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T1000 FAULT LOCATOR

CONNECTING AND SETTING UP THE UNIT

Two voltage signals available on the back panel are designed to produce a display on an oscilloscope. The procedure for connecting and setting up the unit is as follows:–

1. Switch on the oscilloscope and set it to XY mode. Set the 'scope input coupling switches to DC coupled and the X and Y sensitivity to 100 mV/div.
   Adjust the intensity for a visible spot and use the horizontal and vertical position controls of the 'scope to place the dot in the centre of the C.R.T. (cathode ray tube).
   APART FROM MINOR INTENSITY ADJUSTMENTS THE 'SCOPE CONTROLS SHOULD REQUIRE NO FURTHER ADJUSTMENT.
2. Connect the T1000 to a suitable supply voltage.
3. Remove the two black BNC to BNC leads from the pouch on top of the instrument.
4. Connect the two rear panel BNC sockets to the oscilloscope X and Y inputs. (X output to X input and Y output to Y input).
5. Using the power switch on the rear panel, switch on the T1000 – check that the front panel glows red in the POWER box.
6. Push the two A and B buttons so that they are both out i.e. not selected, and push the LO button in.
7. There should be a dot on the CRT of the oscilloscope that can be moved with the ↕ and ↔ position controls of the T1000.
8. If the ↕ control moves the dot horizontally, the BNC leads have been connected the wrong way round. Swap them over and re-check.
9. As mentioned in step 1, it is intended that once the above procedure has been carried out, NO FURTHER ADJUSTMENT of the oscilloscope is required. This is the reason for including vertical and horizontal position controls on the T1000 front panel.

Minor adjustment of the INTENSITY (or BRIGHTNESS) on the oscilloscope may be necessary at first.

T1000 POWER
Approx 12VA, 120V or 220/240V 50/60Hz, selected by internal links.

CONTENTS

THEORY OF OPERATION

This section describes how the T1000 operates and the nature of an impedance signature. Although it is perfectly possible for you to use the unit without a knowledge of these details, we believe that they will add to your appreciation of how to use the instrument. Hence we strongly recommend that you read it.

Impedance Signatures

Most electronic components can be identified or characterised by their response to a voltage applied across them.

E.g. a resistor obeys OHM's law and has a linear current/voltage relationship.

If this is plotted on a graph of current (I) against voltage (V), the result will be a straight line with the slope dependent on the resistance value.

When this procedure is repeated for a diode then we discover that the diode conducts easily if the voltage is in one direction and has negligible conduction (very high resistance) if the voltage is reversed.

Each component has a characteristic response to an applied voltage and this gives rise to the term impedance signature.

Typical impedance signatures for different components are shown on page 7.

The T1000 will plot the impedance signature of a device connected across its probes. By recognising an incorrect signature (or using the comparison mode and comparing it with a known good part) a defective device can be diagnosed.

How the Signatures are produced

The T1000 will plot a signature by applying an a.c. voltage across a device and measuring the resultant a.c. current. These parameters are then plotted on the CRT display.

Connection is made to the device using a pair of handheld probes and these apply the stimulus voltage to the device under test.

Figure 1 shows how the stimulus voltage occurs at line (power) frequency and is current limited by a series resistor.

There are two amplifiers within the instrument. The horizontal (X) amplifier monitors the voltage occurring across the front panel terminals, amplifies it and applies it to the oscilloscope X input.

The other amplifier drives the oscilloscope Y amplifier and monitors the current flowing through the probes.

This is performed by placing a low value series resistor (Rs) in the previous circuit and the voltage occurring across this series resistor will be directly proportional to the current flowing through the device under test.

Figure 2 shows these details and how the T1000 plots an impedance signature of a device connected across its probes.

Comparator Switching Feature

So far we have described how an impedance signature is produced when the probes are connected across two points on a board under test.

The front panel has facilities for two pairs of probes (the black terminal is common to both). These are selected by buttons A and B.

Hence if output A is selected then the red probe must be connected to A. If B is selected, it must be connected to B.

Much of the faultfinding technique relies on comparison with a known good signature. To avoid having to move the probes from one board to another, both buttons A **and** B can be selected.

In this case the unit will stimulate the component connected across output A and display its signature for about one second and then **automatically** switch to stimulate a component connected across output B and display its signature – then it switches back to A etc.

In this way the display alternately shows the two components signatures allowing a comparison to be made easily. Figure 3 shows how a relay switches between front panel sockets A and B.

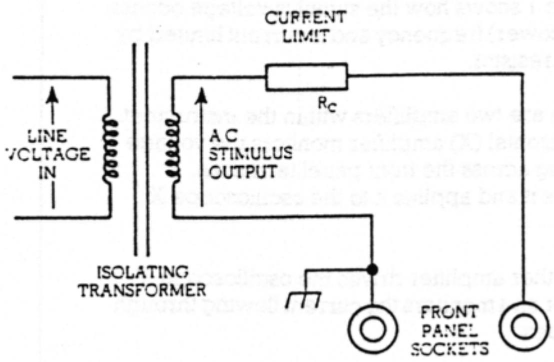


FIGURE 1

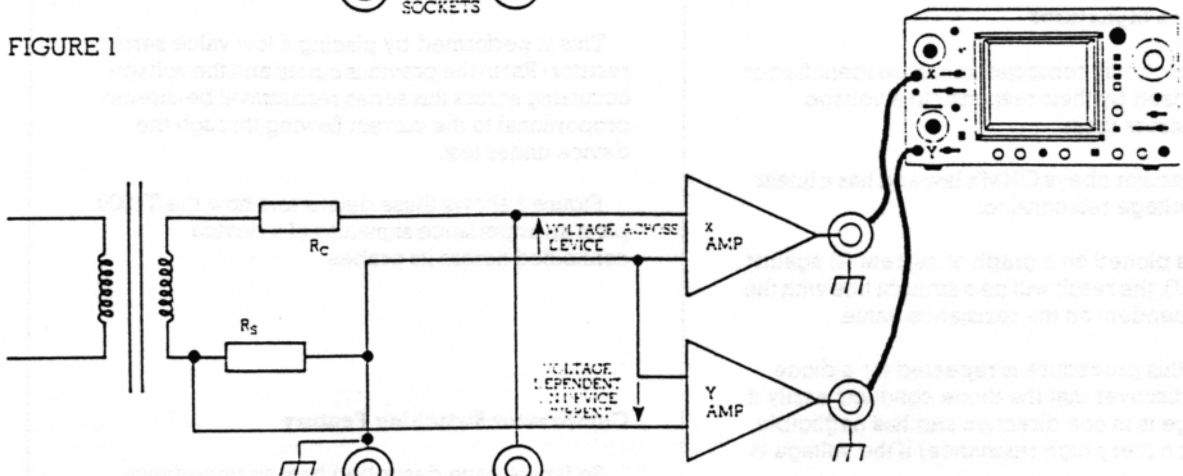


FIGURE 2

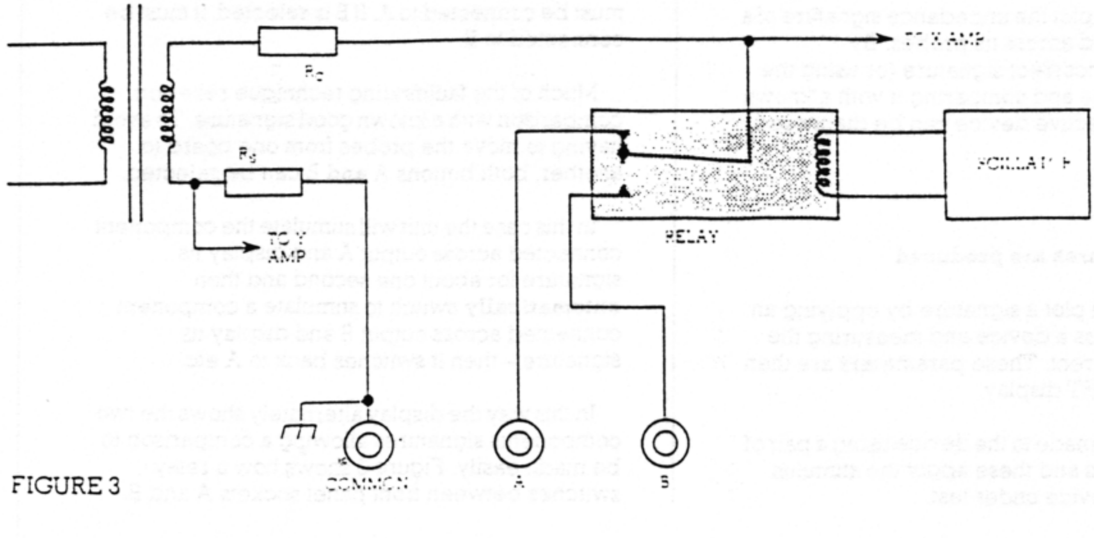


FIGURE 3

Ranges

Two troubleshooting ranges are provided. These are selected by the front panel buttons LO and HI.

Selection of these ranges changes both the transformer open circuit voltage and the value of series current limiting resistor (see figure 1).

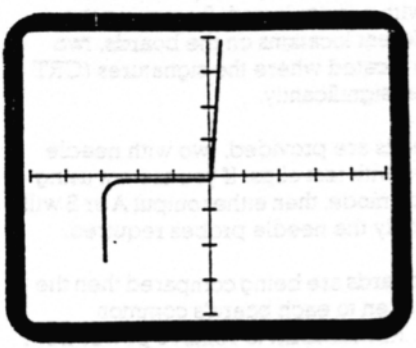
RANGE	PEAK VOLTS	PEAK CURRENT	LIMIT RESISTOR
LO	12.5V	125mA	100Ω
HI	60V	1.5mA	40kΩ

In addition, to ensure that the display occupies the whole screen, the gains of the internal amplifiers are altered by the range switches.

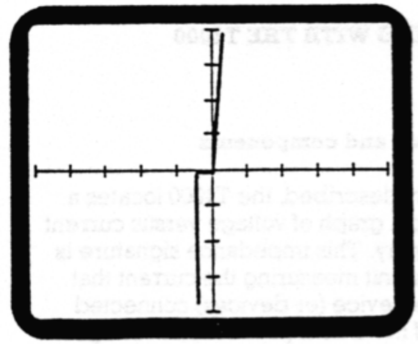
RANGE	X GAIN	Y GAIN
LO	$2V/_{div}$	$20mA/_{div}$
HI	$10V/_{div}$	$0.2mA/_{div}$

These values of sensitivity are stated on the front panel so that measurements can be made from the display.

The optimum range is determined by the type of circuit under test. For instance, to check a 5V6 zener diode, it is better to use the LO range since the display is more detailed and less cramped as shown in figures 6 and 7.



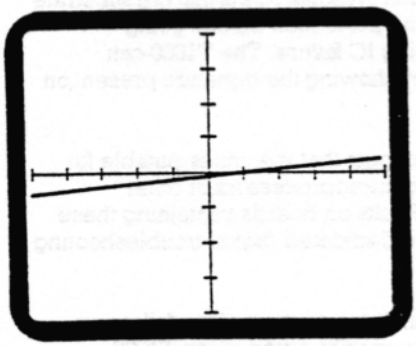
5V6 zener on LO range
FIGURE 6



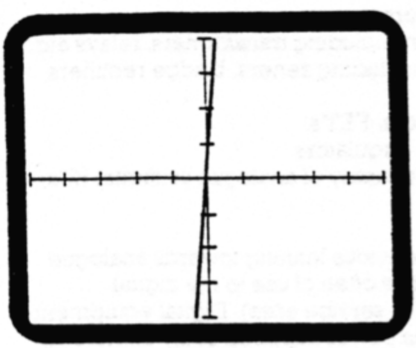
5V6 zener on HI range
FIGURE 7

Also, the same component can give quite different displays on the two ranges as shown in figures 8 and 9. This can arise from the two reasons:–

(i) Display sensitivities are altered.
(ii) The HI range may show certain semiconductor leakages, breakdowns etc. not activated on the LO range.



1k0 resistor on LO range
FIGURE 8



1k0 resistor on HI range
FIGURE 9

FAULT FINDING WITH THE T1000

Types of boards and components

As previously described, the T1000 locates a fault by plotting a graph of voltage versus current on a C.R.T. display. This impedance signature is the result of the unit measuring the current that flows through a device (or devices) connected across a pair of hand held probes. The voltage stimulus is applied from the probes to an UNPOWERED board under test.

An impedance signature is essentially analogue, it gives information on:–

(a) resistance
(b) capacitance and inductance
(c) diode/semiconductor characteristics (turn on voltage, breakdown, leakage etc.)

A common fault in digital IC's is that of a substrate short or the input protection diodes going defective causing IC failure. The T1000 can diagnose this by showing the signature present on the gate input.

We do not suggest that the unit is suitable for troubleshooting microprocessors or other complex IC's. Faults on boards containing these devices require dedicated digital troubleshooting tools.

Boards containing a mixture of the following components are ideally suited to the T1000.

(i) Resistors
(ii) Capacitors
(iii) Inductors including transformers, relays etc.
(iv) Diodes including zeners, bridge rectifiers etc.
(v) Transistors, FET's
(vi) Voltage Regulators
(vii) A small quantity of analogue or digital IC's

Despite the obvious leaning towards analogue boards, the unit is often of use to the digital manufacturer (or service area). Digital equipment usually contains power supplies, relay interfaces, driver boards etc. all using discrete and passive components which the technician has to troubleshoot.

Using the two ranges

The LO and HI buttons select the value of stimulus voltage and the maximum short circuit current available.

The LO range is of use in low impedance circuits, where you wish to check the turn on characteristics of a diode, check zener breakdown voltages up to 10 volts etc. Typical resistances of about 10 ohms to 1000 ohms are dealt with on this range.

The HI range is of use in higher impedance circuits (1000 ohms and above) or where zeners etc, are to be checked up to 50V.

We also recommend that this range is used on boards containing CMOS devices since its short circuit current is limited to 1.5mA peak.

Capacitors and inductors can be checked and will produce a loop on the display because they have a 90° phase difference between the voltage and current.

Typical values are:–

RANGE	CAPACITORS	INDUCTORS
LO	330μF – 3μF	3H – 30mH
HI	3μF – 46nF	above 3H

Troubleshooting

Using the two output channels A and B, the unit can be used to automatically compare a known good board with a faulty board. By moving the probes to different locations on the boards, two points will be located where the signatures (CRT displays) differ significantly.

Four test leads are provided, two with needle points and two with test clips. If you are not using the comparison mode, then either output A or B will be used and only the needle probes required.

When two boards are being compared then the clips can be taken to each board's common (ground) line. REMEMBER to remove power from any board under test – this must include any outside connection to ground to avoid loops. The needle probes will then be plugged into the A and

B front panel sockets and used to connect to similar points on each board so that equivalent signatures can be compared.

It is usual that you will have some idea of whereabouts the fault will lie, i.e. what sector of the board. In this case you would compare the signatures around that area e.g. on transistor bases and collectors, I.C. inputs and outputs, LED's, seven segment displays etc.

If no information is available then the procedure is similar but relies on starting at some known point e.g. compare all the inputs and outputs, compare responses at edge connectors etc.

Interpreting Results

In this booklet there are illustrations of how components affect the display. These are given so that you will have a general understanding of the display shape.

When tests are being made on a board, there will usually be two or more devices in parallel and the display will be composite of the devices across the probes. We suggest that you do not try to interpret each display when using the comparison mode.

It only becomes necessary to analyse display differences when they are significant – it is then that a basic appreciation of how individual devices affect the display will be of use e.g.

(1) Resistors affect the overall slope
(2) Capacitors and inductors cause looping
(3) Semiconductor junctions cause right angle bends.

Figures 10 to 13 illustrate this principle by showing the individual signatures of a resistor, capacitor and zener diode and how in figure 13, the composite signature of the three components in parallel will appear.

Analyse figure 13, the capacitor causes the loop. The parallel resistor gives the loop its slope. The diode cuts the loop with vertical lines in its forward and reverse conduction states.

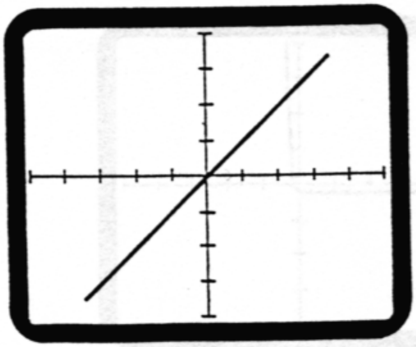


FIGURE 10
47K resistor on HI range

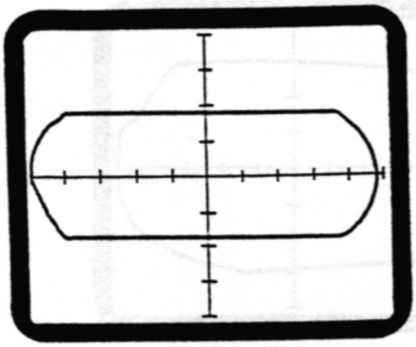


FIGURE 11
22nF capacitor on HI range

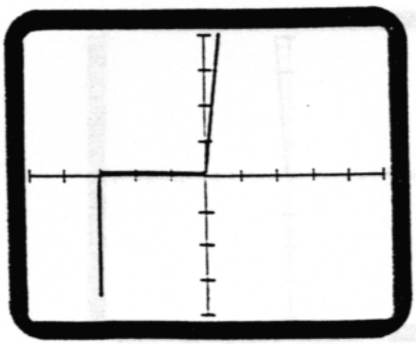


FIGURE 12
30 Volt zener on HI range

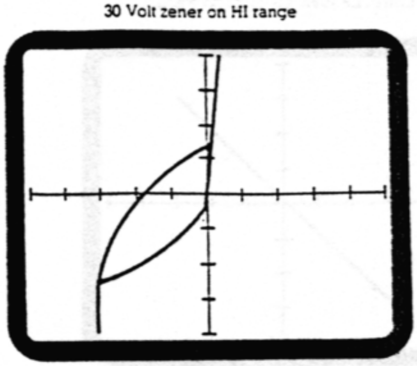
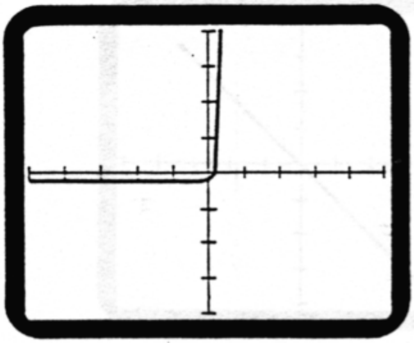
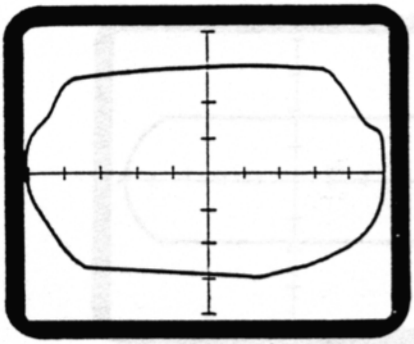


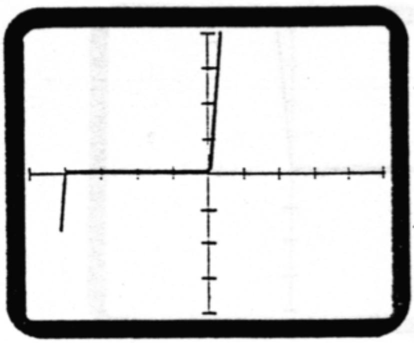
FIGURE 13
47K, 22nF and 30V zener in parallel on HI range



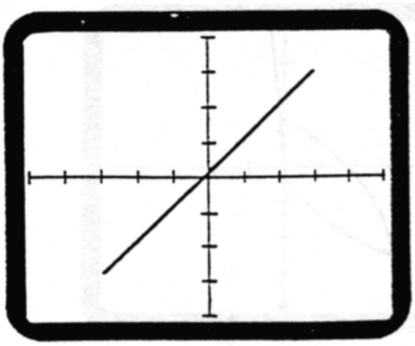
DIODE (LOW RANGE)



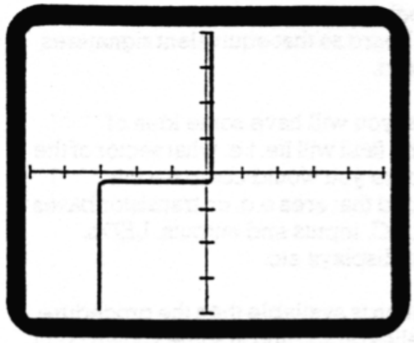
CAPACITOR 47nF (HIGH RANGE)



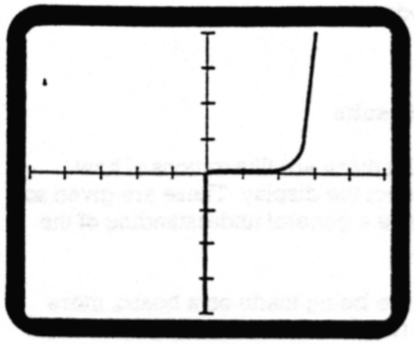
BASE EMITTER JUNCTION (LOW RANGE)



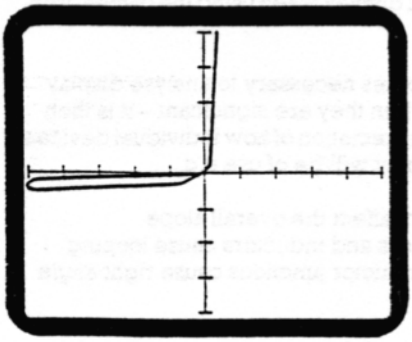
RESISTOR 100Ω (LOW RANGE)



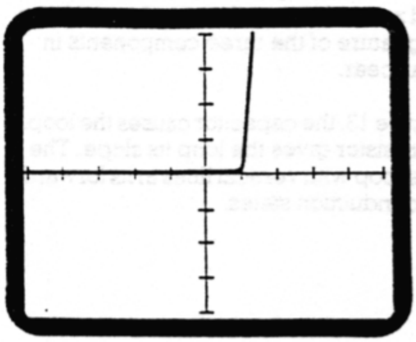
30V ZENER (HIGH RANGE)



74LS00 INPUT (HIGH RANGE)



RELAY COIL WITH DIODE PROTECTION (LOW RANGE)



LED (LOW RANGE)

CURVE TRACING

As an additional feature, the T1000 has a facility for plotting the output characteristics of transistors.

These can often be of use in production test or a field service environment where devices may need to be matched, selected for high gain or low saturation voltages etc. The unit is far easier to use than a conventional curve tracer since the polarity of all applied signals is automatically set up by a single push button. It also has two sockets which can be automatically switched to allow devices to be easily matched.

Bipolar Transistors

NPN and PNP transistors are tested by applying a sweep of voltage across the collector emitter whilst a fixed step of base current is applied.

After each sweep of collector voltage is completed, the base current is increased by 100μA. After eight steps of base current (zero to 700μA inclusive) the base current returns to zero and the cycle restarts.

Pressing the NPN or PNP button moves the origin of the plotted graph to minimise the use of position controls by the operator.

Figure 14 shows the display for an NPN transistor.

The graph is a plot of collector current (I_C) vertically against collector to emitter voltage (V_{CE}) horizontally.

(a) Current gain – (H_{fe} or ß)

This is indicated by the separation of the horizontal lines – the greater the separation, the greater the gain.

To make a measurement from the display, observe the step separation where the lines cut the vertical graticule line.

$$\text{Current gain} = \frac{I_C}{I_B}$$

The technique is to align the $I_B=0$ sweep with the lowest vertical graticule marking using the vertical position control.

The collector current can then be read from where it cuts the vertical graticule markings for a specific I_B.

eg for the NPN in figure 14

for $I_B = 100\mu A$ $\quad I_C = 1.5$ divisions = 15mA

for $I_B = 200\mu A$ $\quad I_C = 3.1$ divisions = 31mA

etc.

Therefore D.C. gain $= \frac{31mA}{200\mu A} = 155$ (for Vce = 4.5V)

Note that D.C. gain can vary with I_C and V_{CE}.

(b) Saturation voltage

This is a measure of the voltage across the transistor ($V_{CE\ SAT}$) for a specific collector current flowing. It is of use when considering power dissipation when a device is used as a switch.

By using the horizontal and vertical position controls, the display can be moved so that it cuts the scaled graticule line to allow measurements to be made e.g. in figure 15, the transistor has $V_{CE\ SAT}$ of 0.4 volt (approx) for I_C= 70mA.

(c) Output resistance

This is indicated by the slope of the horizontal sweeps. The more horizontal the line, the higher the output resistance and (usually) the better the device.

$$R_{out} = \frac{1}{h_{oe}} = \frac{\text{change in } V_{CE}}{\text{change in } I_C} \quad \text{for a fixed } I_B$$

Field effect Transistors

Depletion mode F.E.T.'s are tested in a similar way to bipolar transistors except that the steps are voltage levels between gate and source. Each step is 0.5V.

The characteristic is a graph of drain current (I_D) versus drain to source voltage V_{DS}.

(d) Gain (g_m)

This is measured as for the bipolar device and is given by

$$g_m = \frac{\text{drain current change}}{\text{gate – source voltage change}}$$

The units are siemens (usually millisiemens).

(e) Output resistance

This is measured in the same way as for bipolar devices.

i.e. $R_{out} = \frac{\text{Change in } V_{DS}}{\text{Change in } I_D}$ for a fixed V_{GS}.

NPN DISPLAY

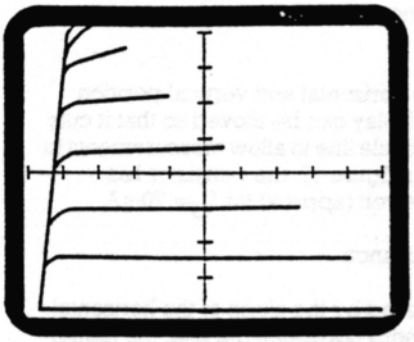


FIGURE 14

NPN DISPLAY

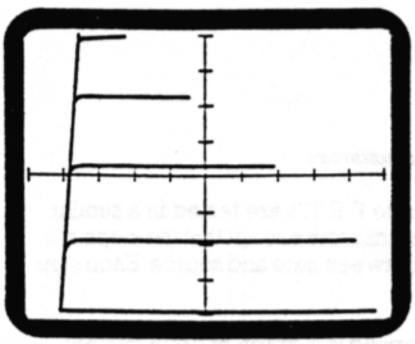


FIGURE 15

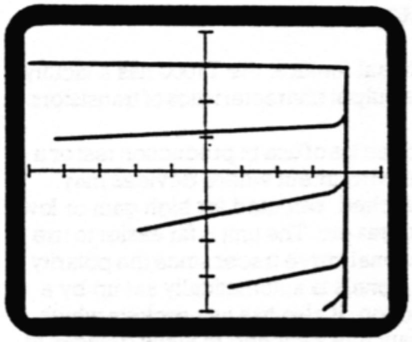


FIGURE 16
Typical PNP display (BC461)

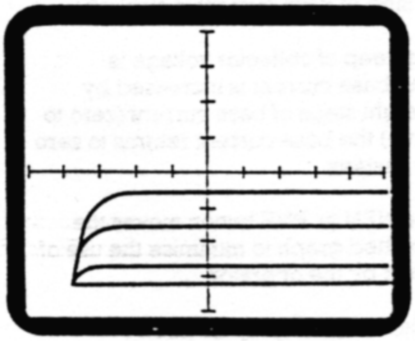


FIGURE 17
Typical N FET display (BF244A)

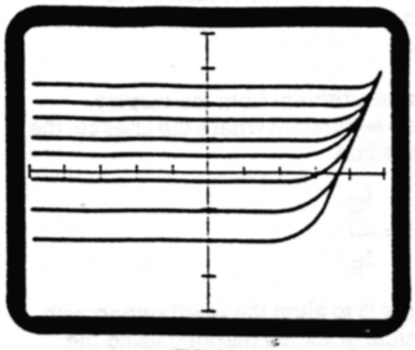


FIGURE 19
Typical P FET display (2N3820)

CIRCUIT DESCRIPTION

BASE STEP GENERATOR (schematic 1)

The function of this circuit is to generate a staircase waveform of correct polarity to be applied to a transistor plugged into the two front panel sockets.

U4 is a counter which is clocked with pulses at line frequency via U2c which is connected as a comparator.

The four 20kΩ and two 10kΩ resistors on the output of U4 form a digital to analogue converter producing a positive going staircase voltage on pins 3 and 5 of U2.

The base level of the staircase is −8V and each step is 0.5V (approx).

U2a and Q3 convert the staircase voltage into a current staircase of 100 μA per step. This is used for testing PNP transistors.

U2b and Q1 invert the voltage staircase and apply it to U3a and Q2 which converts it into a current staircase suitable for testing NPN transistors.

Overall amplitude of the staircase outputs is set by the tracking +8V and −8V supplies shown on schematic 4.

The switching shown on schematic 2 converts the current staircase back to a voltage staircase for testing field effect transistors (using R48 and R52).

The base outputs to the front panel sockets are:-

NPN	+100μA per step.
PNP	−100μA per step.
NFET	−0.5V per step.
PFET	+0.5V per step.

RELAY AND SWITCHING (schematic 2)

Buttons A and B determine which output channel is selected and therefore which red 4mm socket or which transistor has an active signal presented to it.

When both buttons are out, neither channel is selected and there are no signals on the outputs.

With A selected, Q4 is held off (its base is grounded by the B switch which is not selected). RLI applies signals to the A outputs using its normally closed contacts.

When both A and B are selected, U3d switches Q4 alternately on and off at a rate determined by the squarewave from U4 pin 3.

This action alternately switches the relay on and off and hence outputs A and B are alternately activated.

OUTPUT SIGNALS TO PROBES AND COLLECTORS (schematic 2)

Transformer T2 provides the drive signals to the various front panel sockets at supply frequency.

R27, R30, R32 provide short circuit current limiting.

In the LO and HI modes, an alternating sinewave is applied across the selected 4mm sockets.

Bridge rectifier BR1 provides a full wave rectified output for use in the four transistor testing modes. The polarity appearing across the collector emitter terminals is set by the relevant transistor push switch.

HORIZONTAL AND VERTICAL AMPLIFIERS (schematic 3)

The horizontal amplifier comprises of U1a and U1d. The input signal from the relay is attenuated by R37/R38 in the HI mode and R37/R39 in the other modes. U1a acts as an inverting amplifier to drive the output summing amplifier U1d. This adds position current (from R54), signal current from R69 and offset current in the transistor modes (from R58 or R59). R72 gives short circuit protection to the output.

The vertical amplifier is U1c. This summing amplifier adds signal current (from R78), position current (from R81) and offset current in the transistor modes (from R74 or R76). R77 provides a trace rotation offset that would otherwise occur in the HI mode. The voltage signal applied to R78 is produced across a resistor in series with the device under test (R42, R43, R45 and R46 shown on schematic 2).

POWER SUPPLIES (schematic 4)

The +12V and −12V unregulated supplies are produced by bridge rectifiers BR2 and BR3 respectively.

U5 is an adjustable positive voltage regulator and is used to set the +8V supply by adjusting R4.

U2d acts as an inverting unity gain amplifier to produce a tracking −8V supply for use in the base step generator.

CALIBRATION

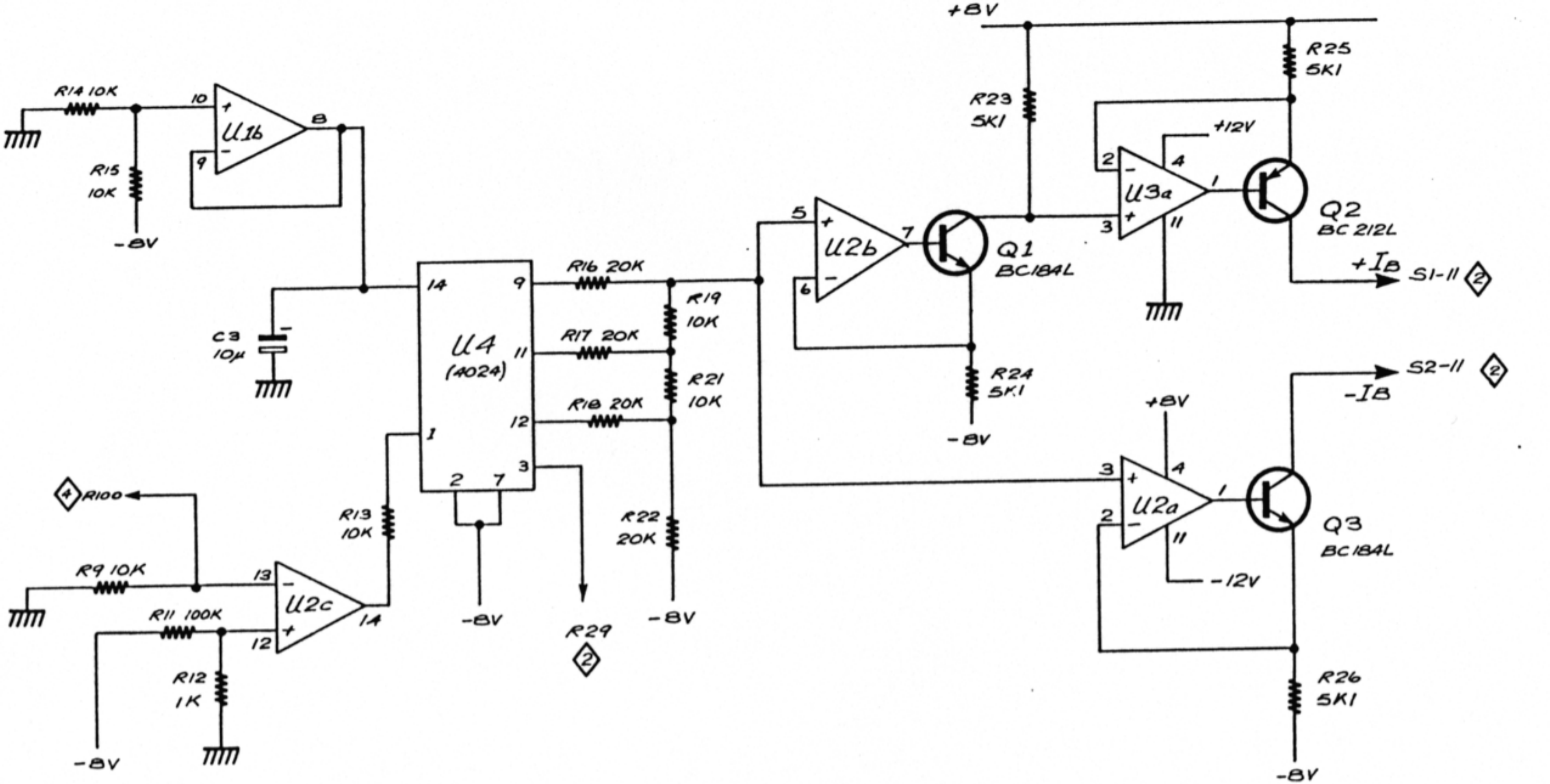
CAUTION – Dangerous voltages are exposed when the case is open. This should be performed by qualified personnel only.

There is only one calibration control (R4) within the instrument. It adjusts the +8 volt supply but is set up so that the base step generator produces accurate current and voltage steps (±4%).

Set the T1000 to P FET and A. Set a test scope to 0.5V/$_{div}$ D.C. coupled, 10 mS/$_{div}$ and connect an X1 probe across R52. Observe a staircase waveform and adjust R4 for an overall amplitude of 3.5V (i.e. 7 steps of 0.5V).
This completes the calibration.

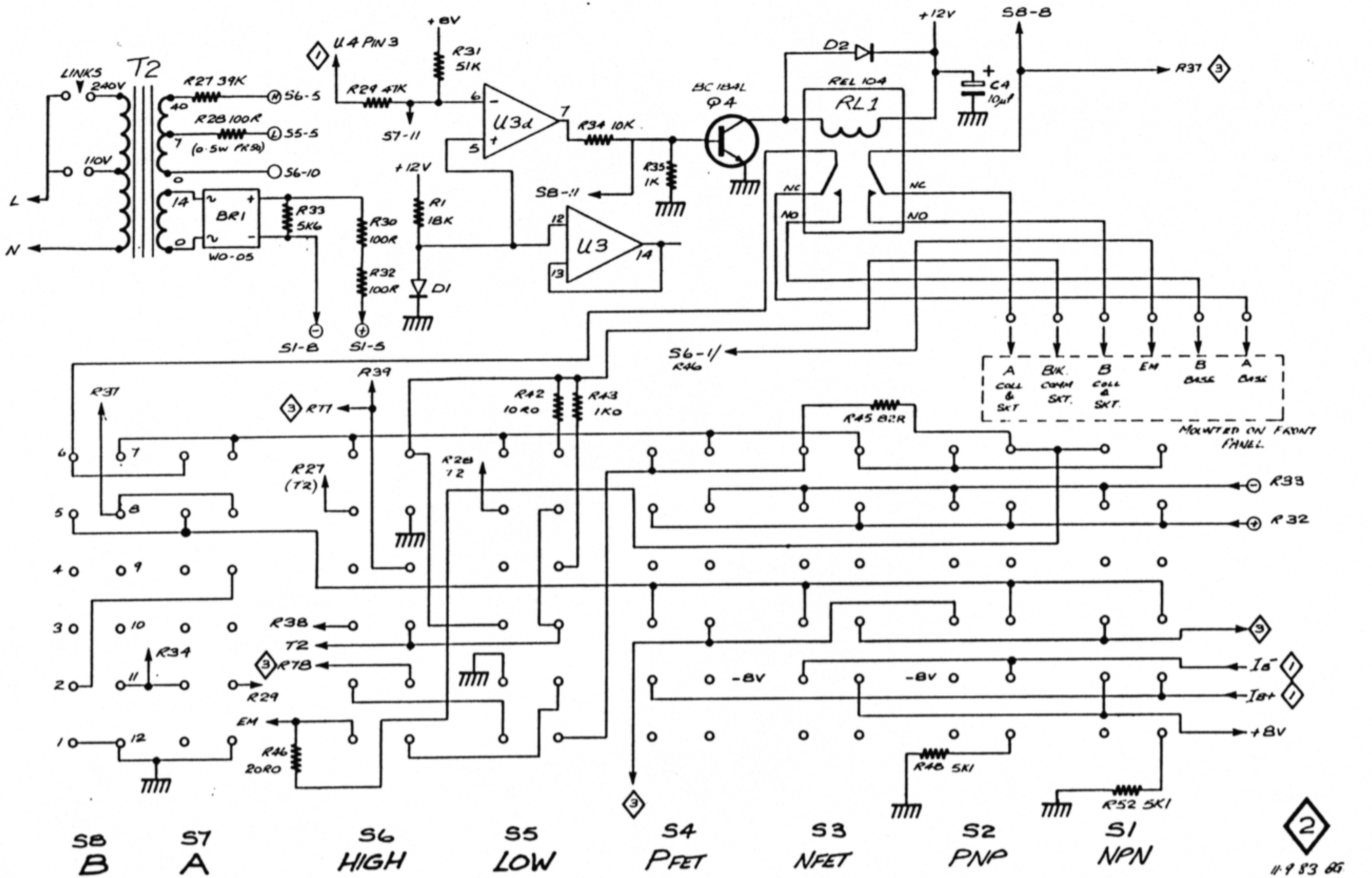
LIMITED WARRANTY

For a period of one year the date of its purchase new and undamaged from Polar Instruments Ltd., POLAR INSTRUMENTS LTD. or its authorised distributors will, without charge, repair or replace at its option, this product if found by it to be defective in materials or workmanship, and if returned to POLAR INSTRUMENTS LTD. or its authorised distributors transportation prepaid. This limited warranty is expressly conditioned upon the product having been used only in normal usage and service in accordance with instructions of POLAR INSTRUMENTS LTD. and not having altered in any way or subject to misuse, negligence or damage, and not having been repaired by any one other than POLAR INSTRUMENTS LTD. or its authorised distributors. EXCEPT FOR THE FOREGOING EXPRESS WARRANTY OF REPAIR OR REPLACEMENT POLAR INSTRUMENTS LTD. MAKES NO WARRANTY OF ANY KIND, INCLUDING BUT NOT LIMITED TO ANY EXPRESS OR IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE AND POLAR INSTRUMENTS LTD. SHALL NOT BE LIABLE FOR ANY DAMAGES, WHETHER DIRECT OR NOT OR OTHERWISE, BEYOND REPAIR OR REPLACING THIS PRODUCT.

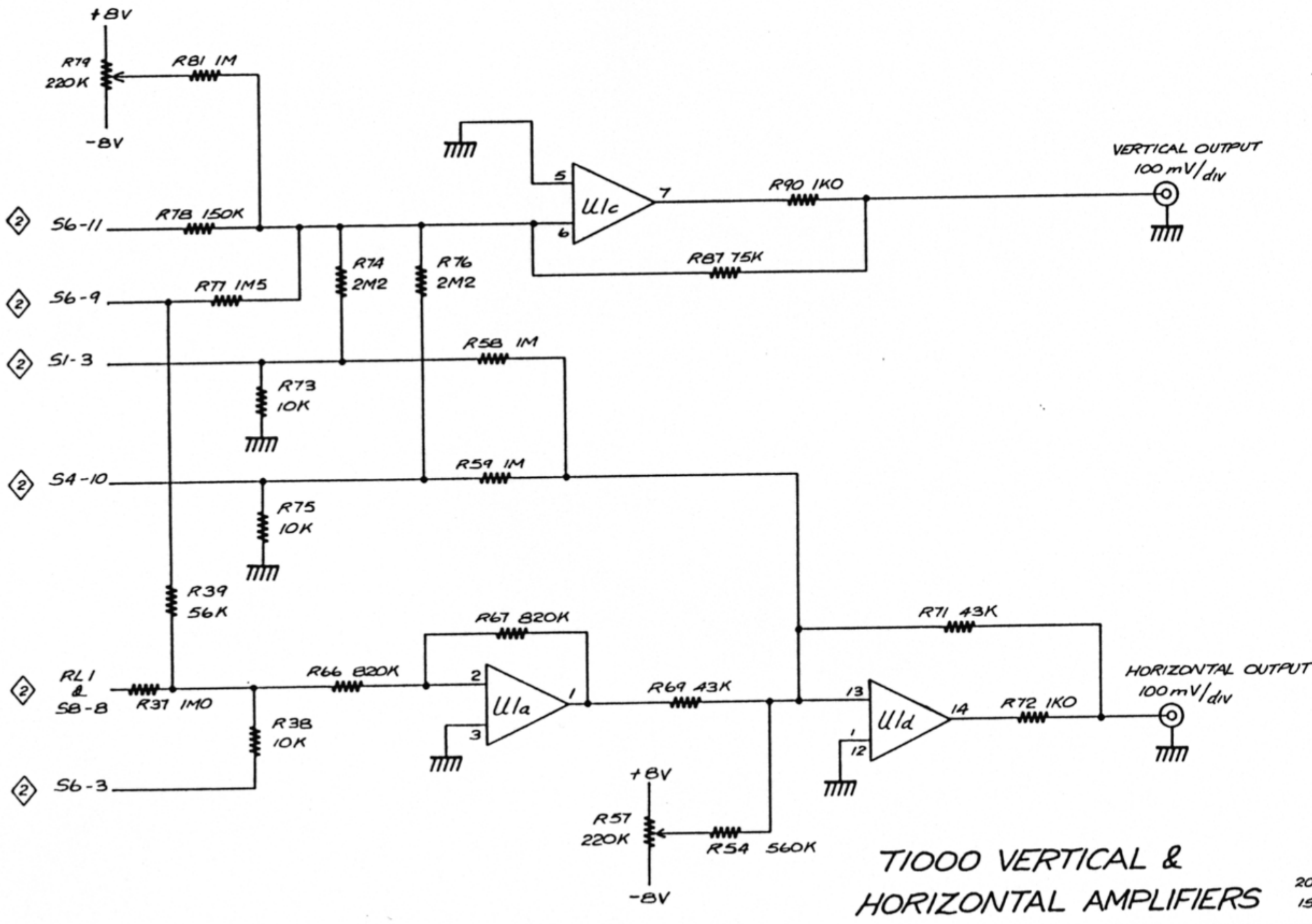


T1000 - BASE STEP GENERATOR

11.9.83 BG
ISSUE 3



T1000 SWITCHING & RELAY OUTPUTS



T1000 VERTICAL & HORIZONTAL AMPLIFIERS

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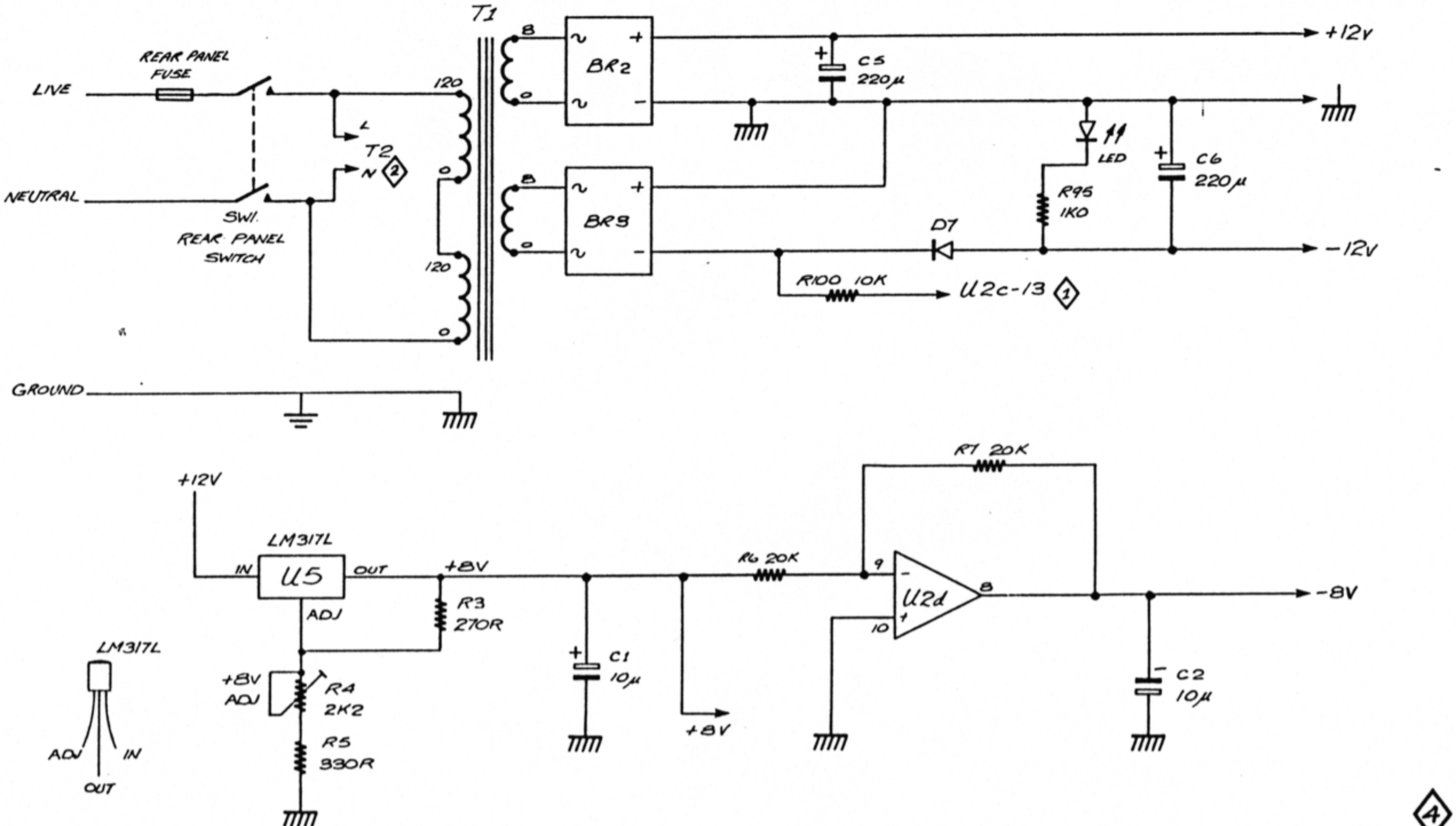

T1000 POWER SUPPLIES

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