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INSTRUCTION MANUAL



**Type 1493** | 1493-9801 Bench  
1493-9811 Rack

# PRECISION DECADE TRANSFORMER

1493

1493

GENERAL RADIO COMPANY  
A

# INSTRUCTION MANUAL

**Type 1493** | **1493-9801 Bench**  
**1493-9811 Rack**

# PRECISION DECADE TRANSFORMER

Form 1493-0100-A

ID 1145

March, 1967

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West Concord, Massachusetts, U.S.A.

**G E N E R A L R A D I O C O M P A N Y**  
**WEST CONCORD, MASSACHUSETTS, USA**

## CONDENSED OPERATING INSTRUCTIONS

1. Connect ac input to INPUT terminals.
2. Connect OUTPUT terminals to external circuit.
3. Switch CONTINUOUS DECADE toggle switch to:  
IN, if slidewire is required;  
OUT, if slidewire is not used.
4. Adjust ratio setting levers to indicate desired digital readout.

### CAUTION

Do not connect a dc voltage to the INPUT terminals of this instrument (refer to paragraph 2.2).

Refer to paragraphs 5.2 and 5.3 before attempting to service this instrument.

## SPECIFICATIONS

**RANGE:**  $-0.1111111$  to  $+1.11111110$  with 7 step decades and continuous slide-wire decade in  $10^{-8}$  position. Each step decade adjustable  $-1$  to  $X$  (10). Continuous decade adjustable 0 to  $X$ .

**ACCURACY**

**Linearity:** Indicated ratio, measured at 100 V, 1000 Hz, with a resolution of  $\pm 1 \times 10^{-9}$ , agrees with a standard calibrated by the National Bureau of Standards to within their limits of uncertainty, stated as  $\pm 2$  digits in the  $10^{-7}$  decade. At frequencies from 50 Hz to 2 kHz, ratio accuracy is approx  $\pm 1$  digit in the  $10^{-6}$  decade. Incremental accuracy of last 4 step decades will be better than  $\pm 2$  parts in  $10^5$ . Continuous decade accurate to  $\pm 1\%$ .

**Phase Error** (at 1 kHz):  $< \pm 6$  microradians for ratio settings from 0.1 to 1.0;  $< \pm 40 \mu\text{rad}$  for 0.01 to 0.1;  $< \pm 125 \mu\text{rad}$  for 0.001 to 0.01.

**INPUT**

**Max Voltage:** 350 V; below 1 kHz, 0.35Hz V.

**Impedance:**  $> 150 \text{ k}\Omega$  at 1 kHz;  $> 20 \text{ k}\Omega$  from 100 Hz to 10 kHz.

**Direct Current:** No dc should be applied to input.

**OUTPUT**

**Impedance (dependent on ratio setting):** Max:  $3.5 \Omega$ ,  $62 \mu\text{H}$ ; min:  $0.5 \Omega$ ,  $6 \mu\text{H}$ . With slide-wire decade switched out, max resistance is reduced to  $2.7 \Omega$ .

**Max Output Current:** 1 A.

**Terminals:** Gold-plated GR 938 Binding Posts.

**Accessories Available:** Recommended generator and null detector for precise comparison or bridge applications: the 1311-A Audio Oscillator and 1232-A Tuned Amplifier and Null Detector or the combination 1240-A Bridge Oscillator-Detector

**Cabinet:** Rack-bench. End-frames for bench mount or rack-mounting hardware included.

**Dimensions** (width x height x depth): Rack,  $19 \times 7 \times 8\frac{3}{8}$  in ( $485 \times 180 \times 215$  mm); bench,  $19 \times 7\frac{3}{8} \times 10\frac{3}{4}$  in ( $485 \times 190 \times 275$  mm).

**Net Weight:** Rack, 28 lb (12.7 kg); bench, 30 lb (13.6 kg).

**Shipping Weight:** Rack, 41 lb (18.7 kg); bench, 43 lb (19.6 kg).

Catalog Number	Description
1493-9801	Type 1493 Precision Decade Transformer, Bench Model
1493-9811	Type 1493 Precision Decade Transformer, Rack Model

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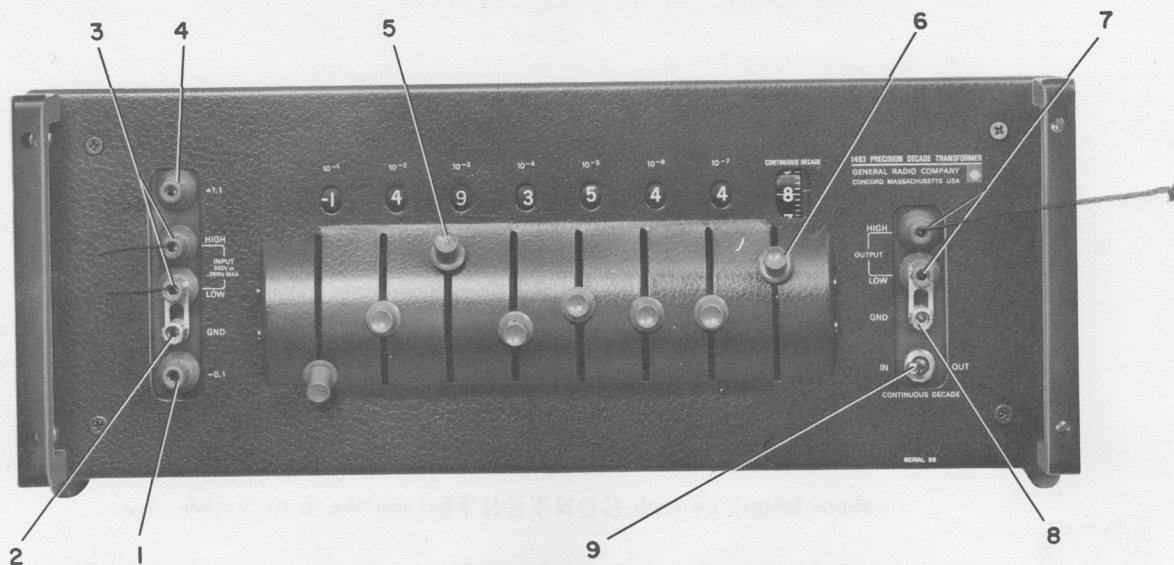


Figure 1-1. Type 1493 Precision Decade Transformer.

## SECTION 1

# INTRODUCTION

### 1.1 PURPOSE.

The Type 1493 Precision Decade Transformer is a highly accurate, adjustable-ratio transformer. When connected to a suitable ac source, this instrument can be set for any output between  $-0.1111111$  and  $+1.1111111$  times the input voltage.

In general, the principal applications of the Type 1493 are the measurement of unknown ratios and the accurate measurement of complex impedances in transformer bridge circuits. Within these two broad measurement areas, the uses for this precision transformer cover a wide range of specific applications (refer to Section 3).

### 1.2 DESCRIPTION.

#### 1.2.1 GENERAL.

The Type 1493 is an assembly of four separate transformers interconnected by appropriate switches to yield seven switched decades. These decades allow ratio settings in incremental steps of  $10^{-1}$  in the first decade to  $10^{-7}$  in the seventh decade. A switch is available to connect a built-in slidewire to the output of the last decade, thus extending the useful

range of the instrument by making available essentially infinite resolution, when a step of one part in  $10^{-7}$  is considered too large.

The decade switches are of the in-line readout, lever type, with short-throw traverse from  $-1$  to  $X$ . These switches were chosen not only for clear, easy-to-read, digital display of setting, but the  $-1$  setting on the first decade would be impractical to attain with conventional rotary switches.

#### 1.2.2 CONTROLS AND CONNECTORS.

All controls and connectors listed in Table 1-1 are conveniently located and plainly marked on the front panel of the Type 1493 (see Figure 1-1).

#### 1.2.3 ACCESSORIES.

Table 1-2 lists accessories supplied, or available, with the Type 1493 Precision Decade Transformer.

The Type 1493 for bench use (part number 1493-9801) is supplied with end frames. For installation in a relay rack, the Type 1493 (part number 1493-9811) is supplied with rack supports.

Refer to the Appendix for information on other accessories that are available for use with the Type 1493 Precision Decade Transformer.

Table 1-1

## TYPE 1493 CONTROLS AND CONNECTORS

<i>Reference (Figure 1-1)</i>	<i>Description</i>	<i>Function</i>
1	-0.1 binding post	Terminal for 10% phase-reversed-voltage (refer to paragraph 2.2.3).
2	GND binding post	For ground connection on INPUT side.
3	HIGH and LOW binding post pair	Terminals ( $\frac{3}{4}$ -inch-spaced) for connection of voltage source to INPUT.
4	+1.1 binding post	Terminal for 10% over-voltage (refer to paragraph 2.2.3).
5	Lever-type switches (7)	For setting decades $10^{-1}$ through $10^{-7}$ .
6	Lever	For continuous adjustment of slidewire.
7	HIGH and LOW binding post pair	Terminals ( $\frac{3}{4}$ -inch-spaced) for connection to OUTPUT.
8	GND binding post	For ground connection on OUTPUT side.
9	CONTINUOUS DECADE toggle switch	For connection of slidewire (IN) between output of $10^{-7}$ decade and HIGH output terminal, and disconnection (OUT) of slidewire from circuit.

Table 1-2

## TYPE 1493 ACCESSORIES

<i>Description</i>	<i>Part Number</i>
End-Frame Set (for bench use)	5310-9648
Rack-Support Set (for relay-rack use)	7863-9648

## SECTION 2

# OPERATING PROCEDURE

### 2.1 INSTALLATION.

#### 2.1.1 SPACE REQUIREMENTS.

The instrument is available equipped for bench or relay-rack mounting. For bench mounting, aluminum end frames are supplied to fit the ends of the cabinet. For rack mounting, rack-support brackets are supplied to attach the cabinet and instrument to the relay-rack.

Refer to Figure 2-1. Dimensions are given for space required when the instrument is mounted on a bench (right-hand side of Figure 2-1) and mounted in a relay rack (left-hand side).

#### 2.1.2 MOUNTING.

To remove the end frames and install the instrument in a standard 19-inch relay rack, proceed as follows:

a. To remove the end frames, insert a screwdriver through the holes in the instrument handle and remove the two panel screws from one side of the instrument.

b. Remove the four 10-32 screws with notched washers which are used to attach the end-frame to the side of the instrument.

c. Remove the end frame. Use the same procedure to remove the end frame from the other side of the instrument.

#### NOTE

Reverse steps a through c to install end frames on the instrument.

d. To install the instrument in a relay rack, see Figure 2-2. Attach each support bracket (A) to the relay rack with two 10-32 screws (B). Use the two inside holes in the bracket.

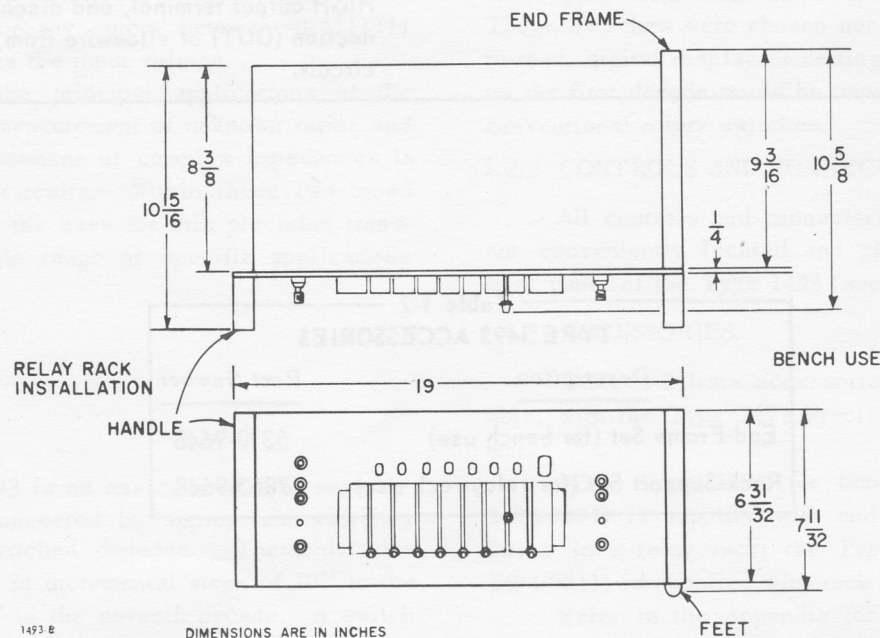


Figure 2-1. Dimensions of the Type 1493 Precision Decade Transformer.

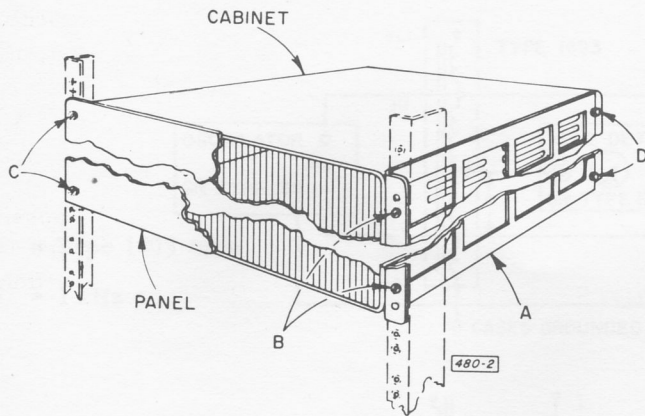


Figure 2-2. Installation of relay-rack model.

e. Slide the instrument onto the brackets as far as it will go.

f. Insert the four panel screws with attached washers (C) through the panel and the bracket. Insert a screwdriver through the hole in the instrument handle and thread screws (C) into the rack.

g. Toward the rear of each bracket, thread a thumb screw (D) through the slot in the bracket and into the hole in the side of the cabinet.

NOTE

To prepare a rack-mounted instrument for installation of end frames, reverse steps d through g.

2.2 OPERATION.

2.2.1 GENERAL.

The Type 1493 Precision Decade Transformer is a passive device with easy-to-operate controls and connectors. Thus, operation of this instrument is discussed briefly in the following paragraphs, and emphasis is on practical applications described in Section 3.

2.2.2 INPUT REQUIREMENTS.

An ac voltage from 0 volts to a maximum of 350 volts, rms; or 0.35 f (Hz) volts, whichever is smaller, can be connected to the input terminals.

CAUTION

Do not connect a dc voltage to the input terminals of this instrument.

2.2.3 CONNECTIONS.

For most applications, connections will be made to the conventional 3/4-inch-spaced binding posts marked HIGH, LOW, and GND on the INPUT and OUTPUT sides of the front panel. See Figure 1-1. For certain other applications, as in some transformer bridge circuits (see Figures 3-6 and 3-8), the -0.1 or +1.1 terminals may be useful.

2.2.4 RATIO SETTINGS.

To set the instrument to a desired ratio, merely position the individual switch levers to obtain a corresponding readout in the digital-display windows located directly above the decade switches. Set decades that are not used to zero. If the slide wire is not used, switch it out of the circuit. Remember that X in the readout is equal to 10 units.

The -1 position on the decade switches permits the setting of ratios to -0.1111111, and it also allows a step backward that might otherwise require the re-setting of preceding decades. For example, consider a ratio of 0.4999998. In addition to the obvious setting of 4, 9, 9, 9, 9, 9, 8, this ratio is also obtained with either of two additional settings:

5, 0, 0, 0, 0, -1, 8

or

4, X, 0, 0, 0, -1, 8

With either of these settings, the algebraic sum yields:

$$\begin{array}{r}
 +0.5000008 \\
 -0.0000010 \\
 \hline
 +0.4999998 \text{ desired ratio.}
 \end{array}$$

This feature is particularly useful when changing from one ratio to another.

When desired, the output of one step in the 10<sup>-7</sup> decade can be continuously divided, with graduated-dial readout of 50 graduations.



## SECTION 3

# APPLICATIONS

### 3.1 GENERAL.

The following paragraphs describe specific applications and circuits for determining unknown ratios, and the measurement of impedances in transformer bridge circuits. Where applicable, equations and useful circuit data are included.

Certain accessories are required to duplicate the circuits discussed:

- Voltage Source. The GR Type 1311 Audio Oscillator (refer to Appendix), or equivalent, is recommended as a suitable source of voltage, and a means of obtaining correct amplitude and frequency. Bear in mind that the best accuracy of the Type 1493 is obtained when the operating frequency is in the vicinity of 1 kHz.
- Null Detector. The GR Type 1232 Tuned Amplifier and Null Detector (refer to Appendix), or equivalent, is recommended to indicate a null. The high resolution of the Type 1493 requires a high-sensitivity detector if its total capabilities are to be exploited. With a 100-V input, for example, one part in  $10^9$  is but  $0.1 \mu\text{V}$ .
- Standards. In general, available standards for bridge impedance measurements will be known to lesser

accuracy than that of the Type 1493 Precision Decade Transformer. Thus, the accuracy of the standards, especially in the more exacting applications, will determine measurement accuracy.

### 3.2 RATIO MEASUREMENTS.

#### 3.2.1 BASIC CIRCUIT.

Simple, low-accuracy ratio measurements can be made using the circuit of Figure 3-1. Because there is no attempt at phase correction, the two components  $Z_1$  and  $Z_2$  must have roughly comparable phase angles, such as two resistors of the same construction. Due to the uncorrected phase defect, there will not be a sharp null. Nevertheless, measurements to an accuracy of 0.1% (1 turn in 1000), or better, are readily obtained.

#### 3.2.2 PHASE-CORRECTED MEASUREMENTS.

Phase-corrected ratio measurements are possible using the circuit of Figure 3-2. The switch in this circuit changes the phase-defect correction from lag to lead.

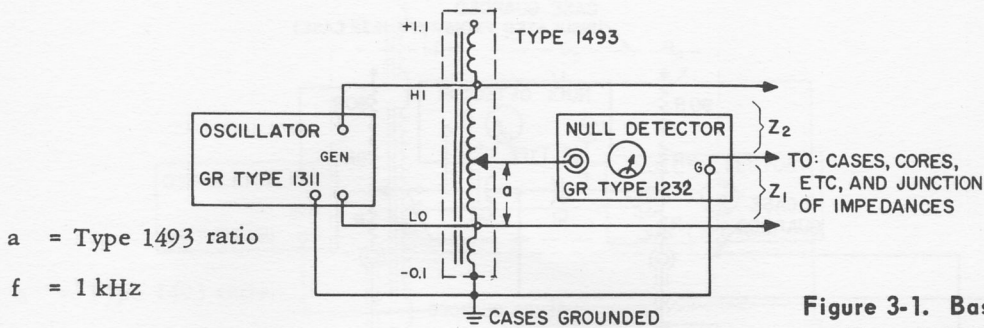
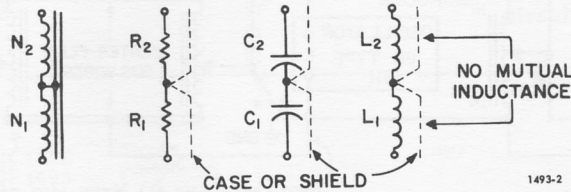


Figure 3-1. Basic ratio measuring circuit using a Type 1493 Precision Decade Transformer.

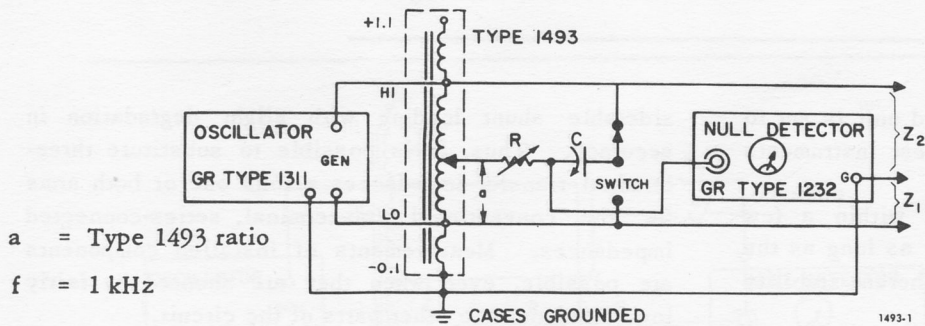


1493-2

Basic Ratio equations:

$$\frac{N_1}{N_1 + N_2} = \frac{R_1}{R_1 + R_2} = \frac{C_2}{C_1 + C_2} = \frac{L_1}{L_1 + L_2} = \frac{Z_1}{Z_1 + Z_2} = a$$

$$\frac{N_1}{N_2} = \frac{R_1}{R_2} = \frac{C_2}{C_1} = \frac{L_1}{L_2} = \frac{Z_1}{Z_2} = \frac{a}{1-a}$$



1493-1

Figure 3-2. Ratio measuring circuit with phase correction, using a Type 1493 Precision Decade Transformer.

#### NOTE

The same equations shown for the circuit in Figure 3-1 apply to this circuit (Figure 3-2).

This circuit will yield measurement accuracies of a few parts in the  $10^{-7}$  decade and is more than adequate for all but the most precise applications.

#### 3.2.3 HIGH-PRECISION MEASUREMENT.

When calibration-quality measurements are required, the circuit of Figure 3-3 permits the highest degree of accuracy and repeatability.

This circuit permits calibration of the test instrument (Type 1493 or equivalent decade transformer)

under conditions which are known, easily duplicated when appropriate equipment is available, and with errors reduced to a minimum.

The guard circuit eliminates stray-capacitance effects. The phase circuit provides the means to correct for phase defects without changing the magnitude of the voltages obtained from the standard and test transformers.

A precision comparison between the standard unit and a test unit can be made if the phase difference between the two instruments is carefully balanced out. In Figure 3-3, the phase instrument applies a voltage through a differential capacitor ( $C_1$  and  $C_2$ ) to the standard and test instruments. A null is obtained by adjusting the differential capacitor, and the resistors (R) if necessary. The phase instrument is

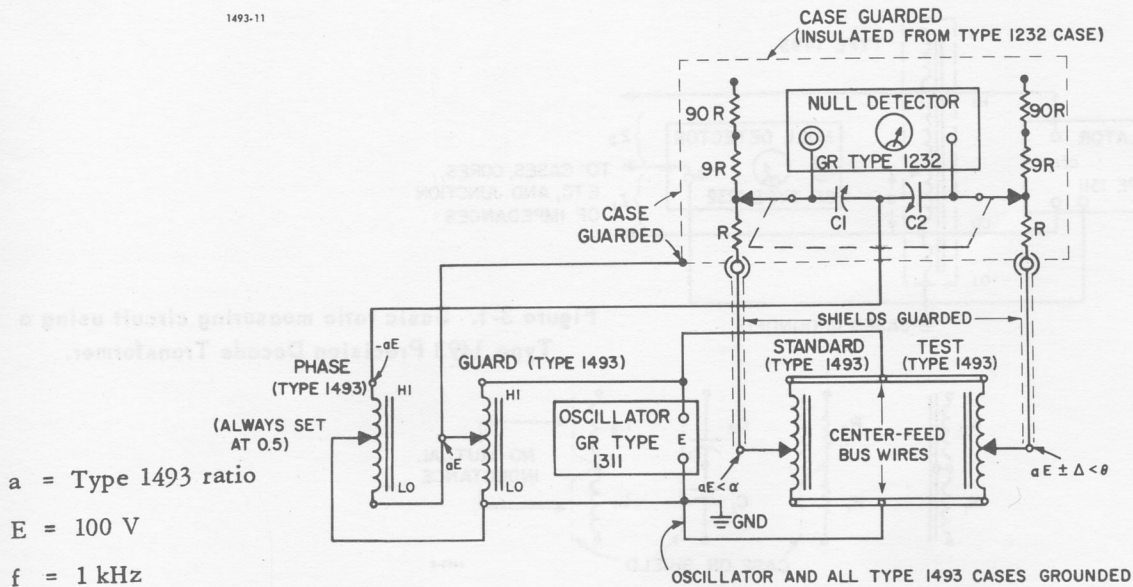


Figure 3-3. Ratio-calibration circuit using a Type 1232 Tuned Amplifier and Null Detector, a Type 1311 Oscillator, and Type 1493 Precision Decade Transformers.

NOTE

Test instrument (Type 1493) lags standard instrument (Type 1493) when  $C_1 > C_2$ ; leads standard instrument (Type 1493) when  $C_1 < C_2$ .

$$\phi = 4\pi 10^{-3} \sum R [C_1 - C_2]$$

where  $\phi = \mu$  radians

$C_1$  and  $C_2$  in pF.

$$\theta = \alpha \pm \phi = \text{phase angle of unknown}$$

where  $\alpha = \text{phase angle of standard}$

always set to a ratio of 0.5. The guard unit is set to the same ratio as the standard and test instruments each time a measurement is made.

Measurements may be repeated within a few parts in  $10^{-9}$  over long periods of time, as long as the standard and test units maintain the inherent stability of a Type 1493.

### 3.3 BRIDGE MEASUREMENTS.

The Type 1493 Precision Decade Transformer is well suited for use in transformer bridge circuits. The technique used in the design and manufacture of this instrument assures a degree of ratio accuracy so high that the accuracy of other bridge components is the limiting factor in practically all cases.

A transformer bridge substitutes two inductively coupled ratio arms for two of the arms in the familiar four-arm bridge. Complex impedances may then be compared by means of the ratio between the two inductively coupled arms. Furthermore, the transformer bridge possesses certain advantages over conventional bridges in that the internal impedance of the transformer bridge arms is sufficiently low to tolerate con-

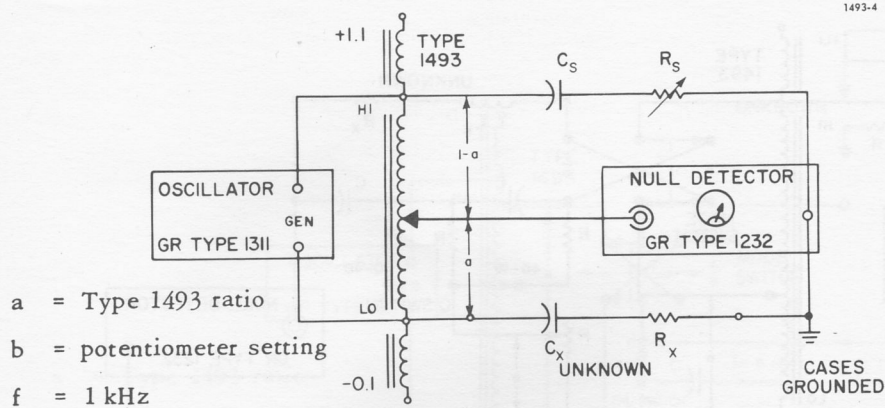
siderable shunt loading with slight degradation in accuracy. Thus, it is possible to substitute three-terminal transfer impedances across one or both arms for the conventional two-terminal, series-connected impedances. Measurements of installed components are possible, even when they are shunted by fairly low impedances to other parts of the circuit.

#### 3.3.1 SERIES- AND PARALLEL-CAPACITANCE BRIDGES.

The simplest capacitance bridge resembles Figure 3-1 in which  $Z_1$  is the unknown and  $Z_2$  is the standard. The standard arm consists of at least two elements, the parameter in question, such as capacitance, and a means of matching the phase angle of the unknown. Figures 3-4 and 3-5 illustrate simple series- and parallel-capacitance bridges.

#### 3.3.2 PARALLEL-INDUCTANCE TRANSFORMER BRIDGE.

Figure 3-6 shows a parallel-inductance transformer bridge in which two transfer impedances are used to provide, respectively, the reactive and resistive components of the standard arm.



- $a$  = Type 1493 ratio  
 $b$  = potentiometer setting  
 $f$  = 1 kHz

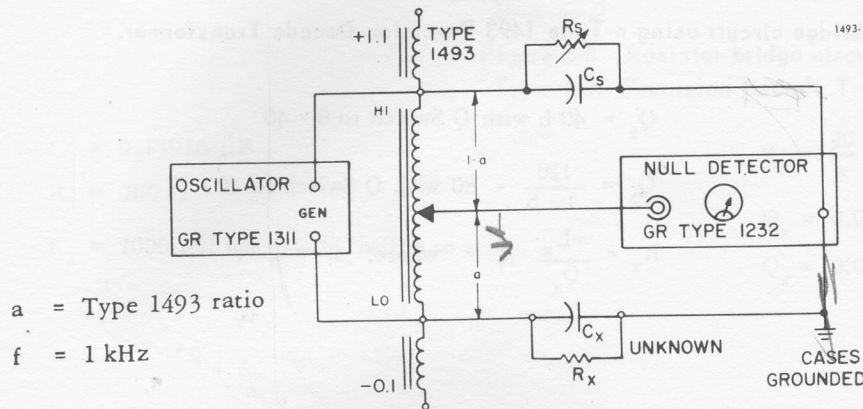
$$C_x = \frac{1-a}{a} C_s$$

$$R_x = \frac{a}{1-a} R_s$$

$$D_x = \omega C_x R_x = \omega C_s R_s$$

where:  $\omega = 2\pi f$   
 $D$  = Dissipation Factor  
 $C_s$  and  $R_s$  are standard-arm components

**Figure 3-4. Series-capacitance bridge circuit using a Type 1493 Precision Decade Transformer.**



- $a$  = Type 1493 ratio  
 $f$  = 1 kHz

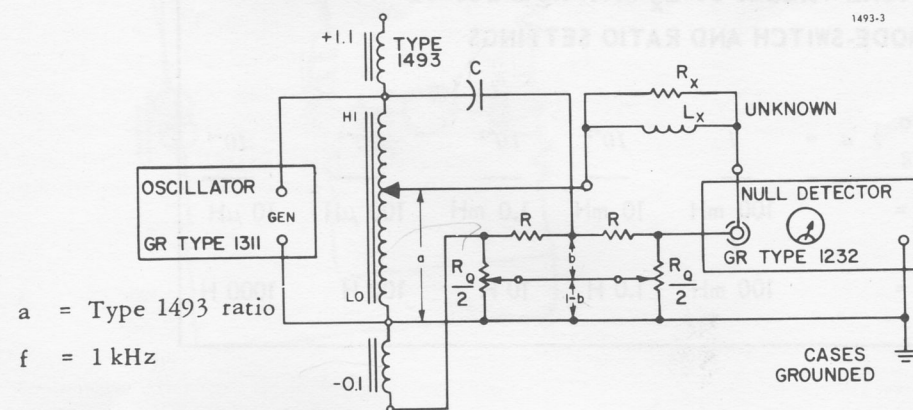
$$C_x = \frac{1-a}{a} C_s$$

$$R_x = \frac{a}{1-a} R_s$$

$$D_x = \frac{1}{\omega C_x R_x} = \frac{1}{\omega C_s R_s}$$

where:  $\omega = 2\pi f$   
 $D$  = Dissipation Factor  
 $C_s$  and  $R_s$  are standard-arm components

**Figure 3-5. Parallel-capacitance bridge circuit using a Type 1493 Precision Decade Transformer.**



- $a$  = Type 1493 ratio  
 $f$  = 1 kHz

$$C = \frac{0.2}{\omega^2 L_e} = \frac{0.005066}{L_e} \mu F$$

$$R = \sqrt{5} \omega L_e = 14,049 L_e \Omega$$

$$L_e = \text{effective inductance} = CR^2$$

Note: Select  $L_e$  to be 1/10 of the maximum desired inductance.

$$L_x = 10 a L_e$$

$$R_x = 10 a R_Q \frac{b}{1-b}$$

**Figure 3-6. Parallel-inductance bridge circuit using a Type 1493 Precision Decade Transformer.**

Example:

$$L_x \text{ max} = 10 \text{ H, therefore } L_e = 1.0 \text{ H}$$

$$C = \frac{0.005066}{L_e} = 0.5066 \mu F$$

$$R = 14,049 L_e = 14.049 \text{ k}\Omega$$

$$Q_x = \frac{6.2832}{6.2832} \frac{b}{1-b} = \frac{b}{1-b}$$

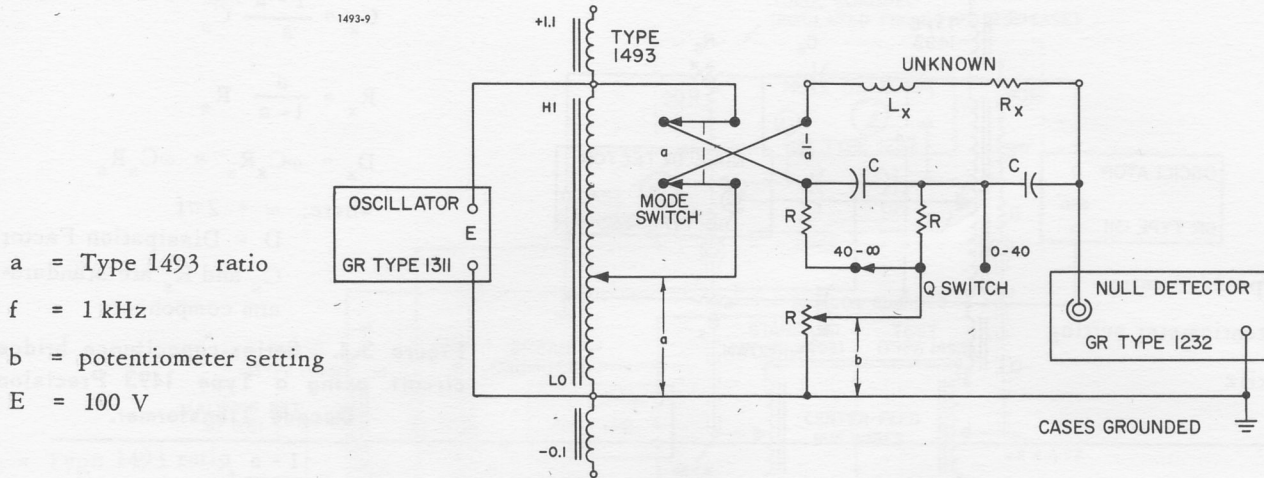
$$Q_x = \frac{R_x}{\omega L_x} = \frac{R_Q}{\omega L_e} \frac{b}{1-b} = \frac{R_Q}{\omega L_e} \text{ when } b = 0.5$$

$$\text{where: } a \left[ \frac{1}{\omega L_x} + \frac{1}{R_x} \right] = 0.1 \left[ \frac{1}{\omega L_e} + \frac{1}{Z_{TQ}} \right]$$

$$Z_{TQ} = R_Q \frac{b}{1-b}$$

$$Q = \frac{\omega L}{R}$$

$$\omega = 2\pi f$$



a = Type 1493 ratio  
 f = 1 kHz  
 b = potentiometer setting  
 E = 100 V

Figure 3-7. Series-inductance bridge circuit using a Type 1493 Precision Decade Transformer.

$R = 6,283.19 \Omega$

$C = 0.506606 \mu F$

$L_x = 100a \text{ mH}$  with Mode Switch to a

$L_x = \frac{100 \text{ mH}}{a}$  with Mode Switch to  $\frac{1}{a}$

$Q_x = 40 b$  with Q Switch to 0 - 40

$Q_x = \frac{120}{1-b} - 80$  with Q Switch to 40 - ∞

$R_x = \frac{\omega L_x}{Q_x}$  where:  $\omega = 2\pi f$

*Residual*

Table 3-1  
 TYPICAL VALUES OF  $L_x$  WITH RESPECT TO  
 MODE-SWITCH AND RATIO SETTINGS

Mode-Switch Position	Ratio Setting	$a = 1$	$10^{-1}$	$10^{-2}$	$10^{-3}$	$10^{-4}$
a	$L_x =$	100 mH	10 mH	1.0 mH	100 $\mu H$	10 $\mu H$
$\frac{1}{a}$	$L_x =$	100 mH	1.0 H	10 H	100 H	1000 H

3.3.3 SERIES-INDUCTANCE BRIDGE.

In Figure 3-7, a single adjustable transfer impedance provides both reactance and resistive balance. This bridge covers practically the entire range of normal inductance values with but a single standard arm.

See Table 3-1 for typical values of  $L_x$  as determined by the mode switch (position a or 1/a) and ratio settings of the transformer. The accuracy of these

values, given as a  $\pm$  percentage of  $L_x$ , is dependent upon the accuracy of the standards used.

3.3.4 RESISTANCE TRANSFORMER BRIDGE.

Alternating-current resistance measurements can be made with the circuit of Figure 3-8. This circuit simulates a variable shunt capacitance for parallel resistance, and a transfer impedance to simulate a variable series inductance for series resistance.

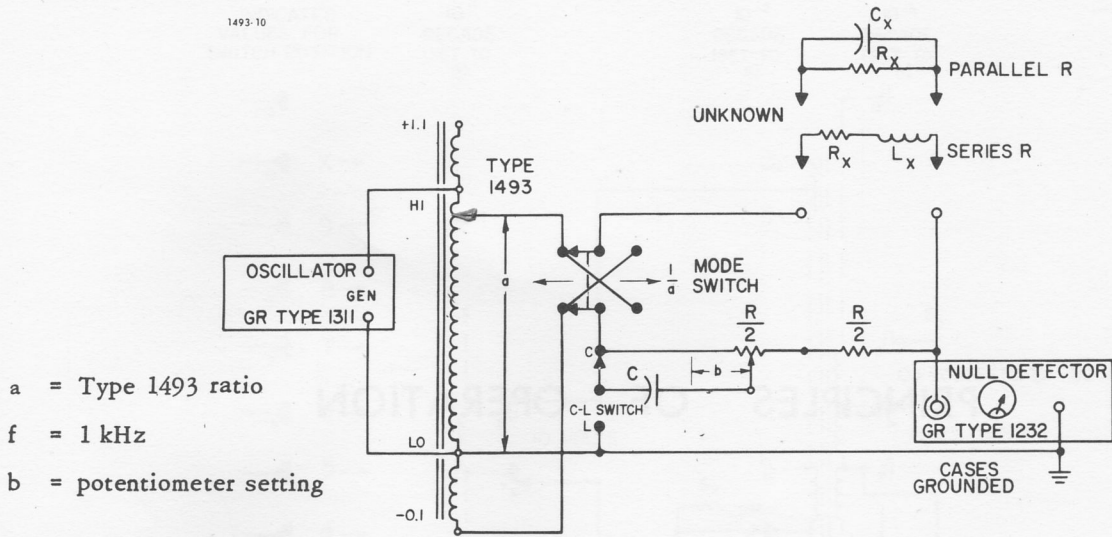


Figure 3-8. Resistor bridge circuit using a Type 1493 Precision Decade Transformer.

$$C = 0.15916 \mu\text{F}$$

$$R = 100 \Omega$$

$$R_x = 1000 a \Omega \text{ with Mode Switch to } a$$

$$R_x = \frac{10}{a} \Omega \text{ with Mode Switch to } \frac{1}{a}$$

$$Q_x = 0.025 b^2 \text{ with C - L Switch to C}$$

$$Q_x = 0.025(2b - b^2) \text{ with C - L Switch to L}$$

## PRINCIPLES OF OPERATION

### 4.1 PHYSICAL CONSTRUCTION.

The Type 1493 Precision Decade Transformer is actually an assembly of four separate transformers, each comprised of a high-permeability toroidal core with one or more tapped windings. See Figure 4-1.

Each transformer winding is a multifilar cable whose individual conductors are obtained from a single spool of wire in order to maintain equality of resistance. These conductors are randomly dispersed and then lightly twisted into a bundle to form a cable. The winding is completed by connecting the individual conductors end-to-end aiding, with taps brought out

from the junction ends. Thus, a high and constant mutual inductance is maintained between the various conductors that make up the steps of each winding. This method also ensures that the resistance and capacitance of each step is nearly equal.

The first transformer has a single winding of twelve equal sections wound with the largest possible wire to minimize the resistance drop under the loading of subsequent transformers. (The number of turns is fixed by voltage considerations). Also, the heavier insulation on larger wire can withstand the maximum stress (420 V, rms) that may occur between adjacent wires in the multifilar cable.

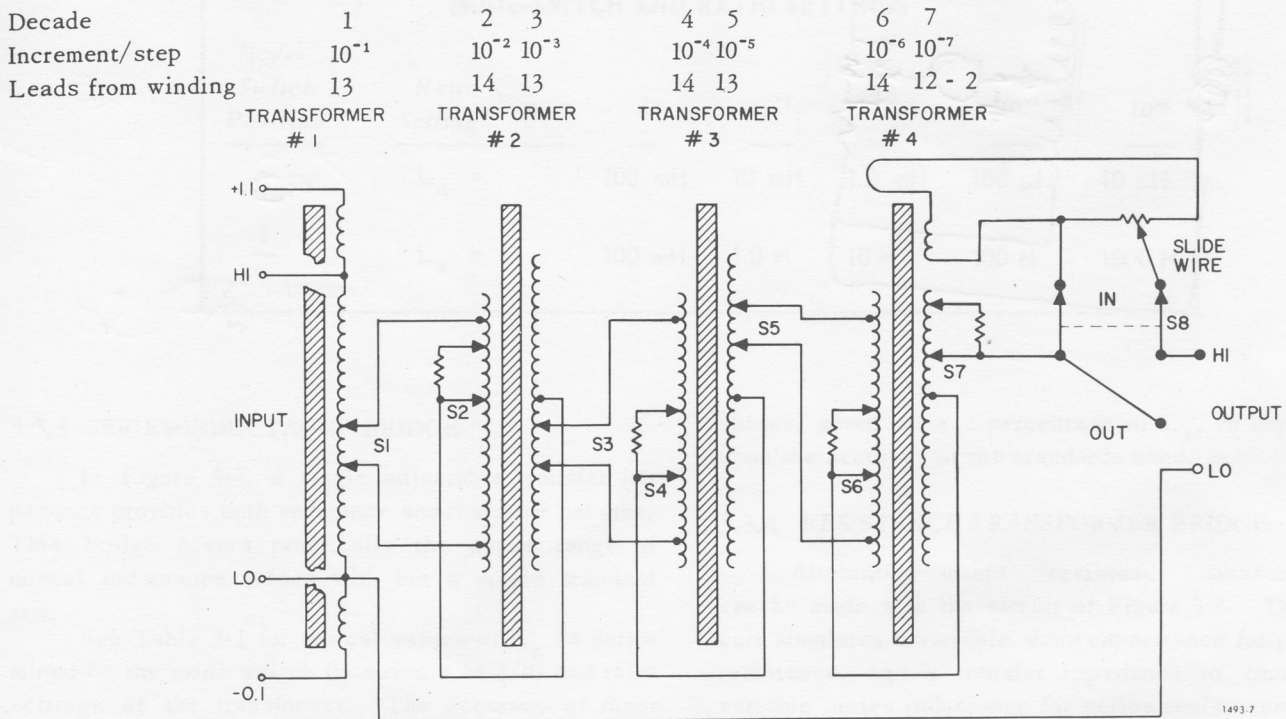


Figure 4-1. Simplified layout showing major components and construction of the Type 1493 Precision Decade Transformer.

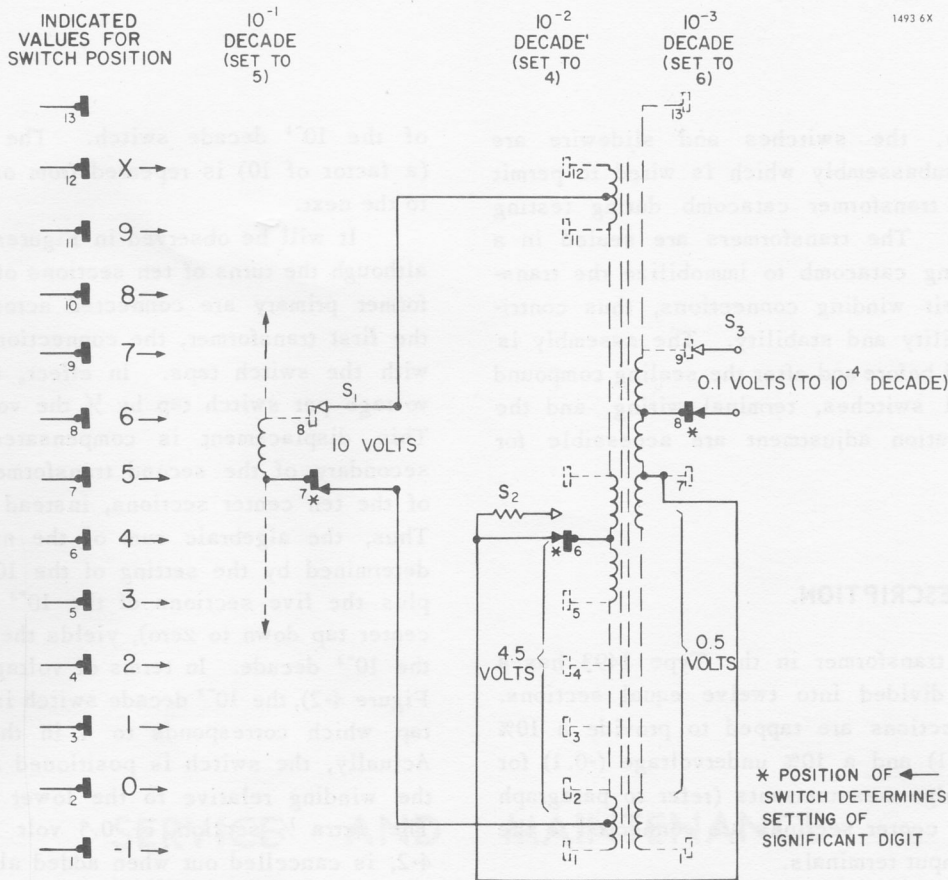


Figure 4-2. Type 1493 displacement method of connection to reduce internal resistance and inductance, and maintain a more constant output impedance.

The effect of loading on the first ( $10^{-1}$ ) decade is important. If the total error is to be within the specified  $\pm 2$  digits in the  $10^{-7}$  decade, the loading error must be less than 0.000002.

The primary winding of the second transformer is bridged across successive decade sections of the first winding by the  $10^{-1}$  decade switch. (See Figures 4-1, 4-2, and 5-1). This switch is a two-sided, printed-circuit, fixed-contact array, traversed by moving contacts on each side of the printed circuit. The contacts are offset and spaced so that at least one set of contacts is always closed, thus ensuring continuity between input and output at all times. The redundant nature of this switch ensures reliability and low contact resistance.

In order to reduce transients in the output during switching, the  $\frac{1}{4}$ -watt resistors in decade switches  $S_2$ ,  $S_4$ ,  $S_6$ , and  $S_7$  (see Figures 4-1 and 5-1), perform the same continuity function as the offset switch contacts in  $S_1$ ,  $S_3$ , and  $S_5$ .

Proceeding from input to output, the accuracy restraints imposed by loading are relaxed by an order of magnitude per decade. Consequently, transformers

3 and 4 are wound with fewer turns of larger wire on smaller cores to minimize internal resistance and inductance.

One conductor of the multifilar secondary winding on the fourth transformer (see Figure 4-1) is isolated from the winding proper; this conductor is the winding that drives the slidewire. To compensate for the voltage drop in this winding, which results from the slidewire current, a turn is added by looping one lead through the core. The end of the slidewire is adjusted so that the voltage at maximum setting is equal to the voltage across the other secondary sections. In order to reduce zero ambiguity to a minimum, current from the exciting coil is supplied to the slidewire through a knife edge at the zero setting of the slidewire. A two-position switch ( $S_8$ ) is used to connect the HIGH output terminal to the slidewire when switched to the IN position. When switched to the OUT position, the slidewire and its drive winding are disconnected from the circuit and the HIGH output terminal is connected directly to the output of the  $10^{-7}$  decade through the decade switch  $S_7$ .



Physically, the switches and slidewire are mounted on a subassembly which is wired to permit access to the transformer catacomb during testing and calibration. The transformers are sealed in a magnetic-shielding catacomb to immobilize the transformers and their winding connections, thus contributing to reliability and stability. The assembly is thoroughly tested before and after the sealing compound is poured. All switches, terminal wiring, and the slidewire calibration adjustment are accessible for inspection.

## 4.2 CIRCUIT DESCRIPTION.

The first transformer in the Type 1493 has a single winding divided into twelve equal sections. The two end sections are tapped to provide a 10% overvoltage (+1.1) and a 10% undervoltage (-0.1) for use in some bridge measurements (refer to paragraph 2.2.3). The ten center sections are connected to the HIGH and LOW input terminals.

The primary and secondary windings of the other transformers are switch tapped for twelve equal setting increments (-1 to X). The secondary of the fourth transformer also uses an additional winding in the slidewire circuit.

The *equivalent* of ten sections of the primary of the second transformer is connected across one section of the first transformer winding (see Figure 4-2). Assuming an input voltage of 100 volts, for example, the  $10^{-1}$  decade switch will pick off and supply 10 volts across the primary of the second transformer. This 10-volt input to the second transformer will remain constant, regardless of the setting

of the  $10^{-1}$  decade switch. The voltage reduction (a factor of 10) is repeated from one decade winding to the next.

It will be observed in Figures 4-2 and 5-1, that although the turns of ten sections of the second transformer primary are connected across one section of the first transformer, the connections do not coincide with the switch taps. In effect, this displaces the voltage per switch tap by  $\frac{1}{2}$  the voltage per section. This displacement is compensated by feeding the secondary of the second transformer at the midpoint of the ten center sections, instead of the lower end. Thus, the algebraic sum of the number of sections determined by the setting of the  $10^{-2}$  decade switch, plus the five sections of the  $10^{-3}$  winding (from the center tap down to zero), yields the indicated ratio of the  $10^{-2}$  decade. In terms of voltage (see example in Figure 4-2), the  $10^{-2}$  decade switch is set at the switch tap which corresponds to 4 in the digital readout. Actually, the switch is positioned at  $4\frac{1}{2}$  sections of the winding relative to the lower input connection. The extra  $\frac{1}{2}$  section, or 0.5 volt shown in Figure 4-2, is cancelled out when added algebraically to the 0.5 volt (5 sections of 0.1 volts-per-section) of the lower half of the  $10^{-3}$  decade winding.

The purpose of the displacement circuitry described above is twofold:

- It reduces the maximum internal resistance and inductance referred to the output.
- It tends to keep the output impedance more constant, and closer to the average value at all times. This is helpful in certain types of measurements in which the internal impedance is an important consideration.

This same method of connection is used for the third and fourth transformers.

## SECTION 5

# SERVICE AND MAINTENANCE

### 5.1 WARRANTY.

We warrant that each new instrument manufactured and sold by us is free from defects in material and workmanship, and that, properly used, it will perform in full accordance with applicable specifications for a period of two years after original shipment. Any instrument or component that is found within the two-year period not to meet these standards after examination by our factory, Sales Engineering Office, or authorized repair agency personnel, will be repaired, or, at our option, replaced without charge, except for tubes or batteries that have given normal service.

### 5.2 SERVICE.

The two-year warranty stated above attests the quality and workmanship in our products. When difficulties do occur, our service engineers will assist in any way possible. If the difficulty cannot be eliminated by use of the following service instructions, please write or phone our Service Department (see rear cover), giving full information of the trouble and of steps taken to remedy it. Be sure to mention the serial and type numbers of the instrument.

Before returning an instrument to General Radio for service, please write to our Service Department or nearest Sales Engineering Office, requesting a Returned Material Tag. Use of this tag will ensure proper handling and identification. For instruments not covered by the warranty, a purchase order should be forwarded to avoid unnecessary delay.

### 5.3 REPAIR AND CALIBRATION.

This instrument has been thoroughly tested and calibrated, and should, with normal use, remain calibrated throughout its life.

#### CAUTION

It is recommended that the instrument be returned to General Radio for service that requires replacement of major parts, detailed trouble shooting of the circuit, or precision calibration. Routine cleaning, and replacement of external parts such as switch knobs and binding posts, on the other hand, can be handled by competent user personnel.

## PARTS LIST

Ref No.	Description	Part No.
J101	Jack, Binding post, +1.1 input	4060-0418
J102	Jack, Binding post, HIGH input	4060-0418
J103	Jack, Binding post, LOW input	4060-0418
J104	Jack, Binding post, GND input	0938-2016
J105	Jack, Binding post, -0.1 input	4060-0418
J106	Jack, Binding post, HIGH output	4060-0418
J107	Jack, Binding post, LOW output	4060-0418
J108	Jack, Binding post, GND output	0938-2016
R101A } R101B }	Resistor, Slidewire	1493-2000
R102A } R102B } R102C } R102D }	Resistor, Composition, 10 k $\Omega$ $\pm$ 5% 1/4 W	6099-3105
	Resistor, Composition, 1 k $\Omega$ $\pm$ 5% 1/4 W	6099-2105
S101	Switch, Lever type, 10 <sup>-1</sup> decade	1493-2110
S102	Switch, Lever type, 10 <sup>-2</sup> decade	1493-2100
S103	Switch, Lever type, 10 <sup>-3</sup> decade	1493-2110
S104	Switch, Lever type, 10 <sup>-4</sup> decade	1493-2120
S105	Switch, Lever type, 10 <sup>-5</sup> decade	1493-2110
S106	Switch, Lever type, 10 <sup>-6</sup> decade	1493-2120
S107	Switch, Lever type, 10 <sup>-7</sup> decade	1493-2120
S108	Switch, 2-position toggle, CONTINUOUS DECADE	7910-1500
T101	Transformer, Toroid	1493-2010
T102	Transformer, Toroid	1493-2020
T103	Transformer, Toroid	1493-2040
T104	Transformer, Toroid	1493-2030
Mechanical Replacement Parts		
	Switch Handle, for S101 through S108	1615-0470
	Handles, Instrument	5360-2017

TYPICAL SWITCH SETTINGS

5

S101

10<sup>-1</sup>

3

S102

S102

10<sup>-2</sup>

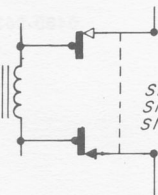
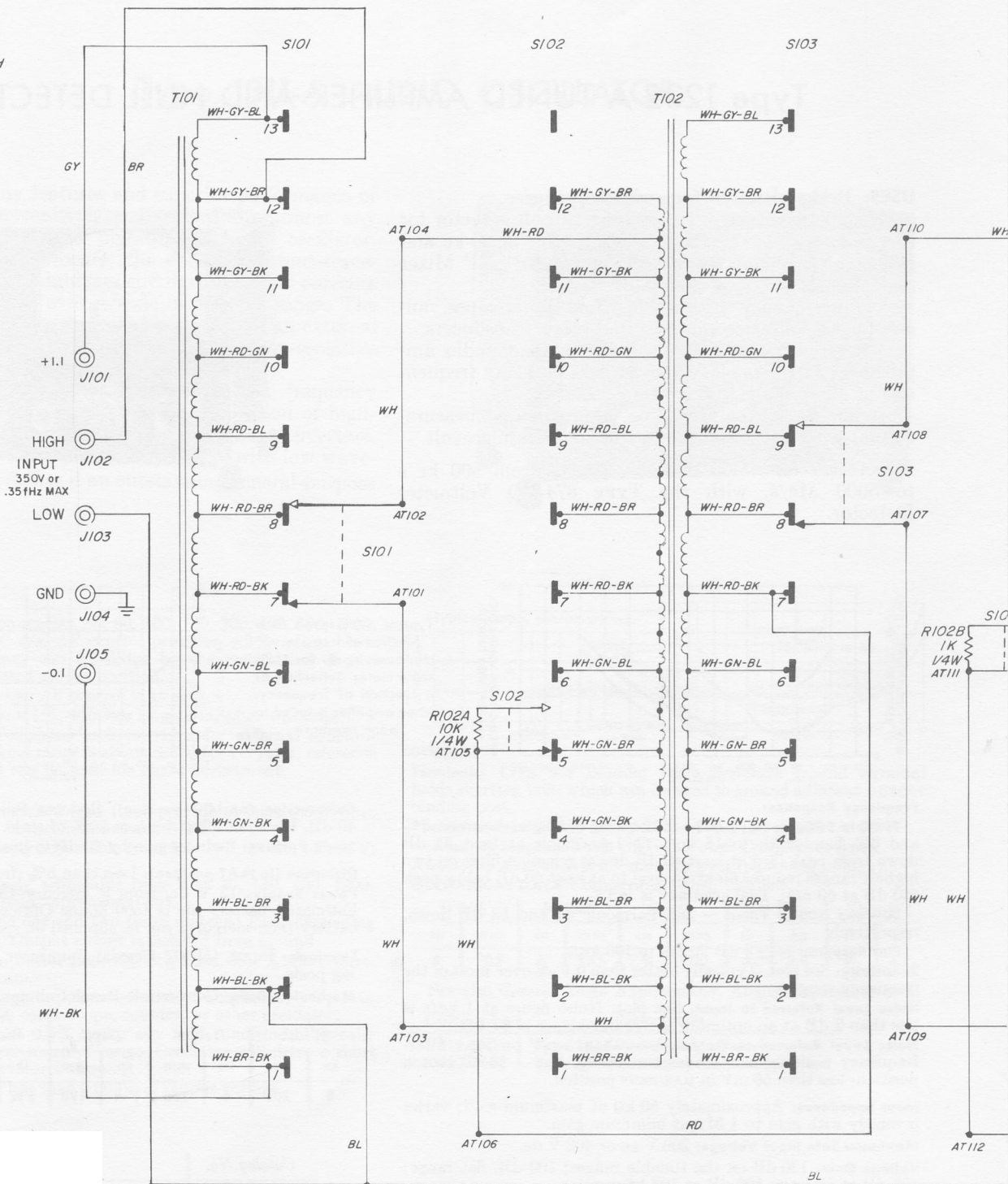
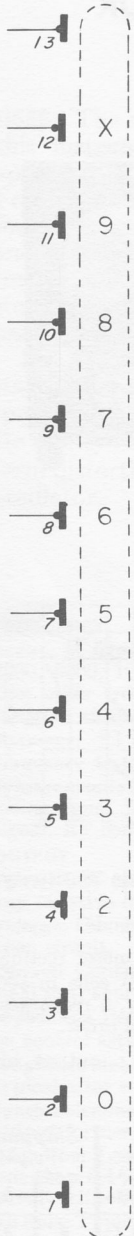
6

S103

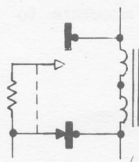
S103

10<sup>-3</sup>

INDICATED VALUES FOR SWITCH POSITION



S102  
S104  
S106  
S107



SWITCHING EXPLANATION  
HOW THEY WORK - SIGNIFICANCE  
OF → VS → & WHICH  
CORRESPONDS TO INDICATED  
VALUE, ETC

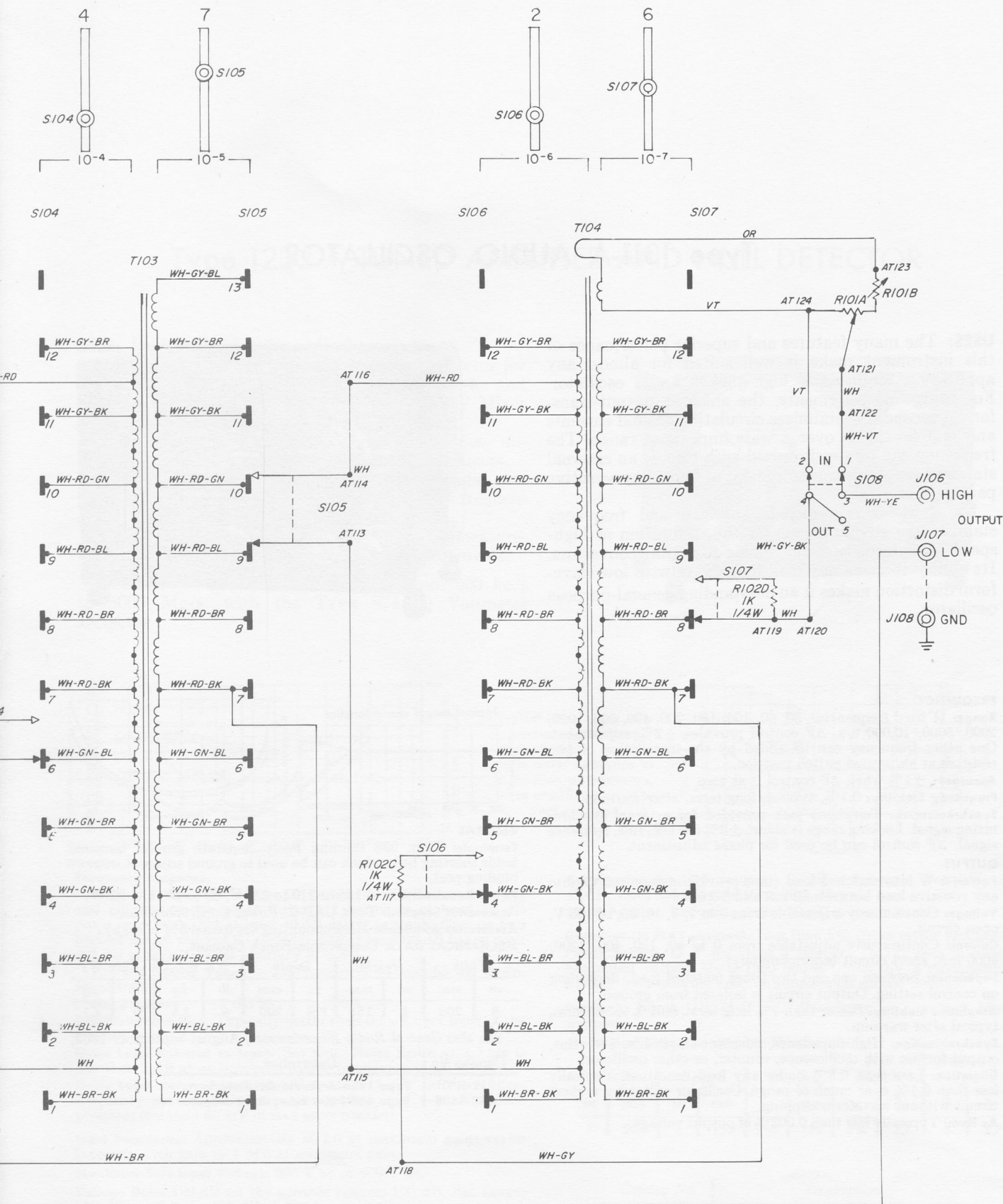


Figure 5-1. Schematic diagram for Type 1493 Precision Decade Transformer.

## Type 1311-A AUDIO OSCILLATOR

**USES:** The many features and superior performance of this instrument make it well suited for almost any application requiring a high-quality audio oscillator. For bridge measurements, the shielded output-transformer secondary minimizes circulating ground currents and matches loads over a wide impedance range. The frequency can be synchronized with that of an external standard for precise measurement of frequency-sensitive parameters.

Its short-term amplitude stability and frequency stability are advantageous for the calibration of high-speed level recorders and analog-to-digital converters. Its ability to drive any load impedance with low waveform distortion makes it an outstanding general-purpose oscillator.



### FREQUENCY

**Range:** 11 fixed frequencies, 50, 60, 100, 120, 200, 400, 500, 1000, 2000, 5000, 10,000 c/s.  $\Delta F$  control provides  $\pm 2\%$  adjustment. One other frequency can be added by the installation of two resistors at an unused switch position.

**Accuracy:**  $\pm 1\%$  when  $\Delta F$  control is at zero.

**Frequency Stability:** 0.1%, typical, long-term, after warmup.

**Synchronization:** Telephone jack provided for external synchronizing signal. Locking range is about  $\pm 3\%$  for 1-V, rms, reference signal.  $\Delta F$  control can be used for phase adjustment.

### OUTPUT

**Power:** 1 W into matched load (taps provide at least 0.5 W into any resistive load between 80 m $\Omega$  and 8 k $\Omega$ .)

**Voltage:** Continuously adjustable from 0 to 1, 3, 10, 30, or 100 V, open circuit.

**Current:** Continuously adjustable from 0 to 40, 130, 400, 1300, 4000 mA, short circuit (approximately).

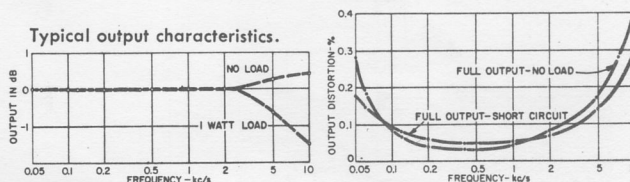
**Impedance:** Between one and two times matched load, depending on control setting. Output circuit is isolated from ground.

**Amplitude Stability:** Better than 1% long term, 0.01% short term, typical after warmup.

**Synchronization:** High-impedance, constant-amplitude, 1-V, rms, output for use with oscilloscope, counter, or other oscillator.

**Distortion:** Less than 0.5% under any load condition. Typically less than 0.1% over much of range. Oscillator will drive a short circuit without waveform clipping.

**Ac Hum:** Typically less than 0.003% of output voltage.



### GENERAL

**Terminals:** TYPE 938 Binding Posts. Separate ground terminal holds shorting link, which can be used to ground adjacent OUTPUT binding post.

**Power Required:** 105 to 125 or 210 to 250 V, 50 to 400 c/s. 22 W.

**Accessories Supplied:** TYPE CAP-22 Power Cord, spare fuses.

**Accessories Available:** Rack-mounting set (panel 5 1/4 in high).

**MECHANICAL DATA** Convertible-Bench Cabinet.

Width		Height		Depth		Net Wt		Ship Wt	
in	mm	in	mm	in	mm	lb	kg	lb	kg
8	205	6	155	7 3/4	200	6	2.8	9	4.1

See also *General Radio Experimenter*, August-September 1962.

Catalog No.	Description
1311-9701	Type 1311-A Audio Oscillator
0480-9638	Type 480-P308 Relay-Rack Adaptor Set

# Type 1232-A TUNED AMPLIFIER AND NULL DETECTOR

## USES: Bridge detector for audio frequencies.

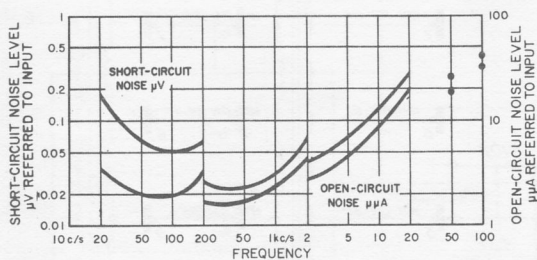
Extremely sensitive, heterodyne, rf null detector for frequencies up to 10 Mc/s, when used as a 20-kc and 100-kc i-f amplifier with the TYPE 1232-P1 RF Mixer and appropriate local oscillator.

Audio-frequency preamplifier for oscilloscopes, microphones, vibration pickups, and other transducers.

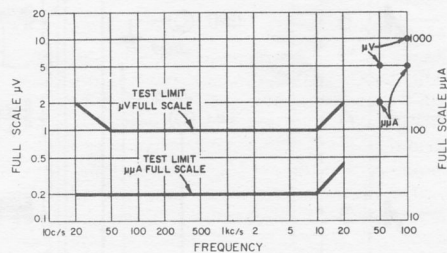
General-purpose, tunable, or broadband audio amplifier ( $\pm 3$  dB from 20 c/s to 20 kc/s plus spot frequencies at 50 kc/s and 100 kc/s).

Audio wave analyzer (for approximate measurements) with a sensitivity of a fraction of a microvolt.

Detector for modulated frequencies from 500 kc/s to 5000 Mc/s, with the TYPE 874-VQ Voltmeter Detector.



Typical noise levels as a function of frequency. Minimum input for full-scale meter deflection as a function of frequency, when amplifier is tuned to peak response.



## Frequency Response:

**Tunable Filters** — 20 c/s to 20 kc/s in 3 ranges; between 2% and 6% bandwidth to 15 kc/s; 2nd harmonic at least 34 dB down from peak, 3rd at least 40 dB down; rejection filter on two highest ranges reduces 60-cycle level to at least 60 dB below peak (50 dB at 50 c/s). Dial accuracy is  $\pm 3\%$ .

**50- and 100-kc Filters** — 2nd harmonic 44 and 53 dB down, respectively.

**Flat Response** —  $\pm 3$  dB 20 c/s to 100 kc/s.

**Sensitivity:** See plot. Typically better than  $0.1 \mu\text{V}$  over most of the frequency range.

**Noise Level Referred to Input:** See plot. Noise figure at 1 kc/s is less than 2 dB at an optimum source impedance of 27 k $\Omega$ .

**Noise Level Referred to Output:** Less than 5 mV on FLAT filter-frequency position, minimum gain setting, and  $-20$  dB switch position; less than 50 mV in MAX SENS position.

**Input Impedance:** Approximately 50 k $\Omega$  at maximum gain; varies inversely with gain to 1 M $\Omega$  at minimum gain.

**Maximum Safe Input Voltage:** 200 V ac or 400 V dc.

**Voltage Gain:** 120 dB on the tunable ranges; 100 dB, flat range; 106 dB at 50 kc/s; 100 dB at 100-kc position.

**Output:** 1 V into 10,000  $\Omega$ . Internal impedance is 3000  $\Omega$ .

**Meter Linearity:** DB differences are accurate to  $\pm 5\% \pm 0.1$  division for input of less than 0.3 V.

**Compression (on LOG position):** Reduces full-scale sensitivity by 40 dB. Does not affect bottom 20% of scale.

**20-dB Position:** Reduces gain by 20 dB in linear mode.

**Distortion (in FLAT position):** Less than 5% (from meter rectifiers).

**Power Supply:** 12 V dc, from 9 mercury (M72) cells in series. Estimated battery life is 1500 hours. Optionally, a rechargeable battery (non-mercury) can be supplied on special order.

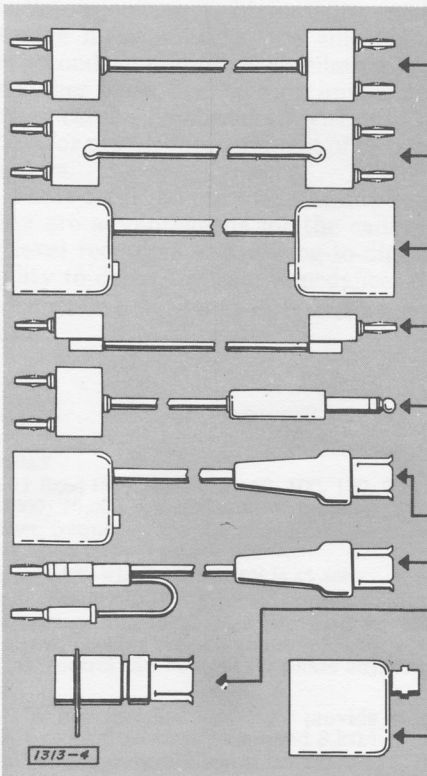
**Terminals:** Input, GR874 Coaxial Connector, output, binding posts.

**Mechanical Data:** Convertible-Bench Cabinet.

Width		Height		Depth		Net Weight		Shipping Weight	
in	mm	in	mm	in	mm	lb	kg	lb	kg
8	205	6	155	7½	190	5¾	2.7	8	3.7

Catalog No.	Description
1232-9701	Type 1232-A Tuned Amplifier and Null Detector
0480-9638	Type 480-P308 Relay-Rack Adaptor Set

# Type 1313-A AUDIO OSCILLATOR



- |          |  |           |
|----------|--|-----------|
| 274-NQ   | Double-plug patch cord, in-line cord, 36" long         | 0274-9860 |
| 274-NQM  | Double-plug patch cord, in-line cord, 24" long         | 0274-9896 |
| 274-NQS  | Double-plug patch cord, in-line cord, 12" long         | 0274-9861 |
| 274-NP   | Double-plug patch cord, right-angle cord, 36" long     | 0274-9880 |
| 274-NPM  | Double-plug patch cord, right-angle cord, 24" long     | 0274-9892 |
| 274-NPS  | Double-plug patch cord, right-angle cord, 12" long     | 0274-9852 |
| 274-NL   | Shielded double-plug patch cord, 36" long              | 0274-9883 |
| 274-NLM  | Shielded double-plug patch cord, 24" long              | 0274-9882 |
| 274-NLS  | Shielded double-plug patch cord, 12" long              | 0274-9862 |
| 274-LLB  | Single-plug patch cord, black, 36" long                | 0274-9468 |
| 274-LLR  | Single-plug patch cord, red, 36" long                  | 0274-9492 |
| 274-LMB  | Single-plug patch cord, black, 24" long                | 0274-9847 |
| 274-LMR  | Single-plug patch cord, red, 24" long                  | 0274-9848 |
| 274-LSB  | Single-plug patch cord, black, 12" long                | 0274-9849 |
| 274-LSR  | Single-plug patch cord, red, 12" long                  | 0274-9850 |
| 1560-P95 | Adaptor cable, double-plug to telephone plug, 36" long | 1560-9695 |
| 874-R34  | Coaxial patch cord, double plug to GR874, 36" long     | 0874-9692 |
| 874-R33  | Coaxial patch cord, two plugs to GR874, 36" long       | 0874-9690 |
| 874-Q9   | Adaptor, double plug to GR874                          | 0874-9874 |
| 274-QBJ  | Adaptor, shielded double plug to BNC                   | 0274-9884 |



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