OPERATING INSTRUCTIONS

TYPE 1305-A

LOW-FREQUENCY OSCILLATOR

1305-A

GENERAL RADIO COMPANY

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LOW-FREQUENCY OSCILLATOR

Form 1305-0100-C
May, 1963

GENERAL RADIO COMPANY
WEST CONCORD, MASSACHUSETTS, USA

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Special Request to the User of This Instrument

We believe that the most effective way to make our products more useful is to learn from the experience and opinions of those who use them. For this reason we have included a questionnaire at the rear of this manual. Your answers to the questions contained, based on your experience in using this instrument, will be of great value to General Radio engineers and other personnel concerned with new products. Such comments will have a strong influence on the direction of future development work. The resulting better products will benefit our customers as well as ourselves.

The questionnaire is its own postage-paid envelope. Simply fold as directed, staple, and mail.

Any information you supply will not go outside our Company without your specific authorization. Your reply will be acknowledged, and your questions answered by GR engineers concerned with this instrument. May we have your comments?

SPECIFICATIONS

Frequency Range: 0.01 to 1000 cps in five ranges.

Frequency Control: The main frequency control dial is engraved from 1 to 10 cps. A range switch multiplies the scale frequencies by 0.01, 0.1, 1, 10, and 100.

Frequency Calibration Accuracy: ±2%.

Frequency Stability: Warm-up drift is less than 1% in the first ten minutes, less than 0.2% in the next hour.

Three-Phase Output: At least 10 volts rms, open circuit, line-to-neutral, behind 600 ohms in each phase, constant with frequency to ±5%. Phase voltages are equal to each other within ±2%.

The DIRECT position of the output attenuator switch provides 75 ohms per phase but must not be loaded with less than 600 ohms per phase, wye-connected, or 1800 ohms per phase, delta-connected. A neutral terminal is provided. Phase-difference between adjacent phases is 120° ±2°.

Output power is 167 milliwatts per phase, maximum, into a 3-phase wye-connected load of 600 ohms per phase.

Four-Phase Output: At least 5 volts, rms, line-to-neutral, behind 600 ohms, from the 4-phase adaptor. Phase accuracy, ±3°

Variable-Phase Output:

Maximum Amplitude: Approximately 0.8 volt. Amplitude does not change more than ±0.5 db with PHASE SHIFT dial setting.

Internal Output Impedance: 50,000-ohm potentiometer shunted across the effective source impedance of the variable-phase-shift network. Maximum output impedance is approximately 15,000 ohms.

Phase-Shift Range: 0 to 360°.

Phase-Angle Accuracy: ±3° with respect to any of the main OUTPUT phases. Phase differences up to about 15° can be measured with an accuracy of ±0.5°.

Waveform: Total harmonic content is less than 2% for all output values and for all frequencies for any load except in the DIRECT position of OUTPUT ATTENUATOR switch. For the DIRECT position of the OUTPUT ATTENUATOR switch, total harmonic content is less than 2% for any wye-connected load of more than 600 Ω per leg or delta-connected load of more than 1800 Ω per phase. Line-frequency hum in the output is less than 10 millivolts.

Terminals: Type 938 Binding Posts. Neutral can be connected to the chassis, which can be grounded through a 3-wire power cord.

Mounting: Aluminum, 19-inch, relay-rack panel; aluminum cabinet. For table mounting (Type 1305-AM), aluminum end frames are supplied to fit ends of cabinet; for relay-rack mounting (Type 1305-AR), brackets for holding cabinet in rack are supplied. Relay-rack mounting is so arranged that panel and chassis can be removed from cabinet, leaving cabinet in rack, or cabinet can be removed from rear of rack, leaving panel attached to rack.

Power Supply: 105 to 125 (or 210 to 250) volts, 50 to 60 cps. Total power consumption is 165 watts.

Power input receptacle will accept either 2-wire (Type CAP-35) or 3-wire (Type CAP-22) power cord. Three-wire cord is supplied.

Tube Complement: Four 6197; three each 6BH6, 5963; one each 5651, 12AX7, 6080; six 1N645 crystal diodes; eight 1N191 crystal diodes; one 1N968A crystal diode.

Accessories Supplied: Type CAP-22 Power Cord, three Type 274-MB Double Plugs, spare fuses, Four-Phase Output Adaptor Type 1305-P1.

Dimensions: Panel, (width) 19 x (height) 7 inches; depth behind panel, 12 inches (485 x 180 x 305 mm).

Net Weight: 35 pounds (16 kg).

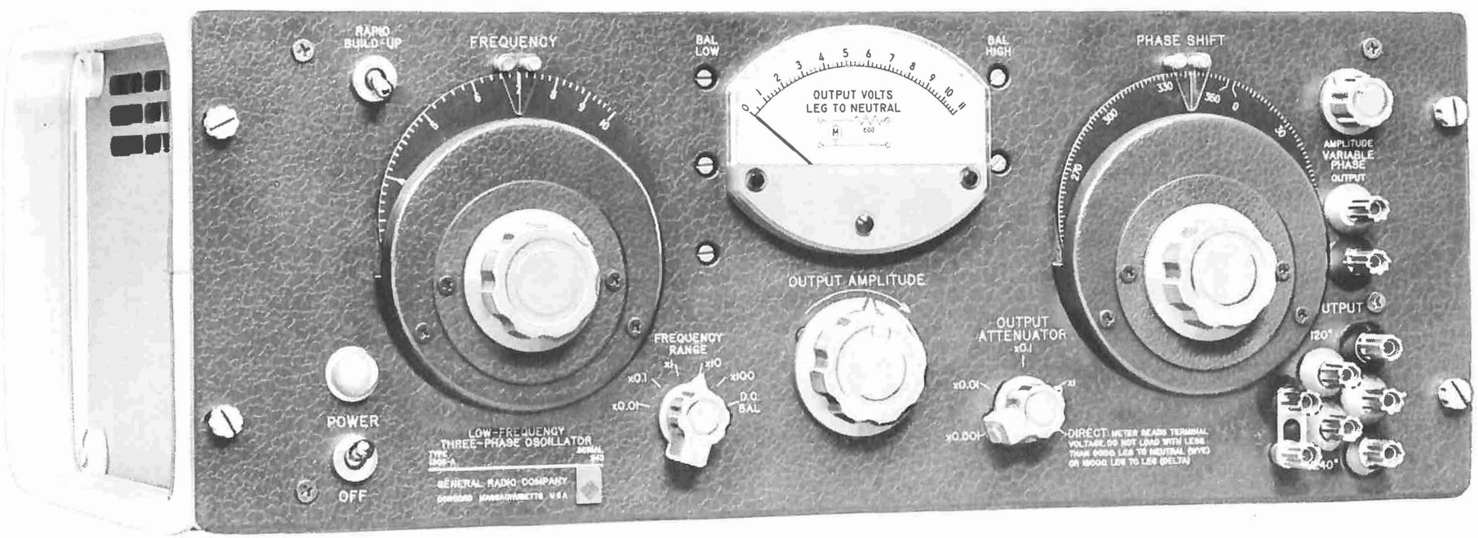


Figure 1. Type 1305-A Low-Frequency Oscillator.

TYPE 1305-A
LOW-FREQUENCY OSCILLATOR

Section 1
INTRODUCTION

1.1 PURPOSE. The Type 1305-A Low-Frequency Oscillator is useful as a source of sinusoidal voltages at frequencies between 0.01 and 1000 cycles per second, or as the basis of a direct phase-gain measuring system for devices normally operated within this frequency range. As such, it should be a valuable tool for those concerned with the design, development, and operation of servomechanisms, graphic recorders, electromedical equipment, geophysical gear, passive sonar, electromechanical analogues, and two-, three-, and four-phase networks.

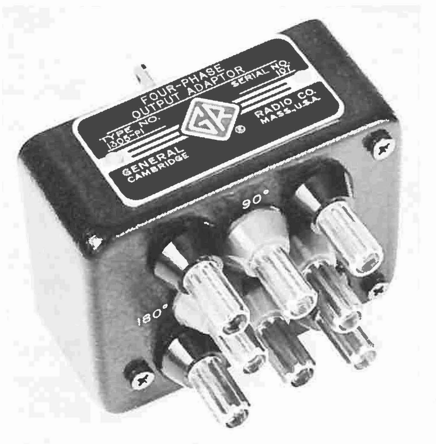


Figure 2.
Type 1305-P1 Four-Phase Output Adaptor.

1.2 DESCRIPTION. The three-phase circuit used in the Type 1305-A should not confuse users accustomed to single-phase techniques, for each phase-to-neutral output may be regarded and used as a single-phase source. The three-phase circuit actually makes possible the inclusion of a frequency-independent phase-shifter and a direct-acting limiter, and permits readable meter indications at low frequencies.

1.3 ACCESSORIES. Supplied with the Type 1305-A Low-Frequency Oscillator are a Type CAP-35 Power Cord, three Type 274-MB Double Plugs, spare fuses, and a Type 1305-P1 Four-Phase Output Adaptor.

The Four-Phase Adaptor (see Figure 2) is a plug-in unit, which contains a purely resistive network to convert the three-phase output to a four-phase output completely independent of frequency. The use of opposed phases on the Type 1305-P1 provides a balanced, center-tapped, single-phase source.

Section 2
OPERATING PROCEDURE

2.1 MOUNTING. The Type 1305-A Low-Frequency Oscillator is supplied for either bench (Type 1305-AM) or relay-rack (Type 1305-AR) mounting. For bench mounting, aluminum end frames are supplied to fit the ends of the cabinet, as shown in Figure 1. For rack mounting, brackets for holding the cabinet in the rack are supplied. Relay-rack mounting is so arranged that panel and chassis can be removed from the cabinet, or the cabinet can be removed from the rear of the rack, leaving the panel attached to the rack.

2.2 POWER SUPPLY. The power connector is a three-wire cord-plug assembly, supplied with two-wire adaptors. Power voltage and frequency must agree with the metal nameplate adjacent to the power connector on the chassis, except that the oscillator can be operated at power frequencies up to 400 cps. The instrument is normally supplied for a nominal 115-volt (105-125-volt), 50-60-cycle supply, but may be adapted for 230-volt nominal (210-250-volt) operation by reconnection of the transformer primary terminals, as shown in Figure 7. When making changes, be sure to insert fuses of the proper values and correct the nameplate legend.

To start the Low-Frequency Oscillator, throw the POWER switch to POWER.

2.3 DC BALANCE. After a few minutes warmup, check the oscillator balance by turning the FREQUENCY RANGE switch to DC BALANCE. The output voltmeter should show little or no deflection. If the meter deflects appreciably, balance the oscillator as follows:

NOTE

Close balance is of utmost importance for minimum distortion and for accurate meter indication.

With the OUTPUT AMPLITUDE control fully counterclockwise, adjust the three BAL LOW screw-driver controls to the left of the meter for minimum meter deflection. Then set the OUTPUT AMPLITUDE control fully clockwise and adjust the two BAL HIGH screw-driver controls to the right of the meter, again for minimum deflection. Unavoidable interaction may require several balances for minimum meter indication.

Over extended operating periods, check balance occasionally, and restore when necessary.

2.4 FREQUENCY DETERMINATION. Oscillator frequency is the product of the logarithmic FREQUENCY dial setting and the setting of the FREQUENCY RANGE switch. The constant-accuracy FREQUENCY dial is calibrated over a 1-to-10 decade. The FREQUENCY RANGE switch has multipliers of 0.01, 0.1, 1, 10, and 100. Any frequency within the oscillator range of 0.01 to 1000 cps may be directly selected by the appropriate setting of these two controls.

2.5 RAPID BUILD-UP SWITCH. In oscillators operating at audio frequencies and higher, the phenomenon of oscillator build-up is usually unnoticed. In the Type 1305-A, where a single cycle at the lowest frequency has a period of 100 seconds, the build-up time, from random noise to sustained, constant-amplitude oscillation, may be measured in hours! To eliminate this intolerable delay, a RAPID BUILD-UP switch, mounted on the front panel, permits the introduction into the oscillator circuit of a transient which exceeds the constant amplitude normally imposed by the limiter. Within one cycle of the release of this switch the oscillator achieves constant amplitude.

For any setting in the X 0.01 range of the FREQUENCY RANGE switch, first apply the build-up technique in the X 0.1 range, and then switch back to the X 0.01 range. The amplitude in the X 0.01 range will be that already established in the X 0.1 range, with a time-saving factor of 10 to 1.

The rapid build-up technique is particularly useful to offset the amplitude decrease that always accompanies the setting of the FREQUENCY dial to a lower value, and which could be most annoying on the lowest frequency range if the RAPID BUILD-UP switch were not available.

2.6 OSCILLATOR OUTPUT AMPLITUDE. The oscillator three-phase output amplitude is subject to two controls: the OUTPUT AMPLITUDE control, continuously variable over a greater than 10-to-1 range, which directly controls the reading of the output voltmeter, and the OUTPUT ATTENUATOR, which multiplies the meter reading by 0.001, 0.01, 0.1, or 1. The resultant voltage (meter reading times multiplier) appears in each wye-to-neutral output behind 600 ohms internal phase impedance. With the OUTPUT ATTENUATOR switch set at DIRECT, the meter indicates direct-wye output-terminal volts. This setting subjects the load to certain limitations noted on the panel and in paragraph 2.8. For the Type 1305-P1 Four-Phase Output Adaptor, the phase voltage is about half the value indicated by meter reading and attenuator setting, also behind 600 ohms internal phase impedance.

A three-phase full-wave rectifier connects the output voltmeter to the oscillator output, permitting useful meter readings at even the lowest frequencies. Meter deflection is subject to a ripple frequency six times the oscillator frequency. At the lowest frequencies, where meter ballistics permit the meter to follow the ripple frequency faithfully, amplitude indications vary between +5% and -10% of true rms value. Thus, at very low frequencies, at 10 volts rms, the meter reading will vary between 9.0 and 10.5 volts.

2.7 PHASE-SHIFTED OUTPUT AMPLITUDE. The phase-shifted output amplitude is also subject to two controls: the continuously variable OUTPUT AMPLITUDE control and a separate AMPLITUDE VARIABLE PHASE OUTPUT control. With the latter set fully clockwise, the phase-shifted output is approximately 1/10 the meter indication, and may be reduced to zero by counterclockwise rotation. Internal impedance varies between zero and a maximum of about 15,000 ohms, but, since this circuit is designed for high-impedance-oscilloscope loading, the impedance is relatively insignificant at the Type 1305-A frequencies.

2.8 LOADS (Except variable-phase output; refer to paragraph 2.9). Multiphase circuits are traditionally considered in terms of balanced loads, and the Type 1305-A, with or without the four-phase adaptor, is no exception. In the DIRECT and X 1 positions of the OUTPUT ATTENUATOR, loads must be balanced to insure the accuracy of the output-voltmeter and phase-shift calibrations. In the DIRECT position the three-phase load on the Type 1305-A alone may not be less than 1800 ohms phase-to-phase (delta connection), or 600 ohms phase-to-neutral (wye connection). With the Type 1305-P1, and at all other settings of the OUTPUT ATTENUATOR, the load may be of any required value, with due consideration for its effect on the 600-ohm internal wye phase impedance.

Aside from these considerations, each phase-to-neutral circuit may be used as a single-phase source, as mentioned in paragraph 1.2.

2.9 VARIABLE-PHASE OUTPUT LOADS. The variable-phase output is designed for high-impedance loads (negligible with respect to 15,000 ohms), such as the deflection circuit of a low-frequency oscilloscope. Low-impedance resistive loads will not alter the phase-angle calibration, but will attenuate the output to varying degrees owing to the varying internal impedance of the phase-shifted output circuit. Low-impedance reactive loads should be avoided.

Section 3
MEASUREMENTS

3.1 GAIN. The gain or loss of any three- or four-terminal passive or active network, whose operating frequency lies within the range of the Type 1305-A, may best be measured by the use of a stable, calibrated oscilloscope, with direct-current deflection circuits and a medium- or long-persistence screen. The input of the network, with any required padding for impedance matching, should be connected to the 0° NEUTRAL terminals of the Type 1305-A, or to the 0° NEUTRAL 180° terminals of the Type 1305-P1, if a balanced input is required. Conform to the requirements detailed under paragraph 2.8. The NEUTRAL terminal may be grounded.

The output of the network should be properly terminated, with the oscilloscope vertical-deflection circuit shunted across the termination. Horizontal sweep is optional. The gain or loss is the ratio of the output amplitude, as indicated on the oscilloscope, to the input amplitude, as indicated on the Type 1305-A. Such gain or loss includes the losses attributable to padding and to the 600-ohm phase source resistance (except in the DIRECT position of the OUTPUT ATTENUATOR switch), and requires correction for network input and output impedance levels.

3.2 PHASE. To measure network phase shift, connect the Type 1305-A VARIABLE PHASE OUTPUT terminals to the horizontal-deflection circuit of the oscilloscope (refer to paragraph 3.1). First, with the 0° NEUTRAL terminals connected directly to the vertical-deflection circuit, observe the slant of the line trace produced with the PHASE SHIFT at 0° or 360°. Now reconnect the network as described in paragraph 3.1. The trace will become an oval if there is phase shift. Manipulate the PHASE SHIFT to close the oval to a line slanting in the sense previously observed. Leading phase shift is indicated directly on the PHASE SHIFT dial. Lagging phase shift is 360° minus the dial reading.

The oval will not close to a proper slant line except at one PHASE SHIFT setting. With complex networks, it may be impossible to tell if a setting of, say, 165° indicates a lead of 165° or a lag of 195° (or even a lead of 525° or a lag of 555°). To eliminate such ambiguities, measurements should be started in a region of minimum phase shift (perhaps in the center of the network pass band). With enough readings to sense both the trend and magnitude of increasing phase shift, measurements may then be extended to and through the limit frequencies.

3.3 PHASE AND GAIN. The simultaneous application of the techniques described in paragraphs 3.1 and 3.2 permits simultaneous measurement of phase and gain.

3.4 ELECTRICAL SERVOMECHANISM ANALYSIS. Most electrical servo systems operate on the error-voltage principle, where the controlled function is compared with a standard, and the resultant error voltage acts as a command to correct the controlled function. Usually the error voltage is amplified until it is adequate to control the correcting mechanism. Both open- and closed-loop performance are of interest, although the latter is the ultimate criterion.

Because of the wide range of circuits and mechanisms employed in servo work, no hard-and-fast rules for the application of the Type 1305-A to servo problems can be formulated. In general, however, the Type 1305-A may be used as an artificial, controlled, error voltage by insertion of its output into the servo circuit at a convenient point. Note that, unless the NEUTRAL is tied to GROUND on the panel, the Type 1305-A Oscillator circuit is "floating", though there is considerable capacitive coupling to ground and to power mains. For this reason it is wise to connect the NEUTRAL terminal to the servo circuit at some point where the effects of grounding or of capacitance to ground will be negligible.

To measure effective phase and gain for both open- and closed-loop conditions, apply the output of the servo system to the vertical scope sweep (refer to paragraph 3.1) and apply the phase-shifted output of the Type 1305-A to the horizontal circuit (refer to paragraph 3.2). For closed-loop measurements, use the Type 1305-A to vary the standard voltage. Performance may then be judged by the magnitude and phase of the error voltage as the system strives to correct.

Irregularities and discontinuity in the scope trace will result from mechanical backlash or nonlinear response, and will soon become readily identifiable as the user gains experience.

3.5 THE TYPE 1305-A AS A POWER SOURCE. The oscillator, with its choice of one, two, three, or four phase-shifted outputs, is a convenient power source, with or without additional amplification, for the study of single-phase and polyphase motors, networks, and analogues. Current and voltage relations may be examined under the methods outlined in paragraph 3.2, by use of the voltage drop across a small resistor as the vertical-deflection voltage. Proper scaling of circuit elements will permit the leisurely examination of surge and transient phenomena at the low frequencies available from the Type 1305-A.

Section 4
PRINCIPLES OF OPERATION

4.1 GENERAL. The Type 1305-A is effectively a direct-coupled, re-entrant, three-stage amplifier. Each of the three identical stages incorporates a resistance-capacitance (R-C) network to produce a 60°-lagging phase shift at the operating frequency. The algebraic sum of the network phase shift and the 180°-leading phase reversal in the amplifier yields a net grid-to-grid phase shift of 120° leading, per stage. The three stages yield a total phase shift of 360° (3 X 120°), satisfying the phase requirement for oscillation and establishing the phase relationship of the three stages as that of a three-phase, wye-connected system.

Each R-C network attenuates the operating signal by a factor of two, requiring a direct-current loop gain in excess of 8 to 1 (2^3) to meet the requirement of at least unity gain at the operating frequency, necessary for oscillation. At dc there are three 180° phase reversals and no reactive phase shift, so the circuit is highly degenerative against dc drift and changes in balance.

4.2 FUNCTIONAL BLOCK DIAGRAM. In the functional block diagram, Figure 3, the three phases (the amplifier stages of paragraph 4.1) are shown at the left. Each identical phase consists of a "Miller effect"[1] amplifier, in which all voltage amplification is concentrated. The output of each amplifier divides into three circuits:

a. A logarithmic potentiometer (ganged with the other two phases), whose slider is connected to the low side of the input capacitor to multiply its apparent value by the Miller effect, forming a frequency control. This method of frequency control has three advantages:

(1) The logarithmic taper yields a "constant-accuracy" scale.

(2) The variable element can be a stable wire-wound unit of a practical value.

(3) The multiplication of capacitance materially reduces the investment in precision polystyrene capacitors for the lowest frequency range.

b. A second logarithmic potentiometer, also ganged to the other two phases, which controls the input to a cathode-follower output amplifier. This is the OUTPUT AMPLITUDE control.

c. A limiter amplifier, whose output forms the excitation for the next phase, and which holds the output constant within ½ db over the operating range.

[1] Miller, J. M., Bureau of Standards Scientific Paper No. 354. June 11, 1919.

The capacitance and resistance values of the phase R-C networks are varied in decade steps by the FREQUENCY RANGE switch.

A neutral output amplifier provides a low-impedance neutral at the same dc potential as the three-phase outputs.

A three-phase output attenuator extends the range of the OUTPUT AMPLITUDE control in decade steps.

The output amplifiers are connected to a closed potentiometer at points separated by 120 electrical degrees to permit continuously adjustable phase-shifting with respect to any fixed phase of ±360° or more. The output of this potentiometer, which is carefully "padded" to preserve linearity of calibration and constant amplitude versus setting, terminates in a high-resistance (50,000-ohm) potentiometer to adjust the amplitude of the phase-shifted output.

4.3 SCHEMATIC DIAGRAM. In the schematic diagram, Figure 7, as in the block diagram, the three identical phases start at the upper left. Each Miller-effect amplifier consists of a pentode voltage-amplifier (V101, V201, V301) whose plate circuit drives the grid of a cathode follower (V104A, V204A, V304A) through two neon glow tubes in series. The neon glow tubes act as direct-current capacitors to accommodate the voltage difference between pentode plates and the cathode-follower grids. The output of the Miller-effect amplifier is as described in paragraph 4.2, except for certain trimming and compensating components.

The limiting mechanism is a three-phase, full-wave diode rectifier, bridged across the input-attenuator networks of the three limiter cathode-follower triodes (V104B, V204B, V304B). This rectifier is termi-

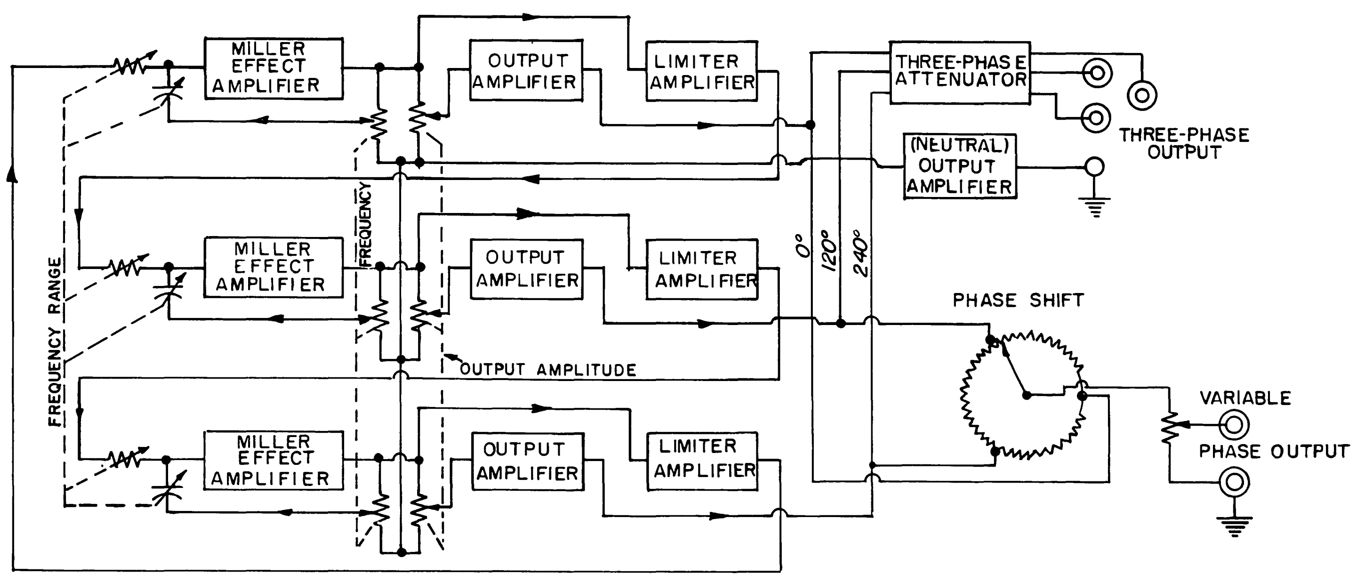


Figure 3. Functional Block Diagram.

nated in a voltage-reference diode (D9), which permits voltage build-up until the diode breakdown voltage is exceeded. At this point the rectifier loads the input-attenuator networks sharply to clamp the level at a constant value. Because the limiter functions six times per cycle, its action does not introduce serious waveform distortion, nor does it require a time delay (intolerable at the lower frequencies) as does the conventional AVC circuit.

Output-voltage indication (refer to paragraph 2.6) is obtained by a similar rectifier. With the FREQUENCY RANGE switch in the DC BAL position, two additional rectifiers connect the cathode of the neutral output amplifier (V1) to the cathodes of the phase output amplifiers (V106, V206, V306), permitting intercomparison of these four cathode voltages for balance.

The power supply is an electronically regulated diode-doubler of conventional design. A thermal breaker (F3), self-restoring on cooling, is installed at the cabinet hot spot, adjacent to the series-regulator tube (V501). Breaker operation indicates probable serious difficulty. The air filter may be clogged with dirt. The blower intake may be blocked by accident or by adjacent apparatus. The intake air may be too hot. There may be overheating from circuit fault or partial fault.

Section 5
SERVICE AND MAINTENANCE

5.1 GENERAL. The two-year warranty given with every General Radio instrument attests the quality of materials and workmanship in our products. When difficulties do occur, our service engineers will assist in any way possible.

In case of difficulties that cannot be eliminated by the use of these service instructions, 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 serial and type numbers of the instrument

Before returning an instrument to General Radio for service, please write to our Service Department or nearest district office (see back cover), 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.

5.2 AIR FILTER. In normal operation, the air filter should be cleaned and recharged every four to six months. (Long duty cycles or a dusty location may necessitate more frequent attention.)

The air filter is located at the rear of the chassis (upper right-hand corner of Figure 6). To gain access to the filter, first remove the chassis from the cabinet. To remove the filter, press on the bottom rear of the filter, against the retaining springs, until the filter can be slipped out of the bottom of the chassis.

Clean the air filter by immersing it in a solution of any good commercial detergent and hot water, agitating the filter until all dirt is removed. Then rinse and dry the filter thoroughly.

Recharge the filter by brushing or spraying with a good grade of lubricating or diesel oil of SAE 30 viscosity. If the odor of the oil is obnoxious, use "Filter-Cor" Recharging Adhesive (Air Filter Corporation, Milwaukee, Wisconsin, USA) or equivalent. Tap the filter to remove excess drops so that they will not be drawn into the instrument when the fan is turned on.

5.3 REPLACEMENT OF 6BH6 TUBES (V101, V201, V301). Since phase-voltage amplification is derived solely from the 6BH6 pentodes, these tubes are highly sensitive to changes in characteristics from aging or replacement. To correct for such changes, the following trimmer adjustments are provided:

R110, R210, R310, ganged, beneath chassis
R108, R208, R308, not ganged, beneath chassis
C107, C207, C307, on printed-circuit board.

To restore calibration and phase balance, remove the oscillator from its cabinet, and set it in a position that permits access to the trimmer resistors. Connect the oscillator output to the vertical-deflection circuit of an oscilloscope. Connect the horizontal-deflection circuit to a 100- and 1000-cps reference source (if one is expert at reading Lissajou figures, 50- or 60-cps power mains may be used).

With the oscillator operating, set the FREQUENCY dial to 10, the FREQUENCY RANGE switch to X 10, and adjust the ganged resistors R110, R210, and R310 for 100 cycles per second. Then set the FREQUENCY dial to 1, the FREQUENCY RANGE switch to X 100, and connect a sensitive ac voltmeter between the TP1 and B- test points on the circuit board.

WARNING

> B- is approximately 100 volts negative with respect to the neutral output (and to the chassis if it is connected at the panel binding posts to the neutral). Use caution in making connections to both the B- and B+ test points.

Adjust R108, R208, and R308 for both 100 cycles and minimum voltmeter reading. The minimum reading is necessary for proper phase balance (i.e., each phase spaced 120° from the adjacent phase). Set the FREQUENCY dial to 10 and the FREQUENCY RANGE switch to X 10, and reset the ganged trimmers R110, R210, and R310 if necessary. Repeat both procedures until frequency and phase balance cannot be noticeably improved.

Set the FREQUENCY dial to 10, the FREQUENCY RANGE switch to X 100, and adjust capacitors C107, C207, and C307 for 1000 cycles and phase balance, as described for R108, R208, and R308 above. Do not change any resistor setting! When frequency accuracy and phase balance are satisfactory, the oscillator is ready to operate.

5.4 REPLACEMENT OF OTHER OSCILLATOR TUBES.

Since the three Type 5963 tubes (V104, V204, and V304) and the four Type 6197 tubes (V106, V206, V306, V1) are all operated as cathode followers, the circuit is relatively insensitive to aging or replacement of these tubes. Restoration of dc balance is normally all that is required.

5.5 REPLACEMENT OF POWER-SUPPLY REGULATOR TUBES.

Replacement of the series regulator tube (V501), the regulator voltage-amplifier tube (V502) or the regulator voltage-reference tube (V503) may necessitate adjustment of R508 on the printed-circuit board to secure 300 volts dc between test points B+ and B- on the circuit board.

TABLES OF VOLTAGES AND RESISTANCES

TUBE (TYPE)	PIN	VOLTS DC
V1	1	100
V106	2,9	95
V206	6	300
V306	9 to 1	-4.3
(6197)		
V101	1 to 2	-3.2
V201	2	106
V301	5	200
(6BH6)	6	250
	7	106
V104	1	290
V204	2 to 3	-7.0
V304	3	95
(5963)	6	300
	7	95
	7 to 8	-12
	8	107
V501	1,4	250
(6080)	2,5	430
	3,6	300

TUBE (TYPE)	PIN	VOLTS DC
V502	1	250
(12AX7)	2	180
	2 to 3	0.9
	3	180
	6	180
	7	84
	7 to 8	-1.0
	8	85
V503 (5651)	1,5	85

Line voltage = 115v ac, 60c.
Attenuator at DIRECT.
OUTPUT AMPLITUDE fully clockwise.
FREQUENCY at 100 c.
Voltages are to B−, measured by vtvm, unless otherwise indicated.

TUBE (TYPE)	PIN	RES TO B−
V1	1,7	1.8 k*
V106	1,7	2.0 k**
V206	2,9	240 k
V306	3,6,8	0
(6197)		
V101	1	5.7 M
V201	2	15 k
V301	3,4	10 k
(6BH6)	5	75 k
	6	33 k
	7	15 k
V104	1	900
V204	2	1 M
V304	3	8.5 k
(5963)	6	0
	7	90 k
	8	105 k

B+ shorted to B− for above resistance measurements.
* V1 only.
** V106, V206, V306.

Type 1305-A To be placed at bottom of page 7.

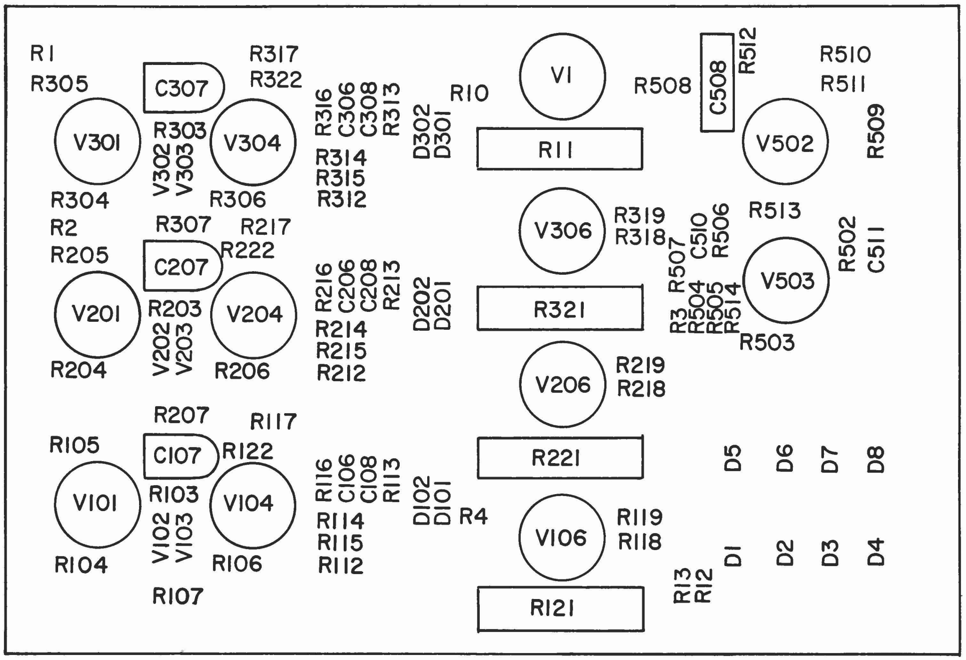
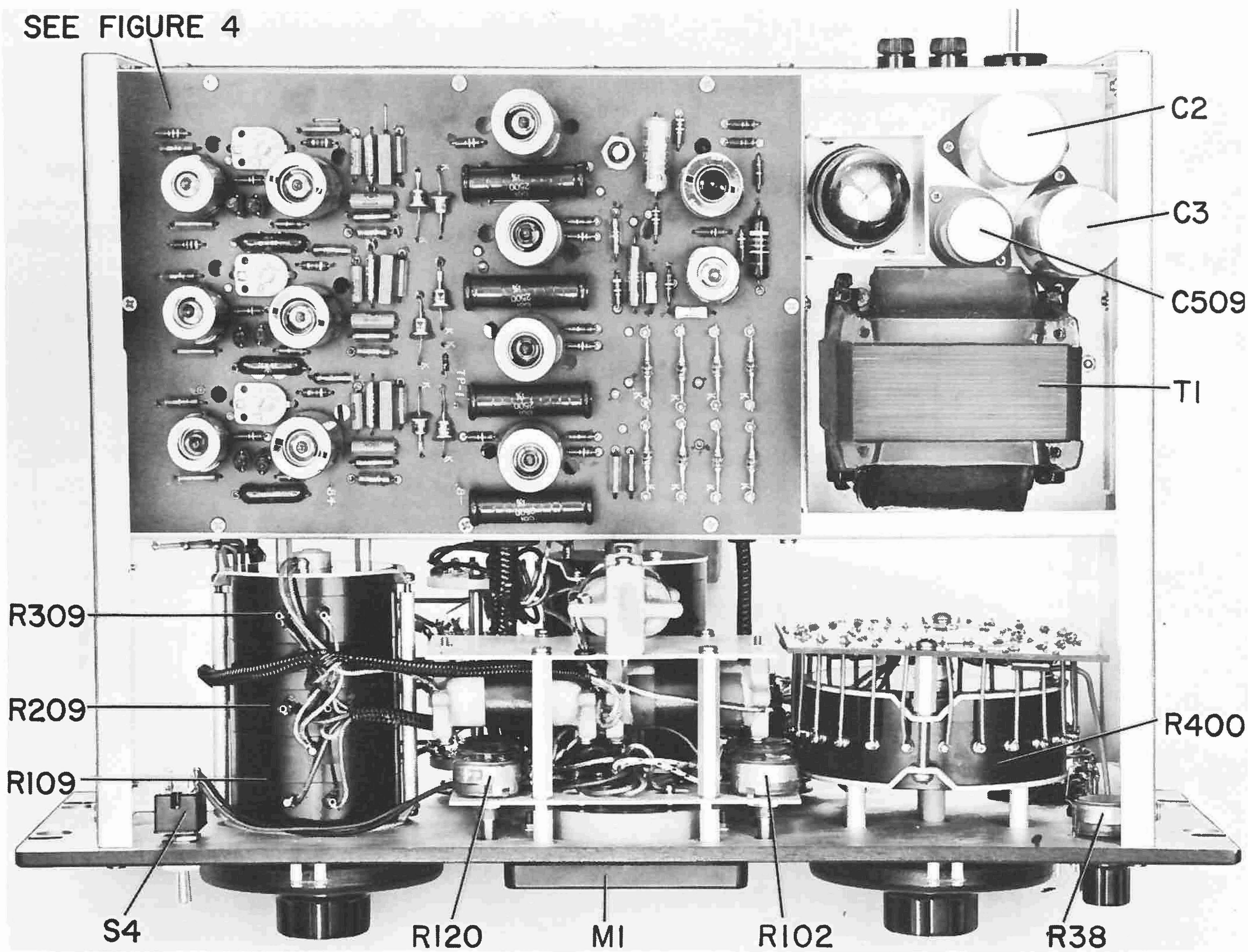


Figure 4. Etched Board Layout.

Figure 5. Top Interior View.



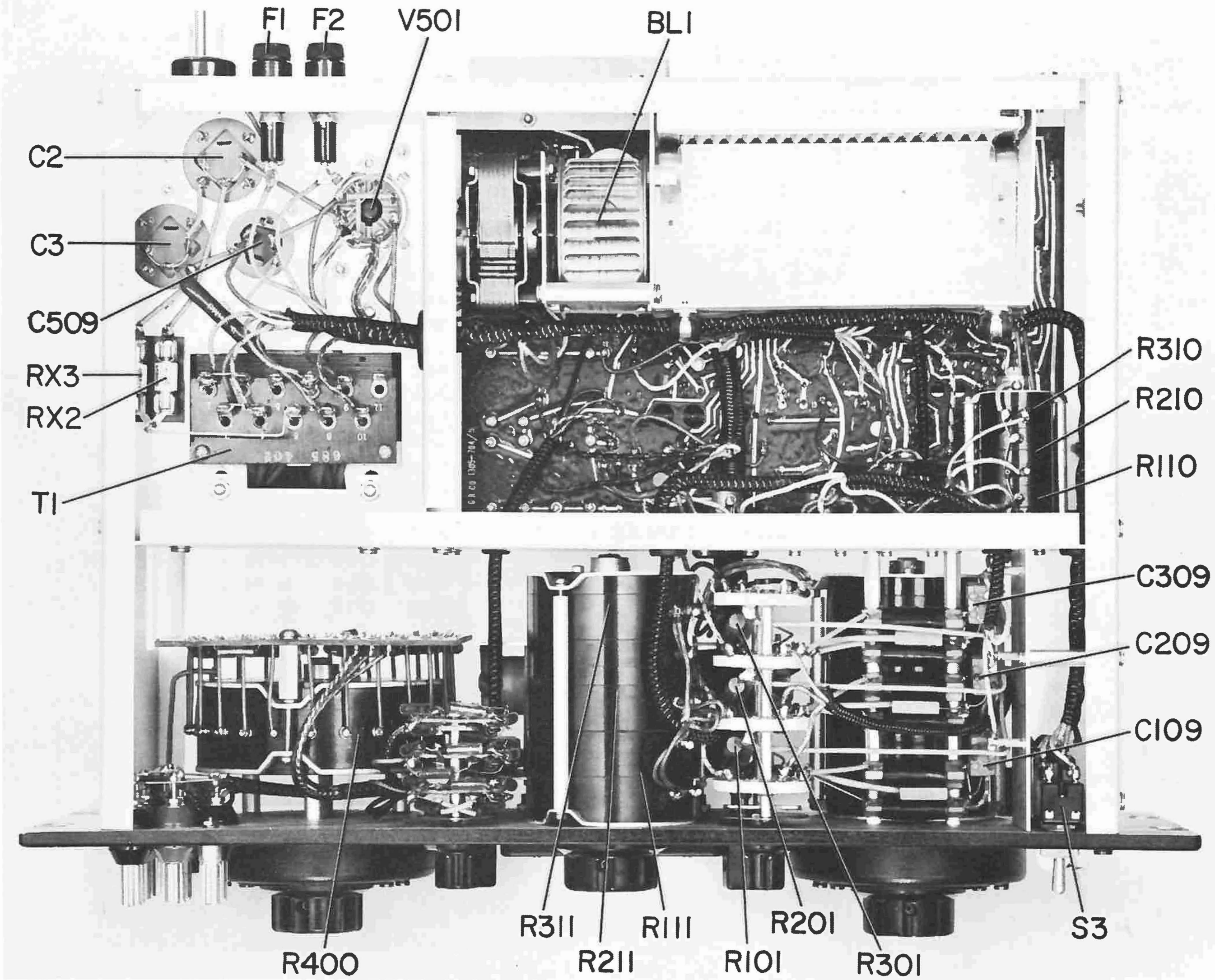


Figure 6. Bottom Interior View.

Section 6
PARTS LIST

REF	PART NO. (NOTE A)			
RESISTORS (NOTE B)				
R1	15 k	±10%	2 w	REC-41BF
R2	33 k	± 5%	1/2 w	REC-20BF
R3	91 k	± 5%	1/2 w	REC-20BF
R4	200 k	± 5%	1/2 w	REC-20BF
R5	5 k	±10%		POSW-3
R7	330	± 5%	1/2 w	REC-20BF
R8	330	± 5%	1/2 w	REC-20BF
R9	4.7	±10%	10 w	REPO-44
R10	200 k	± 5%	1/2 w	REC-20BF
R11	2.5 k	± 1%	5 w	REF-1-4
R12	130 k	± 1%	1/4 w	REF-65
R13	15 k	± 1%	1/4 w	REF-65
R14	667	± 1%	1/4 w	REF-65
R15	667	± 1%	1/4 w	REF-65
R16	600	± 1%	1/4 w	REF-65
R17	5.4 k	± 1%	1/4 w	REF-65
R18	5.4 k	± 1%	1/4 w	REF-65
R20	5.4 k	± 1%	1/4 w	REF-65
R21	667	± 1%	1/4 w	REF-65
R22	667	± 1%	1/4 w	REF-65
R23	667	± 1%	1/4 w	REF-65
R24	600	± 1%	1/4 w	REF-65
R25	5.4 k	± 1%	1/4 w	REF-65
R27	5.4 k	± 1%	1/4 w	REF-65
R28	5.4 k	± 1%	1/4 w	REF-65
R29	667	± 1%	1/4 w	REF-65
R30	667	± 1%	1/4 w	REF-65
R31	667	± 1%	1/4 w	REF-65
R32	600	± 1%	1/4 w	REF-65
R33	5.4	± 1%	1/4 w	REF-65
R35	5.4 k	± 1%	1/4 w	REF-65
R36	5.4 k	± 1%	1/4 w	REF-65
R37	667	± 1%	1/4 w	REF-65
R38	50 k	±10%		POSC-12
R39	15	±10%	1/2 w	REW-3C
R100	555 k	± 1%	1/2 w	REF-70
R101	5.06 M	± 1%	1 w	REF-3-2
R102	5 M	±20%		POSC-12
R103	.150 k	± 5%	1/2 w	REC-20BF
R104	80.6 k	± 1%	1/4 w	REF-65
R105	2.4 k	± 1%	1/4 w	REF-65
R106	510 k	± 5%	1/2 w	REC-20BF
R107	12 k	± 5%	5 w	REPO-43
R108	2 k	± 5%		971-411
R109	25 k	± 2%	Part of	975-400G3
R110	1 k	± 5%	Part of	971-412
R111	25 k	± 2%	Part of	975-400G3
R112	1.25 k	± 1%	1/4 w	REF-65
R113	220 k	± 1%	1/4 w	REF-65
R114	180 k	± 1%	1/4 w	REF-65
R115	100 k	± 1%	1/4 w	REF-65
R116	5 k	± 1%	1/4 w	REF-65
R117	100 k	± 1%	1/4 w	REF-65
R118	270 k	± 5%	1/2 w	REC-20BF
R119	2 M	± 5%	1/2 w	REC-20BF
R120	1 M	±20%		POSC-7
R121	2.5 k	± 1%	5 w	REF-1-4
R122	910	± 5%	1/2 w	REC-20BF
R200	555 k	± 1%	1/2 w	REF-70
R201	5.06 M	± 1%	1 w	REF-3-2
R202	5 M	±20%		POSC-12
R203	150 k	± 5%	1/2 w	REC-20BF
R204	80.6 k	± 1%	1/4 w	REF-65
R205	2.4 k	± 1%	1/4 w	REF-65
R206	510 k	± 5%	1/2 w	REC-20BF
R207	12 k	± 5%	5 w	REPO-43
R208	2 k	± 5%		971-411
R209	25 k	± 2%	Part of	975-400G3
R210	1 k	± 5%	Part of	971-412
R211	25 k	± 2%	Part of	975-400G3
R212	1.25 k	± 1%	1/4 w	REF-65
R213	220 k	± 1%	1/4 w	REF-65
R214	180 k	± 1%	1/4 w	REF-65
R215	100 k	± 1%	1/4 w	REF-65
R216	5 k	± 1%	1/4 w	REF-65
R217	100 k	± 1%	1/4 w	REF-65
R218	270 k	± 5%	1/2 w	REC-20BF
R219	2 M	± 5%	1/2 w	REC-20BF
R220	1 M	±20%		POSC-7
R221	2.5 k	± 1%	5 w	REF-1-4
R222	910	± 5%	1/2 w	REC-20BF
R300	555 k	± 1%	1/2 w	REF-70
R301	5.06 M	± 1%	1 w	REF-3-2
R303	300 k	± 5%	1/2 w	REC-20BF
R304	80.6 k	± 1%	1/4 w	REF-65
R305	2.4 k	± 1%	1/4 w	REF-65
R306	510 k	± 5%	1/2 w	REC-20BF
R307	12 k	± 5%	5 w	REPO-43
R308	2 k	± 5%		971-413
R309	25 k	± 2%	Part of	975-400G3
R310	1 k	± 5%	Part of	971-412
R311	25 k	± 2%	Part of	975-400G3
R312	1.25 k	± 1%	1/4 w	REF-65
R313	220 k	± 1%	1/4 w	REF-65
R314	180 k	± 1%	1/4 w	REF-65
R315	100 k	± 1%	1/4 w	REF-65
R316	5 k	± 1%	1/4 w	REF-65
R317	100 k	± 1%	1/4 w	REF-65
R318	270 k	± 5%	1/2 w	REC-20BF
R319	2 M	± 5%	1/2 w	REC-20BF
R320	1 M	±20%		POSC-7
R321	2.5 k	± 1%	5 w	REF-1-4
R322	910	± 5%	1/2 w	REC-20BF
R400	48 k, 2 k	±2%	(taps)	977-400
R401	264 k	± 1%	1/4 w	REF-65
R402	178 k	± 1%	1/4 w	REF-65
R403	140 k	± 1%	1/4 w	REF-65
R404	123 k	± 1%	1/4 w	REF-65
R405	235 k	± 1%	1/4 w	REF-65
R406	235 k	± 1%	1/4 w	REF-65
R407	123 k	± 1%	1/4 w	REF-65
R408	140 k	± 1%	1/4 w	REF-65
R409	178 k	± 1%	1/4 w	REF-65
R410	8.67 k	± 1%	1/4 w	REF-65
R411	24.3 k	± 1%	1/4 w	REF-65
R412	68.8 k	± 1%	1/4 w	REF-65
R413	264 k	± 1%	1/4 w	REF-65
R414	178 k	± 1%	1/4 w	REF-65
R415	140 k	± 1%	1/4 w	REF-65
R416	123 k	± 1%	1/4 w	REF-65
R417	235 k	± 1%	1/4 w	REF-65
R418	235 k	± 1%	1/4 w	REF-65
R419	123 k	± 1%	1/4 w	REF-65
R420	140 k	± 1%	1/4 w	REF-65
R421	178 k	± 1%	1/4 w	REF-65
R422	8.67 k	± 1%	1/4 w	REF-65
R423	24.3 k	± 1%	1/4 w	REF-65
R424	68.8 k	± 1%	1/4 w	REF-65
R425	264 k	± 1%	1/4 w	REF-65
R426	178 k	± 1%	1/4 w	REF-65
R427	140 k	± 1%	1/4 w	REF-65
R428	123 k	± 1%	1/4 w	REF-65
R429	235 k	± 1%	1/4 w	REF-65
R430	235 k	± 1%	1/4 w	REF-65
R431	123 k	± 1%	1/4 w	REF-65
R432	140 k	± 1%	1/4 w	REF-65
R433	178 k	± 1%	1/4 w	REF-65
R434	8.67 k	± 1%	1/4 w	REF-65
R435	24.3 k	± 1%	1/4 w	REF-65
R436	68.8 k	± 1%	1/4 w	REF-65
R501	1 M	±10%	1/2 w	REC-20BF
R502	2.4 M	± 5%	1/2 w	REC-20BF
R503	36 k	± 1%	1/4 w	REF-65
R504	26 k	± 1%	1 w	REF-75
R505	36 k	± 1%	1/4 w	REF-65
R506	470 k	± 5%	1/2 w	REC-20BF
R507	30 k	± 1%	1/4 w	REF-65
R508	10 k	±10%		POSW-3
R509	5.6 M	±10%	1/2 w	REC-20BF
R510	100	±10%	1/2 w	REC-20BF
R511	100	±10%	1/2 w	REC-20BF
R512	470 k	± 5%	1/2 w	REC-20BF
R513	620 k	± 5%	1/2 w	REC-20BF
R514	120 k	± 5%	1/2 w	REC-20BF

PARTS LIST (CONT)

CAPACITORS (NOTE C)

REF	PART NO. (NOTE A)			
C1	0.1	±10%	600 dcwv	COL-71
C2A	90 }			
C2B	30 }		300 dcwv	COE-52
C2C	30 }			
C3A	90 }			
C3B	30 }		300 dcwv	COE-52
C3C	30 }			
C101	400 μμf	± 1%	500 dcwv	COM-5F
C102	0.004	± 1%	500 dcwv	ZCOP-7
C103	0.04	± 1%	500 dcwv	ZCOP-8
C104	0.40	± 1%	50 dcwv	ZCOP-9-1
C105	0.01	±10%	100 dcwv	COW-17
C106	0.01	±10%	100 dcwv	COW-17
C107	7-45 μμf			COT-12
C108	47 μμf	± 2%	500 dcwv	COM-5E
C109	150 μμf	±10%		COM-20B
C110	0.001	±10%	500 dcwv	COM-20B
C201	400 μμf	± 1%	500 dcwv	COM-5F
C202	0.004	± 1%	500 dcwv	ZCOP-7
C203	0.04	± 1%	500 dcwv	ZCOP-8
C204	0.40	± 1%	50 dcwv	ZCOP-9-1
C205	0.01	±10%	100 dcwv	COW-17
C206	0.01	±10%	100 dcwv	COW-17
C207	7-45 μμf			COT-12
C208	47 μμf	± 2%	500 dcwv	COM-51
C209	150 μμf	±10%		COM-20B
C210	0.001	±10%	500 dcwv	COM-20B
C301	400 μμf	± 1%	500 dcwv	COM-5F
C302	0.004	± 1%	500 dcwv	ZCOP-7
C303	0.04	± 1%	500 dcwv	ZCOP-8
C304	0.40	± 1%	50 dcwv	ZCOP-9-1
C305	0.01	±10%	100 dcwv	COW-17
C306	0.01	±10%	100 dcwv	COW-17
C307	7-45 μμf			COT-12
C308	47 μμf	± 2%	500 dcwv	COM-5E
C309	150 μμf	±10%		COM-20B
C310	0.001	±10%	500 dcwv	COM-20B
C508	0.1 μμf	±10%	400 dcwv	COW-25
C509A	10 }		450 dcwv	COE-5
C509B	10 }			
C510	0.001	±20%	500 dcwv	COC-60
C511	0.0047	±10%	600 dcwv	COL-71

CRYSTAL DIODES

REF	PART NO. (NOTE A)	REF	PART NO. (NOTE A)
D1	1N191	D9	1N968A
D2	1N191		
D3	1N191	D101	1N645
D4	1N191	D102	1N645
D5	1N191	D201	1N645
D6	1N191	D202	1N645
D7	1N191	D301	1N645
D8	1N191	D302	1N645

FUSES

REF	PART NO. (NOTE A)
F1	115 v: 2.0 amp Slo-Blo 3AG FUF-1
	230 v: 1.0 amp Slo-Blo 3AG FUF-1
F2	115 v: 2.0 amp Slo-Blo 3AG FUF-1
	230 v: 1.0 amp Slo-Blo 3AG FUF-1
F3	FUC-14

METER

REF	PART NO. (NOTE A)
M1	200 μa, MEDS-120

LAMP

REF	PART NO. (NOTE A)
P1	6.3 v, 1/4 amp Mazda 44 2LAP-939

RECTIFIERS

REF	PART NO. (NOTE A)
RX2	1N1694
RX3	1N1694

SWITCHES

REF	PART NO. (NOTE A)	REF	PART NO. (NOTE A)
S1	SWRW-147	S3	SWT-333NP
S2	SWRW-148	S4	SWT-8NP

TRANSFORMER

REF	PART NO. (NOTE A)
T1	685-402

TUBES

REF	PART NO. (NOTE A)	REF	PART NO. (NOTE A)
V1	6197	V206	6197
V101	6BH6	V301	6BH6
V102	NE-81	V302	NE-81
V103	NE-81	V303	NE-81
V104	5963	V304	5963
V106	6197	V306	6197
V201	6BH6	V501	6080
V202	NE-81	V502	12AX7
V203	NE-81	V503	5651
V204	5963		

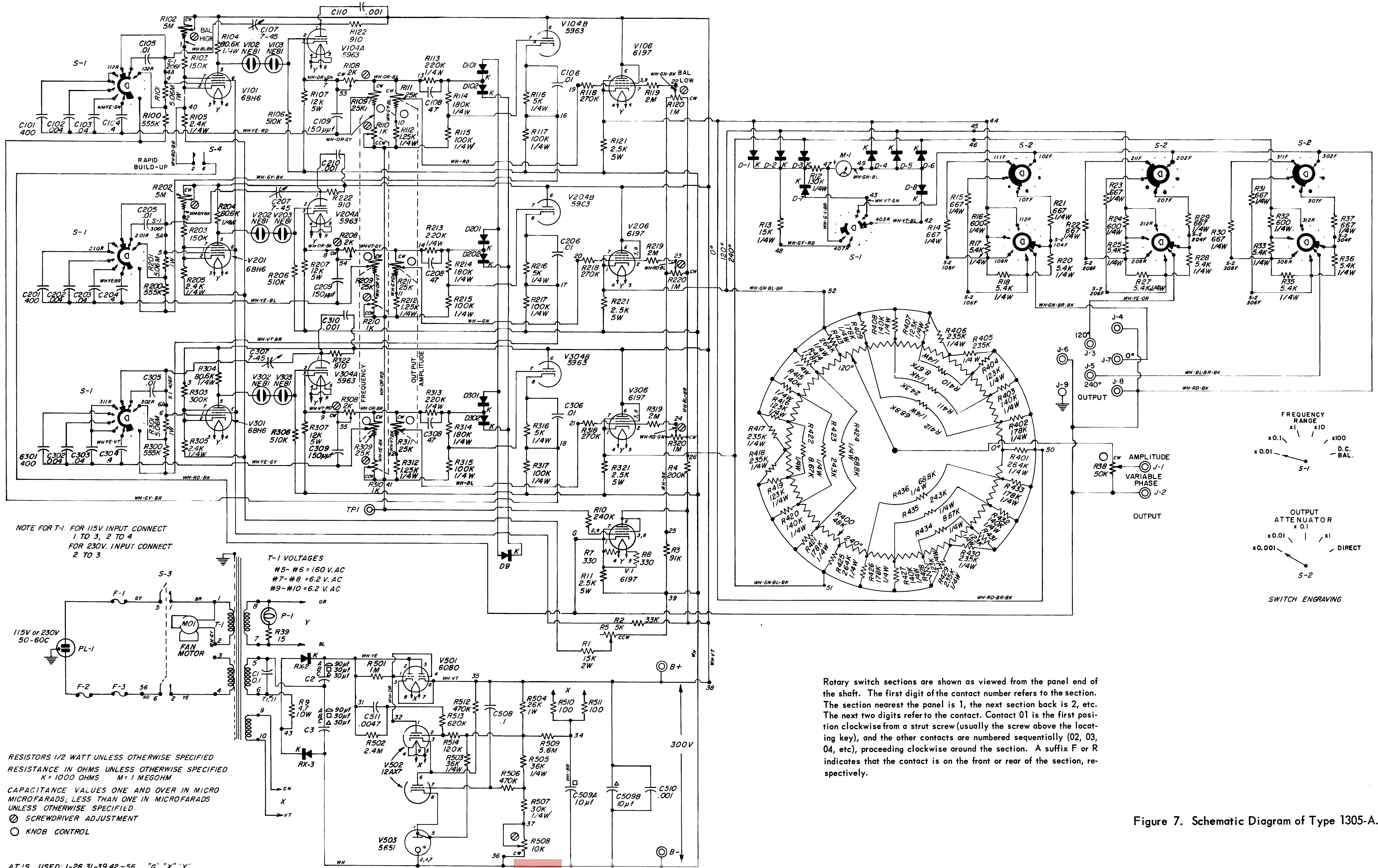
NOTES

(A) Type designations for resistors and capacitors are as follows:

COC - Capacitor, ceramic
COE - Capacitor, electrolytic
COL - Capacitor, oil
COM - Capacitor, mica
COP - Capacitor, plastic
COT - Capacitor, trimmer
COW- Capacitor, wax
POSC - Potentiometer, composition
POSW - Potentiometer, wire-wound
REC - Resistor, composition
REF - Resistor, film
REPO - Resistor, power

(B) All resistances are in ohms, except as otherwise indicated by k (kilohms) or M (megohms).

(C) All capacitances are in microfarads, except as otherwise indicated by μμf (micromicrofarads).



Rotary switch sections are shown as viewed from the panel end of the shaft. The first digit of the contact number refers to the section. The section nearest the panel is 1, the next section back is 2, etc. The next two digits refer to the contact. Contact 01 is the first position clockwise from a strut screw (usually the screw above the locating key), and the other contacts are numbered sequentially (02, 03, 04, etc), proceeding clockwise around the section. A suffix F or R indicates that the contact is on the front or rear of the section, respectively.

Figure 7. Schematic Diagram of Type 1305-A.

The resistors listed below are all ±1%, 0.30-watt, Type REPR-22 resistors. Values are in ohms, except k = kilohms.

R1	900
R2	1.8 k
R3	1.8 k
R4	3.6 k
R5	3.6 k
R6	965
R7	965
R8	1.2 k
R9	1.2 k
R10	13.4 k
R11	13.4 k

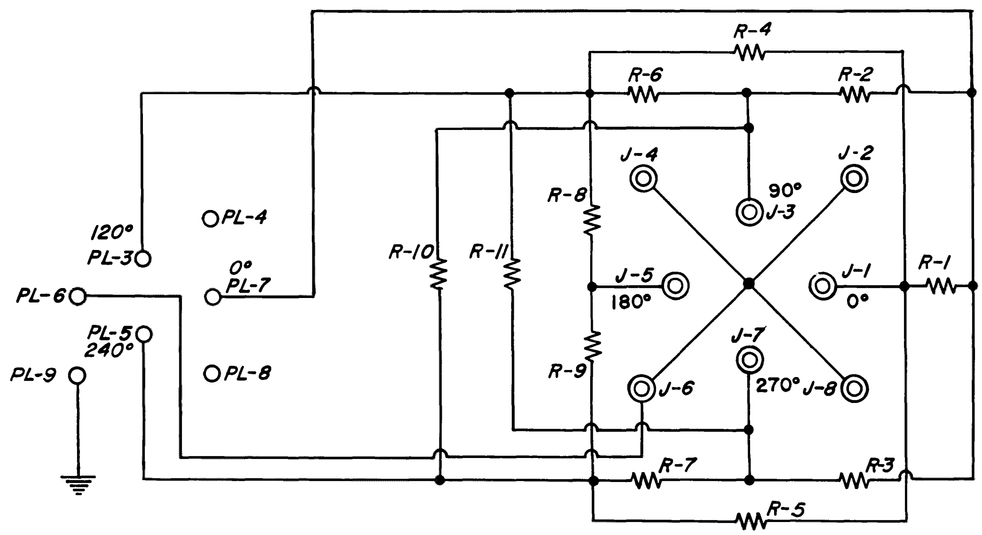


Figure 8. Schematic Diagram of Type 1305-P1 Four-Phase Output Adaptor.

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