gating Adapter input. The amplifier remains "on" for the duration of the pulse, and is "off" during the time between pulses.

In order for the output of the 'A' amplifier and the oscilloscope display to be coherent, both the sweep and the gating pulse must bear a fixed time relationship to the 'A' input signal. One way to accomplish this is to externally trigger the oscilloscope sweeps with the 'A' amplifier input signal and to use the plus gate output of the oscilloscope as the gating signal. Oscilloscopes such as the Tektronix Types 535A, 545A, 555, and 585, which have a delaying sweep feature, will provide greater flexibility in the gating operation. The set-up and compensation procedure at the end of this manual contains several extra steps to show how the delayed sweep gate may be used to turn on the 'A' amplifier at a selected time after the beginning of the oscilloscope sweep.

Theory of Operation

The Zener diode and capacitor at the Gating Adapter input have the effect of a battery. Repetitive positive-going pulses produce a voltage drop across the diode and maintain a charge on the capacitor. Because of this charge, the input pulses are negatively offset after passing through the diode-capacitor network.

The 'B' Operational Amplifier is connected as a unity gain, inverting amplifier. Hence, pulses of opposite polarity, but equal amplitude are applied across the diode bridge. For the duration of a pulse, all four diodes are back-biased and exhibit a resistance of about 200×10^9 ohms in parallel with the 'A' amplifier Z_f. Since this high parallel resistance does not effectively alter the Z_f value (in most practical applications), the 'A' amplifier is turned on.

When a gating pulse ends, the stored charge in the input capacitor reverses the polarity of the voltage across the diode bridge. All four diodes conduct and appear as a low resistance in parallel with the 'A' amplifier Z_f. With Z_f reduced to nearly zero ohms, there is essentially no signal at the 'A' output.

Limiting Factors

The 'A' amplifier should be turned off no more than 90% of the gating signal period or 2 seconds, whichever is the shorter time, so the charge on the Gating Adapter input capacitor is maintained. If the charge falls below a certain value, the forward bias of the diode bridge is removed and the 'A' amplifier will pass the signal during "off" time. Remember that the duty-factor of the oscilloscope plus gate output signal is a function of the sweep triggering rate as well as the ratio of the 'A' sweep duration to the 'B' sweep duration.

During the time the amplifier is gated "on", the 'A' out- 'A' input signal can produce sufficient current through the 'A' Z_i component to significantly alter the diode bridge forward current. If this occurs, a small amount of signal will be passed to the 'A' output. The amount of voltage that can be applied to the 'A' input without causing signal feed-through is directly proportional to the Z_i impedance.

During the time the amplifier is gate "on", the 'A' output voltage swing must be limited to about ±20 volts. This is to prevent variation in the Z_f value due to overriding of the diode bridge back-bias. The exact output voltage limit is directly proportional to the gating pulse amplitude.

During the transition from off to on, 'A' amplifier is unstable for a few microseconds. This generally is of little consequence except when very short gating periods are used. The effects of the transitional instability are minimized by proper adjustment of the two compensating capacitors in the Gating Adapter.

The gate period for integration is limited to about 20 times the selected integrator time constant. The limit can be raised considerably by turning on the 'A' amplifier INTEGRATOR LF REJECT, but this partially defeats the purpose of gating.

The 200 x 10^9 ohms resistance of the back-biased diode bridge parallels the 'A' Z_f during 'A' "on" time. Hence, this determines the minimum useable integrator capacitance because the bridge resistance tends to discharge the integrator capacitor. This discharge will not be noticeable unless the time constant of the bridge resistance and the integrator capacitor is a significant percentage of the integrator network time consant.

Set-Up and Compensation

The following steps give the necessary information to establish the 'A' Operational Amplifier in a Type O Plug-In unit as a gated, unity-gain amplifier. These steps should be performed regardless of the type of operation to be performed by the 'A' amplifier. Also included is the procedure for adjusting the compensating capacitors in the Gating Adapter. This procedure is intended for use with an oscilloscope having a delaying sweep feature. Other oscilloscopes may be used by substituting the appropriate control settings into the procedure for the oscilloscope used.

1. Set the oscilloscope controls and switches as follows:

'A' STABILITY	clockwise
'A' TRIGGERING MODE	AC
'A' TIME/CM	.5 mSEC
VARIABLE	CALIBRATED
HORIZONTAL DISPLAY	'B' INTENSIFIED BY 'A'
5X MAG.	OFF
'B' STABILITY	clockwise
'B' TRIGGERING MODE	AC
'B' TIME/CM	1 mSEC
'B' LENGTH	clockwise
DELAY-TIME MULTIPLIER	2.00
AMPLITUDE CALIBRATOR	1 VOLTS

2. Plug the Gating Adapter into the 'B' Operational Amplifier. The cam on the adapter housing should trip the ±GRID SEL to (—).

3. Plug the Gating Adapter leads into the 'A' Operational Amplifier —GRID and OUTPUT jacks.

4. Set the Type O Plug-In Unit controls and switches as follows:

'A' ±GRID SEL	(—)
'A' and 'B' INTEGRATOR LF REJECT	OFF
'A' Z_i and Z_f	1 MEG.
'B' Z_i and Z_f	EXT.
VOLTS/CM	.5
VARIABLE	CALIBRATED
VERTICAL DISPLAY	EXT. INPUT + DC
VERTICAL POSITION	to center trace

5. After the plug-in unit has warmed-up, check for proper adjustment of the DC BAL. and GAIN ADJ. controls, using a free running display.

6. Set the plug-in unit VERTICAL DISPLAY switch to OUTPUT —B.

7. Adjust B OUTPUT DC LEVEL as described in the Type O unit manual.

8. Set the plug-in unit VERTICAL DISPLAY to OUTPUT A.

9. Adjust A OUTPUT DC LEVEL.

NOTE

The OUTPUT DC LEVEL adjustments are very important to proper operation and should be rechecked often.

10. Connect the oscilloscope +GATE 'A' output to the Gating Adapter input.

11. Set 'A' TIME/CM to 2μSEC and 'B' TIME/CM to 5 μSEC.

12. Set the Type O Unit VOLTS/CM to 2.

13. With the cover-plate in place, adjust the Gating Adapter compensation capacitors:

    a. Adjust C_1 for minimum amplitude of the pulse at the left end of the intensified trace zone.

    b. Adjust C_2 to make the portion of the intensified trace zone following the pulse appear as straight as possible.

    c. Balance the two adjustments for the smoothest transition from the pulse to the remainder of the intensified trace zone.

NOTE

Step 13 completes the compensation and basic set-up procedure. The remaining steps are provided to illustrate a few of the basic operating procedures which can be used to obtain maximum measurement versatility.

14. Set 'A' TIME/CM to .5 mSEC and 'B' TIME/CM to 1 mSEC.

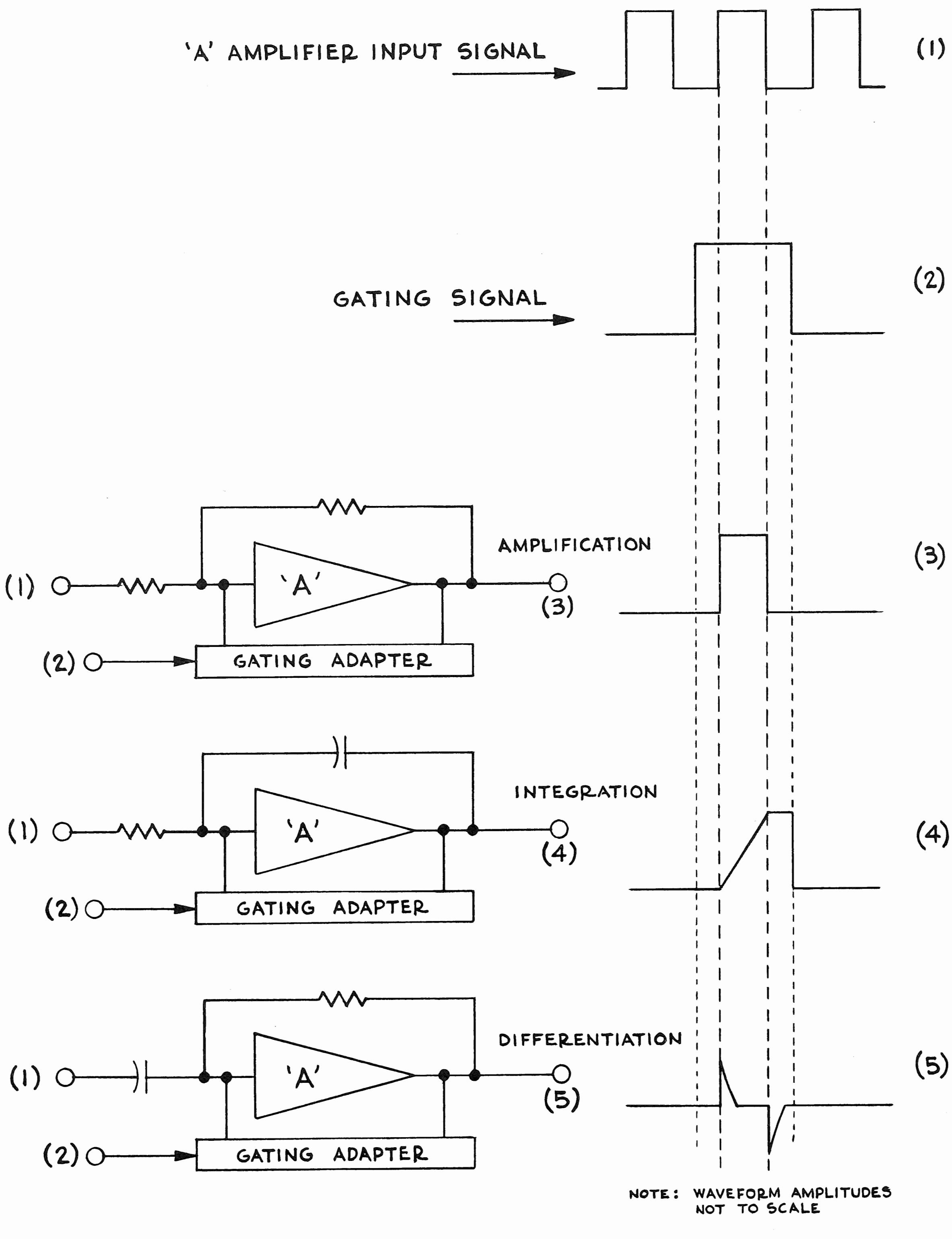
15. Connect the oscilloscope CAL. OUT to Time Base 'B' TRIGGER INPUT and to the 'A' Operational Amplifier INPUT.

16. Set the Time Base 'B' triggering controls for an externally triggered display.

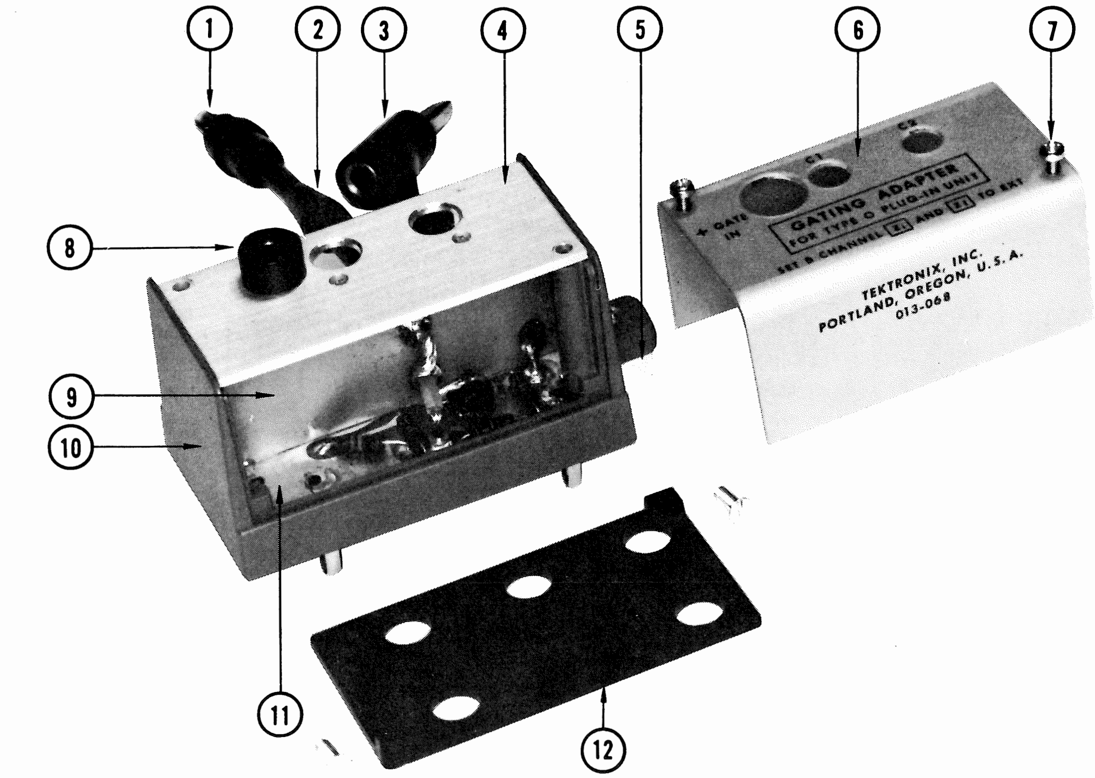
The trace should display a signal only in the intensified zone. The 'A' TIME/CM switch and the VARIABLE control settings can be changed to include the desired number of pulses in the display. The DELAY TIME MULTIPLIER control can be set so the display begins between pulses or during a pulse. The 'B' TIME/CM switch, the 'B' LENGTH control, and the 'B' sweep triggering rate determine the time seperation between the groups of pulses.

The oscilloscope controls mentioned in the foregoing paragraph are used in much the same manner when the system is operated as a gated integrator or a gated differentiator.

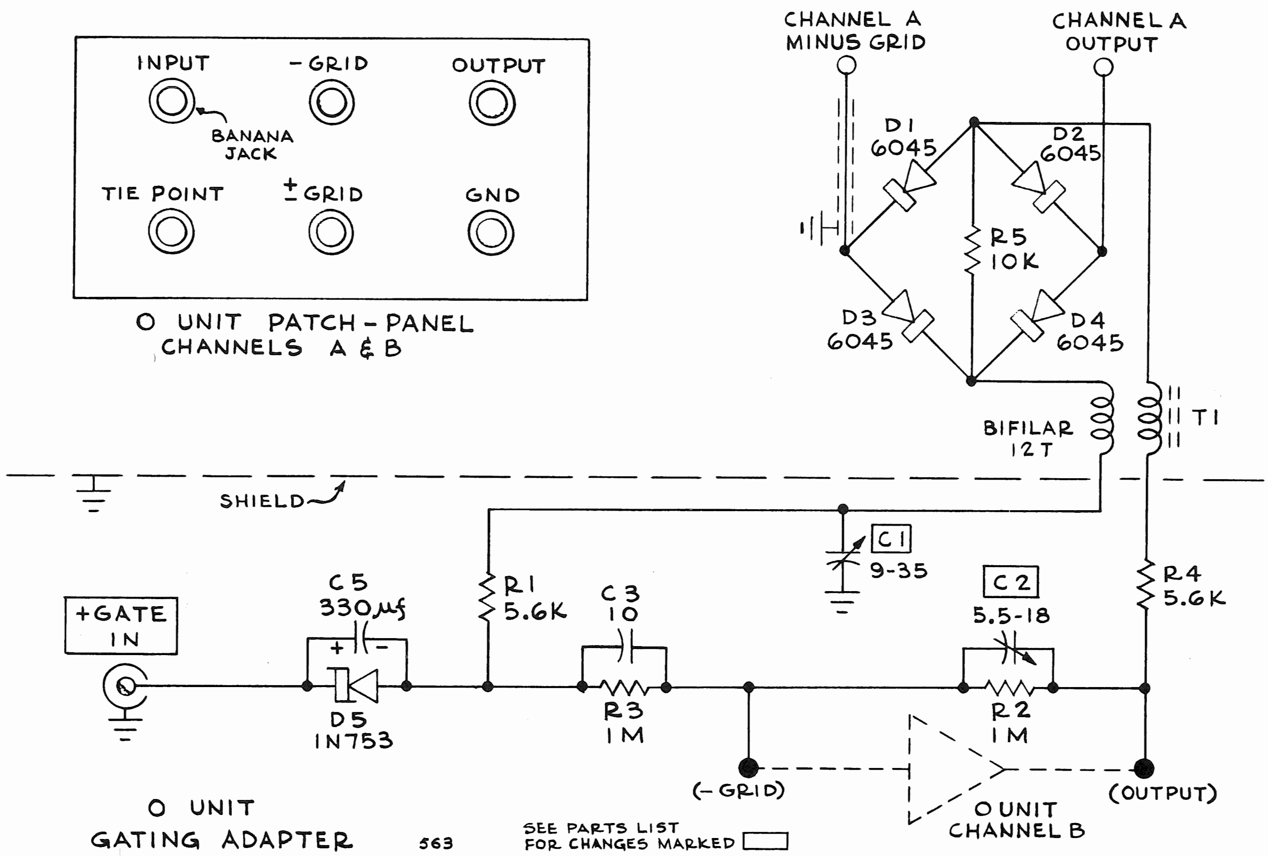
The Type O Unit, 'A' amplifier and Preamplifier controls and switches are used as described in the O unit manual, with one exception; the 'A' amplifier INTEGRATOR LF REJECT switch is normally left in the OFF position.



GATING ADAPTER 563



REF. NO.	PART NO.	SERIAL NO. EFF.	SERIAL NO. DISC.	QTY.	DESCRIPTION
1	175-294			1	CABLE ASSY., MINUS GRID (Consisting of)
	134-024			1	PLUG, Banana, Male
	200-489			1	COVER, connector
	175-026			1	CABLE, Coax. 75 Ω 5"
	358-117			1	BUSHING, outer sleeve
2	200-491			2	COVER, cable relief
3	175-295			1	CABLE ASSY., OUTPUT
4	387-799			1	PLATE, subpanel
5	401-022			1	CAM, switch actuating
					Mounting Hardware: (not included)
	213-055			1	SCREW, thread cutting, 2-56 x $^3/_{16}$ PHS
6	200-490			1	COVER
7	211-079			4	SCREW, 2-56 x $^3/_{16}$ Pan Head steel
8	136-138			1	SOCKET, Banana Jack Assy.
	210-223			1	LUG, solder
	210-895			1	WASHER, insulating
	210-583			1	NUT, hex, $^5/_{16}$ brass, $^1/_4$-32
9	337-579			1	SHIELD, gating adapter
10	204-163			1	BODY, casting
11	388-550			1	BOARD, Circuit
	131-285			2	Connector
12	392-146			1	BOARD insulating
					Mounting Hardware: (not included)
	211-095			2	SCREW, 2-56 x $^5/_{16}$ FHS 80°
	134-070			1	PLUG



REF. NO.	PART NO.	SERIAL NO. EFF.	SERIAL NO. DISC.	QTY.	DESCRIPTION
	120-319			1	T1 TRANSFORMER, 12T TD103
	152-034			1	D5 DIODE, zener 1N753 6.2 V 400MV 10%
	152-045			4	D1, 2, 3, 4 DIODE silicon 6045
	281-061			1	C2 CAPACITOR, 5.5-18 pf cer. var.
	281-063			1	CI CAPACITOR, 9-35 pf cer. var.
	281-504			1	C3 CAPACITOR, 10 pf cer. 500 V 10%
	290-138			1	C5 CAPACITOR, 330 μf EMT 6 V 20%
	315-562			2	R1, R4 RESISTOR, 5.6 K 1/4 W 5%
	318-004			2	R2, R3 RESISTOR, 1 meg 1/8 W prec. 1%
	315-103			1	R5 RESISTOR, 10 K 1/4 W 5%

GATING ADAPTER

Description: The Type O gating adapter makes use of one of the O-Unit's operational amplifiers to invert the +Gate of the oscilloscope for symmetrical (push-pull) drive to a diode bridge. The diode bridge gates the other operational amplifier to permit gated amplification or integration of any desired signal within the operational amplifier's capabilities. The diode gate is "open" during the time the +Gate of the oscilloscope is positive, and closed when the scope gate is down.

The primary purpose of the adapter is to facilitate integration, especially in areas where the O-Unit's LF Reject circuits contribute excessive error or inconvenience in measurements.

Gating also provides a means of eliminating unwanted or confusing portions of a waveform to be amplified, differentiated or integrated, so the operation can be performed only on the desired portion of the signal. Gated operation can thus be used to avoid severe overloads of the oscilloscope preamplifier and enhance operational accuracy.

The leads on the gating adapter are arranged for plugging the adapter itself into Operational Amplifier B, to gate operations in A via the two external leads, which connect to the -Grid and Output jacks on A.

The gate of the delayed sweep in a delaying-sweep scope or the delayed gate of the Type 532 may be used to provide gating of only a selected portion of the waveform which triggers the sweep. In other scopes, the gate is open during the entire sweep. An external gating signal may also be used. Ideal levels are +20 v for "on" and -3 v for "off".

External triggering of the scope is required for gated operation in most cases, except where synchroscope techniques can be used.

Limitations: The maximum output signal which can be handled is about ±20 v, depending on the amplitude of the scope gate output. If the output waveform exceeds this value during the gated interval, the gate will come into partial conduction, distorting the output.

The maximum input signal which can be handled is 20 v, provided that the gating duty cycle is 10% or more and the R_i resistor is 1 M. For R_i = 200 K, max input is 20 v with 10% duty cycle; for R_i = 100 K, max input is 10 v. With R_i at 10 K, duty cycle must be kept at 20% or more, max interval between gates 500 msec and input to 2 v or less for 5% feed-through during "off time" (signal current pulling open the diode gate).

The signal "pulling open" the diode gate will not affect integration accuracy if the integrator output is measured from the start of the intensified portion to the end.

The gating adapter as furnished is primarily for the gated amplification or integration of repetitive signals only, where the time during which the gate is closed is no more than 9 times the "on" time, or 2 sec, whichever is shorter. You will notice that in working from a cold start, it takes several sweeps to stabilize. Modification of the scope or the adapter is required for low rep-rate or single-shot work, to provide a negative gate voltage during "off" time. Modifications are discussed below.

There is a transient during the turn-on of the gate which can be minimized, but not completely eliminated, by compensating adjustments. The transient is usually negligible during integration, but is definitely noticeable during amplification. The transient -- its exact shape depends on diode switching characteristics, etc. -- typically consists of a short duration spike of about 1 v amplitude, followed by a smaller swing of opposite polarity and about 1 μsec duration, followed by a 1/2 v pulse of the first polarity and 30 μsec decay time.

Figs. 1 and 2 show the effect of the switching transient. Fig. 1 shows its effect on gated amplification ($R_i = R_f =$ 1 M, 5 µsec/cm, 500 mv/cm). Fig. 2, at 100 µsec/cm and 50 mv/cm shows its possible effect on integration. In the case shown, with 1 M and 100 pf (100 µsec time constant) the indicated error -- unchanged over 5 time-constants -- is 70 mv, or 7 µv sec.

In amplifying the 20 v gate, the B operational amplifier shifts the decoupled -150 v supply in the plugin by about 400 mv. This causes a level shift in A of about 10-20 mv for the duration of the gate. This level shift, unless corrected, will be integrated during gated integration, producing a fixed error of 10-20 microvolt seconds per millisecond of gate duration. In most cases this error can be significantly reduced by careful setting of the A and B dc level adjustments. Where not, the no-signal integral should be separately measured and subtracted from the measurement.

To measure the no-signal integral, be sure to ground the input end of Z_i so that all effects of zero-shift, grid-current, etc., will be included. Grid current will contribute an error up to 20 mv/msec in the output, using a 10 pf value for Z_f. Normally, the 10 pf capacitor is never used for integrating intervals in excess of 100 µsec or so.

Differential leakage through the diode gate with 20 v across it is typically on the order of 0.1 nanoampere for an effective resistance of 200 X 10^9 ohms. For this reason, it is a good idea -- where you have the choice -- to use a large value integrating capacitor to keep the leakage error to a minimum. Again, this sort of error is negligible in most cases, and is of less effect than the typical 0.3 to 0.5 nanoampere grid current.

Modifications: For single-shot work, the zener diode-capacitor network used to obtain a negative level between gates, to keep the diode bridge conducting, will not work. Two solutions are available:

Scope mod: The +Gate of the scope may be made to go negative between sweeps by adding a resistor between the cathode of the +Gate output CF and the -150 v supply. The value of this resistor should be about 60 times the value of the existing cathode resistor, for a level of about -2 v between sweeps. A lower level will be needed when Z_i = 10 K.

Hookup mod: A small penlite cell or mercury battery connected in series between the +Gate output and the gating adapter input (+ end of the battery toward the +Gate output connector) will provide a -1.5 v level between sweeps.

Adapter mod: Where it is necessary that sudden changes in sweep rep rate and duration have minimal effect on the system, one of the above modifications plus a minor mod to the adapter will be required. The adapter mod consists of installing a jumper across the zener diode. Wire from the connector to the far lead of the zener. This prevents the DC levels around the gate from shifting as the duty cycle changes.

Gated Differentiation: The switching transients discussed above might indicate at first glance that gated differentiation is impossible. Not so, fortunately. The transients are not differentiated, being impressed across Z_f only. For this reason, the "glitches", etc., shown in Fig. 1 appear about the same during differentiation as in amplification and may be accounted for in the final answer by comparison with the "no signal" waveform. For minimum interference, use a low value R_f, or (with 1 M R_f) open the gate about 30 µsec before the start of the signal to be differentiated. Fig. 3 shows gated differentiation of the trigger feed-through on the +Gate of a 535A (the gate was attenuated to 4 v so as not to overload the gating circuit). The high rate of dv/dt at the start of the gate -- about 700 x 10^6 v/sec -- would severely overload the oscilloscope preamplifier at these sensitivities, masking the smaller feed-through signal, were it not for the gating function.

Gated Slideback Amplifier: The gating adapter may also be used for gated amplification with slideback, the input signal and offset voltages being summed at the -grid and gated together, thus preventing overload of the oscilloscope preamp.

FIG. 1. Switching transient. (Worst case: $Z_i = Z_f = 1$ M, uncompensated) 5 μsec/cm, 0.5 v/cm. Transient at end of gate does not affect measurements, of course. The aberrations are materially reduced if smaller values are chosen for R_f and R_i or if R_f and R_i are compensated.

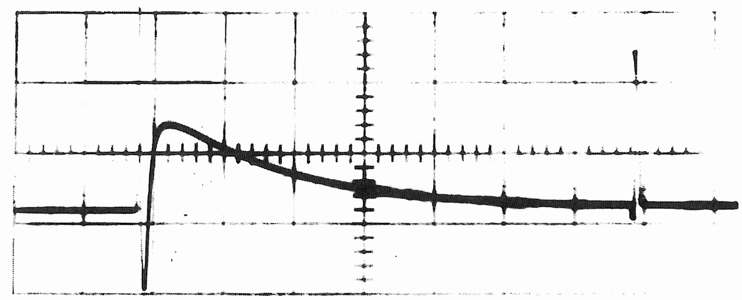


FIG. 2. Integral of switching transient. 100 μsec/cm, 0.05 v/cm, $Z_i = 1$ M, $Z_f =$ 100 pf. 70 mv error represents 7 μv-sec. Note that error is relatively constant after first 30 μsec. The error value will change with increased integrating interval because of grid-current, leakage, etc. Integrating beyond about 20 RC's not usually recommended.

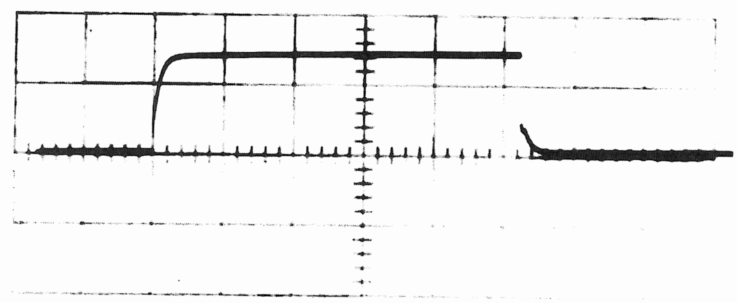
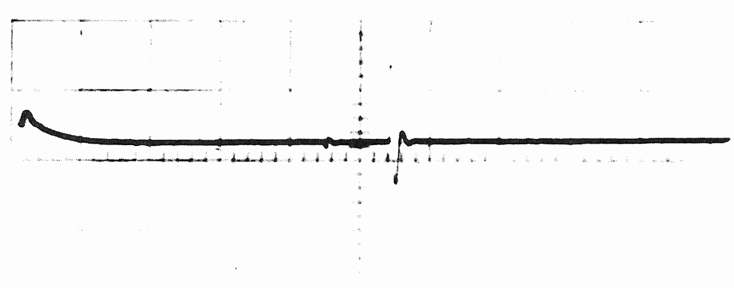


FIG. 3. Gated differentiation of trigger feed-through on 535A +Gate. 20 μsec/cm, 0.2 v/cm. $Z_i = 100$ pf, $Z_f = 200$ K. Switching transient artifact is seen at left. Gating eliminates severe scope overload (60 v at 0.2 v/cm) which would have been caused by leading edge of signal waveform.



Installation:

Using 535A or 545A Oscilloscope, O-Unit and Gating Adapter.

1. Plug gating adapter into Channel B banana jacks. Leads from gating adapter to Channel A minus grid and Channel A output.

2. Set Channel B Z_i and Z_f to external.

3. Set vertical display to B minus, adjust B dc level; set vertical to A minus, adjust A dc level.

4. Set A Channel Z_i and Z_f to 1 megohm.
   Set 535A or 545A sweep to 0.2 msec/cm.
   Set B sweep to 0.5 msec/cm.
   Horizontal display B intensified by A.
   A plus gate out to gating adapter.

5. Set volts/cm to 0.5.

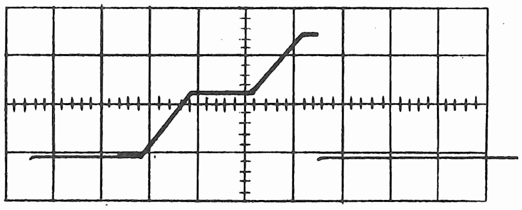
6. Adjust A Channel dc output level so that the intensified and unintensified portions of the sweeps are level.

7. Adjust C1 and C2 of gating adapter for minimum overshoot and roll-off. C1 affects the switching time of the diode gate. C2 compensates the external Z_f resistor for Channel B.

8. Connect a 1 volt calibrator signal to A input, and also to external trigger of B sweep.
   A output should be 1 volt in the intensified portion of trace.
   No signal on unintensified portion of trace.

9. Set A Channel Z_i to 1 megohm.
   Set A Channel Z_f to 0.001 µf, LF Reject Switch "off".
   Set calibrator to 20 volts.
   Set volts/cm to 10 volts.
   Output waveform will be as shown with no signal or unintensified portion of trace.

10. Reduce calibrator level to 1 v and volts/cm to 0.5 v/cm.
    Check to see that the level portions of the waveform are quite level. If not, recheck A and B dc levels, and adjust (repeat steps 6-8-9) as necessary to obtain minimum tilt to this portion of the waveform.

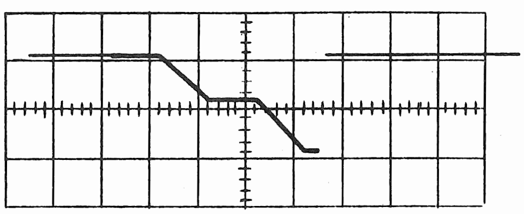


20 volt calibrator signal

≈ 40% gate cycle

Z_i 1 meg, Z_f 0.001

11. Connect signal from 105 square wave generator, 1 kc, 20 volts to A input of O Unit.
Signal will be negative going with no signal on unintensified portion.



≈ 20 volt 105 signal

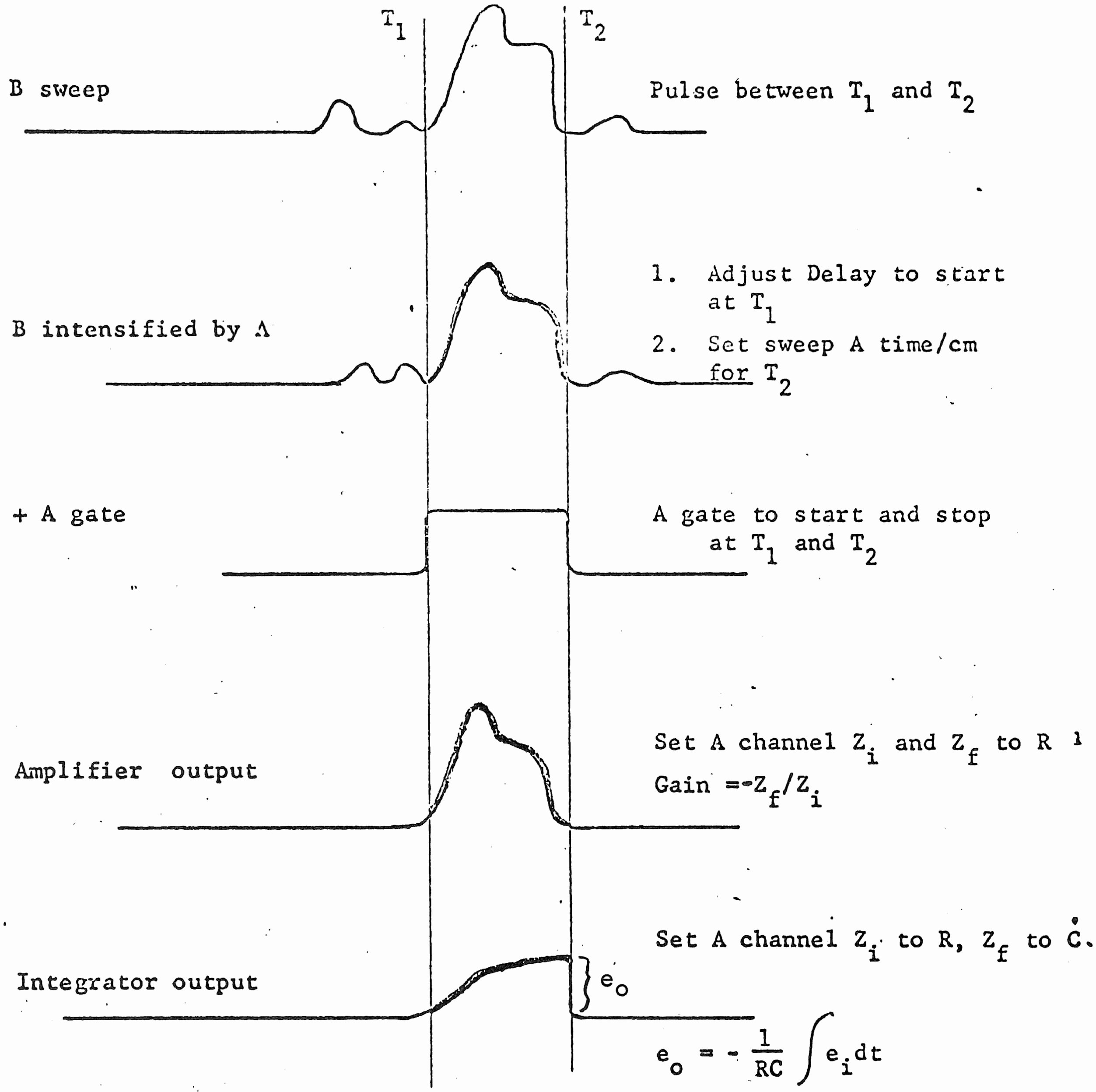
≈ 40% gate cycle

Z_i 1 meg, Z_f 0.001

12. Switch A sweep to 50 µsec (10% gate cycle).
There should be no signal appearing on the unintensified portion of the trace.
A decrease to 5% gating cycle will cause the diode gate to open during the unintensified portion.

Sample Gated Amplifier and Gated Integrator Operation

To amplify or integrate a specific pulse:



Input volt-seconds $= \int e_i\,dt = -R_i C_f\, e_o$

Bob M. Johnson
Accessories Design

Bill Lukens
Manufacturing Staff Engineering

Future Product: A completely external gating adapter which uses a separate (AC) power supply has been designed by Chuck Edgar and may be made available later through Chuck Nolan. It would cost quite a bit more ($50 to $100 more) than the passive-component adapter, but would offer these advantages:

1. Adapter ties up only one operational amplifier, not two.
2. Two gates could be used on one O-Unit, powered from one ($60-$75) power supply, permitting gated double integration or gated amplification plus gated integration.
3. Gating is cleaner and does not shake up DC supplies in plug-ins.
4. Power supply also usable for other purposes.

Progress of the design presently awaits decisions on the power supply (just how versatile to make it).