

RESEARCH  
ANALYSIS

82174

# PRELIMINARY INSTRUCTION MANUAL

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This instruction manual is not complete and it may contain errors. We are sending it with your instrument so you will have something to use until the permanent manual is completed. Please put your name and address on the post card and mail it to us. We will send you a permanent manual just as soon as they are ready.



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Type 661 Sampling System First Time Operation

The Type 661, Type 4S1 and Type 5T1 instruments have been individually calibrated prior to shipment. Therefore, these insert pages should replace part of the section of this manual on First Time Operation, Page 2-11, replacing material up to the step called Dual Trace Operation on Page 2-12.

First time operation of the sampling system should include triggering, gain and timing checks as follows:

4S1 control settings:

MODE switch.....A ONLY  
'A' POSITION control....midrange  
'A' SMOOTHING.....clockwise  
'A' MILLIVOLTS/CM.....200  
'A' VARIABLE.....CALIBRATED  
'A' DISPLAY.....NORMAL  
TRIGGERING.....A - AC  
DC OFFSET.....set to zero with meter  
connected to OFFSET  
MONITOR jack.

5T1 control settings:

SWEEP TIME/CM.....10 nSEC  
VARIABLE.....CALIBRATED at detent  
SWEEP MODE.....REPETITIVE  
TRIGGERING SOURCE.....INT  
POLARITY..... -  
TIME DELAY..... 0  
THRESHOLD.....pointing at the +

Connect a short length of 50- $\Omega$  cable between the DELAYED PULSE 50  $\Omega$  connector to the A INPUT connector, do not use an attenuator. This checks that the 5T1 triggering circuits are working.

There should now be a negative going step crt display of about two centimeters vertical amplitude 40 to 50 n-seconds after the start of the sweep. It may be necessary to adjust the vertical and horizontal POSITION controls to center the display. If there is not a step, remove the 661 right side panel, locate the Delayed Pulse Generator Bias potentiometer at the lower side near the front panel. Adjust it for a crt display as described above.

Check the gain of the 4S1 A channel.

Disconnect the 50- $\Omega$  cable from the DELAYED PULSE 50  $\Omega$  connector and connect it to the AMPLITUDE/TIME CALIBRATOR output connector. Set the AMPLITUDE/TIME CALIBRATOR controls to .1  $\mu$ SEC/CYCLE and 1000 mV AMPLITUDE. Change the 5T1 SWEEP-TIME/CM to .1  $\mu$ SEC.

The front-panel screwdriver adjust control labeled A-B BAL is the channel A Gain control. The panel is labeled as A-B BAL to indicate the control permits a quick small adjustment of the A channel gain when operating the 4S1 in the Added Algebraic MODE. The control does not interact with the B channel Gain.

The display as above should be a 10 mc sine-wave crt display  $\pm 3\%$  of five centimeters in the vertical dimension. Adjust the A-B BAL control if the display is other than five centimeters.

Check the gain of the 4S1 B Channel.

Set the B channel controls identical to the A channel controls, and switch the TRIGGERING control to B-AC. Measure the OFFSET control to be at zero volts. Move the 50- $\Omega$  cable to the B channel INPUT connector.

If the vertical display is not within  $\pm 3\%$  of five centimeters, the internal B CAL control needs adjustment. The B channel gain control, B CAL R2174 is located at the rear of the 4S1 Plug-In Unit. With a long screwdriver, adjust the B CAL R2174 control for proper vertical display amplitude.

Check the timing of the 5T1.

Leave the 5T1 SWEEP TIME/CM at .1  $\mu$ SEC/CYCLE and the AMPLITUDE/TIME CALIBRATOR at .1  $\mu$ sec/cm and 1000 mV AMPLITUDE.

The crt display should now be a 10 megacycle sine-wave with one cycle each horizontal centimeter. Tolerance with this test method is  $\pm 3\%$ . If the timing is inaccurate, locate the SWEEP CAL control in the middle of the right side of the 5T1, and adjust it to correct the 5T1 basic timing for proper crt display.

With the checks just completed, the Type 661, Type 4S1 and Type 5T1 are calibrated as a unit within 3% vertically and horizontally. Replace the 661 side panels.

Both the vertical and horizontal systems can be made to be more accurate with external voltage and time references. By careful calibration of the vertical, and by using the DC OFFSET with an accurate meter, vertical signals can be measured within 1%. Thus the above system of gain calibration is not the ultimate. A calibration procedure for greater accuracy than above will be included in the Type 4S1 permanent manual.

## CHARACTERISTICS

## General

The Type 661 Oscilloscope with Type 4S1 50 $\Omega$  Dual-Trace Sampling Unit and the Type 5T1 Timing Unit is a complete 0.35-nanosecond risetime sampling system. The system is capable of presenting an accurate dual-trace display of repetitive high-speed signals with fractional nanosecond risetimes. By taking successive samples of a repetitive signal, each sample at a slightly later time with respect to the previous sample, the system reconstructs the signal on a relatively long time base.

## Type 4S1

Input Impedance--50 $\Omega$ . Provision is made for either a passive or a cathode follower probe, both offering higher input impedance.

Risetime--Approximately 350 picoseconds or less, measured between 10% and 90% amplitude points.

Sensitivity--Fixed steps of 2, 5, 10, 20, 50, 100, and 200 mv/cm. Uncalibrated variable sensitivity control with 3:1 range makes it possible to increase the sensitivity of each range. The 2 mv/cm sensitivity can be increased to about  $2/3$  mv/cm.

Dynamic Range--Input signals as high as 2 volts may be viewed without overloading the system, even at  $2/3$  mv/cm. Safe overload,  $\pm 10$  volts dc.

Noise--Less than 1 millivolt unsmoothed, or  $1/2$  millivolt smoothed.

Trigger Takeoff--Triggers from either A or B channel, approximately  $1/8$  of the input signal amplitude, ac or dc coupled, internally coaxially coupled to 5T1.

Operating Modes--A Only, B Only, Dual Trace, Added Algebraically, and A Vertical-B Horizontal (Lissajous patterns).

Display--Normal or Inverted, permitting the addition of lissajous patterns for the observation of hysteresis loops; or with Dual-Trace display, for inverting the phase of signals in or out of an amplifier for phase comparison.

Smoothing Control--Each channel smoothing control reduces system noise. Valuable when operating at highest sensitivities.

DC Offset--The dc component of a signal may be offset about  $\pm 1$  volt (with a five-turn control) to bring the display back on the crt. Panel DC Offset Monitor: 100 k output impedance, 100 times the voltage of the offset control.

Type 5T1

Sweep Time/Cm--Sweep rates in 16 calibrated steps of equivalent time of 1, 2, 5, 10, 20, 50 nsec/cm, 0.1, 0.2, 0.5, 1, 2, 5, 10, 20, 50, and 100  $\mu$ sec/cm. Uncalibrated variable control has 3:1 range between steps. All calibrated rates typically better than 3%. Variable control extends the fastest rate to about  $1/3$  nsec/cm.

Samples/Cm--5, 10, 20, 50, and 100, with an unmagnified display. Typically better than 3% accuracy.

Sweep Mode--Repetitive or single display.

Trigger Source--External, internal, free run, and calibrator; plus or minus slope.

Triggering Threshold--Continuously variable,  $\pm 200$  mv.

Trigger Sensitivity--Internal: 40 mv for a 2-nsec wide pulse (with 4S1). External: 5 mv for a 2-nsec wide pulse.

Recovery Time--Variable from nominally 10 to 13  $\mu\text{sec}$  on sweep rates faster than 0.2  $\mu\text{sec}/\text{cm}$ , longer on slower sweep rates.

Time Delay--Provides 100 nsec continuously variable time delay window.

Time Jitter--Less than 30 picoseconds, or  $10^{-4}$  of fast ramp duration, whichever is greater.

Type 661

Sweep Magnification--1, 2, 5, 10, 20, 50, and 100, symmetrical about the crt center. When using the magnifier, the time per dot remains the same.

Horizontal Position--Coarse and Fine controls that shift the display one crt diameter about its center unmagnified, and the total trace can be shifted into view on all ranges of sweep magnification.

Manual Scan--Choice of slow or fast ranges, operated by horizontal POSITION control.

External Horizontal Input--0.05, 0.1, 0.2, 0.5, 1, 2, and 5 volts/cm sensitivity at 25 k input impedance, ac or dc coupled.

Amplitude/Time Calibrator--Amplitude: 1000 mv  $\pm$  2% into a 50 $\Omega$  load except at 0.01  $\mu\text{sec}/\text{cycle}$ , 100 mv  $\pm$  4%, 10 mv  $\pm$  5%, and 1 mv  $\pm$  6%.

Time: 0.1, 1, and 10  $\mu\text{sec}/\text{cycle}$ ,  $\pm$  0.2%; 0.01  $\mu\text{sec}/\text{cycle}$ ,  $\pm$  2%.

Delayed Pulse Output--50 $\Omega$  impedance at a signal level of at least 350 mv. Risetime not more than 0.2 nsec. Pulse occurs approximately 50 nsec after undelayed sweep start. Risetime appears approximately as 0.4 nsec viewed by 4S1 system.

Signal Outputs--Vertical A, Vertical B, and Horizontal, each at 10 k impedance with an amplitude of 200 mv/cm referred to the crt display.

Cathode-Ray Tube--Tektronix T503, P2. Other phosphors available on special order.

Beam Position Indicators--Indicate direction of off-crt spot or trace.

Power Supply--Temperature compensated, electronically regulated, including dc voltage for some heater supplies.

Mechanical--Height: 17 1/2 inches.

Width: 13 inches.

Depth: 22 inches.

Weight: All three units: 44 1/4 pounds.

Accessories--

661

1 - Power cord - 103-013

1 - 3 wire to 2 wire power cord adaptor - 161-010

1 - Green crt filter - 378-514

4S1

2 - 50 $\Omega$  X10 T attenuators, GR Type 874 connectors -  
017-044

2 - 50 $\Omega$  5 nsec cables, GR Type 874 connectors -  
017-502

5T1

2 - 50 $\Omega$  X10 T Attenuators, GR Type 874 connectors -  
017-044

1 - 50 $\Omega$  10 nsec cable, GR Type 874 connector - 017-501

## OPERATING INSTRUCTIONS

## General

The Type 661 Oscilloscope, Type 4S1 500 Dual-Trace Sampling Unit, and Type 5T1 Timing Unit form a dual-channel servo-type, slide-back sampling system. Each channel contains a sampling gate and ratchet memory. The sampling principle is essentially that of an error signal device that corrects the memory output voltage each time a sample is taken, to produce a null at the input sampling gate.

The sampling system is complete within itself under normal signal conditions. External trigger pick-off or trigger cables are not required if the input signal is at least 40 mv.

Sensitivity of about  $2/3$  mv/cm may be employed to view low-level portions of signals with a peak-to-peak value up to 2 volts, permitting maximum resolution of fast-rise waveforms, within the limits of the  $\pm 1$  volt DC OFFSET control.

High resolution amplitude measurements may be made on any waveform, or any part of a waveform, through the use of a dc offset control. A front-panel terminal permits voltmeter measurements to be taken of the offset voltage, at 100 times the internal  $\pm 1$  volt maximum offset value.

At maximum sensitivities, system noise can be reduced by use of a smoothing control. Smoothing will not significantly affect the display risetime, but will reduce noise if each sample taken represents only a small increment of the total signal amplitude. Normally, system noise is less than 1 millivolt peak-to-peak unsmoothed.

## Functions of Front-Panel Controls and Connectors

4S1

## MODE Switch

Selects one of five operational modes.

A ONLY: Only Channel A operates.

B ONLY: Only Channel B operates.

DUAL-TRACE: Both channels display separate signals simultaneously.

ADDED ALGEB: Both channels operate at the same time and display the algebraic sum of the two channels as a single trace.

A VERT. B HORIZ., with SWEEP MAGNIFIER at X1: Channel A controls vertical deflection, and Channel B controls horizontal deflection, permitting X-Y operation at full bandwidth.

## VERT. POSITION Control

Permits about an 8-centimeter control of the vertical position. Each channel has a vertical position control.

## MILLIVOLTS/CM Switch

Selects the desired vertical deflection factor. For example, with the MILLIVOLTS/CM switch set at 100, each major division of vertical deflection corresponds to 100 millivolts of applied signal. Each channel has a MILLIVOLTS/CM switch.

## VARIABLE Control

Three-to-one range uncalibrated VARIABLE sensitivity control makes possible an increase in sensitivity at each position of the MILLIVOLTS/CM switch. Maximum system sensitivity at 2 MILLIVOLTS/CM is then about  $2/3$  millivolts/cm. Each channel has a VARIABLE control.

## SMOOTHING Control

A gain control in the servo amplifier permits reduction of system noise at high sensitivity. Each channel has a SMOOTHING control. See information regarding dot transient response, in part 6 beginning on page 2-13.

## DC OFFSET Control

Provides an internal variable signal offset voltage from -1 volt to +1 volt. This may be used to effectively cancel the dc component of an input signal in the presence of a small signal. This permits a chosen portion of the waveform to remain relatively fixed on the crt when the vertical sensitivity is changed. By monitoring the voltage at the OFFSET MONITOR jack, highly accurate voltage-difference measurements can be taken. (See information dealing with OFFSET MONITOR, below.)

X100 OFFSET MONITOR 100  $\Omega$ 

The output voltage of this jack corresponds to 100 times the setting of the DC OFFSET control. Useful for making voltage-difference measurements of the displayed signal. By positioning a display with the DC OFFSET control, the difference between two voltage levels can be measured. Each channel has an OFFSET MONITOR jack.

## DISPLAY Switch

In the NORMAL position of the DISPLAY switch, the crt display has the same polarity as the applied signal, + up, and - down. By placing one DISPLAY switch in + and the other in -, the MODE switch placed in ADDED ALGEB. permits the subtraction of two signals.

INPUT 50 $\Omega$  Connector

50 $\Omega$  connector for applying the input signal. There is

an INPUT connector for each channel; each channel has its own trigger take-off, delay line, termination, and sampling bridge.

#### PROBE POWER

The PROBE POWER outlets are for an active, cathode follower probe. Provides 12.6-volt filament power and +100 volts anode power for the vacuum tube in the Type P6032 Probe. There is a PROBE POWER outlet for each channel.

#### A-B BAL.

Front-panel control for the A channel gain adjustment. B channel gain adjustment is internal. Thus the A-B BAL. control permits the gain of the A channel to be adjusted equal to the B channel gain. Useful when making common mode and/or differential measurements.

#### TRIGGERING Switch

Allows selection of the trigger source from either channel for internal triggering.

#### AC-DC Switch

Red knob concentric with TRIGGERING switch permitting the triggering signal to be either ac or dc coupled to the 5T1 trigger circuitry.

#### 5T1

#### SWEEP MODE

Establishes REPETITIVE or SINGLE DISPLAY condition.

#### SWEEP TIME/CM

When the VARIABLE control is in the CALIBRATED position, the SWEEP TIME/CM control establishes the display equivalent time.

**VARIABLE Control**

The uncalibrated VARIABLE control permits a 3:1 variable SWEEP TIME/CM between sweep ranges. Control increases all ranges three times when in its maximum clockwise position, extending the 1 nSEC/CM range to about 1/3 nSEC/CM.

**SAMPLES/CM**

Establishes the number of dots (samples) per horizontal centimeter of the crt display.

**TIME DELAY (nSEC)**

Permits moving the equivalent-time sweep start from nominally -5 to +95 nSEC with respect to a fast-rise trigger. Acts as a moveable time-delay window for the display.

**TRIGGERING SOURCE**

Permits selection of triggering signals from the 4S1 internally, or from the EXTERNAL TRIGGER INPUT connector. A third position places the sweep system in a free-run mode at which time stable displays are obtained from the 661 DELAYED PULSE generator, or from a system that has been triggered by the DELAYED PULSE.

**TRIGGERING POLARITY**

Permits starting the display on a negative polarity pulse (-), or on a positive polarity pulse (+). A third position permits triggering on the 661 AMPLITUDE/TIME CALIBRATOR signal, internally connected. This third position is valuable when the display (from the calibrator) is less than the required 40 mv for stable internal triggering.

## TRIGGERING THRESHOLD

The 5T1 trigger system is sensitive to signals exceeding a certain threshold. The THRESHOLD control moves the triggering signals with respect to the threshold. With the triggering POLARITY control in the + position, positioning the THRESHOLD control fully clockwise will hold off the triggering system for normal amplitude positive triggers. Rotation of the THRESHOLD control in the counterclockwise direction will permit proper triggering as the trigger-to-threshold voltage difference is brought to zero. Triggering occurs as the extreme positive portion of the triggering information reaches the threshold voltage. Further counterclockwise rotation of the THRESHOLD control will finally produce a free-running sweep, at the condition when the trigger signal base-line level reaches the threshold voltage. The same conditions exist, with opposite direction of rotation of the THRESHOLD control, when the POLARITY switch is at -.

## RECOVERY TIME

The RECOVERY TIME control is in the circuit that locks out the trigger circuit for a definite recovery time after each sample has been taken. It is normally left in the minimum position, and clockwise rotation will then increase the lock-out period after each sample. With the adjustable lock-out time, it is usually possible to adjust for a correct display for the few special cases of irregular displays caused by the triggering information persisting or a second trigger arriving at the same time as the lock-out is released.

#### EXTERNAL TRIGGER INPUT

A nominally 50 $\Omega$ , ac coupled, external trigger input. Allows direct connection of the 5T1 to the triggering signal when the signal is less than the required 40 mv for internal triggering. Signals from 5 to 250 mv will permit proper operation of the timing unit. Due to the ac coupled input, the triggering system will function properly with the above signal amplitude limits having fast risetimes, compared to a microsecond. For proper triggering on slow rise signals, 10 mv/ $\mu$ sec minimum rate of change is required. A 100 kc, 200 mv peak-to-peak is required.

661

#### HORIZONTAL DISPLAY

The horizontal display is controlled by the large knob located in the HORIZONTAL DISPLAY outlined area of the panel.

SWEEP MAGNIFIER - EXT. HORIZ. INPUT - MANUAL SCAN: Permits horizontal scan to be X1 through X100 the rate of the 5T1 Timing Unit SWEEP TIME/CM control setting. In addition, it permits a MANUAL SCAN of signals with the horizontal POSITION control.

#### AMPLITUDE/TIME CALIBRATOR

Sinusoidal signal, intended as an aid in checking the calibration of the 4S1 vertical sensitivity, and the 5T1 sweep rates. Tolerances of amplitude and time are given in the Characteristics section of this manual. Output must feed a 50 $\Omega$  system in order to maintain amplitude accuracies stated.

### DELAYED PULSE 50Ω

The DELAYED PULSE is formed by a tunnel diode pulse generator that is triggered by the 5T1 trigger regenerator system. Output pulses are timed to occur nominally 50 nsec after the undelayed sweep start. Permits the 661 Sampling System to serve as a rate generator to trigger external circuitry. Signal is at least 350 mv in amplitude, and rises in at least 0.2 nsec between 10% and 90% points.

### SIGNAL OUTPUTS - 200 mV/CM THRU 10 K

VERT. A - VERT. B--Permits external reconstruction of crt display for either channel. Each output remains attached to its own channel even during Dual-Trace or other multiple MODES.

HORIZ.--Permits external reconstruction of crt display of horizontal waveform.

The SIGNAL OUTPUTS are valuable for driving mechanical waveform recorders, or remote large-screen crt systems.

If the recorder is very slow, use of the MANUAL SCAN will permit faithful reproduction of the display.

### Installing The Plug-In Units Into The Type 661 Oscilloscope

Mechanical tolerances of plug-in cell and plug-in unit have been carefully controlled to permit sliding each plug-in unit directly into place.

Begin by placing the gray locking latch perpendicular to the oscilloscope front panel, then pushing the plug-in unit as far into the cell as possible by hand. Then move the locking latch flush with the panel to complete the plug-in insertion, locking it in place.

To remove a plug-in, first turn the power off, then move the gray locking latch to be perpendicular with the

front panel, and withdraw the unit by hand.

#### Cabling Considerations

In high-speed pulse work, proper transmission lines, connections, and terminations are an important part of the system. If transmission lines or connections are improper, reflections, standing waves, or undue loading on the device under test may cause distortion of the displayed waveform. If it is necessary to use other than 50-ohm cables, suitable matching devices should be used to couple between the cables or inputs that have different characteristic impedances. Be sure to keep all transmission lines as short as practical to minimize cable losses and time differences.

The signal to be displayed may be connected to either INPUT 50Ω connector on the front panel of the Type 4S1. Both units are GR Type 874 50-ohm connectors and should be mated to a 50-ohm cable with the same type connector.

Another factor that may be important is the signal velocity of propagation within coax cables. This is especially important when you are making time-difference measurements between two signals in dual-trace or X-Y operation. In such a case, each signal should travel through cables of identical time delay in order to preserve their time relationships.

#### Coupling a Signal From the Signal Source

In many applications, you will want to observe a signal at the output of an instrument. If the output impedance is 50 ohms, connect a 50-ohm coaxial cable directly between the instrument output and an input connector of the Type 4S1. If the instrument output is other than 50 ohms, a suitable coupling device should be used.

If you want to observe a signal at some point within a given circuit, additional factors must be kept in mind.

First, be sure the circuit is not heavily loaded by the coupling method. Otherwise, the signal display may be false. Also, the coupling network should be equally responsive to all frequencies within the limits of the system. In constructing coupling networks, it is advantageous to use 1/4- or 1/8-watt resistors since their small size improves frequency response.

Figs. 2-1 and 2-2 show two coupling methods. In the parallel method (Fig. 2-1), a resistor ( $R_s$ ) is connected in series with the 50 $\Omega$  input cable to the 4S1.  $R_s + 50$  ohms is then placed across the impedance in the circuit under test. A reasonable maximum circuit loading might be when the total resistance of  $R_s$  plus the 50-ohm input of the 4S1 is 5 times the impedance in the device ( $R_L$ ), requiring only 20% correction.

In the series coupling method (Fig. 2-2), the 50-ohm input of the 4S1 replaces the impedance in the circuit under test. If the replaced impedance (shown as  $R_L$  in Fig. 2-2) is more than 50 ohms, place a resistance in series with the cable input to the 4S1. The size of this resistance, plus 50 ohms, should equal the original impedance in the circuit. If  $R_L$  equals 50 ohms, you can simply substitute the cable to the 4S1 input with no additional series resistance.

A variation of the parallel method is the probe-type network shown in Fig. 2-3. The probe network is highly versatile and may be reasonably used across any impedance up to about 200 ohms. At higher source impedances, circuit loading will require more than 20% correction. The 0.01- $\mu$ f capacitor in the probe network blocks the dc component and protects the 91 $\Omega$  resistor. Use of the 0.01- $\mu$ f capacitor is optional.

Refer again to Fig. 2-3. The two 100Ω resistors placed directly across the cable input serve to back-terminate any small reflections due to connectors, imperfect cables, terminations, etc. If signals of short duration are to be observed, the reflections may occur off the time-base and will not be seen, or if reflections of a few percent are unimportant, then the two resistors can be deleted with a two times increase in signal to the 4S1. In general, the two 100Ω resistors are needed only when observing signals at high gain, and when a small reflection will distort the display.

The passive probes described are easily made, or are available as the Tektronix Type P6026 Passive Probe. They are useful when the source has only a moderate static and dynamic impedance. Probes useful with high static source impedance circuits are active probes, such as the Tektronix Type P6032 Cathode Follower Probe. The best results, from the point of view of fidelity, is usually obtained by designing the probe into the circuit wherever it is required that the signal be accurately monitored. This amounts to the substitution technique of Fig. 2-2 used permanently in the circuit. When not monitoring the circuit, merely substitute a 50-ohm termination resistor for the 4S1 input.

#### Displaying a Signal

First time operation of the sampling system can perhaps be made easier by the following procedure.

4S1 control settings:

MODE switch.....A ONLY  
 'A' POSITION control.....midrange  
 'A' SMOOTHING.....clockwise  
 'A' MILLIVOLTS/CM.....20  
 'A' VARIABLE.....CALIBRATED

'A' DISPLAY.....NORMAL  
 TRIGGERING.....A - AC  
 DC OFFSET.....Trace Centered (free run  
 briefly to obtain base  
 line)

B Channel controls may be in any position.

Apply the signal to be observed to the A INPUT 50 $\Omega$  connector on the front panel of the Type 4S1. Be sure that the applied signal is over 40 mv peak-to-peak amplitude. Adjust the triggering controls of the 5T1 for a stable display. By changing the setting of the MILLIVOLTS/CM switch you can change the vertical deflection in the display. Vary the vertical position of the display with the POSITION control. The DC OFFSET control on the Type 4S1 will also vary the vertical position of the display.

CAUTION: Be sure the peak input is under 2 volts for proper display.

#### Dual-Trace Operation

##### NOTE

Remember that the triggering signal is taken at the 4S1 input, and even though the system operates at a 40-kc switching rate between the A and B channels, the triggering signal to the 5T1 Timing Unit does not contain any 40-kc signal. Thus, triggering is assured to be from one input signal only, and not the dual-trace chopping signal as in some non-sampling oscilloscopes.

The DUAL TRACE feature of the 4S1 permits viewing signals into and out of an amplifier, or signals of differing

amplitude and time delay; but not signals of differing repetition rate or frequency, unless harmonically related or otherwise synchronously coupled.

After connecting the two signals, preferably with equal delay coaxial cables so the display time difference will be that of the amplifier being tested, use the following procedure for setting up the 4S1.

1. Set the MODE switch to DUAL TRACE.
2. Set the MILLIVOLTS/CM switches to the approximate values for 2 or 3 centimeters of display on each channel.
3. Place the TRIGGERING switch to either A or B. (If measuring time delay, choose the trigger from the channel fed by the earlier input signal.)
4. If the amplifier inverts the signal, if desired, place one channel DISPLAY switch to NORMAL, and the other channel DISPLAY switch to INVERTED.
5. If there is a signal dc component of over 2 volts, be sure to ac couple the inputs to the two cables. The rms input should not exceed 10 volts.
6. Smoothing Control Adjustments.

When operating at the extremes of vertical sensitivity and/or sweep rate, time and amplitude noise may become objectionable. This is frequently true when making documentation photographs. The smoothing control changes the loop gain of the automatic slide-back servo system. This will restrict the ability of the servo to move from one point on a waveform to

the next in one sample, such as when moving from the base line to the top of a step at low sweep rates. If the loop gain is cut to 63% of optimum, the dot on the crt can jump only 63% of the way toward the required value. Thus the number of dots required to approach equilibrium is similar to the number of time constants to complete an exponential rise to a new level. The dot transient response is independent of sweep rate if the dots are required to go from a base line to a new level in one dot; at any slower sweep rate they will still be required to make the jump in one dot. If for practical purposes it takes 5 dots to get to essentially 100% of a new step level, it will require 5 dots whether using 5 SAMPLES/CM or 100 SAMPLES/CM. However, notice in the former case it takes a centimeter to reach equilibrium, whereas in the latter it takes 1/2 millimeter. Thus the dot transient response is a function of the sampling density, and is improved by having as many samples/cm vertically as is practical. To test for satisfactory dot transient response, change the 5T1 SAMPLES/CM switch a factor of 2 or 2.5 and observe the amount of change on the crt. If the change is insignificant, the smoothing control is not substantially affecting the dot transient response. The smoothing knob reduces random noise, not systematic noise. This is because if the dot cannot go to the full noise

amplitude in one dot, it will average out the random signals but not the systematic signals, thus following the signal more closely than the noise.

To complete the operation, set the 5T1 controls as follows:

1. Set the TRIGGERING SOURCE knob to equal the polarity of the signal in the 4S1 channel selected for triggering.
2. Select a SWEEP TIME/CM that will permit viewing two or three cycles of the waveforms. If unknown, start at 10 nsec/cm.
3. Set the SAMPLES/CM to 5. This can be increased to a larger number if it is desired to have a more continuous trace.
4. Set the TIME DELAY control to zero. It can later be set to bring the proper signals in view on the crt.
5. Set the RECOVERY TIME to MIN.
6. Set the THRESHOLD control to hold off the sweep (cw +, ccw -). Rotate the control toward zero to obtain proper triggering.
7. If triggering difficulties appear, establish whether the trouble is due to: (a) insufficient or too much amplitude, (b) too high or too low a rate of change of trigger signal, (c) interference due to recovery time. The cause can usually be found by operating the THRESHOLD, SWEEP TIME/CM, and RECOVERY TIME controls. Inability to hold off the sweep signifies too large a trigger signal. Use a

coaxial input attenuator. If advancing the THRESHOLD control causes the sweep to free-run before obtaining a stable display, continue to free-run, and measure the amplitude to determine whether or not the signal is large enough to meet the 40-mv minimum requirement. If inadequate, provide external triggering by a "T" or other signal divider.

If confused triggering results, establish whether the problem is high repetition rate by means of the SWEEP TIME/CM control. If it is, then external triggering may be needed. For sine waves, the 40-mv 2-nsec pulse rating requires 80 mv peak-to-peak at below about 250 mc. Higher repetition rates require larger inputs. A 1-volt peak-to-peak internally triggered signal will synchronize to over 600 mc. External synchronizing operates to over 1000 mc; operating above 1500 mc may result in sweep distortion due to high-frequency feed-thru. If confused triggering results, and moving the SWEEP TIME/CM control establishes that the signal has a low rate of change (for example, sinewaves below about 200 kc), then try the DC position of the red 4S1 TRIGGERING knob (DC triggering is available internally only).

If confused triggering results in the form of multiple traces, try operating the RECOVERY TIME control while varying the SWEEP TIME/CM

A combination of recovery time and sweep rate can be found which will produce a stable display except at low frequencies. The object is to time the signal with respect to the recovery of the trigger circuits to prevent premature retriggering. This is accomplished by having the signal interval of opposite polarity to that selected on the trigger POLARITY switch to provide supplementary hold-off.

If making time or voltage measurements directly from the face of the crt it is usually advantageous to align the display with the appropriate vertical or horizontal graticule markings. The graticule can then serve as a scale from which to make either time or amplitude measurements.

With the aid of the DC OFFSET control, any point on a waveform within  $\pm 1$  volt of ground can be made to stay relatively fixed on the crt independent of vertical sensitivity. The VERT. POSITION control will then place that portion of the waveform wherever desired within the vertical limits of the position control. Remember: The VERT. POSITION control is a  $\pm 5$ -cm control. The OFFSET is an input  $\pm 1$ -volt control.

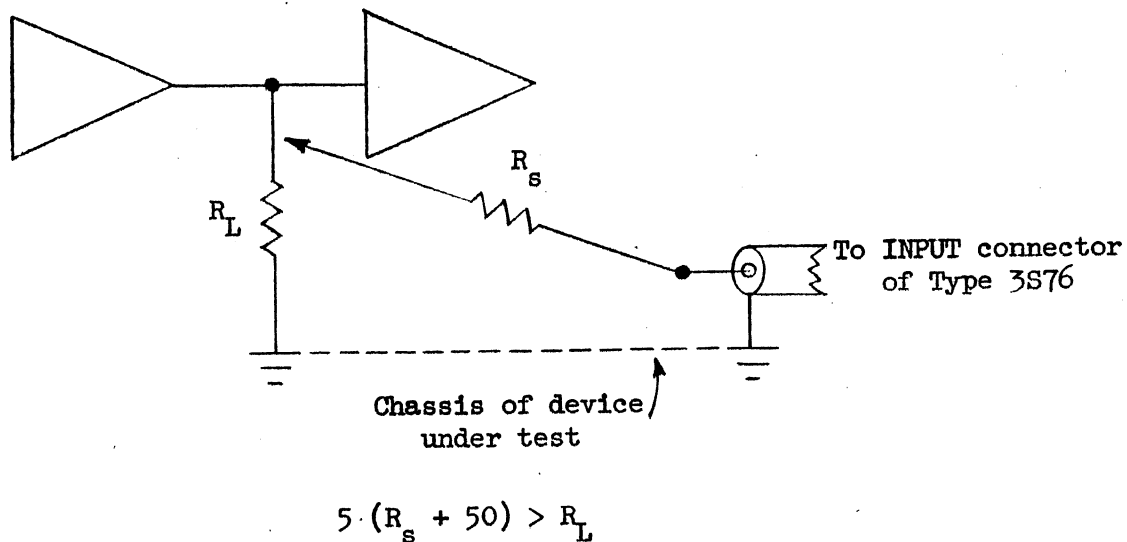


Fig. 2-1. Shunt method for coupling a signal from within a device.

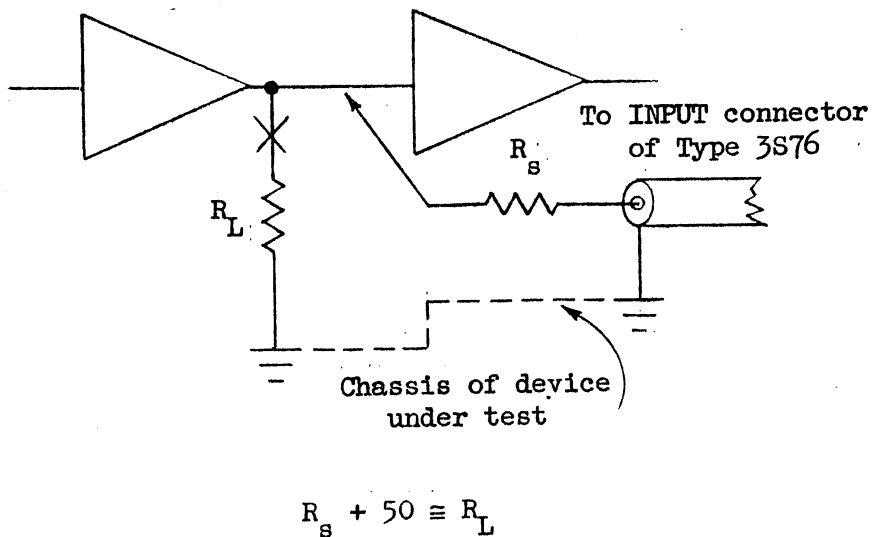


Fig. 2-2. Series method for coupling a signal from within a device.

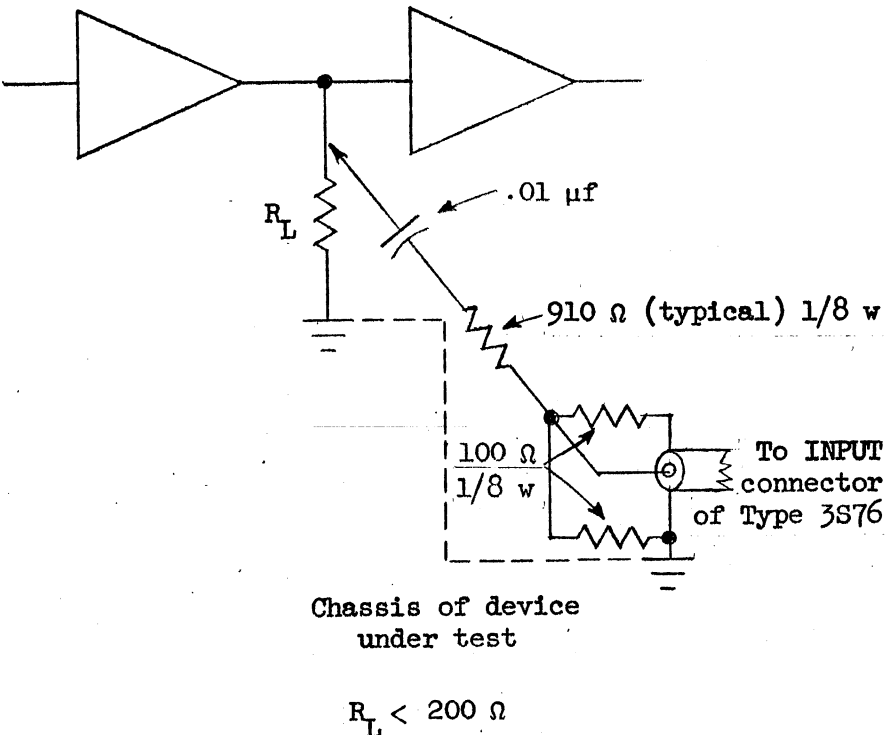
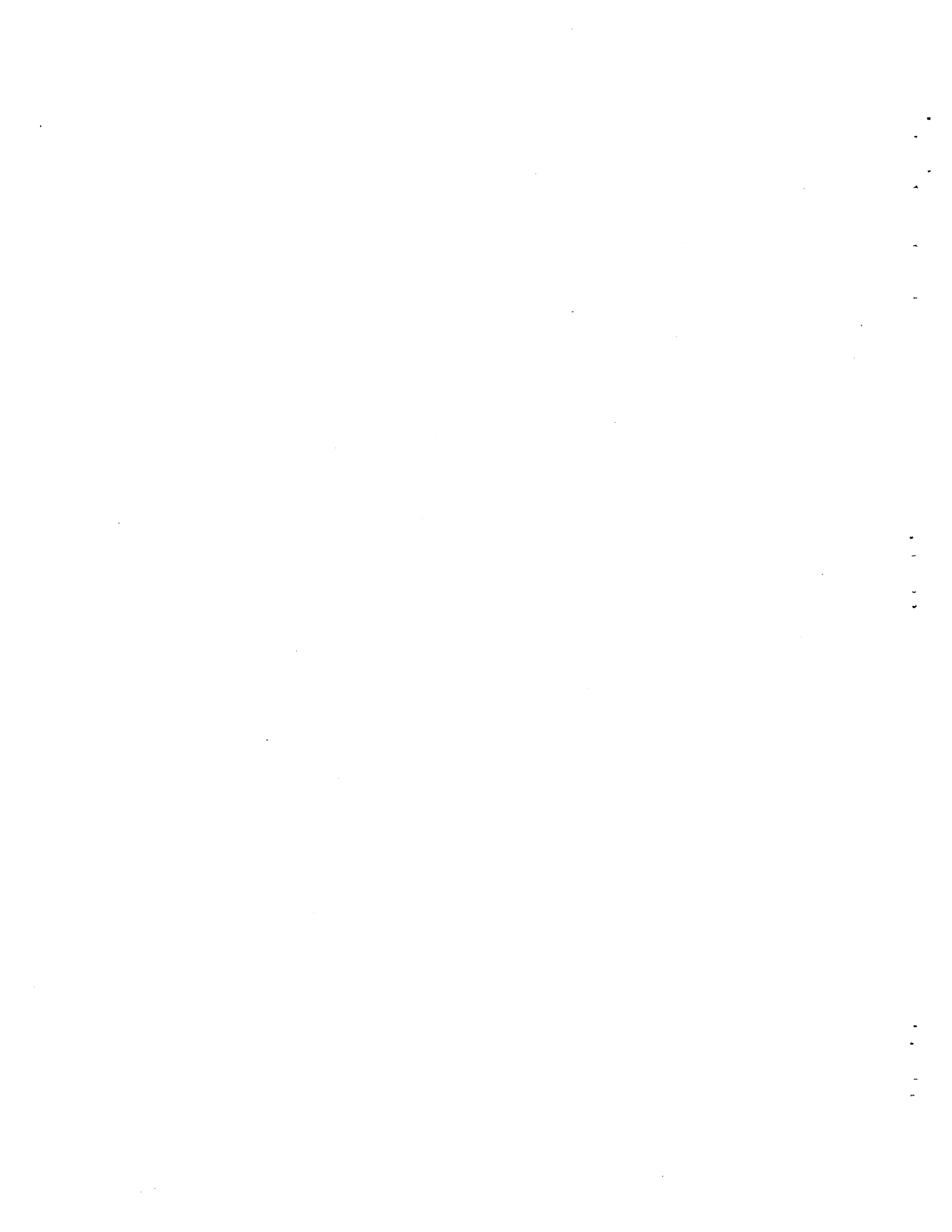


Fig. 2-3. Probe method for coupling a signal from within a device.



## APPLICATIONS

## Introduction

The portion of the manual describes some basic applications of the sampling system, including various voltage-measuring methods.

Vertical displacement of the crt trace is directly proportional to the voltage at the INPUT connector. The amount of displacement, for a given voltage, can be selected with the MILLIVOLTS/CM switch. To provide sufficient deflection for best resolution, set the MILLIVOLTS/CM switch so the display spans a large portion of the graticule. Also, when measuring between points on a display, be sure to measure consistently from either the bottom, middle, or top of the trace. This will keep you from including the width of the trace in your measurements.

To make a voltage-difference measurement between two points on a display, proceed as follows.

1. Using the graticule as a scale, note the vertical deflection, in divisions, between the two points on the display. Make sure the VARIABLE control is in the CALIBRATED position.

2. Multiply the divisions of vertical deflection by the numerical setting of the MILLIVOLTS/CM switch and the attenuation factor (if any) of an attenuator or probe. The product is the voltage difference between the two points measured.

As an example, suppose you measure 4.4 divisions of deflection between two points on the display. With the MILLIVOLTS/CM switch set at 20, multiply 20 by 4.4 (the amount of deflection) for a produce of 88 millivolts. This is the voltage at the INPUT connector of the 4S1. Now assume

there is a 10X attenuator in the cable between the INPUT connector and the signal. To determine the signal voltage at its source, multiply 88 millivolts (the voltage at the INPUT connector) by 10 (the attenuation factor). The product of 880 millivolts (0.88 volt) is the voltage at the source.

If desired, you can measure the instantaneous (or dc) voltage-to-ground of a signal. This is accomplished in the same general manner as described previously. The difference is, with no signal applied, to first establish a ground reference point on the crt. To do this, allow the timing unit to present a free-running trace. Then, vertically position the trace so that it is exactly aligned with one of the horizontal graticule lines. This assumes no vertical shift in the trace base-line due to unequal duty cycle of an ac coupled pulse train. The actual graticule line selected will be largely determined by the polarity and amplitude of the applied signal. After this point, make no further adjustments with the VERT. POSITION control. Once the ground reference is established, apply the signal and measure the voltage in the same manner as described previously. Use the established ground-reference as the point from which to make all measurements.

If the applied signal has a relatively high dc level, the ground-reference point and the actual signal may be so far apart that one or both will not be in the viewing area of the graticule. In this case, refer to the following discussion regarding DC OFFSET Voltage Measurements.

#### DC OFFSET Voltage Measurements

The DC OFFSET voltage allows you to cancel the effects of a relatively high (up to  $\pm 1$  volt) applied dc level in the presence of a low ac signal amplitude. Also, by measuring the offset voltage at the OFFSET MONITOR, you can determine

the instantaneous voltage-to-ground at any point on a signal, or its peak-to-peak amplitude.

To measure the instantaneous voltage-to-ground at any point on an applied signal, proceed as follows. (NOTE: If you wish only to measure the peak-to-peak signal amplitude you may neglect steps 1, 2, 6, and 7.)

1. With a free-running trace and no signal applied, position the trace to the horizontal centerline of the graticule. After this point, do not further adjust the VERT. POSITION control of the Type 4S1.

2. Measure the voltage at the OFFSET MONITOR. Note the voltage.

3. Apply the signal that you wish to measure to the INPUT connector of the 4S1.

4. With the DC OFFSET control, position the display within the viewing area of the graticule.

5. On the time-base plug-in unit, set the triggering controls for a stable display at the desired sweep rate.

6. With the DC OFFSET control, position the display point to be measured to the horizontal centerline of the graticule.

7. Measure the voltage at the OFFSET MONITOR. Note the voltage.

8. The instantaneous voltage-to-ground is the difference of the voltages measured in steps 2 and 6, divided by 100. For peak-to-peak voltage measurement with the DC OFFSET, position the top and bottom of the display to the graticule centerline and measure the OFFSET MONITOR voltage at each point. The difference of the two voltages, divided by 100, is the peak-to-peak voltage.

## X-Y Phase Measurements

X-Y operation is obtained by placing the MODE switch in the A VERT. B HORIZ. position. This allows CHANNEL A to control vertical deflection and CHANNEL B to control horizontal deflection.

To measure the phase difference between two sine waves of the same frequency, proceed as follows.

1. Set the front-panel controls of the Type 4S1 as indicated:

MODE Switch	A ONLY
DISPLAY Switches	NORMAL
DC OFFSET Controls	midrange
TRIGGER SOURCE	A or B as desired

2. Apply each sine wave to an INPUT connector through identical electrical lengths of coaxial cable.

3. With the SWEEP MAGNIFIER at X1, set the triggering controls of the timing unit for a stable display showing at least one complete cycle.

4. Adjust the following Channel A controls, as required, to obtain a vertically-centered 4-division display:

MILLIVOLTS/CM

VARIABLE

DC OFFSET

VERT. POSITION

5. Set the MODE switch to B ONLY and repeat steps 3 and 4 using the Channel B controls.

6. Set the MODE switch to A VERT. B HORIZ.

7. Using the Channel A VERT. POSITION control and either the Channel B DC OFFSET control or the 661 HORIZONTAL POSITION control, center the display on the graticule (both vertically and horizontally).

8. The display at this point may be an ellipse. (NOTE: If the display appears as a diagonal straight line the two sine waves are either in phase or  $180^\circ$  out of phase, or if the display is a circle, the two sine waves are  $90^\circ$  out of phase. In any case, these instructions still apply.)

9. Measure the distance of A and B on the display as shown in Fig. 3-2. A divided by B equals the sine of the phase angle between the two sine waves.

#### Impedance Error Measurement by Reflection

The high-frequency response of the Type 4S1 permits the display of transmission-line characteristics. Reflections caused by the transmission line or connections can be detected as a vertical deflection directly from the oscilloscope display, if they are of nanosecond or more duration. At 2 MILLIVOLTS/CM sensitivity, a step signal from -1 volt to +1 volt will show a 1-cm signal from a 0.2% impedance error reflection.

As a signal travels down a transmission line, a reflection is generated each time it encounters a mismatch or different impedance. The reflection travels back along the line to the signal source where it either adds to or subtracts from the input signal at that instant. The amplitude and polarity of the reflection depend upon the value of the mismatched impedance. If the mismatch impedance is higher than the nominal impedance, the reflection will be the same polarity as the applied signal. If the mismatch impedance is lower than nominal, the reflection will subtract from the input signal at the source.

The amplitude of the reflected waves increases with the degree of mismatch. In the two extremes of mismatch, zero and infinite impedance, the reflection amplitude equals the

amplitude of the applied signal. The result in this case is that the reflection either doubles or cancels the applied signal at the instant it returns to the source.\*

#### Algebraic Addition or Subtraction of Signals

The algebraic sum or difference of two signals is displayed on the crt when the MODE switch is in the ADDED ALGEB. position. The sum of the signals is obtained with both DISPLAY switches set in the same position. The signal difference is obtained with the DISPLAY switches set in opposite positions.

The foregoing mode of operation is particularly useful for cancelling the effects of an undesired common-mode signal. For example, suppose the signal to be observed contains an undesired power supply hum component. In normal operation, this would cause an apparent unstable display. However, in the ADDED ALGEB. mode, the effect of the hum can be cancelled by applying only the hum component to the opposite channel and experimenting with the MILLIVOLTS/CM, VARIABLE, and DISPLAY controls. However, be sure that the hum component that you apply to the opposite channel does not contain any of the signal to be observed.

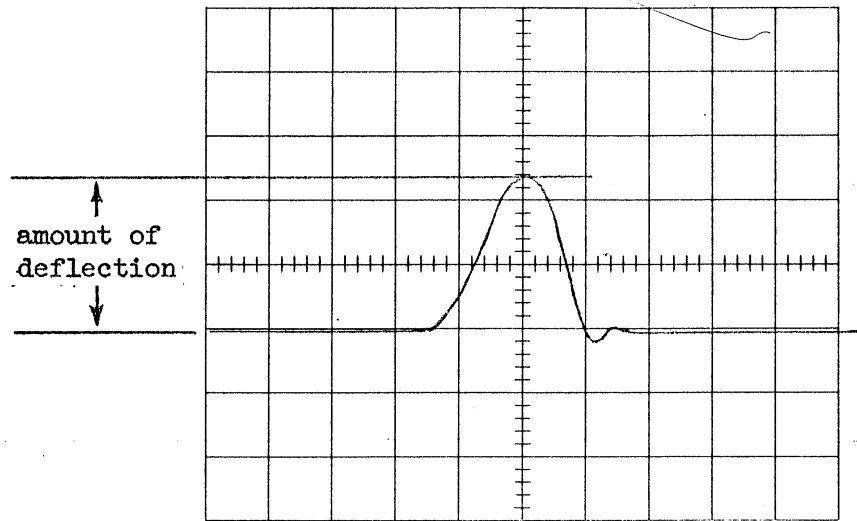
#### Dual-Trace Applications

The dual-trace mode of the 4S1 allows two separate events to be viewed simultaneously. This is most useful when you wish to compare either the amplitude or time of two signals. To obtain a suitable display, the two signals must have the same repetition rate or frequency, or be harmonically or otherwise synchronous, and must occur in a period

\*See: Lewis and Wells, "Millimicrosecond Pulse Techniques".

that does not exceed the maximum equivalent sweep duration of the sampling time-base unit. See the ~~Dual-Trace~~ explanation in section 2 of this manual.

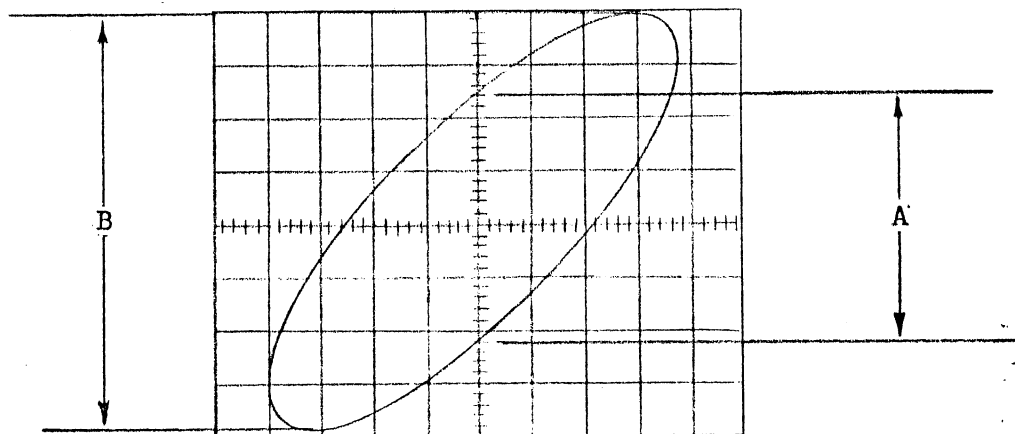
The differences in delay time between two coaxial cables can easily be displayed in dual-trace operation (see Fig. 3-3). Apply a common signal through two lengths of coax to the two INPUT connectors of the 4S1. By knowing the delay through one of the cables and comparing the time difference between the displayed signals, it is a simple matter to determine the delay through the unknown cable. For example, suppose the known cable had a delay of 10 nanoseconds. If the two displayed signals showed a time difference of 5 nanoseconds, the unknown cable had either 5 nanoseconds more or less delay than the known cable. The longer of the two cables had the most delay.



$$\text{Voltage at INPUT connector} = \text{amount of deflection} \times \text{setting of MV/DIV. switch}$$

example:  $120 \text{ mv (peak)} = 2.4 \text{ div.} \times 50 \text{ (MV/DIV.)}$

Fig. 3-1. Peak voltage measurement.



$$\frac{A}{B} = \sin \theta$$

Fig. 3-2. X-Y method of calculating phase difference ( $\theta$ ) between two sign waves.

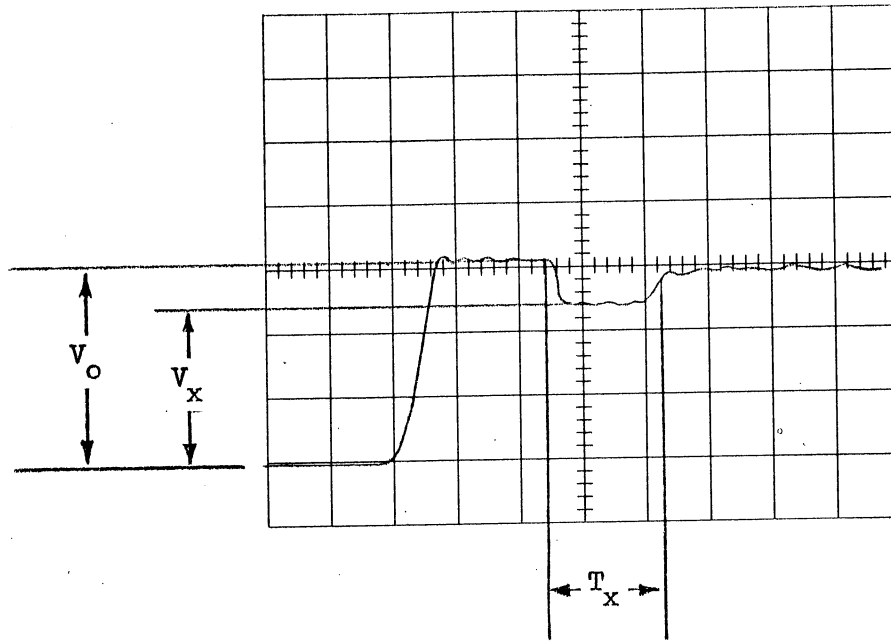


Fig. 3-3. Waveform obtained from a charged-line pulse generator with a section of 90-ohm coax inserted between two sections of nominal 50-ohm charge line.

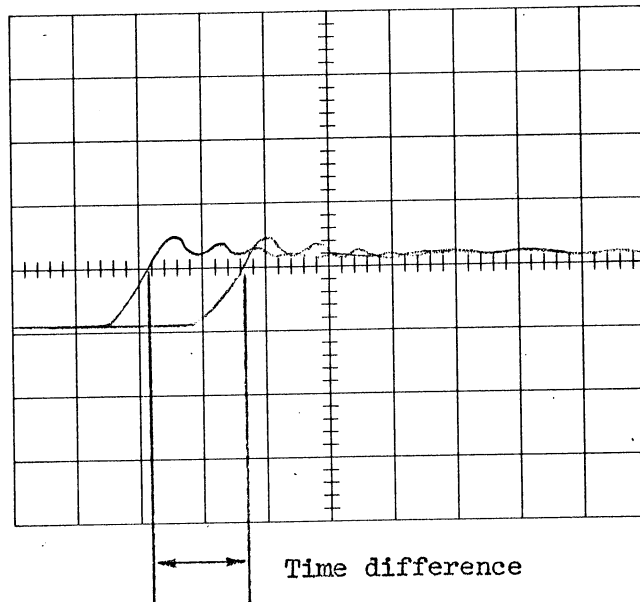
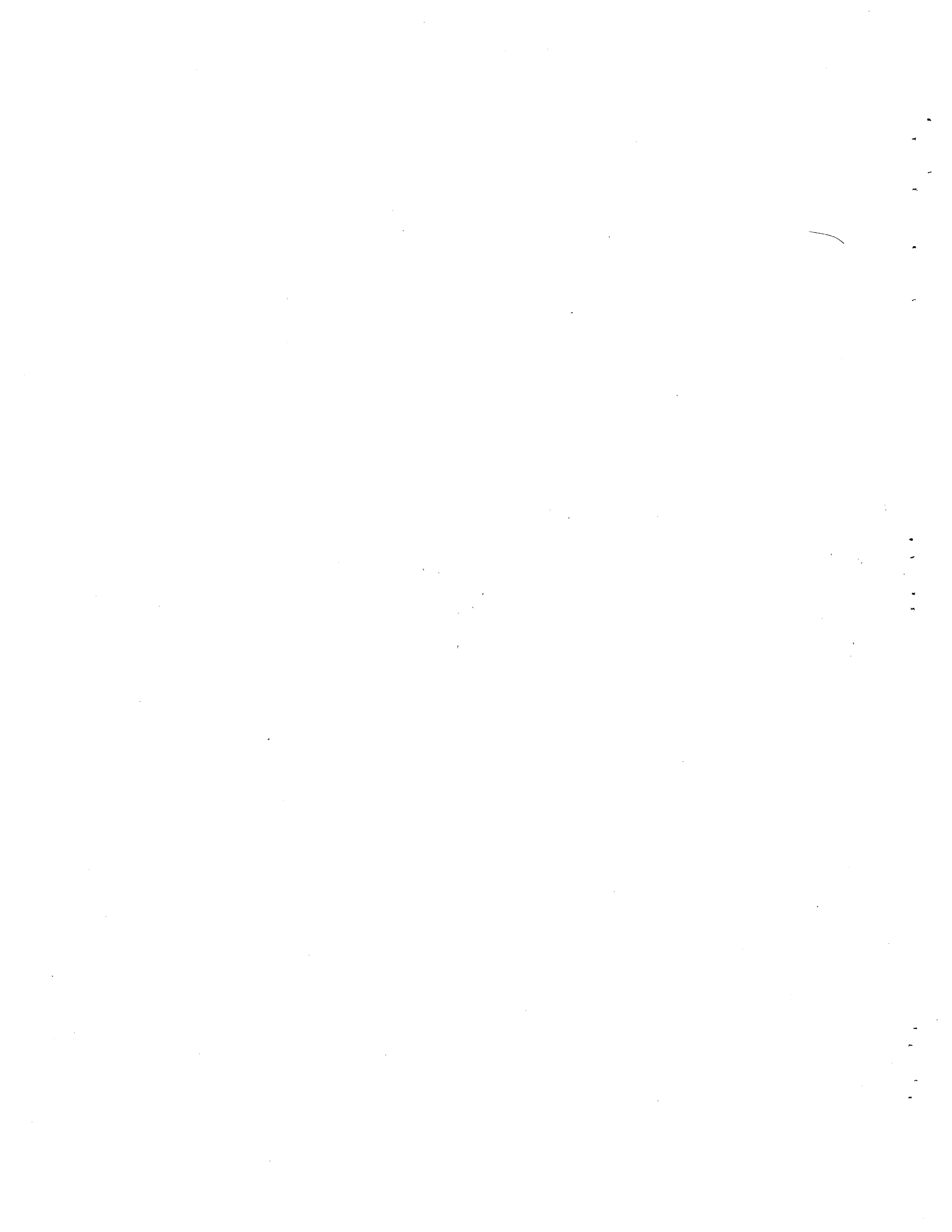
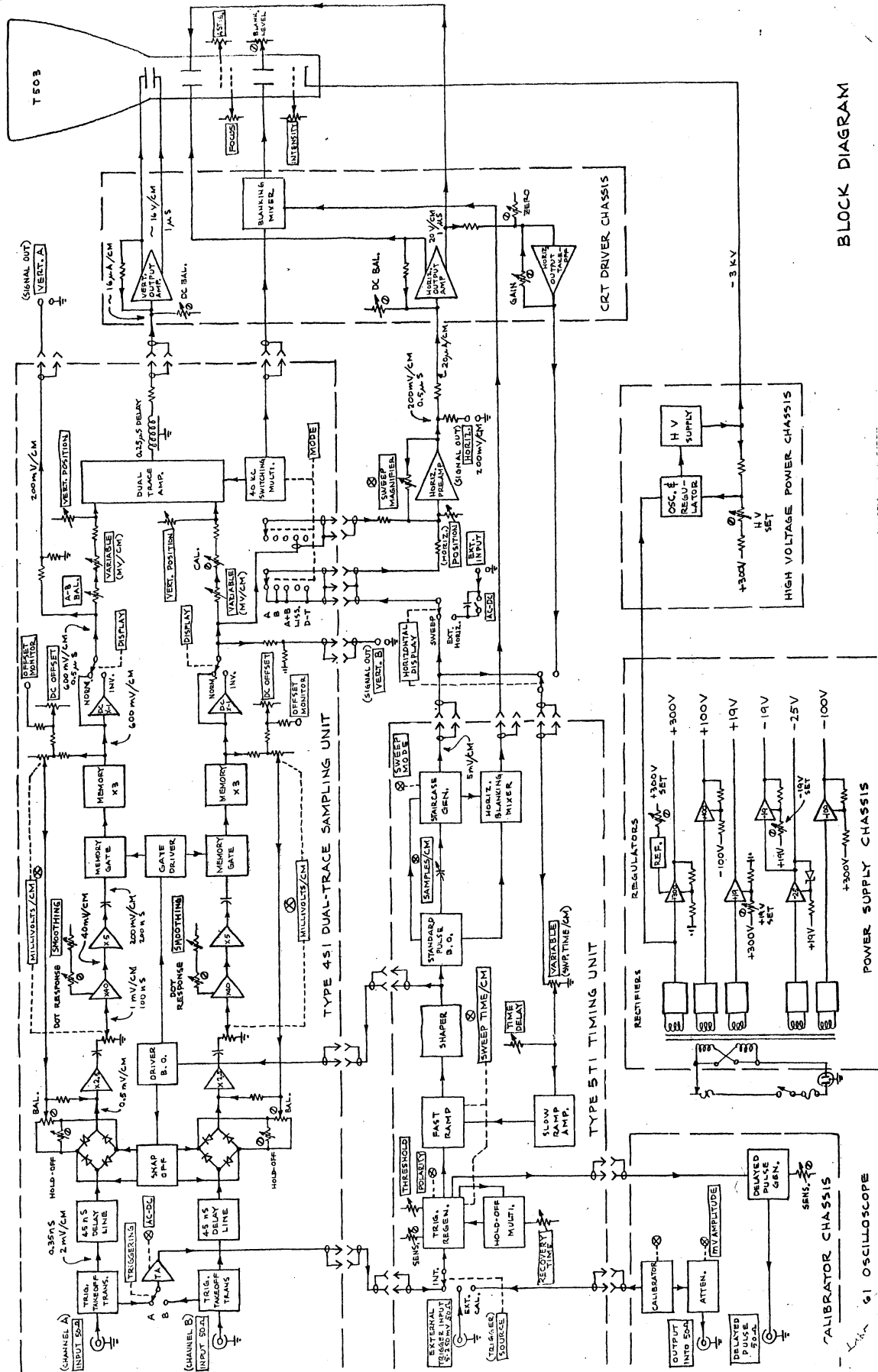


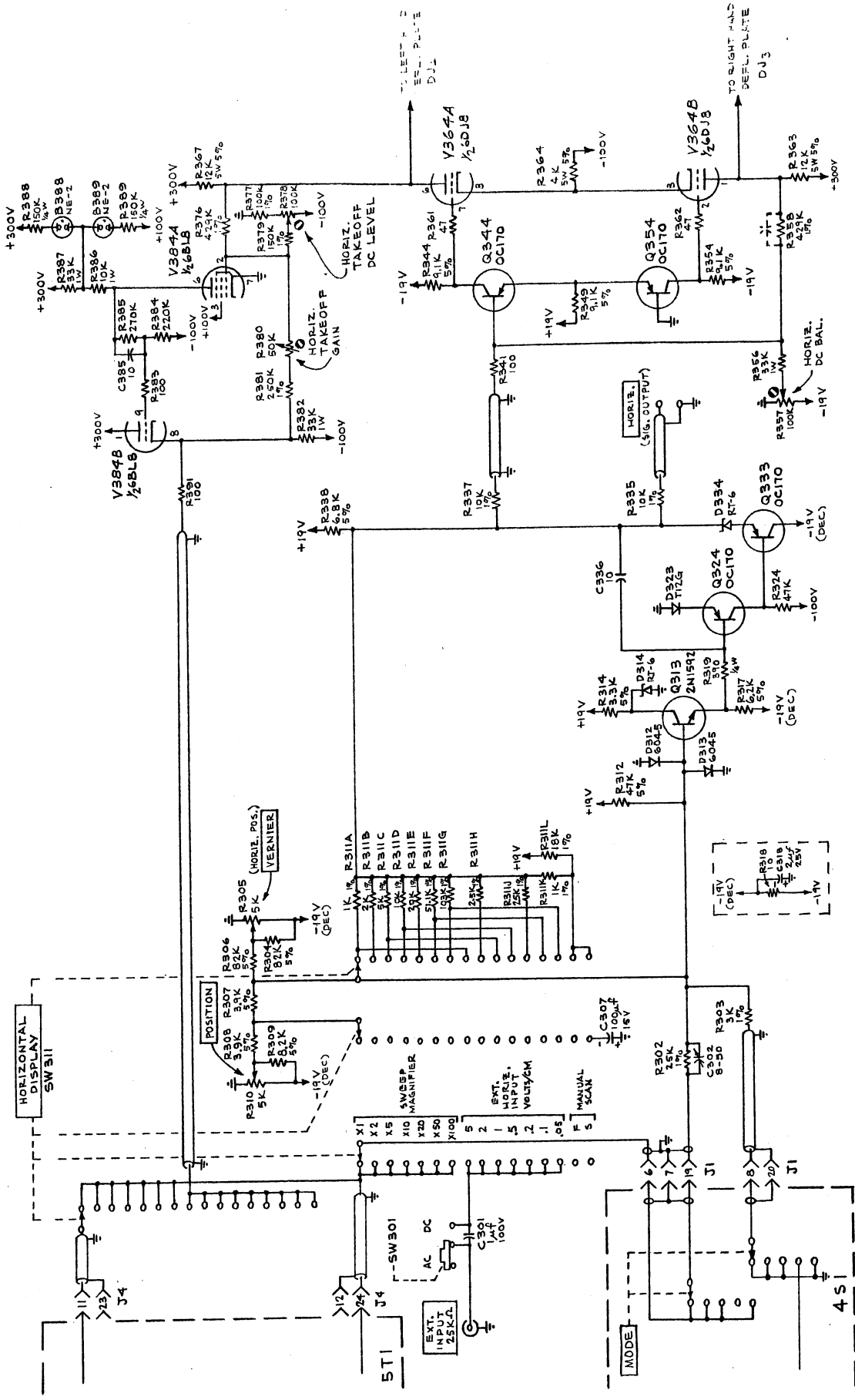
Fig. 3-4. Dual-trace display showing time delay between output signals of unequal lengths of coaxial cable.





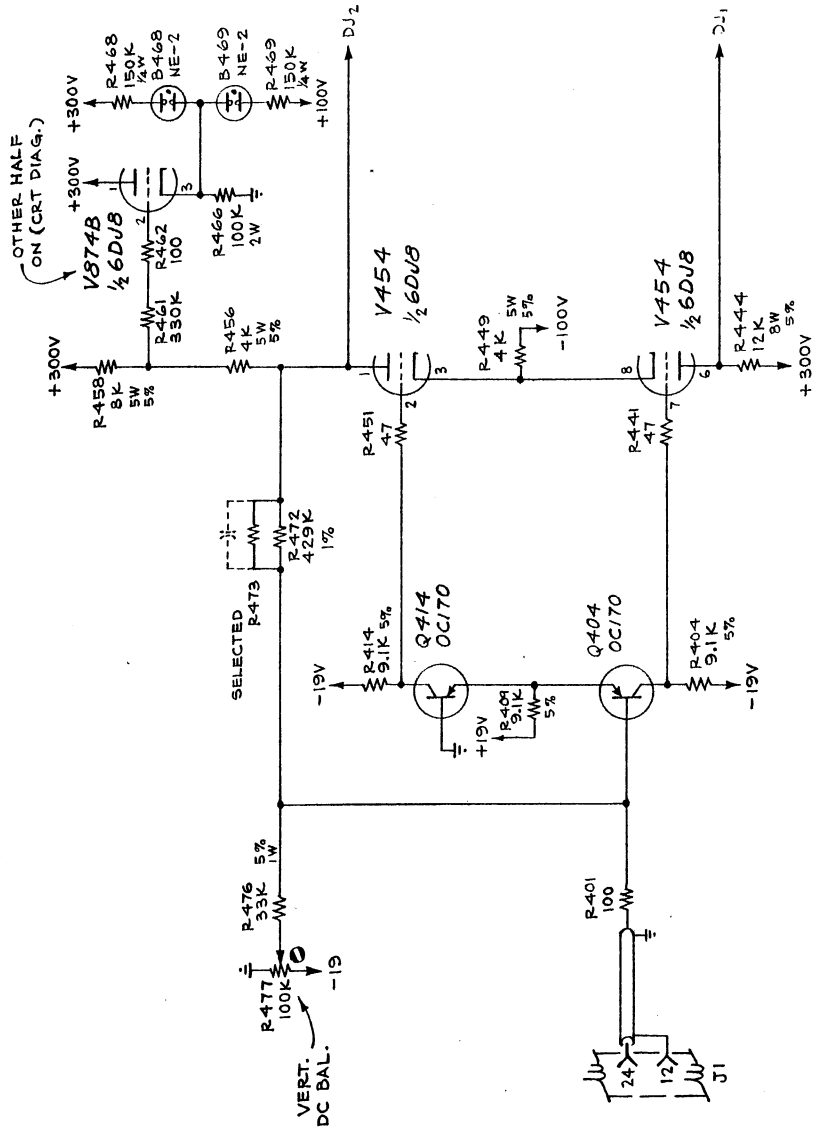
BLOCK DIAGRAM

61 OSCILLOSCOPE



HORIZONTAL AMPLIFIER.

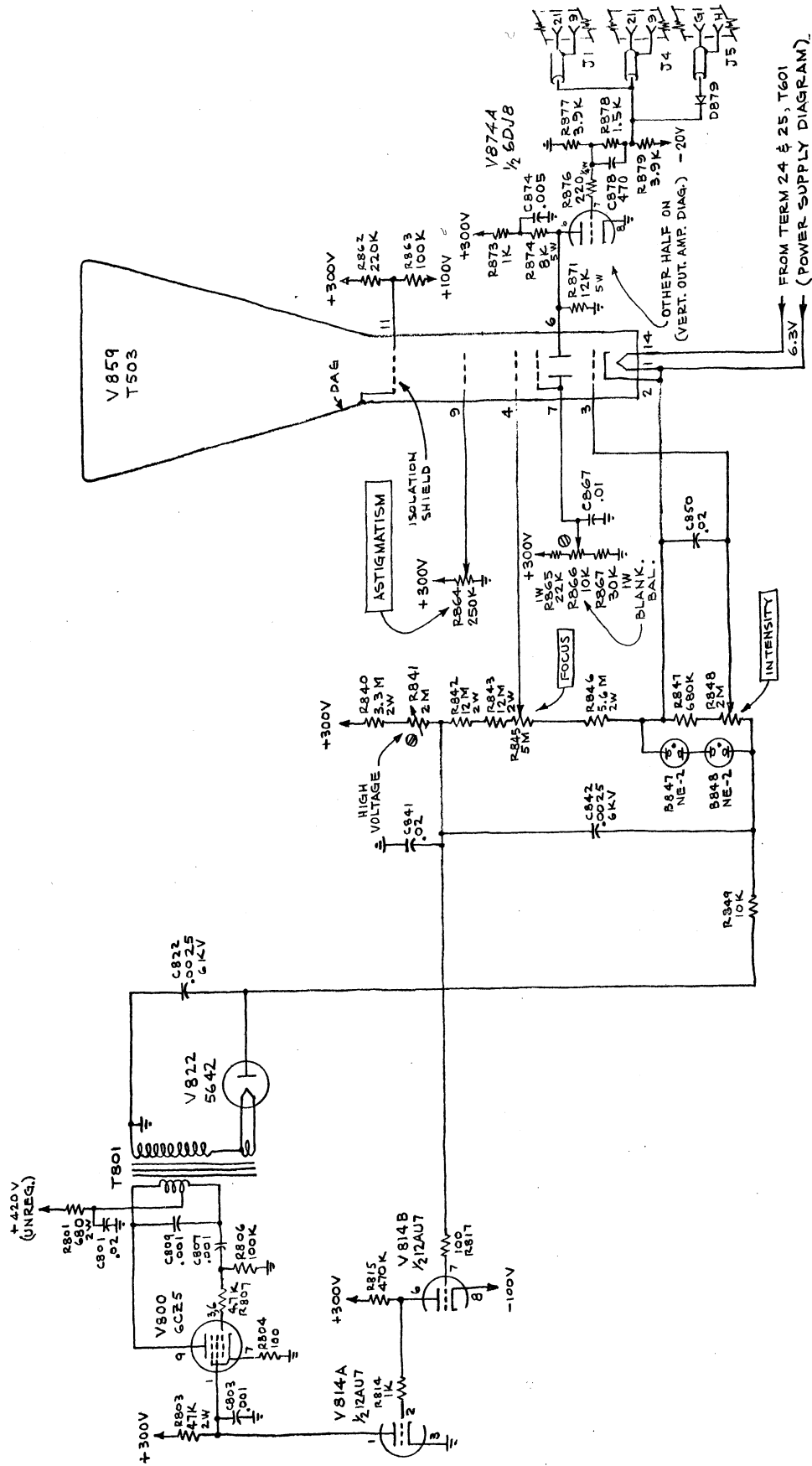
TYPE 661 OSCILLOSCOPE



TYPE 661 OSCILLOSCOPE

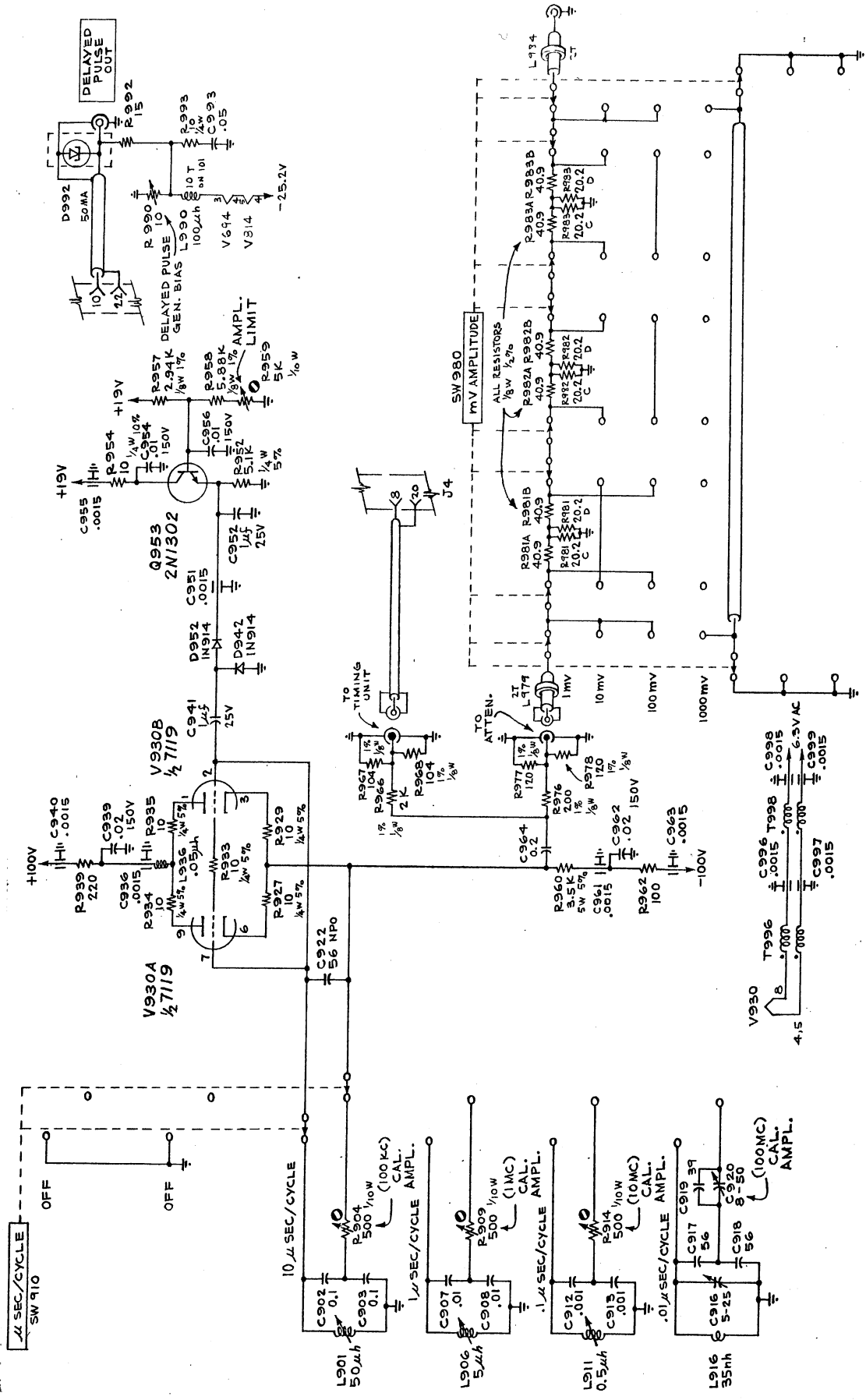
VERTICAL OUTPUT AMPLIFIER



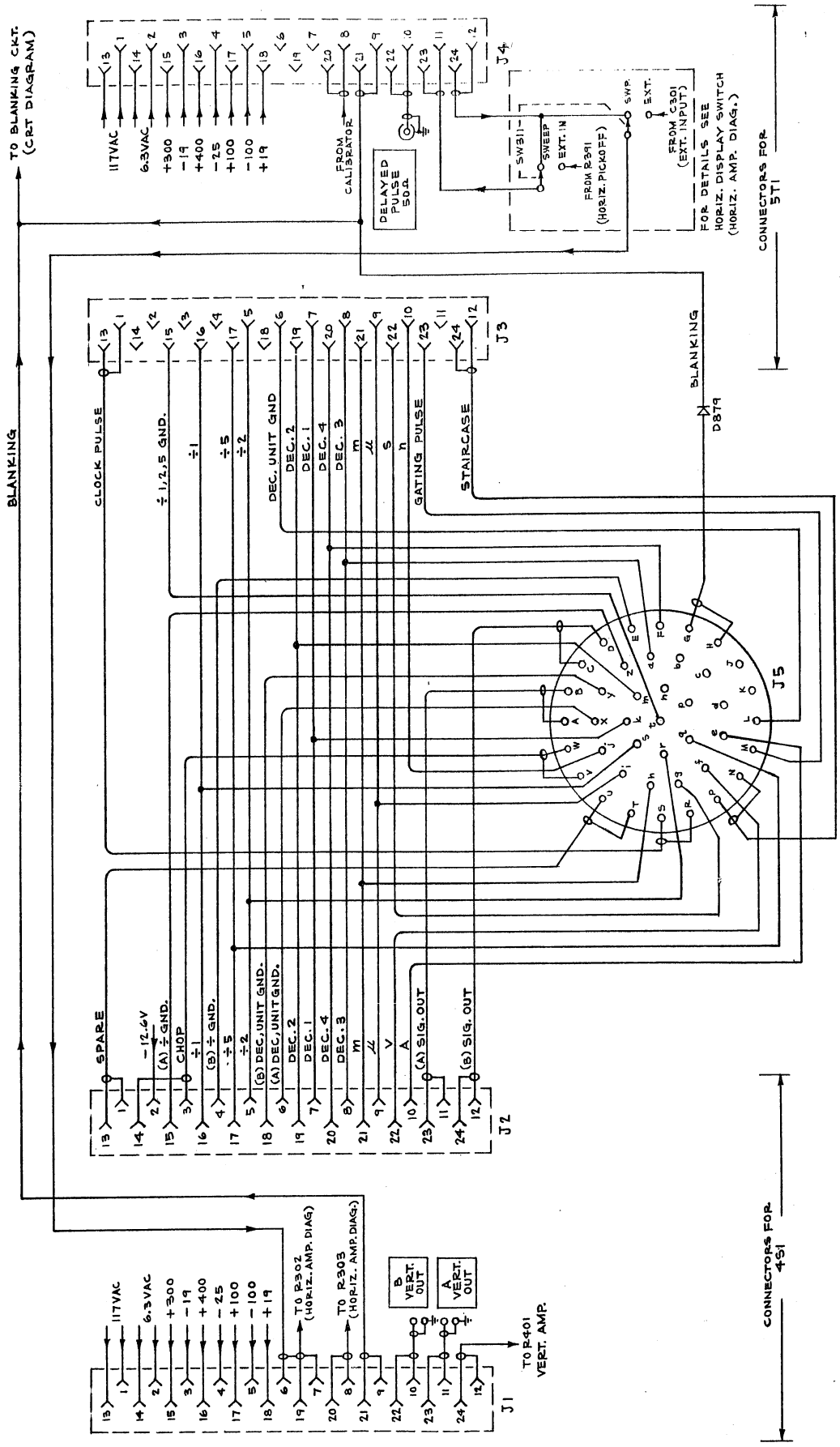


CRT CIRCUIT

TYPE 661 OSCILLOSCOPE



TYPE 661 OSCILLOSCOPE AMPLITUDE/TIME CALIBRATOR



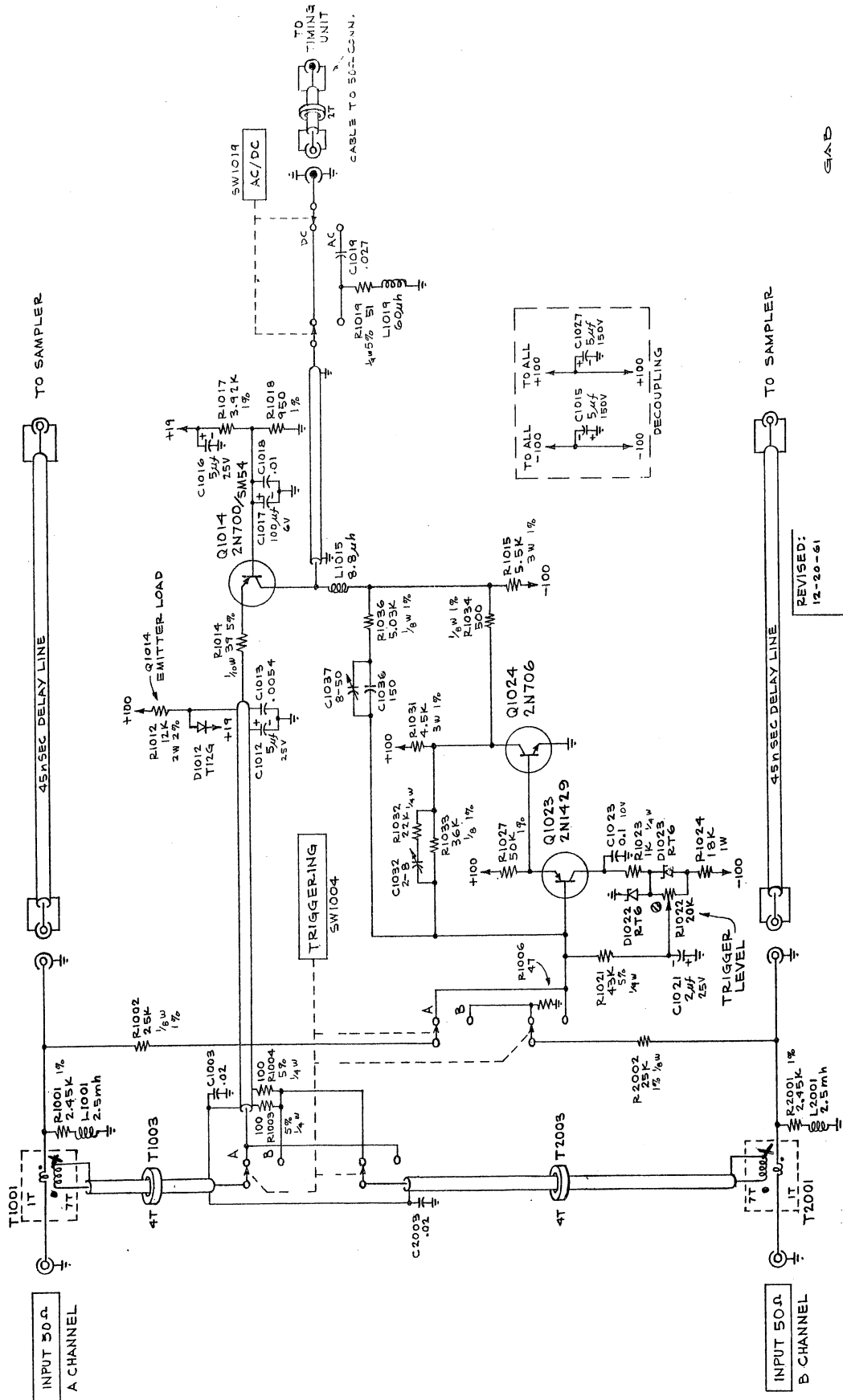
GAB

PLUG-IN CONNECTORS

TYPE 661 OSCILLOSCOPE

CONNECTORS FOR 451

CONNECTORS FOR 5T1

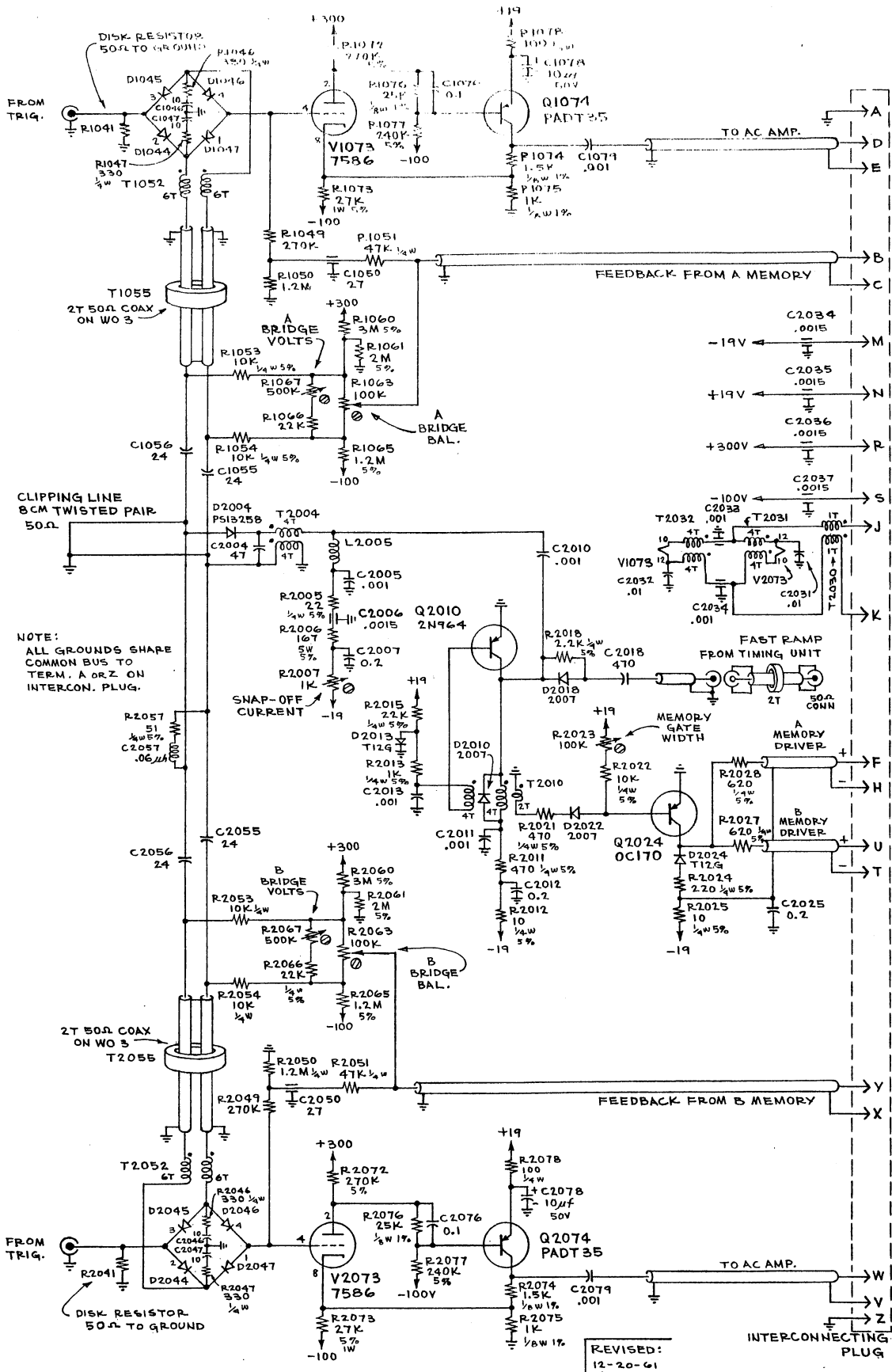


REVISED:  
12-20-61

TRIGGER AMPLIFIER

TYPE 4S1

5448



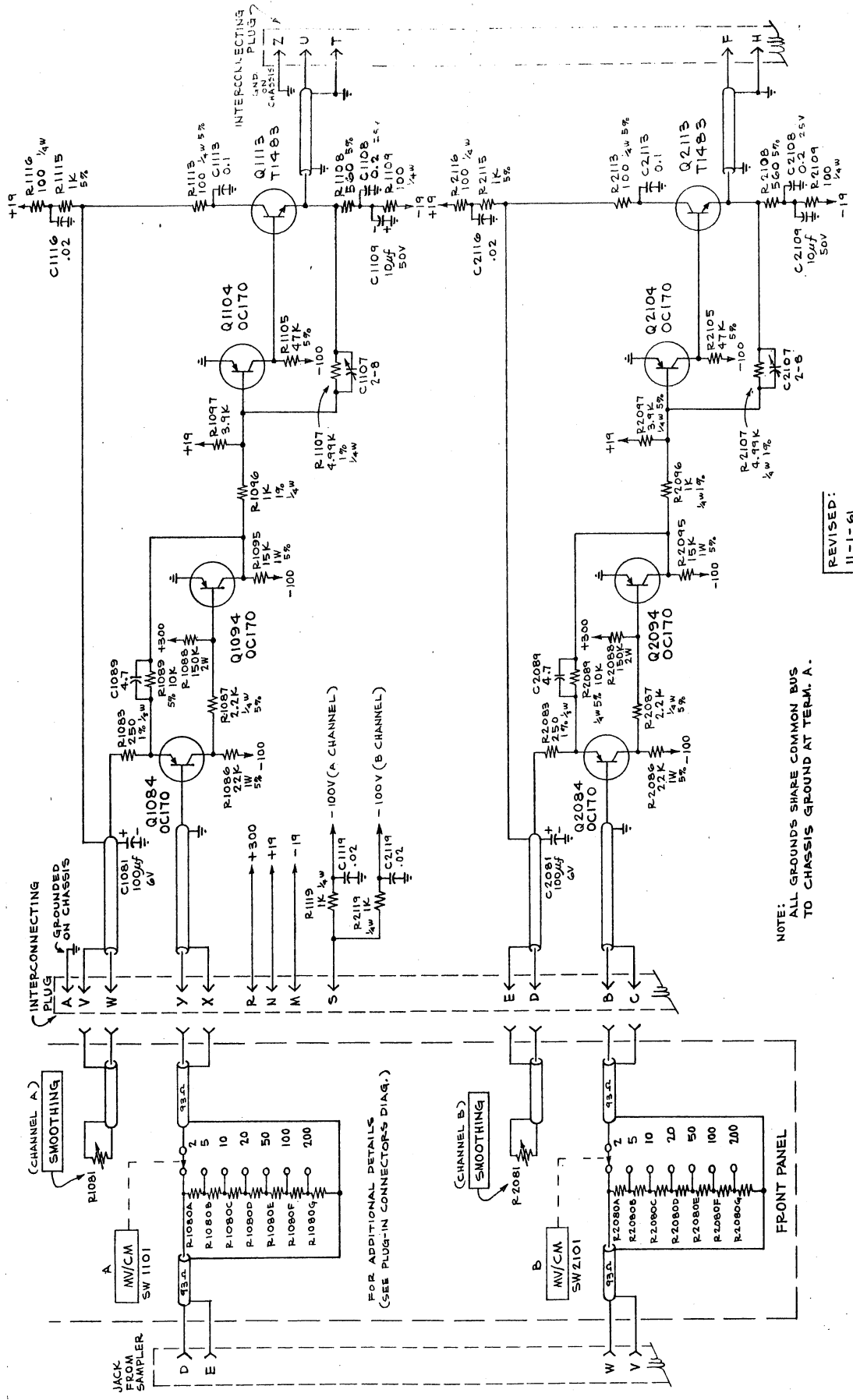
NOTE:  
ALL GROUNDS SHARE  
COMMON BUS TO  
TERM. A OR Z ON  
INTERCON. PLUG.

REVISED:  
12-20-61  
1-4-61

TYPE 4S1

SAMPLER

GAB



REVISED:  
 11-1-61  
 11-9-61  
 12-20-61  
 1-4-61

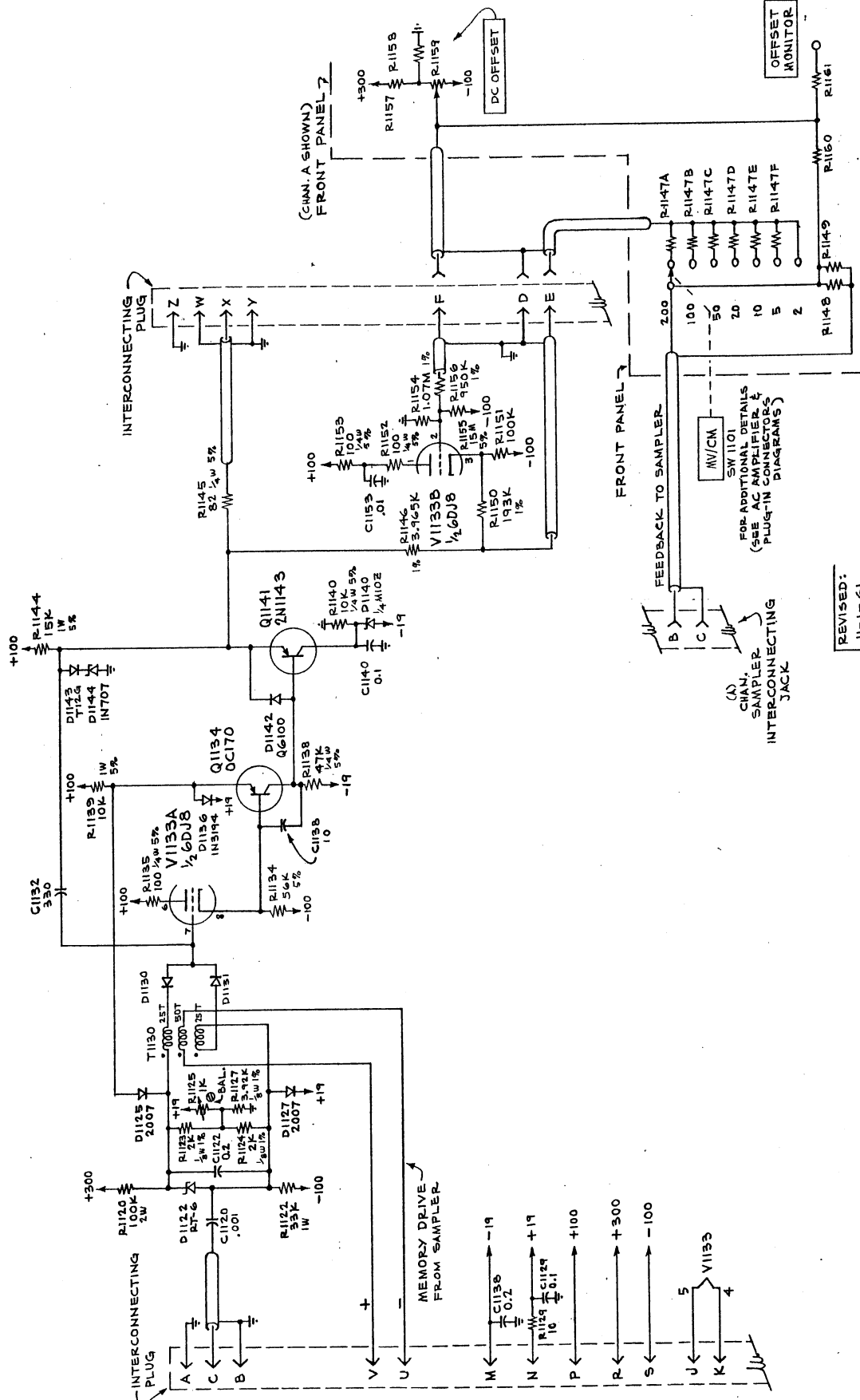
NOTE: ALL GROUNDS SHARE COMMON BUS TO CHASSIS GROUND AT TERM. A.

GRAB

AC AMPLIFIER

TYPE 4S1

FOR ADDITIONAL DETAILS (SEE PLUG-IN CONNECTOR'S DIAG.)

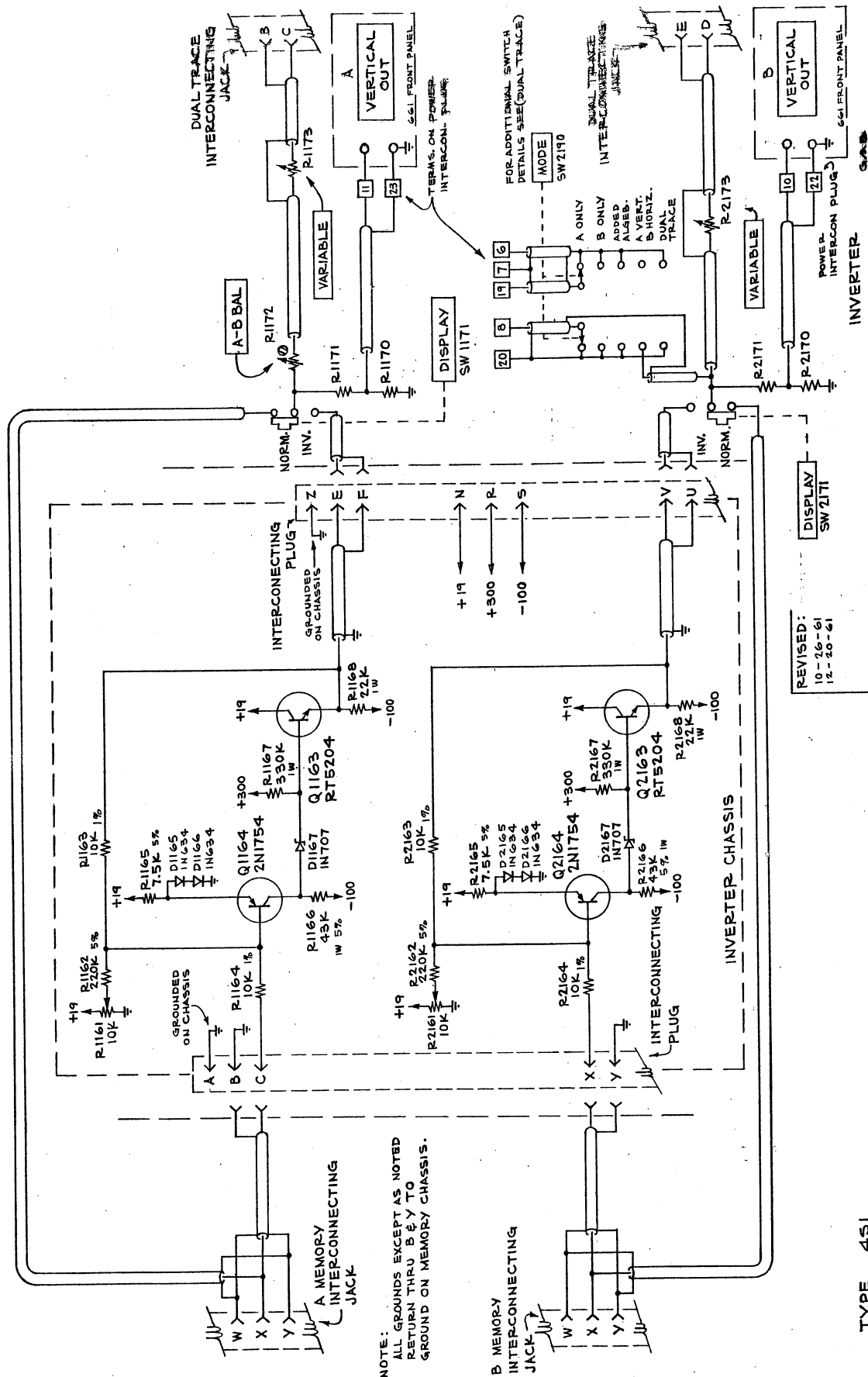


REVISED:  
 11-10-61  
 12-20-61  
 1-3-61

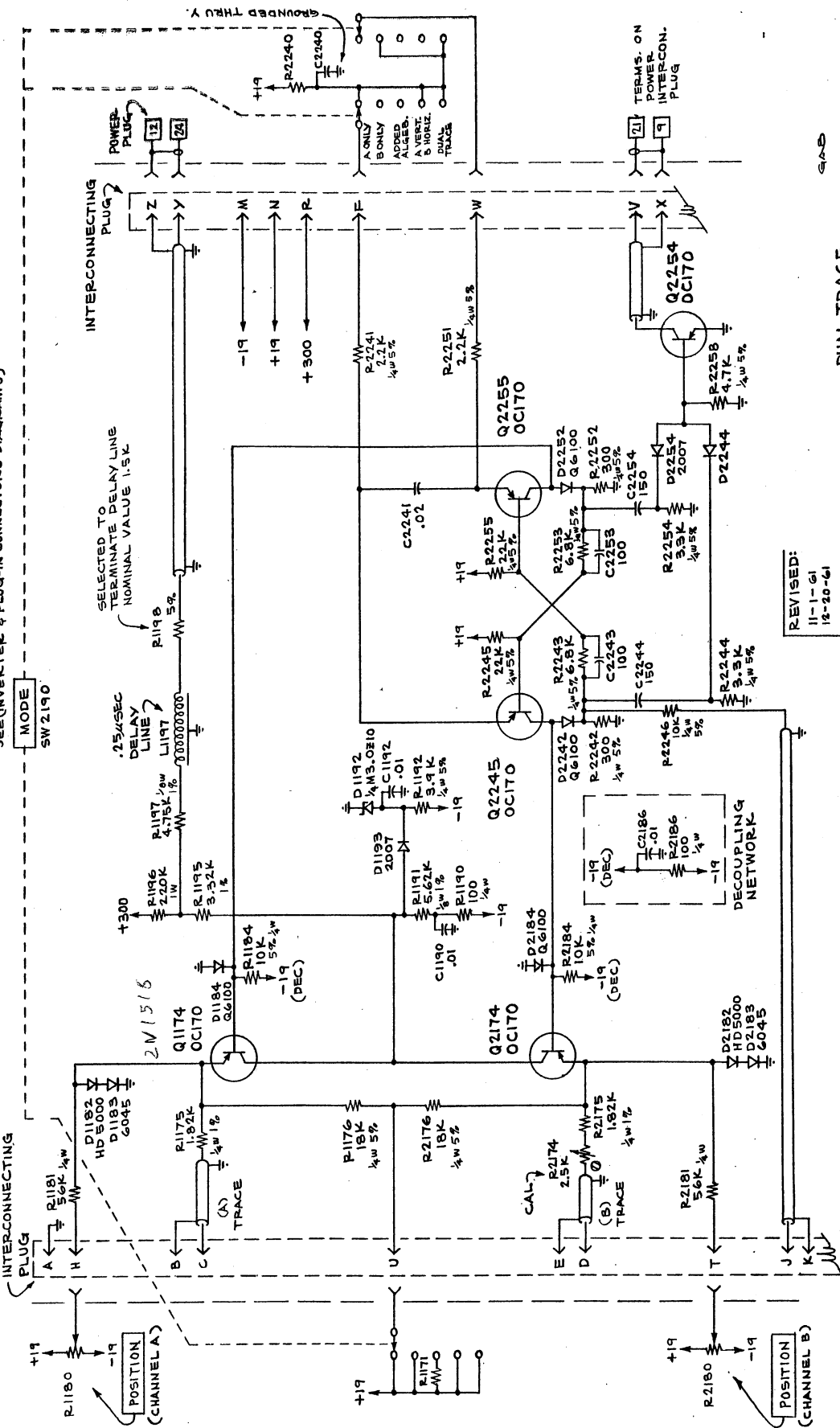
MEMORY (2 REQUIRED)

TYPE 451

5A-D



FOR ADDITIONAL SWITCH DETAILS  
SEE (INVERTER & PLUG-IN CONNECTORS DIAGRAMS)

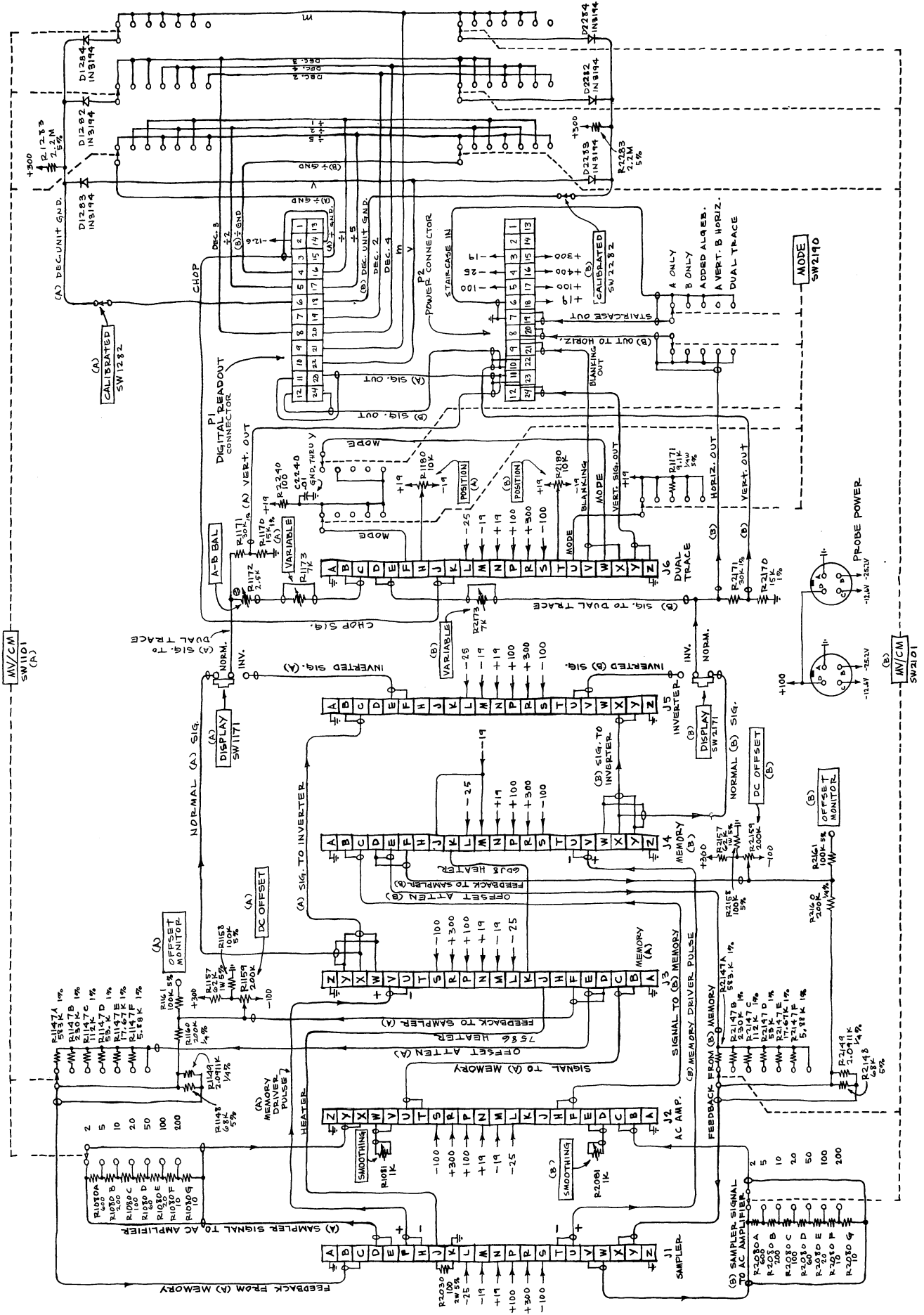


REVISED:  
11-1-61  
12-20-61

QAD

DUAL TRACE

TYPE 4S1

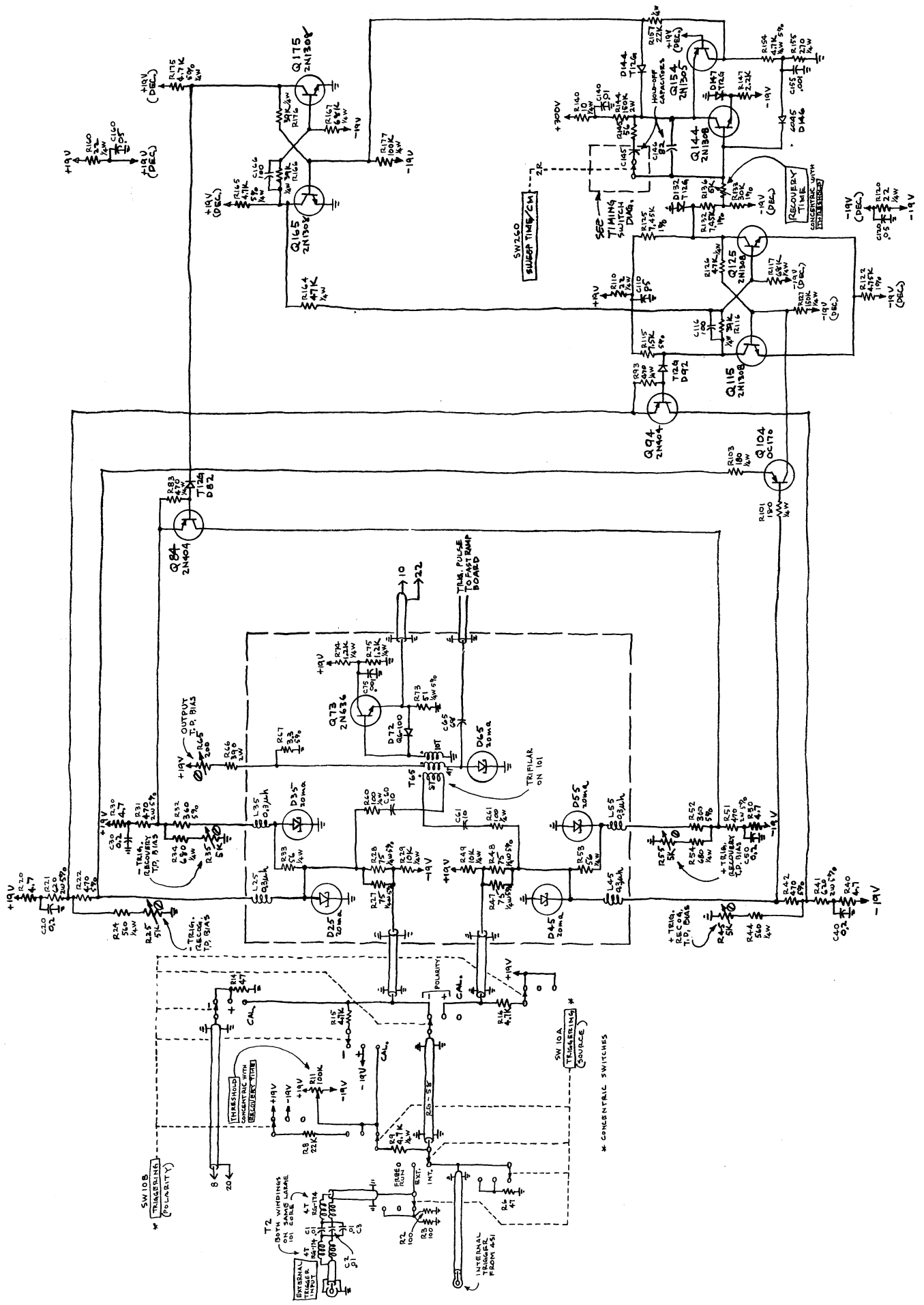


REVISED:  
 11-1-61  
 12-20-61  
 1-4-61

648

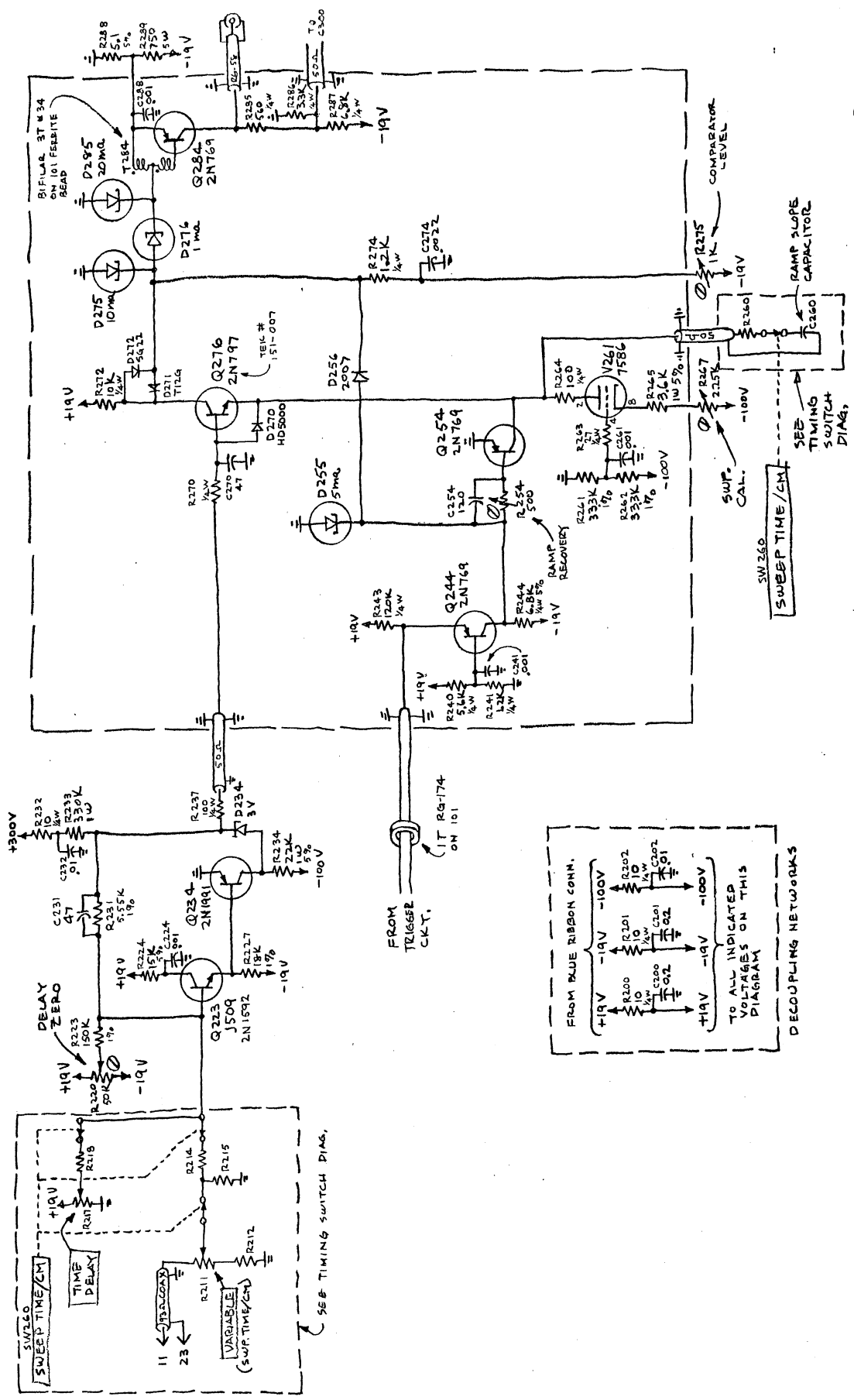
PLUG-IN CONNECTORS & SWITCHING

TYPE 451

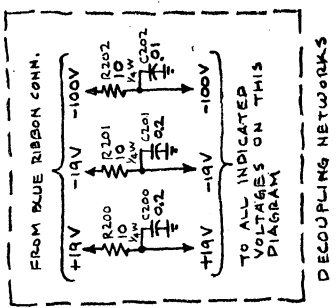


TRIGGER & HOLD-OFF

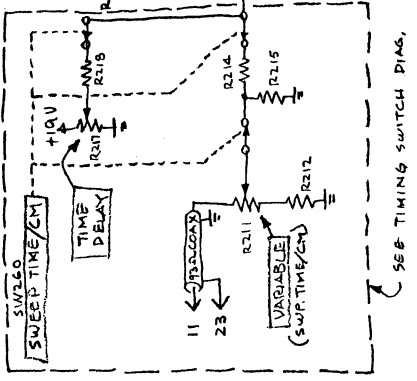
TYPE 5T1



FAST RAMP



TYPE 5T1

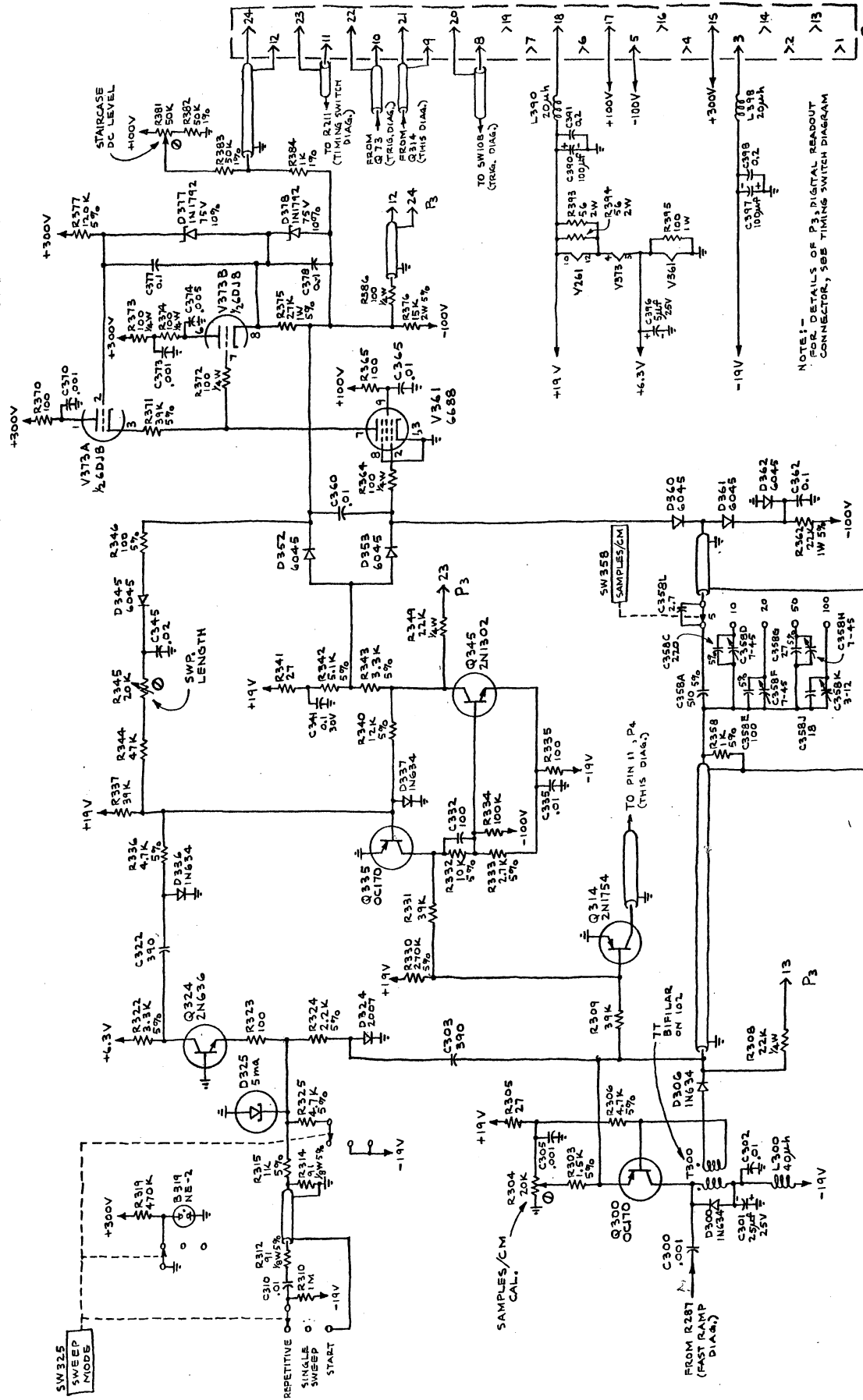


SWEEP TIME/CM

SEE TIMING SWITCH DIAG.

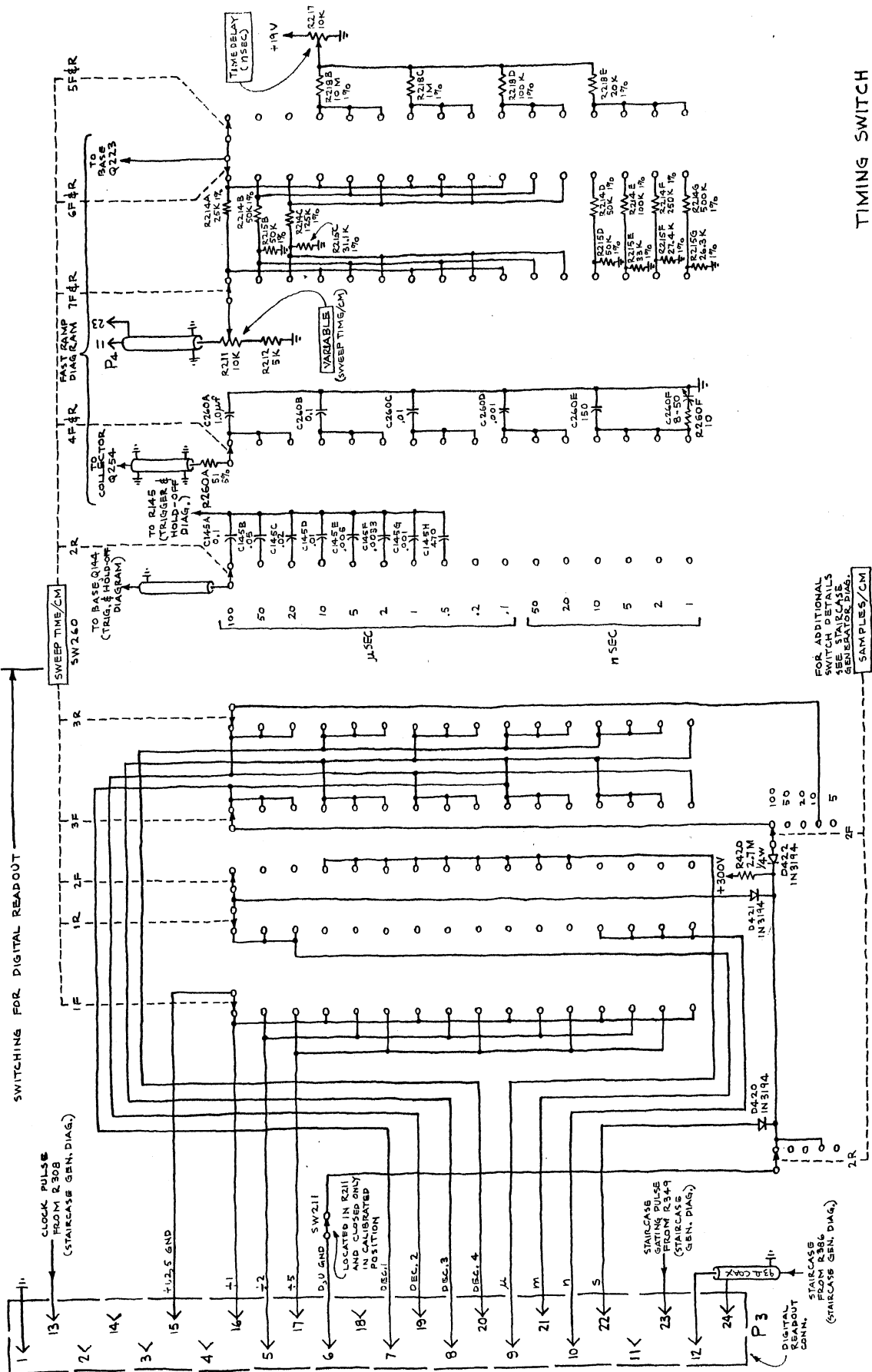
RAMP SLOPE RAMP CAPACITOR

COMPARATOR LEVEL



STAIRCASE GENERATOR

TYPE 5T1



SWEEP TIME/CM  
 SW 260  
 TO BASE Q144 (TRIG. & HOLD-OFF DIAG.)  
 TO MOTOR COLLECTOR Q254  
 TO R145 (CHOOSE 1 HOLD-OFF DIAG.)  
 TO R146  
 TO R147  
 TO R148  
 TO R149  
 TO R150  
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 TO R152  
 TO R153  
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 TO R200

FOR ADDITIONAL SWITCH DETAILS SEE GENERATOR DIAG.  
 SW 358  
 SAMPLES/CM

TIMING SWITCH

STI PLUG-IN UNIT

SWEEP TIME/CM  
 SW 260  
 TO BASE Q144 (TRIG. & HOLD-OFF DIAG.)  
 TO MOTOR COLLECTOR Q254  
 TO R145 (CHOOSE 1 HOLD-OFF DIAG.)  
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 TO R200

FOR ADDITIONAL SWITCH DETAILS SEE GENERATOR DIAG.  
 SW 358  
 SAMPLES/CM

TIMING SWITCH

STI PLUG-IN UNIT

SWEEP TIME/CM  
 SW 260  
 TO BASE Q144 (TRIG. & HOLD-OFF DIAG.)  
 TO MOTOR COLLECTOR Q254  
 TO R145 (CHOOSE 1 HOLD-OFF DIAG.)  
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 TO R199  
 TO R200

FOR ADDITIONAL SWITCH DETAILS SEE GENERATOR DIAG.  
 SW 358  
 SAMPLES/CM

TIMING SWITCH

STI PLUG-IN UNIT

