♦ PRECISION INSTRUMENTS FOR TEST AND MEASUREMENT ♦

1546 Strobotac

Digital Stroboscope

User and Service Manual

Historical Note

IET Labs continues to carry the torch lit by Harold Edgerton in the 1930's by his designing and making practical stroboscopes with extremely short flashes at very high intensity. General Radio/GenRad developed an extensive line of Strobotac Stroboscopes and accessories a over a 50 year period.

The workhorse 1531 and 1538 models are still widely used, and IET Labs supplies and supports them. The basic 1542 is widely used in the printing industry. The Model 1539 Stroboslave is also built and supported. The Model 1546 is the most modern of the Strobotacs. With its digital readout and sensitive trigger input, it will meet nearly every challenge that a user may impose. IET manufactures, calibrates and supports all these models and others.

IET Labs is proud to maintain the tradition of quality and excellence that is rooted in technological history and now thrives in a new responsive environment.

1546 im/June, 2002

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GenRad
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TEL: (516) 334-5959 • (800) 899-8438 • FAX: (516) 334-5988
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WARRANTY

We warrant that this product is free from defects in material and workmanship and, when properly used, will perform in accordance with applicable IET specifications. If within one year after original shipment, it is found not to meet this standard, it will be repaired or, at the option of IET, replaced at no charge when returned to IET. Changes in this product not approved by IET or application of voltages or currents greater than those allowed by the specifications shall void this warranty. IET shall not be liable for any indirect, special, or consequential damages, even if notice has been given to the possibility of such damages.

THIS WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING BUT NOT LIMITED TO, ANY IMPLIED WARRANTY OF MERCHANTIBILITY OR FITNESS FOR ANY PARTICULAR PURPOSE.

WARNING

OBSERVE ALL SAFETY RULES
WHEN WORKING WITH HIGH VOLTAGES OR LINE VOLTAGES.

Dangerous voltages may be present inside this instrument. Do not open the case
Refer servicing to qulified personnel

HIGH VOLTAGES MAY BE PRESENT AT THE TERMINALS OF THIS INSTRUMENT

WHENEVER HAZARDOUS VOLTAGES (> 45 V) ARE USED, TAKE ALL MEASURES TO AVOID ACCIDENTAL CONTACT WITH ANY LIVE COMPONENTS.

USE MAXIMUM INSULATION AND MINIMIZE THE USE OF BARE CONDUCTORS WHEN USING THIS INSTRUMENT.

Use extreme caution when working with bare conductors or bus bars.

WHEN WORKING WITH HIGH VOLTAGES, POST WARNING SIGNS AND KEEP UNREQUIRED PERSONNEL SAFELY AWAY.

CAUTION

DO NOT APPLY ANY VOLTAGES OR CURRENTS TO THE TERMINALS OF THIS INSTRUMENT IN EXCESS OF THE MAXIMUM LIMITS INDICATED ON THE FRONT PANEL OR THE OPERATING GUIDE LABEL.

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Section 1
INTRODUCTION

1. Purpose

The IET 1546 Strobotac® digital stroboscope is a versatile flashing light source that is used to measure the speed of fast-moving objects or to produce the optical effect of stopping or slowing down high-speed motion for purposes of observation, analysis, or high-speed photography.

1.2 Description

1.2.1 General

The 1546 digital stroboscope emits a high-intensity, short-duration flash of light. The instrument features an electronic pulse generator that controls the flash rate, a line-operated power supply, and a light-emitting diode (LED) readout in flashes per minute. The instrument has internally and externally triggered modes of operation. In the **Internal** mode, the instrument flash is triggered by an internal oscillator pulse which can also drive other IET stroboscopes for additional light sources. In the **External** mode, the 1546 operates as a digital tachometer.

The instrument, weighing 1.25 kg (2.75 lb), is sufficiently light in weight to permit convenient hand-held operation. Thus, the light can be aimed at most moving objects, including those in otherwise inaccessible areas. The instrument is contained in a high-impact, injection-molded plastic housing. The strobe can be held in the operator's hands, placed on any convenient flat surface, or mounted on a tripod.

1.2.2 Controls, Connectors and Displays

See Figure 1-1 for location of controls and connectors referred to in Table 1-1.

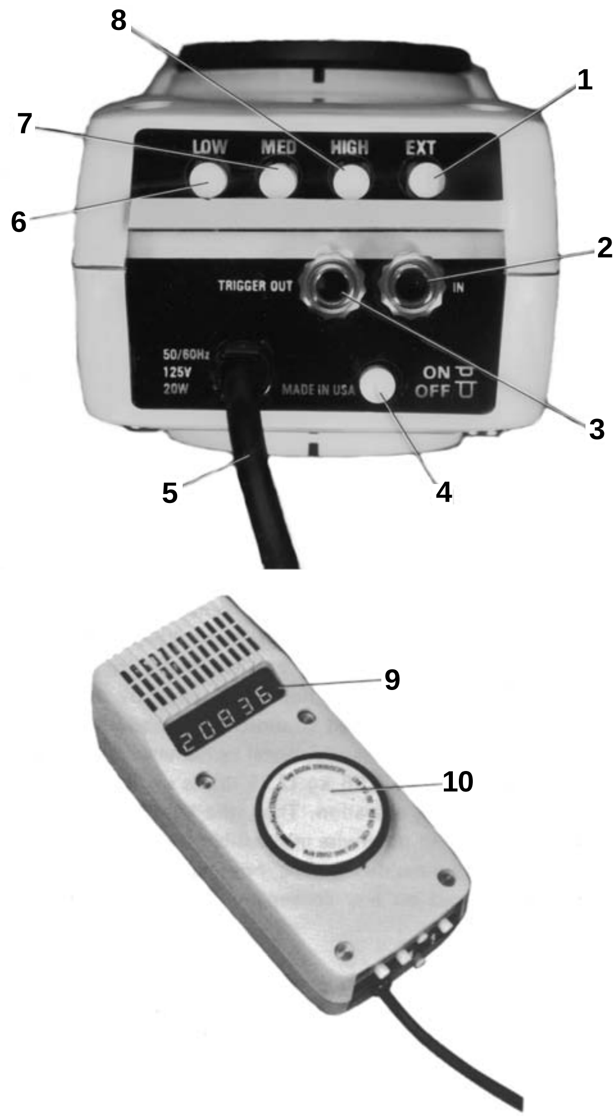

Figure 1-1. Controls, Connectors and Display of the 1546.

Table 1-1

Controls, Connectors and Display

Fig. 1-1 Ref	Name	Use
1	EXT Switch	Selects internal or external mode
2	TRIGGER IN Jack	Used to input externally generated signal
3	TRIGGER OUT Jack	Used to provide signal to operate a slave strobe
4	ON/OFF Switch	Turns the instrument on or off
5	POWER CORD	Makes connection to power line
6	LOW Range Switch	Sets the instrument flash rate at 100 - 700 fpm
7	MED Range Switch	Sets the instrument flash rate at 600 - 4,200 fpm
8	HIGH Range Switch	Sets the instrument flash rate at 3,600 - 25,000 fpm
9	LED DISPLAY	Provides digital display of flash rate
10	FLASH RATE CONTROL	Adjusts the flash rate

1.3 Accessories

Table 1-2 is a list of compatible light sources that can be used with the 1546. Refer to the IET Catalog for further information.

Table 1-2
Additional Light Sources

1538	Strobotac® Electronic Stroboscope
1539	Stroboslave® Stroboscopic Light Source
1546	Stroboslave® Stroboscopic Light Source

Section 2
SPECIFICATIONS

Flashing Rate Range: 100 to 25,000 flashes per minute (fpm) in three overlapping ranges;

Range 1	**LOW**	100 - 700 fpm
Range 2	**MED**	600 - 4,200 fpm
Range 3	**HIGH**	3,600 - 25,000 fpm

Readout Accuracy: ±0.01%, using crystal-controlled time base.
Display Resolution: ±1 fpm.
Flash Duration:

Range 1	~ 2 µs
Range 2	~ 2 µs
Range 3	~ 1.2 µs

Tachometer Function: LED display reads fpm for both internal and external modes. User may convert to other units of measure if required.
External Trigger: Three-terminal phone jack,
>+1.0 V pulse,
>0.75 Vrms sine wave,
or contact closure.

Trigger Output: >2.5 V in series with 1 kΩ.
Power Requirements: 105 to 125 Vac, 50 to 60 Hz, 20 W.
Mechanical: Molded plastic case with plastic face plate to protect lamp, diffused finish anodized-aluminum reflector, and standard 0.250 - 20 threaded hole for tripod mounting or handle grip.
Dimensions: 108 x 110 x 235 mm
(4.25 x 4.3 x 9.25 in.)
Weight: 1.25 kg (2.75 Ib.).
Environmental:
Operating Temperature: 0 - 50°C.
Storage Temperature: -40 to +75°C .
Humidity: 95% RH at 40°C:
Vibration: 0.03 in. DA from 10-55 Hz; Bench handling: 4 in. or 45°; Shock; 30 g, 11 ms.
Accessories Supplied: 3-conductor phone plug for external triggering.

Condensed Operating Instructions

General
Plug power cord into a standard 105-125 Vac,
50 - 60 Hz grounded receptacle.
Push the **ON/OFF** switch in.

Internal Mode
a. Be sure that the switch labeled EXT is out.
b. Select the desired flash rate from among the 3 overlapping ranges listed below.

HIGH	3600 - 25,000 fpm
MED	600 - 4200 fpm
LOW	100 - 700 fpm

The instrument is ready for use immediately. Rotate the large dial to vary the flash rate within each range. The digital readout will indicate accurately the number of flashes per minute.

External Mode
(In this model the stroboscope will flash synchronously with an external signal.)
a. Push the **EXT** switch in.
b. Plug the phone plug (included) into the jack labeled **IN** after the other end of the synchronizing cable has been connected to an appropriate trigger signal.

Section 3
Operation

3.1 Power Requirements

The 1546 operates from a line frequency of 50 to 60 Hz, 105 to 125 Vac, and requires 20 W of power as noted on the panel of the instrument.

3.2 Instrument TURN-ON

WARNING

The power plug has 3 terminals. Operator safety requires that the power receptacle be properly grounded.

To turn the 1546 on:

a. Connect the power cord to a power receptacle. Ensure that the power source used corresponds to the data on the instrument panel.

b. Push the **ON/OFF** switch in. The stroboscope is ready for use immediately.

3.3 Flash Rate Adjustment

The 1546 can be adjusted to flash at any rate between 100 to 25,000 flashes per minute (fpm). To adjust the instrument flash rate:

a. Select the appropriate range for operation from among the 3 overlapping ranges of the instrument. These ranges are: 100 to 700 fpm, 600 to 4,200 fpm, and 3,600 to 25,000 fpm.

b. Turn the flash rate control on the top of the instrument until the motion of the object under observation appears stationary. The control turns continuously with no stop. When the control is turned clockwise, the flash rate increases until a point is reached when the flash rate jumps abruptly from maximum to minimum for the range selected. When the dial is turned counterclockwise, the flash rate decreases until it jumps from minimum to maximum.

Because the control has no stops, when the maximum flash rate is reached in the low and medium ranges, the flash rate can be increased by continued clockwise rotation of the control and selection of the next higher range. Conversely, when the minimum flash rate is reached in the high and medium ranges, the flash rate can be decreased by continued counterclockwise rotation of the control and selection of the next lowest range.

3.4 Speed Measurements

3.4.1 Fundamental Speed Measurements

When measuring the rotational speed of an object, set the flash rate initially to a higher setting than the estimated speed of the object. Then, slowly reduce the flash rate until the first single image appears. At this point, the strobe flash rate is equal to the rotational speed of the object, and the speed can be read directly from the digital display.

When using the middle - or low-speed ranges, switch to the next higher range without moving the setting on the potentiometer to determine whether the stroboscope is flashing at the fundamental speed of the object. Since the ratio between ranges is exactly 6:1, 6 images will appear at the next higher range, if the strobe has been set to the fundamental speed. If only 3 images appear, for example, then the strobe has been set to only 1/2 the correct flash rate. On the **HIGH**-speed range, double the speed setting to check for fundamental speed operation.

A double image should occur when the frequency is doubled. If the fundamental speed of the device is over 12,500 rpm, it will not be possible to check for the correct speed setting by the method outlined above. In this case, refer to para 3.4.3.

With practice, an operator can measure the speed of rotating objects quickly and accurately, especially when the approximate speed of the object can be estimated. It is necessary, however, to fully understand the following basic principles when making speed measurements:

- The operator must distinguish between single and multiple images. Odd-shaped objects usually cause little difficulty, but objects which are symmetrical in shape (gear, disc, fan, etc.) must be marked to provide a visible reference (see section 4.1.2).
- Multiple images will be observed when the flash rate is set to a multiple of the fundamental speed of the object.
- When reducing the flash rate from a rate higher than the fundamental speed of the object, the first single image will be seen when the flash rate is equal to the fundamental speed.
- When the flash rate is below the fundamental speed of the object, single and multiple images will be observed. The single images will occur at integral submultiples of the fundamental speed of the object (see section 3.4.2).

3.4.2 Submultiple Speed Measurements

If the 1546 is set to flash at an integral submultiple of the fundamental speed of a rotating object, a single image will be observed. At flash rates between submultiples, multiple images will be observed. Table 3-1, shows the number of images that are obtained at various flash rates (below the fundamental speed) of a device rotating at 1800 rpm.

Note the exact numerical relationship between the numerator of the submultiple fraction and the corresponding number of images seen. This relationship will always hold true regardless of the speeds involved. Table 3-1 lists a few of the more useful submultiple speeds and corresponding images; many other multiple images are possible (for example, 5 images will be seen at 5/7, 5/8, etc.).

Submultiple flashing is necessary to observe or measure the speed of objects moving at rates above 25,000 rpm. Refer to para 2.4.3 for the method of determining the fundamental speed when submultiple operation is necessary.

Table 3-1

Submultiple Speed/Image Relationship

Submultiples of Fundamental Speed (1800 rpm)	Number of Images Seen*	FPM Dial Setting
1	1	1800
5/6	5	1500
4/5	4	1440
3/4	3	1350
2/3	2	1200
3/5	3	1080
1/2	1	900
2/5	2	720
1/3	1	600
1/4	1	450
1/5	1	360
1/6	1	300

* At dial settings above fundamental speed, only multiple images will be observed.

3.4.3 Measurement of Speeds Above 25,000 RPM

Speeds up to 250,000 rpm can be measured by making calculations based upon submultiple measurements. The procedure is as follows:

a. Starting at 25,000 fpm, decrease the strobe flash rate until a single image appears. Record the LED reading and call it **X**.
b. Continue decreasing the flash rate until the next single image occurs. Record this reading and call it Y.
c. Calculate the harmonic number, n, by:

$$n = \frac{Y}{X - Y}$$

and round off the value, n, to the nearest whole number.
d. Calculate the fundamental speed, **S**, by:

$$S = nX$$

Example:
If X is 22,500 rpm, and Y is 16,800 rpm, then:

$$n = \frac{16{,}800}{22{,}500 - 16{,}800} = 2.95$$

This number will always be very close to an integral value, limited only by reading accuracy; so round it off to the nearest whole number (in this example, 3). Therefore, the fundamental speed is:

$$S = 3 \times 22{,}500 = 67.500 \text{ rpm}$$

3.4.4 Low-Speed Operation

The measurement of speeds on the **LOW** range of the 1546 may be difficult because of flicker resulting from lack of persistence-of-vision. These measurements are best made in a darkened environment, or with the operator wearing dark glasses, in order to reduce the confusing effect of room lighting on the pattern observed.

Speeds below 100 rpm can be measured by means of multiple images. For example, if the flash rate of the stroboscope is twice the fundamental speed of the device, 2 images, 180° apart will appear. At 3 times the fundamental, 3 images, 120° apart, will appear. This multiple image technique can also be used for higher speeds within the range of the 1546 where flicker makes it difficult to tell when the correct flash rate is obtained. Refer to para 4.1.2.

3.4.5 Slow-Motion Studies

High-speed motion can be observed in “slow motion” if the rotating or reciprocating motion occurs at a constant rate. If the instrument flash rate is adjusted to a setting which is slightly lower than the fundamental speed of the object under observation, the object will appear to move slowly in the same direction as the actual motion, at a speed equal to the difference between the actual speed of the object and the strobe flash rate. If the flash rate is set slightly higher than the speed of the object, the same slow motion will result, but in the opposite direction.

The stroboscopic technique of slowing motion is useful in investigating the operation of a device under actual use conditions. Examples of such use include the study of excessive vibration in a machine and the observation of misaligned parts or vibrating reeds. On a textile spinning frame, for example, the actual relation between traveler and thread can be observed during a complete revolution of the traveler.

3.5 External Synchronization

The flash of the 1546 can also be triggered by use of an external signal. This signal can be produced electrically or mechanically using a contact-closure device with contactors attached to a machine. The 1546 will provide a display of the flash rate. Hence, the 1546 can operate as a true digital tachometer as well as a stroboscope. To operate the 1546 in the external mode:

a. Turn the instrument on. Push in the **EXT** switch.
b. Select the flash rate appropriate for the speed of the machine to be observed.
c. Connect the externally produced signal into the **TRIGGER IN** jack on the panel of the instrument. The instrument will now flash and indicate the speed of the machine.

The input signal must be ground-based and have a greater-than +1 V swing. Do not apply more than 100 V to the external input. The strobe will not flash or display if the signal frequency is greater than 75 Hz for the **LOW** and **MED** ranges or 466 Hz for the **HIGH** range.

To use the 1546 with a contact closure device, 5.5 Vdc is available at the ring of the 3-terminal input phone jack.* By connecting the ring of the 3-terminal phone plug to one side of the contactor and connecting the other side of the contactor to the tip of the phone plug, the **Strobotac** will be triggered for each contact closure.

• Switchcraft part no. 267 (a 0.25 in., 3-circuit telephone plug) is compatible with the **IN** jack of the 1546. Switchcratt part no. 40 or no. 250 (0.25 in., 2-terminal plug) is compatible with the **TRIGGER OUT** jack. Equivalents may be substituted.

3.6 Use with additional Light Sources

A cable with a 2-terminal phone plug on each end can be used to connect the 1546 trigger output (**TRIGGER OU**T jack) to the trigger input of an IET 1538 Strobotac, an IET 1539-A Stroboslave, or another IET 1546 Strobotac. Refer to the Instruction Manual of the instrument to be used for additional applications and instructions.

3.6.1 Use with a Stroboslave

The 1539-A Stroboslave® stroboscopic light source is available for use with the 1546. The 1539 is an inexpensive, miniature, electronic stroboscope. It has no internal oscillator for setting the flash rate, but must be triggered by an external device. It cannot be used for direct measurement of rotational speed. The small stroboscope is suitable for high-speed photography applications and motion studies other than tachometry. The 1539 is also used when a second light source is needed, or when a difficult-to-illuminate object requires the use of a compact light source mounted on the end of a flexible cord.

Since the 1539 has no internal oscillator, the trigger signal is supplied directly from the **TRIGGER OUT** of the 1546 to the **INPUT** jack of the 1539. The lamp and reflector of the 1539 are connected to the unit by a 1.54 m (5 ft) flexible cable, to permit the lamp to be positioned close to the moving object.

3.6.2 Use with another Strobotac

An IET 1538-A or another IET 1546 may be used as either a slave or master to the 1546. Connect the **TRIGGER OUT** of the master unit to the **TRIGGER IN** jack of the slave unit using the phone plug cable described above.

Section 4
Theory

4.1 Basic Stroboscope Operation

4.1.1 What is a Stroboscope?

A stroboscope is a source of flashing light that can be synchronized with any fast, repetitive motion so that a rapidly moving device seems to stand still, or to move slowly.

To illustrate this principle, consider the following example:

Assume a white disk with a single black dot mounted on the shaft of an 1800-rpm motor.

When the disk is rotating at 1800 rpm, it is impossible for the human eye to distinguish a single image and the dot will appear to be a blurred continuous circle.

When illuminated by the flashing stroboscope light, synchronized to flash once every revolution of the disk (when the dot is at 3 o'clock, for example), the dot will be seen at this position - and only at this position - at a rate of 1800 times each minute. Thus, the dot will appear to "freeze" or stand still.

If the flash rate of the stroboscope is slowed to 1799 flashes per minute, the dot will be illuminated at a slightly different position each time the disc revolves, and the dot will appear to move slowly in the direction of rotation through 360° and arrive at its original position 1 minute later.

A similar movement, but in a direction opposite the rotation of the dot, will be observed if the flash rate of the stroboscope is increased to 1801 fpm. If desired, the rate of apparent movement can be speeded up by further increases or decreases in the strobe flash rate.

When the image is stopped, the flash rate of the strobe equals the speed of the moving object and, since the flash rate is known, the speed of the object is also known. Thus the stroboscope has a dual purpose of measuring speed and of apparently slowing down or stopping rapid motion for observation. The practical significance of the slow-motion effect is that, since it is the true copy of the high speed motion, all irregularities (vibration, torsion, chattering, whip) present in the high speed motion can be studied.

4.1.2 Single and Multiple Images

Single images will occur at the fundamental speed of the object under observation, and at predictable sub-multiples of the fundamental speed. Multiple images will be observed at various speeds above and below the fundamental speed. Refer to para 3.4.1 and 3.4.2. When the 1546 is used for observation purposes only, the ability to distinguish between single and multiple images is usually unnecessary. When making speed measurements, however, the operator must be able to make this distinction. Generally, odd shaped objects (those which are not symmetrical) cause little difficulty. Assume, for example, a fan with only one blade: 1 blade will be seen when a single image occurs, 2 blades (180° apart) will be seen when a double image occurs, 3 blades (120° apart) will be seen when a triple image occurs, etc.

When the object is symmetrical in shape (fans with 4 blades, or a gear, for example), multiple images cannot always be distinguished from a single image. This difficulty is overcome by upsetting the symmetry of the object by applying a reference mark with paint, chalk, tape, etc.

Gear not marked for speed measurement. Simple observation is possible but the observer cannot be certain if the image is single or multiple.

A single image is observed with tape applied to one tooth of the gear.

A multiple (double) image is observed with tape applied to one tooth of the gear. The images are 180° apart. (Stroboscope is flashing twice in one revolution of the gear.)

A multiple (triple) image is observed with tape applied to one tooth of the gear. The images are 120° apart. (Stroboscope is flashing three times in one revolution of the gear.)

4.2 Circuit Details

4.2.1 General

The 1546 Strobotac consists of a strobotron lamp, a charging circuit, a high-voltage power supply to charge the discharge capacitors, a regulated low voltage power supply, a flash rate oscillator, flash rate counting circuits, and 5 digit LED display. A block diagram of the circuitry is shown in Figure 4-1.

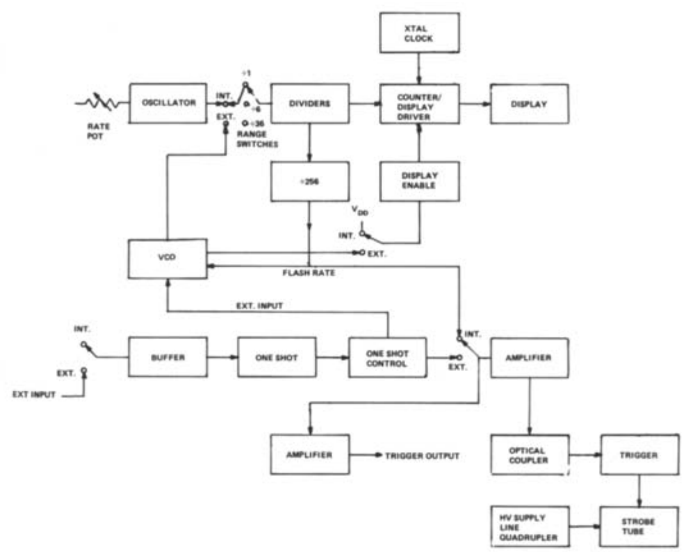

Figure 4-1. 1546 Digital Strobotac Block Diagram.

4.2.2 The Strobotron Tube

The Strobotron tube contains an anode and a cathode in an envelope filled with xenon gas. A capacitor acts as a low-impedance source to supply high voltage to the electrodes. The gas remains nonconducting until a high-voltage pulse is applied to trigger wires spaced between the electrodes. The trigger pulse ionizes the gas, allowing a high peak current to flow through it and generate an intense flash of white light.

4.2.3 The Power-Supply Board (Figure 5-4)

A voltage-quadrupling power supply, consisting of 4 diodes (CR1 to CR4) and 4 capacitors (C13 to C16) provides the power needed to charge the storage capacitors.

An optical isolator isolates signals from the high-voltage circuits on the power board (which are referenced to one side of the power line) from signals on the logic board, which are earth-grounded.

The trigger is generated by Q3, a silicon-controlled rectifier (SCR). The SCR rapidly discharges C18 through the trigger transformer, T1. The secondary of T1 produces the trigger pulse to fire the Strobotron lamp. The SCR is driven by the output of the optical isolator.

4.2.4 The Digital Logic Board (Figure 5-6)

Low-Voltage Power Supply: A low-voltage power-supply circuit produces 5.5 Vdc to power all components on the Logic Board. Transformer T2 provides a 10 Vac signal to the Logic Board. This signal is rectified by a full-wave bridge and filtered by capacitors and a 5-V regulator. Resistors R50 and R51 increase the final output voltage to 5.5 V.

Rate Oscillator: The rate oscillator establishes the flash rate of the stroboscope in the Internal mode. A voltage comparator oscillator controlled by R66 (the flash rate potentiometer) generates a pulsed output of 16 to 110 kHz. Positive feedback through R66 and R64 sets the voltage swing for the comparator input. R64 sets the minimum oscillator frequency to approximately 16 kHz with the rate potentiometer set for the lowest output frequency. Negative feedback to the comparator is adjusted by the rate potentiometer, which controls the oscillator frequency over a 7:1 range. Capacitor C35 is charged through R59 at a variable rate that is dependent upon the rate potentiometer setting. R46 limits the discharge current when the comparator output is low.

Oscillator Output Dividing Circuit: Three CMOS dividers establish the 3 flash-rate ranges and divide the counter input signal by 256 to produce the flash rate. The 3 flash-rate ranges are established by 2 dividers at the output of the oscillator. U3 and U4 each divide by 6, and are switched into the circuit to establish the low and medium ranges. U7 divides the rate-oscillator output by 256, and is always in the circuit. Thus, the oscillator output of 16 to 110 kHz is divided as shown in Table 4-1 to achieve the final flash rates.

Table 4-1

Range	Flash Rate	Divisor
LOW	100-700 fpm	9,216 (6 x 6 x 256)
MED	600 - 4,200 fpm	1,536 (6 x 256)
HIGH	3,600 - 25,000 fpm	256 (1 x 256)

Rate Counter and LED Display: Five light-emitting diodes (0.43 in., 7 segment) display the flash rate and are driven by a CMOS LSI Counter/Display Driver Integrated Circuit (U5). This IC functions as a complete rate counter and 7-segment LED driver. The input to the counter is 256 times the final flash rate. By counting this input rate for 0.234375 s, a display readout 60 times the flash rate is obtained. Thus, the LED readout displays the flash rate in fpm (multiplication by 0.234375 is mathematically equivalent to multiplying by 60/256).

A crystal-controlled clock IC (U6) drives the LSI counter with control signals for gating, storing, resetting, and display multiplexing.

External Input Circuitry: A 3-terminal phone jack on the panel is provided to trigger the strobe from ground-based signals and contact closures. The tip and rear section of the phone jack are directly coupled to the input buffer. Zener diode CR14, in series with R39, protects the input buffer from excessively high voltages.

The ring of the 3-terminal phone jack is connected to 5.5 Vdc to provide a voltage source for connection to one side of a contact closure. The strobe will flash for each contact closure when the contact is connected between the tip of the plug and the ring of the phone jack.

A 1-shot multivibrator protects the lamp from excessively high flash rates. The 1-shot uses the leading edge of the buffer output signal to discharge the capacitor, C9. The positive buffer output drives the second voltage comparator negative, causing C9 to discharge. C9 recharges through R32 or R32 in parallel with R31. R31 is switched into the circuit to change the 1-shot delay time between the low and medium ranges and the high range.

When the voltage across C9 exceeds 52% of the supply voltage, the third voltage comparator is driven negative. This third comparator must be in the "low" output state for the strobe to flash. Thus, if the external input rate exceeds the rate at which C9 can be sufficiently charged, there will be no flash output.

Display of the external mode flash rate is accomplished using the display circuitry of the internal mode, plus a voltage-controlled oscillator (VCO) and phase-locked loop (U2). The VCO, operating at 1 to 120 kHz, is phase-locked to the external input signal. A low pass filter, made up of R44, R45 and C30, controls the loop dynamics and permits lock-up down to 1.25 Hz (75 fpm). R43 and C11 set an upper limit for VCO operation. The output frequency of the VCO is equal to the external input rate times the range divisor. Prior to phase-lock acquisition, the flash-rate display is blanked. The blanking feature uses a lock indicator output signal from the phase comparator. This signal, when filtered by the network consisting of R25, R26, C31 and CR13, inhibits the counter/display driver IC.

Section 5
Service and Maintenance

WARNING
These servicing instructions are for use by qualified personnel only.
Dangerous voltages are present inside the case of this instrument.
For safety, disconnect power plug and wait 3 minutes before opening.

5.1 Warranty

The warranty attests the quality of materials and workmanship in our products. When difficulties do occur, our service engineers will assist in any way possible. If the difficulty cannot be eliminated, please write or phone our Service Department, giving full information of the trouble and of steps taken to remedy it. Be sure to mention the type and serial number of the instrument.

5.2 Instrument Return

Before returning an instrument to IET for service please call our Service Department at 800-899-8438 for Return Material Authorization (RMA). Include a Purchase Order Number to insure expedient processing. Units under warranty will be repaired at no charge. For any questions on repair costs or shipment instructions, please contact our Service Department at the above number. To safeguard an instrument during shipment, please use packaging that is adequate to protect it from damage, (i.e., equivalent to the original packaging) and mark the box "Delicate Electronic Instrument".

Return material should be sent freight prepaid to:

IET Labs, Inc.
10 Dedham Street
Newton, MA 02461

Attention: Service Department

5.3 Functional Operation Checks

One method of verifying proper operation of the internal mode of the 1546 is to compare the instrument flash rate with the rotation of a motor that is synchronized to the power-line frequency. To make the verification, set the flash rate of the 1546 initially higher than the speed of the motor (generally 1800 rpm) and lower the flash rate until motion is stopped. The number displayed on the LED readout should be within ±0.1% of the nominal synchronous motor speed. For an 1800 rpm motor, this would be ±1.8 rpm/fpm. If the actual value is outside of the specified tolerance, the instrument most likely has a defective crystal oscillator or counting circuit.

At times, the power line frequency may drift, so that the stable 1546 counter may correctly show that the flash rate is out-of-spec. When in doubt, measure the power-line frequency with a frequency counter to determine where the problem lies, or observe the motor over an extended period of time to verify that the powerline frequency is drifting.

To verify the rate when using the **EXT** mode, input a pulse of a known repetition rate from a signal generator. Compare this input with the display reading. The value from the display should be within ±0.01% the value of the input. If the value is not within this specification, or if no display is present, refer to para. 5.5.3.

5.4 Lamp Replacement

The lamp should be replaced whenever the 1546 fails to flash, flashes erratically or holds over (continuous arcing). To replace the lamp:

a. Unplug the power cord and wait at least 3 minute before proceeding.
b. Remove the lens by turning the 4 lens screws counter-clockwise using a small Phillips head screwdriver.
c. Pull the lamp out of its socket by grasping it on the glass envelope and pulling outward with a rocking motion. The lamp may still be not.
d. Align the new lamp's pins in the socket and carefully push the lamp forward until it is seated firmly.
e. Replace the lens of the instrument and tighten the screws; do not over-tighten.

If, after replacement, the 1546 still fails to operate properly, refer to para 5.5.

5.5 Etched Board Maintenance

Handling Precautions
For Electronic Devices
Subject To Damage By Static Electricity

Place instrument spare parts (which should be in anti-static envelopes or carriers), hand tools, etc., on a conductive work surface (typically a bench top), that is reliably connected to earth ground through a safety resistance of approximately 250 kΩ to 500 kΩ. Also, for personnel safety, the surface must NOT be metal. (A resistivity of 30 to 300 kΩ per square is suggested.) Avoid placing tools or electrical parts on insulators such as books, paper, rubber pads, plastic bags, or trays.

Ground the frame of any line-powered equipment, test instruments, lamps, drills, soldering irons, etc. directly to earth ground. Accordingly, (to avoid shorting out the safety resistance) be sure that the grounded equipment has rubber feet or other means of insulation from the work surface. The instrument or system component being serviced should be similarly insulated while grounded through the power-cord ground wire, but must be connected to the work surface before, during, and after any disassembly or other procedure in which the line cord is disconnected.

DO NOT USE any hand tools or any other items that can generate static charge. (Examples are non-conductive plunger-type solder suckers and rolls of tape.) Ground yourself reliably, through a resistance, to the work surface; use a conductive strap or cable with a wrist cuff. The cuff must make electrical contact directly with your skin; DO NOT wear it over clothing. (Resistance between skin contact and work surface through a commercially available personnel grounding device is typically in the range of 250 kΩ to 1MΩ.) If any circuit boards or IC packages are to be stored or transported, enclose them in conductive envelopes and/or carriers. Remove the items from such envelopes only with the above precautions; handle IC packages without touching the contact pins.

Avoid circumstances that are likely to produce static charges, such as wearing clothes of synthetic material, sitting on a plastic-covered or rubber-footed stool (particularly while wearing wool), combing your hair, or making extensive erasures. These circumstances are most significant when the air is dry.

When testing static-sensitive devices, be sure dc power is on before, during, and after application of test signals. Be sure all pertinent voltages have been switched off while boards or components are removed or inserted, whether hard-wired or plug-in.

5.5.1 Preliminary Checks

Make the following checks before disassembling the instrument:

a. Ensure that voltage is available at the power receptacle to which the instrument is connected, and that the voltage and power-line frequency agree with the data on the rear panel of the instrument.
b. Ensure that the instrument is on Internal mode, and that one of the flash rate range switches is pushed in.

5.5.2 Disassembly

To disassemble the 1546:

a. Unplug the instrument and wait at least 3 minutes.

b. Turn the instrument so that the dial for the rate potentiometer is up. Find the slot on the raised portion of the instrument, and turn the dial until a set screw hole can be seen. Insert a no. 6 Allen wrench in this hole and loosen the set-screw. Remove the dial by lifting it straight up.

c. Turn the instrument over and remove the 4 screws at each corner of the housing. Separate the halves of the housing.

WARNING

High voltage may still be present. on the exposed circuit board.

d. All components can be accessed without separating the printed-circuit boards. The boards should not be separated until the instrument fault is isolated to a specific component.

5.5.3 Trouble Analysis

General. This section is intended to assist qualified service personnel in isolating operating problems of the 1546 to a specific component or group of components. Figure 5-2 shows typical waveforms found at various test points of the instrument. Figures 5-4 through 5-7 show schematic diagrams and layouts of the printed circuit boards in the instrument. When testing the circuits of the 1546, the following procedures should be used:

a. Make the set-up as shown in Figure 5-1.

b. Check the operation of the instrument on all 3 ranges.

c. Make a general determination as to which functions are being performed by the instrument (i.e., does the instrument exhibit no flash and no LED display? Does the instrument have a display but no flash or a flash with no display? Is the external mode operating properly, or is there a trigger output signal?). Generally, the cause of a problem can be isolated to within a few circuits, thus reducing trouble analysis time.

Table 5-1

Required Test Equipment

Instrument	Minimum Specifications
Oscilloscope	Single trace; dc to 15 MHz; 400 Vdc input
Voltage Probe	Attenuation: X10; rating 600 Vdc
DMM	Resolution: 10 µV, 10 µΩ; Ranges: 10 µV to 1000 Vdc, 10 µV to 750 Vac; 10 µΩ 10 MΩ
Oscillator	60 Hz ±2 Hz, 2 V peak to peak
Adjustable Autotransformer	0-140 Vac output; 150/750 W. and 150 V meter ranges
Isolation Transformer	115 Vac input; 150 VA output
Frequency Counter	dc to 5 MHz; resolution to 0.1 µs; 10 mV sensitivity

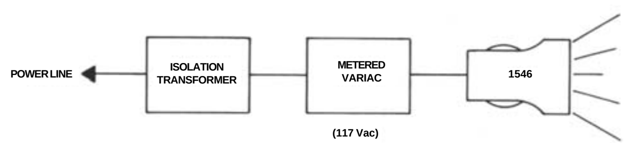

Figure 5-1. Trouble Analysis Set-Up.

Trouble Analysis With No Flash and No LED Display.

When the instrument fails to operate on all 3 ranges of the internal mode, the problem can usually be traced to fuses (F1, F2), or the 5.5 Vdc power supply. To test the 1546 when this type of failure occurs, the following procedures are recommended:

a. Check F1 and F2 ; Replace the fuse(s) if blown.

b. After replacing fuse(s), make the set-up shown in Figure 5-1. Use caution while reapplying power. Adjust the output of the metered variac slowly while observing the wattmeter. Shut down the power immediately if the wattmeter shows any indication that the instrument is drawing greater than 25 W. If this condition exists, remove plug P4 from jack J1 on the power-supply board. Reapply power as before. If the 1546 is still drawing high wattage, remove power and troubleshoot for shorted conditions on the power-supply board.

c. After repairing the shorted condition, reconnect P4 to J1 and reapply power as before. The 1546 should draw approximately 18 W with an input of 117 Vac (measured on the variac) while operating normally.

Instrument Inoperative But Fuses Not Defective.

If the fuses are not defective but the instrument will not flash and the LED display is blank, check the 5.5 Vdc power-supply circuit. The following is the recommended procedure for checking this circuit:

a. Make the set-up shown in Figure 5-1.

b. Determine if 5.5 Vdc is present between pin 2 of U5 and earth ground. If 5.5 Vdc is not present, check back through the regulator circuitry to isolate the faulty component. Approximately 10 Vdc should be present at pin 1 of U8 (referenced to ground) and 10 Vac should be present between WT24 and WT23 (secondary side of T2). Line voltage should appear between terminals 1 and 2 of T2 (primary side of the transformer). Refer to waveforms A and B shown in Figure 5-2.

c. If the instrument fails to operate after Vdd has been restored, further defects exist on the logic board and possibly on the power board. If Vdd is present at pin 9 of U5, then the LEDs will display all zeros at the least, unless U5 or U6 are defective.

No Flashing, LED's Read Zero on All Ranges.

The condition of no flashing and a reading of zero on the LED display on all ranges is indicative of a rate-oscillator failure. To troubleshoot for this condition:

a. Make the set-up shown in Figure 5-1.

b. Connect the X10 probe to pin 13 of U1 and the probe ground lead to earth ground. A series of pulses should be observed whose rate changes as R66 (potentiometer) is adjusted. If pulses cannot be observed, the problem is in U1 or its associated circuitry. Refer to waveforms C through E of Figure 4-2 (waveform C shows the typical oscillator output at an instrument flash rate of 3600 fpm, on the **MED** range, with an input of 117 Vac).

LEDs Display Zeros, No Flashing on LOW/MED Ranges.

If the instrument operates correctly on the high flash-rate range, but fails to flash on the low and medium ranges (or just the low range), the fault can be isolated to the digital divider circuitry.

a. If only low range operation is faulty, connect the probe to pin 6 of U4, using ground as a reference. Refer to waveform G, Figure 5-2. Replace U4 if pulses are not present.

b. If the instrument fails to operate on both low and medium ranges, connect a X10 probe to pin 6 of U3. Connect the ground lead to earth ground. If no pulses are present at pin 6, replace U3 (refer to waveform F).

No Flashing With Correct LED Display.

The condition of no instrument flash with an LED display is indicative of a problem with the lamp, or a possible problem on one of the boards. To troubleshoot the instrument for this condition:

a. Replace V1 and determine if the problem has been corrected.

b. If the instrument still fails to flash, make the setup shown in Figure 5-1. Set the Variac for 125 Vac output and the flash rate for 3600 fpm (MED range).

c. Connect the oscilloscope X10 probe to pin 13 of U7 and the probe ground to earth ground. If output pulses are not present, suspect U7. Refer to waveform H, Figure 5-2.

d. If output pulses are present at pin 13 of U7, check to determine if pulses are getting through SW1 and Q1 to WT22. If pulses are not present at WT22, check SW1, Q1, and associated circuitry. If pulses are present, the problem is most likely on the power board. Refer to waveforms I and J of Figure 5-2.

e. Determine if pulses are present at pin 4 of U9 (refer to waveform X, Figure 5-2). Use the negative side of C16 or pin 6 of S5 as ground reference. If these pulses are present, go to step f. If these pulses are absent, check for +20 Vdc at the anode of CR14. If the 20 V is present suspect U9. If 20 V is not present, check CR14 and C32. If these components are not defective, the high-voltage power supply must be checked.

f. To check the high-voltage power supply, set the 1546 to EXTERNAL mode. Connect the scope probe to WT8 or the positive side of C16 using pin 6 of S5 or the negative side of C16 as referenced. Check for approximately 176 Vdc at this point. Check next at the positive side of C15 for 530 Vdc. Move the ground lead of the probe to the negative side of C13. Check for approximately 360 Vdc at the positive side of C13, and approximately 700 Vdc at the positive side of C14 and C25.

g. If large differences between the voltages measured and the voltages specified in step f are present in the high-voltage power supply, remove the power from the instrument and disconnect the red lead from WT1. Reapply power and check for the same voltages using the same reference points. If these voltages are still faulty, remove power from the instrument and check CR1 through CR4, C13 through C16, Q3 and C18. If the voltages specified are present with the red lead disconnected, remove power from the instrument and check C25, C26, CR16 and associated components.

h. If C25, C26, CR16 and their associated circuitry are not defective, switch the instrument to internal mode. Determine if the SCR (Q3) is firing by placing a X10 probe at the anode of Q3 and the probe ground lead on the negative side of C16 (refer to waveform Y, Figure 5-2). Pulses will be observed if the SCR is not defective. If these pulses are present, suspect the trigger transformer (T1). If these pulses are not present, the problem will most likely be in Q3 or its related trigger circuitry.

Instrument Flashes, Incorrect LED Display. The condition of an incorrect LED display while the 1546 is flashing can usually be traced to failure in the Counter/Display Driver IC (U5), or crystal-controlled clock IC (U6 and Y1). To check the instrument for this condition:

a. Make the setup shown in Figure 5-1.

b. Check for the signals shown in Table 5-2.

If all the above signals are present replace U5; if any signal except the **INPUT** signal is not present, suspect U6 or the crystal (Y1).

c. Check crystal (Y1) by placing a counter probe at pin 6 of U6. Use earth ground as a reference. The crystal normally oscillates at a rate 2.236962 MHz (±0.005%). Refer to waveform K, Figure 5-2.

Instrument Inoperative in EXT Mode.

When the instrument fails to operate properly while on external mode, but operates correctly on internal mode, a problem with U1 or related circuitry exists. To check for this condition:

a. Make the set-up shown in Figure 5-1. Connect an oscillator to the instrument through the EXTernal IN jack, using the tip and shaft connections to the 3-termina! plug. The oscillator should be set to produce a 60 Hz (3600 fpm) sine wave, 2 V pk-pk. Set the instrument range switch to medium range. Insure that the signal is present at pin 9 of U1.

b. Apply an oscilloscope probe to pins 14, 6, 1, and 2 of U1 (refer to waveforms Q, R, S, and T) to determine if the signals are getting through the input buffer, and the one-shot circuitry. If the signal is not present at any of these test points, suspect U1 and associated circuitry.

c. If the instrument flashes while on external mode, but does not display the flash rate correctly, check U2 and its associated circuitry using waveforms T, U, V, and W. Also check pin 9, U5 for a 5.5 Vdc display enable signal.

No Trigger Output Signal. If the instrument fails to produce a trigger output signal, a problem exists in Q2 and related components. To troubleshoot for this condition:

a. Make the set-up shown in Figure 5-1. Set the instrument to 3600 fpm on the internal mode.
b. Apply the oscilloscope probe to WT13 on the logic board. Use earth ground as a reference. Refer to waveform P, Figure 5-2. If the signal shown is not present, check Q2 and its related circuitry.

Table 5-2

U5 Counter/Display Driver Input Signals

Signal	Pin Number	Waveform
INPUT	12	F
STORE	11	0
GATE	13	L
RESET	14	N
DISPLAY		
ENABLE (5.5 Vdc)	9	
MULTIPLEX	19	M

5.6 Adjustment of the Internal Oscillator

When any portion of the internal oscillator U1 or the 5.5 Vdc power supply is replaced, the internal oscillator of the 1546 should be readjusted. To perform this adjustment:

a. Disassemble the instrument, and make the set-up as shown in Figure 5-1.
b. Turn the instrument on and set it to the low range of the internal mode.
c. Turn the FLASH RATE CONTROL counter-clockwise until the instrument stops flashing. Slowly turn the FLASH RATE CONTROL until the instrument begins flashing.
d. Adjust R64 until the LED display is 95 ±1 fpm.
e. Without fuming the FLASH RATE CONTROL, verify that the medium range is between 550 and 600 fpm, and that the high range is between 3,300 and 3,600 fpm.
f. Set the instrument to the high range of the internal mode.
g. Turn the FLASH RATE CONTROL clockwise until the instrument stops flashing.
Slowly turn the FLASH RATE CONTROL counter-clockwise until the instrument begins flashing.
h. Without turning the FLASH RATE CONTROL, verify that the high range is between 25,000 and 28,000 fpm, that the medium range is between 4,200 and 4,800 fpm, and that the low range is between 700 and 800 fpm.

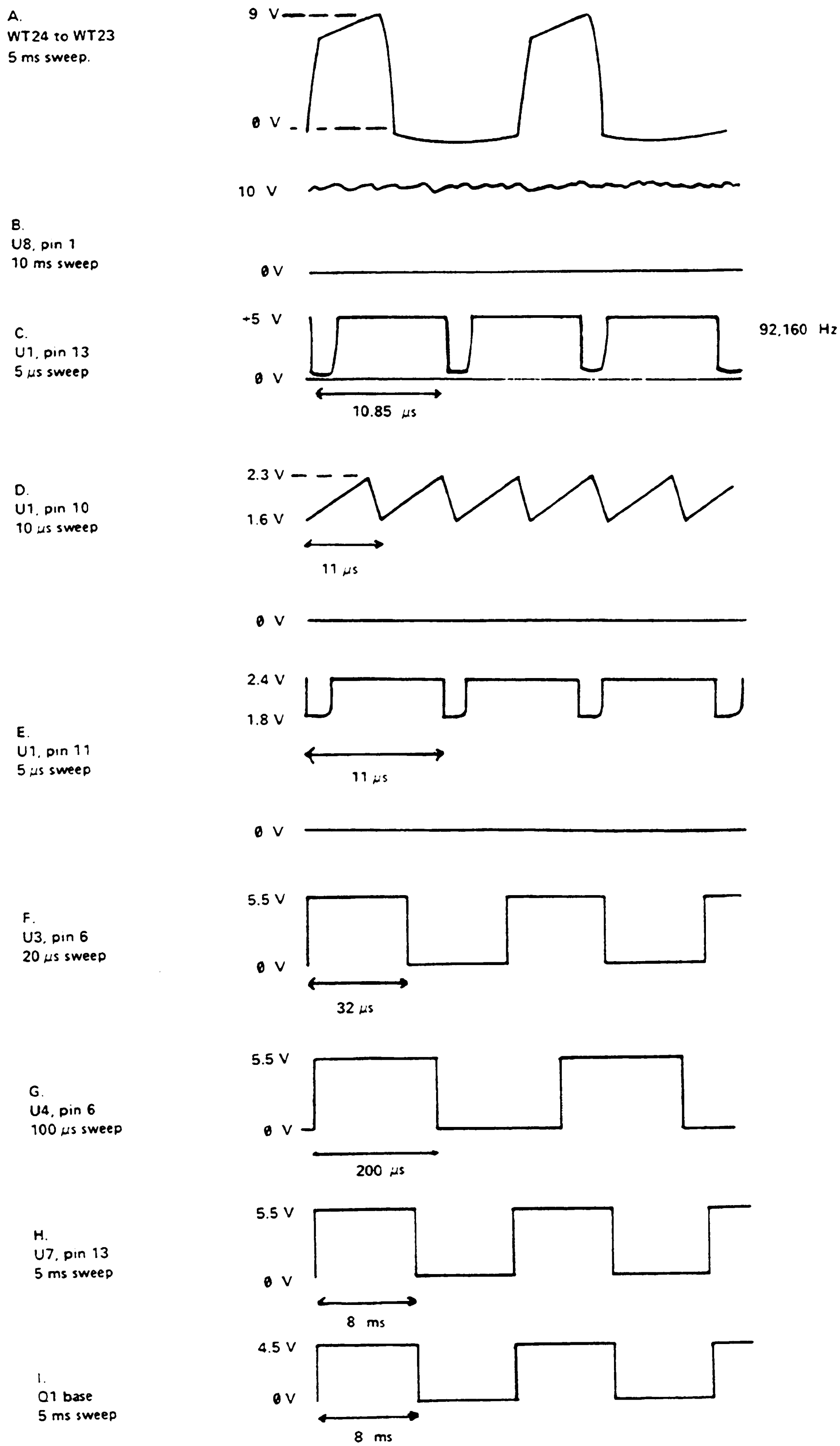

Figure 5-2. Troubleshooting Waveforms. 1546 set to Internal mode, MED range, 3600 fpm. 117 Vac, 60 Hz line. Waveforms A through W are referenced to Vss (earth ground).

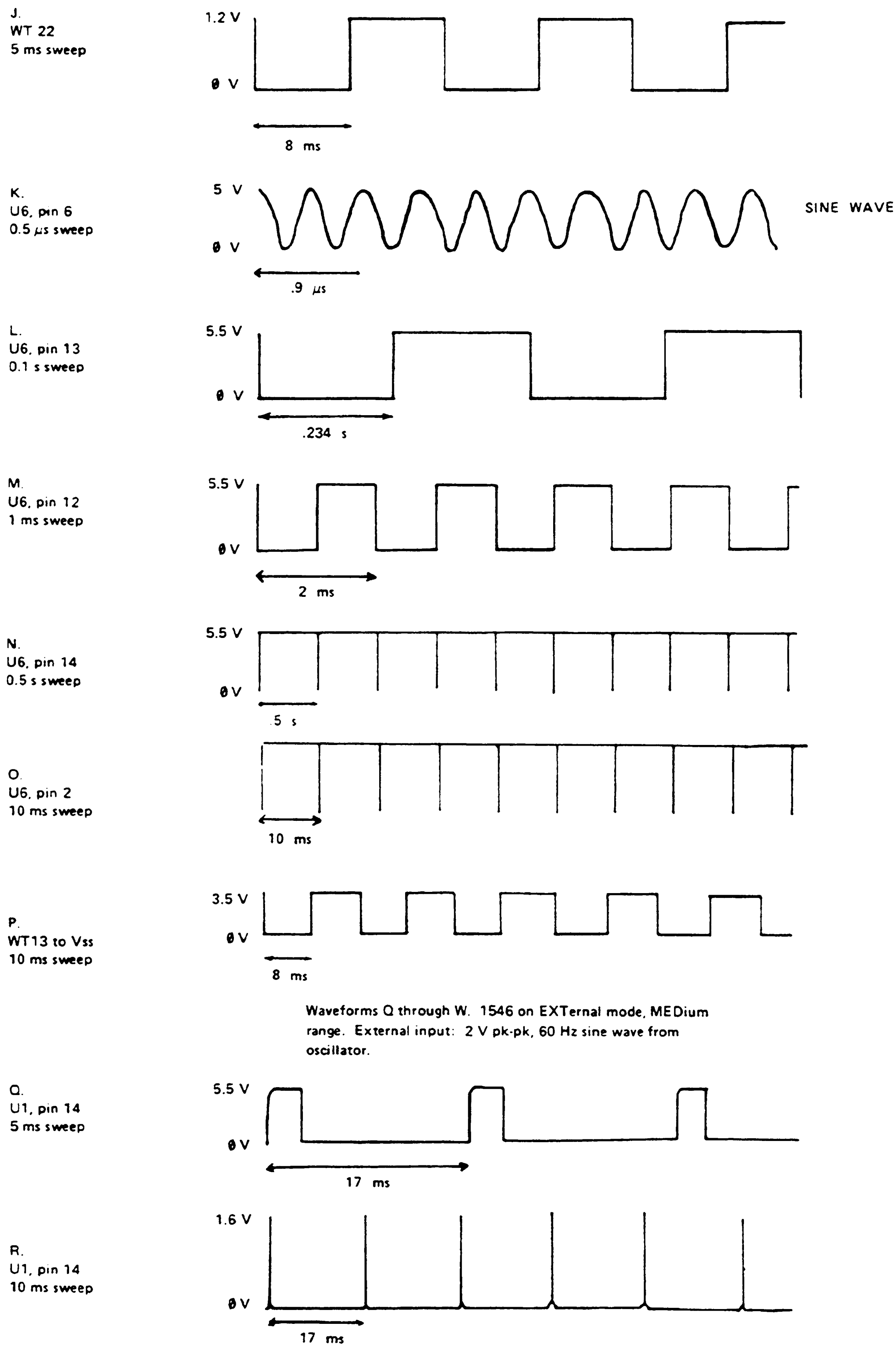

Figure 5-2. Troubleshooting Waveforms (continued).

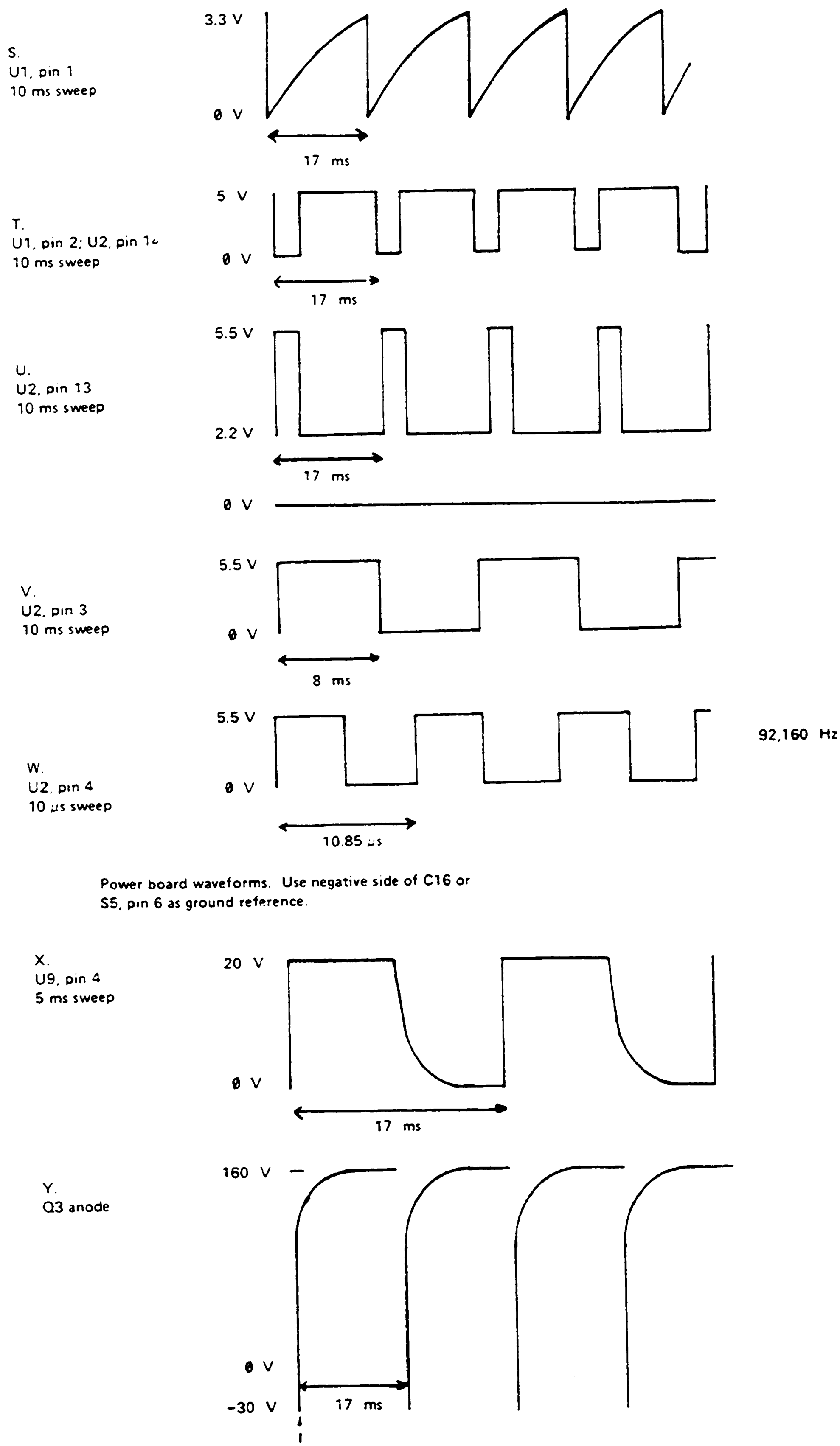

Figure 5-2. Troubleshooting Waveforms (continued).

Reference Designator Abbreviations

C	=	Capacitor	R	=	Resistor
CR	=	Diode	S	=	Switch
DS	=	Lamp	T	=	Transformer
F	=	Fuse	U	=	Integrated Circuit
J	=	Jack	VR	=	Diode, Zener
L	=	Inductor	X	=	Socket for Plug-In
P	=	Plug	V	=	Crystal
Q	=	Transistor	Z	=	Network

Mechanical Parts List

Figure 5-3 Ref.	Description	Part No.	Quan.
1	Dial asm.	1546-1020	1
2	Friction washer (under dial)	1546-7400	1
3	Housing, uppercase asm.	1546-1010	1
4	Front-cover screws .112-40 2A, .250 in	7044-1102	4
5	Front-cover 0 rings 1/16 in diam. nom.	5855-0062	8
6	Front Cover	1546-7030	1
7	Reflector asm.	1546-1030	1
8	Housing, lowercase asm.	1546-1000	1
9	Housing screws .190-32 2A, 2.5 in (hidden)	7044-1412	4
10	Lock washers for housing screws (hidden)	8040-2400	4
11	Power cable	1546-0230	1
12	Strain-relief clamp for power cable (hidden)	4350-0800	1
13	Push buttons for switch (hidden)	5511-0402	5

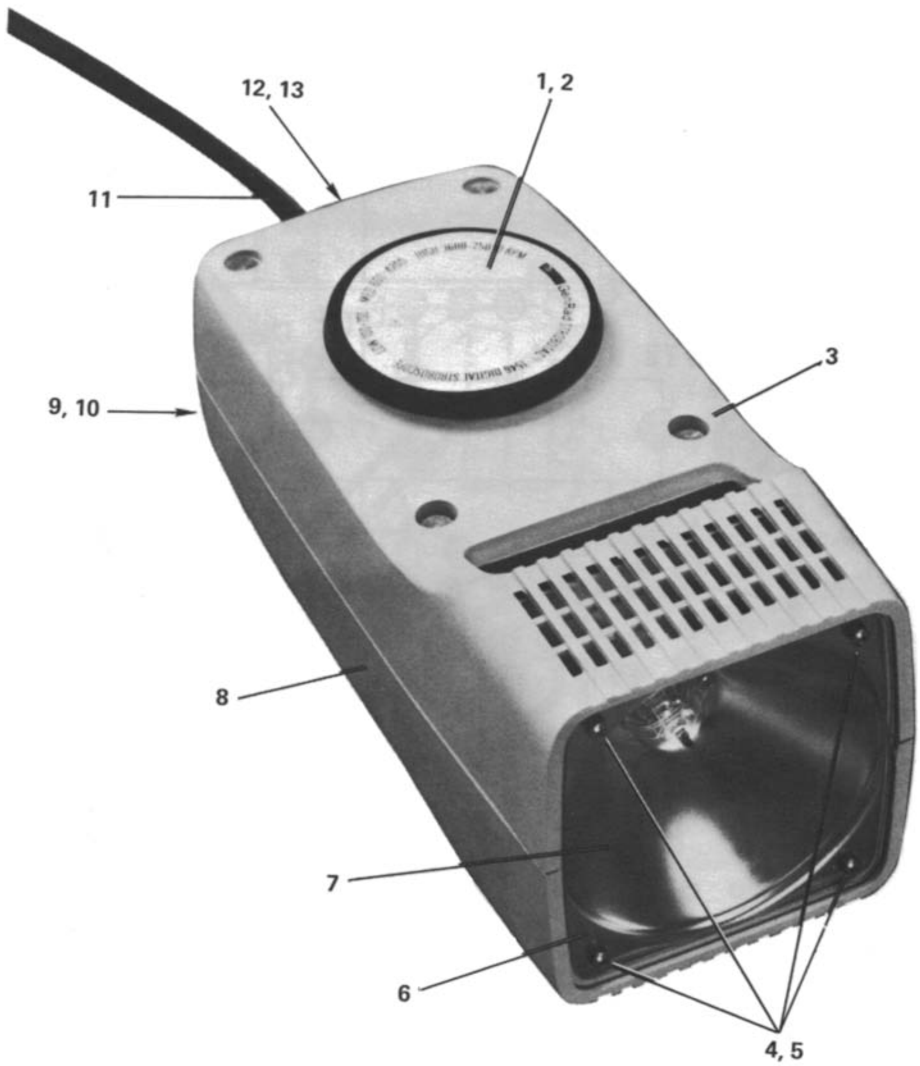

Figure 5-3. Mechanical Parts of the 1546.

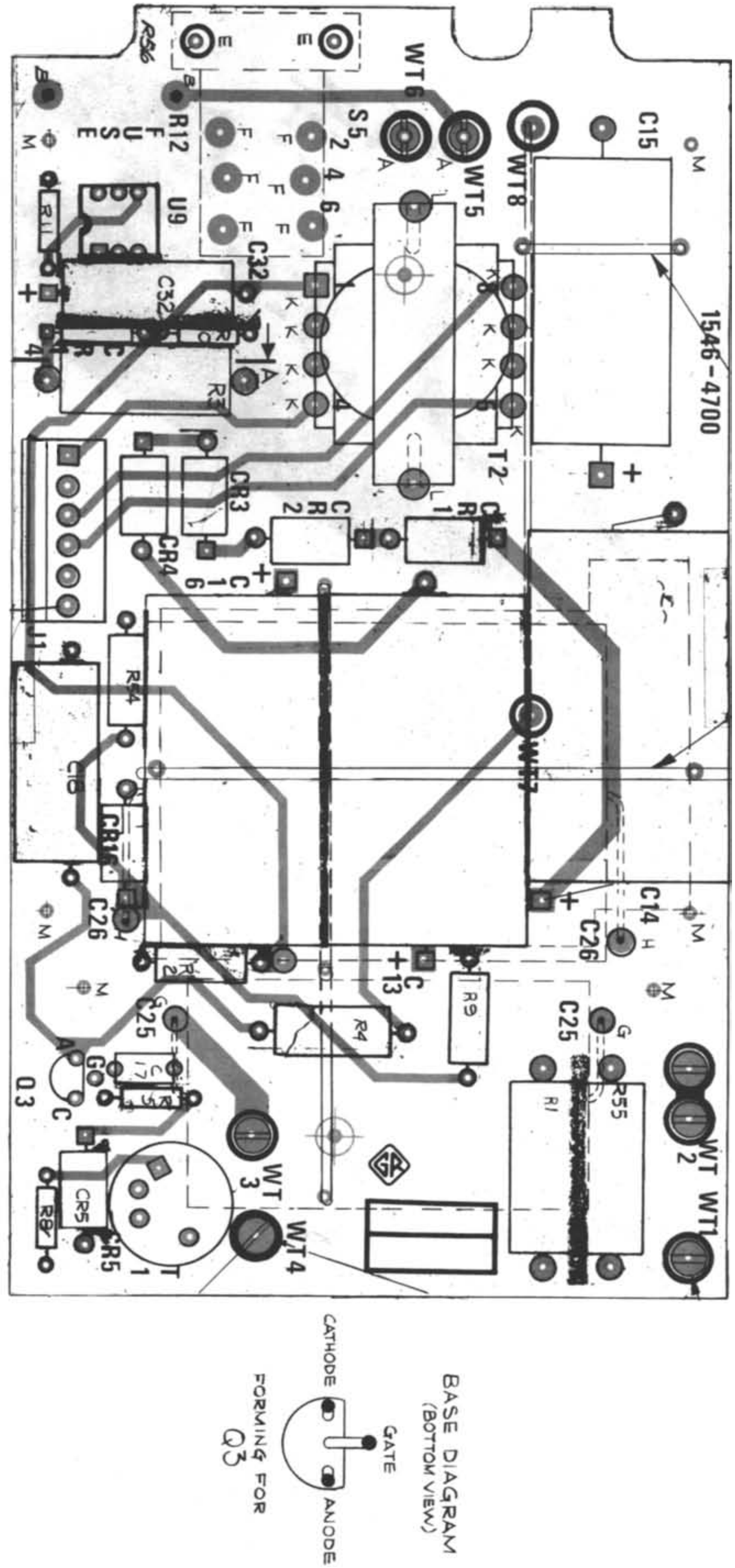

Figure 5-4 Etched Board Layout of the Power Supply Board (1546-4700)

Electrical Parts List
Power Supply PC Board P/N 1546-4700

REFDES	DESCRIPTION	PART NO.
C13, 14	CAP ALUM 35 µF 375 V	4450-6166
C15	CAP ALUM 7 µF 400 V	4450-6168
C16	CAP ALUM 80 µF 200 V	4450-6167
C17	CAP CER MONO 0.1µF 20% 50 V	4400-2050
C18	CAP MYLAR .1 µF 10% 200 V	4860-8253
C25	CAP POLYPR. 0.11 µF 10% 750 V	4860-1220
C26	CAP, POLYPR., 0.66 µF, 10%, 750 V	4860-1230
C32	CAP TANT 22 µF 20% 35 V	4450-5612
CR1-5, 16	RECT 1N4006 800PIV .5A SI	6081-1004
CR14	ZENER 1N5250B 20V 5% ,400 mW	6083-1018
	ALTERNATE PART 1N4747A	
F1	FUSE, SLOW BLOW, ¼ A, 250 V, PIGTAIL, 2 AG	5330-4005
F2	FUSE, FAST BLOW, ½ A , SUBMIN.	5330-4360
J1	CONNECTOR MULT PIN .045DIA	4230-4612
Q1	TRANS, 2N3414 or 2N3416	8210-1290
Q3	SCR, C203D/2N5064	8210-1215
R1, R25	RES MOX 1 M 5% 2 W	500077-1
R2, 9	RES COMP 51 K OHM 5% 1/2 W	6100-3515
R3	RES COMP 33 K 5% 2 W	6120-3335
R4	RES MF 10 K 5% 1 W	6110-3105
R5	RES COMP 100 OHM 5% 1/4 W	6099-1105
R8	RES COMP 10 OHM 5% 1/4 W	6099-0105
R10	RES COMP 10 K 5% l/4 W	6099-3105
R11	RES COMP 100 K 5% 1/4 W	6099-4105
R54	RES COMP 200 OHM 5% 1/2 W	6100-1205
R55	RES COMP 1 M 5% 2 W	6120-5105
R56	RES PWR WW 10 OHMS 10% 2 W	6620-2201
S5	SWITCH PUSHBUTTON DPDT	7870-1573
T1	TRANSFORMER, TRIGGER	1542-0410
T2	TRANSFORMER, POWER	7997-0400
U9	IC, PHOTO-ISOLATOR, MCT2	5434-0108

Flash Tube Socket Asm P/N 1546-2100

REFDES	DESCRIPTION	PART NO.
C19-24, 40	CAP CER DISC 22 pF 20% 4000 V	4428-3116
CR1-4	RECT 1N4006 800 PIV .5A SI	6081-1004

Reflector Asm Complete P/N 1546-2200

REFDES	DESCRIPTION	PART NO.
R6, 7	RES WW 4.7K OHM 5% 10 W	6640-2475
XV1	FLASH TUBE SOCKET ASM	1546-2100

Note: Preferred replacements for carbon composition resistors are either carbon film or metal film resistors.

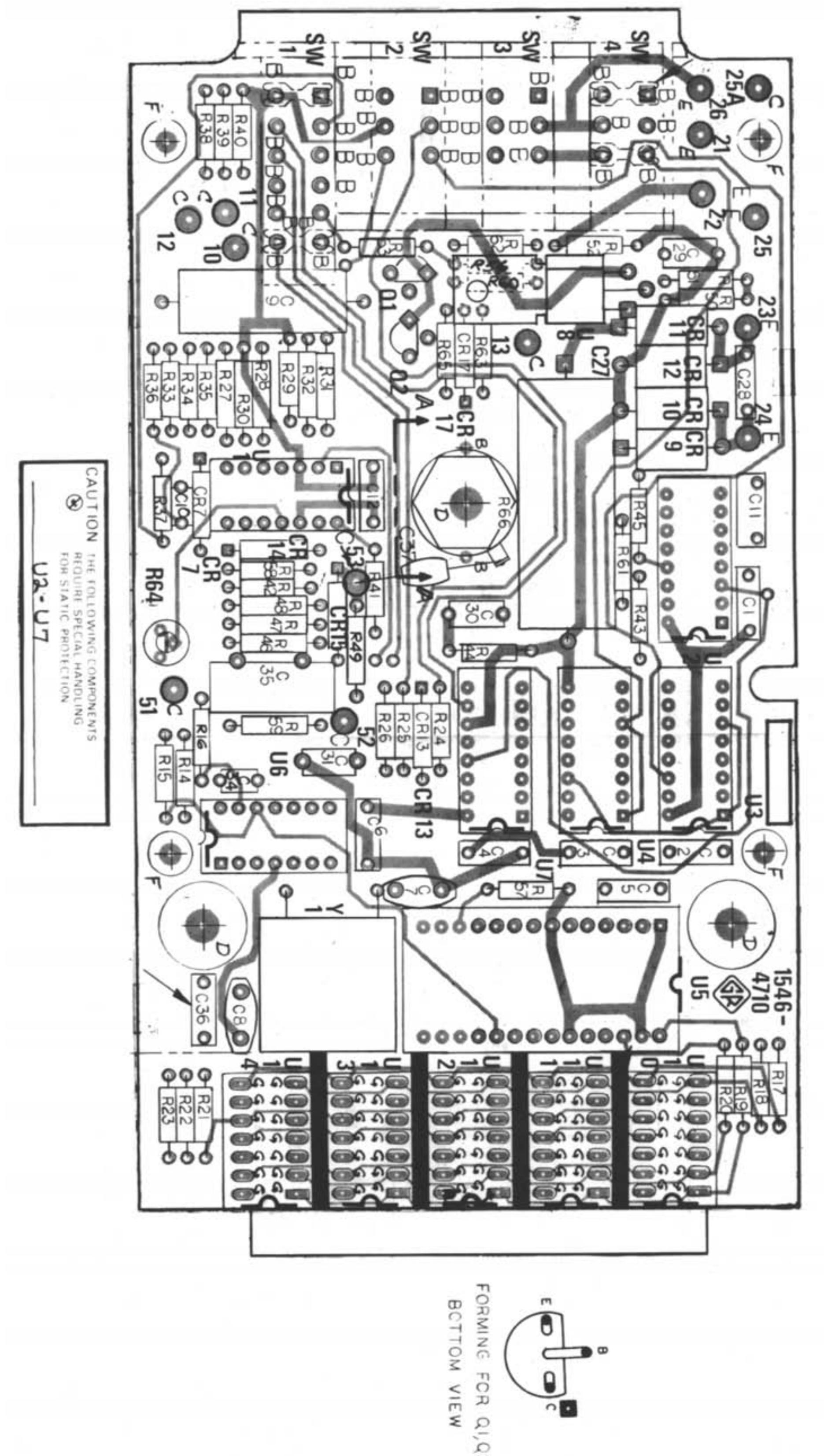

Figure 5-6. Etched Board Layout of the Digital Logic Board (1546-4710)

Electrical Parts List
Logic PC Board P/N 1546-4710

REFDES	DESCRIPTION	PART NO.
C1-6,12,28,36,37	CAP CER DISC .01 μF 80/20 % 100 V	4401-3100
C7,8	CAP CER DISC 22 pF 5% 510 V	4404-0225
C9	CAP MYLAR .1 μF 2% 100 V	4860-8351
C10,34	CAP CER MONO .047 μF 20% 50 VGP	4400-2040
C11	CAP MICA 274 pF 1% 500 V	4710-0448
C27	CAP ALUM 680 μF 15V	4450-6015
C29	CAP CER MONO 0.1 μF 20% 50 VGP	4400-2050
C30, 31	CAP CER MONO 1 μF 20% 50 VGP	4400-2070
C35	CAP MICA 1000 pF 1% 500 V	4710-0100
CR7,13,15	DIODE IN4151 75 PIV IR.1UA SI	6082-1001
CR9-12	RECT IN4004 400 PIV .75A SI	6081-1002
CR14	ZENER 1N750A 4.7V 5 % .4W	6083-1028
CR17	ZENER IN753A 6.2V 5 % .4W	6083-1006
Q1,2	TRANSISTOR MPS-A14	8210-1246
R14	RES COMP 1.0 K 5 % 1/4 W	6099-2105
R15,16	RES COMP 47 K 5 % 1/4 W	6099-3475
R17-23	RES COMP 100 OHM 5 % 1/4 W	6099-1105
R24,35,38-40	RES COMP 10 K 5 % 1/4 W	6099-3105
R25	RES COMP 15 K 5 % 1/4 W	6099-3155
R26,34,44	RES COMP 470 K 5 % 1/4 W	6099-4475
R27,30,43	RES FLM 10.0 K 1 % 1/8 W	6250-2100
R28	RES FLM 100 K 1% 1/8 W	6250-3100
R29	RES COMP 1.2 K 5 % 1/4 W	6099-2125
R31	RES FLM 31.6 K 1 % 1/8 W	6250-2316
R32	RES FLM 178 K 1 % 1/8 W	6250-3178
R33,42	RES COMP 100 K 5 % 1/4 W	6099-4105
R36	RES COMP 2.4 K OHM 5 % 1/4 W	6099-3245
R37	RES COMP 200 K OHM 5 % 1/4 W	6099-4205
R41	RES COMP 3.0 K OHM 5 % 1/4 W	6099-2305
R45	RES COMP 2.7 K 5 % 1/4 W	6099-5275
R46	RES FLM 2.05 K 1 % 1/8 W	6250-1205
R47	RES FLM 1 K 1 % 1/8 W	6250-1100
R48	RES FLM 2.37 K 1 % 1/8 W	6250-1237
R49	RES FLM 1 K 1 % 1/8 W	6250-1100
R50	RES COMP 30 OHM 5 % 1/4 W	6099-0305

Electrical Parts List (continuation)
Logic PC Board P/N 1546-4710

REFDES	DESCRIPTION	PART NO.
R51	RES COMP 360 OHM 5%1/4 W	6099-1365
R52,57,58, 60, 61, 65	RES COMP 10 K 5% 1/4 W	6099-3105
R53,63	RES COMP 1.0 K 5% 1/4 W	6099-2105
R56	RES COMP 100 K 5% 1/4 W	6099-4105
R59	RES FLM 30.1 K 1% 1/8 W	6250-2301
R62	RES COMP 75 OHM 5% 1/4 W	6099-0755
R64	POT CERM TRM 1 K 20% 1T	6049-0106
R66	POT COMP KNOB 5 K OHM 10% 1 W	6045-0470
R67	POT CERM TRM 200 OHM 20% 1T	6049-0104
SW1-4	SWITCH PUSHBUTTON MULT 4 SECT	7880-1546
U1	IC LINEAR LM339N	5432-1065
U2	ICD, CD4046BE (STATIC PROTECT REQ)	5431-7064
U3,4	ICD, CD4018BE (STATIC PROTECT REQ)	5431-7063
U5	ICD, M7208 (STATIC PROTECT REQ)	5431-7216
U6	ICD, M7207A (STATIC PROTECT REQ)	5431-7215
U7	ICD, MC14040BCP (STATIC PROTECT REQ)	5431-7018
U8	IC LINEAR LM342P-5	5432-1058
U10-14	READOUT, LED, 7-SEGMENT, .43 INCH HT	5437-1310
Y1	CRYSTAL 2.236962 MHz	5075-1101

⚠ CAUTION ⚠

IC'S U2-7 are static-sensitive. Use standard precautions when servicing.