INSTRUCTION AND OPERATING MANUAL

FOR

MODEL 100C

LOW FREQUENCY STANDARD

Serial 57 and Above

HEWLETT-PACKARD COMPANY
395 PAGE MILL ROAD, PALO ALTO, CALIFORNIA, U.S.A.

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3-2-50 100C Serial 31 to

PRODUCTION CHANGES

Serial 57 and Above

Table of Replaceable Parts

Change V7, V8, V9, V10 to:
Tube: 6 CB6, HP stock #212-6CB6

Change V14 to:
Tube: 6AV6, HP stock #212-6AV6

Change R9, R18, R27 to:
Resistor: fixed, composition, 3900 ohms, ± 10%, 1W
HP stock #24-3900, Mfr. Allen-Bradley, #GB-3921

Change R5, R15, R24 to:
Resistor: fixed, composition, 39,000 ohms, ± 10%, 1W
HP stock #24-39K, Mfr. Allen-Bradley, #GB-3931

LOW FREQUENCY STANDARD

MODEL 100C

C A U T I O N

READ BEFORE TURNING ON THE INSTRUMENT

The heating of the crystal oven in this instrument is regulated by a mercury-column switch. Occasionally, the mercury column is separated by jarring and vibration of the unit in shipment.

After turning the instrument on for the first time, keep a close check on the temperature of the crystal oven as indicated by the thermometer in the front panel. When the instrument has been on about 30 minutes, the crustal oven should remain automatically at a constant temperature. This condition will be indicated by a shutting off of the crystal oven indicator lamp from time to time, and by the fact that the thermometer will reach a steady reading of 65°C ±2oC.

However, if the crystal pilot light stays on continuously, or the thermometer goes up beyond 70 degrees, the mercury column in either the thermostat or the thermometer has probably separated in shipment. Turn the instrument off immediately and proceed as follows:

1. Remove the instrument from the cabinet and remove the crystal oven unit which plugs into tube socket adjacent to thermometer window.

2. Disconnect the thermostat wires from the terminals (#3, Fig. 1). Remove the thermostat clamp by unscrewing the two screws (#4, Fig. 1). Draw the thermostat out of the oven. (#5, Fig. 1)

3. Inspect the thermostat for mercury column separation and minute air bubbles in the mercury bulb.

4. If either air bubbles or separation are present, place the mercury switch bulb in ice water until mercury occupies only the bulb compartment. Tap lightly to remove air bubbles or mercury globules left in column.

Then place the bulb in a vessel of water and heat until mercury completely fills column and a small portion of the enlargement at the top of the column. Then remove the thermostat and watch the mercury descent to room temperature. If there is no separation or bubbles present, the thermostat may now be put back in service. It may be necessary to repeat the above procedure more than once to unite all the mercury and remove all bubbles.

CAUTION: Immerse only the bulb portion of the thermostat. If the thermostat leads get wet or any moisture collects beneath the plastic insulator covering the contact rings, remove the plastic insulator and dry tube and insulator and leads thoroughly before placing back in service. Otherwise, leakage between leads may cause heater relay to remain open.

5. Unscrew the two nuts holding the thermometer clamps (#2, Fig.1), and withdraw thermometer from the oven.

6. To unite the mercury column and remove air bubbles in the thermometer, use the same procedure as that used on the thermostat.

7. Replace the thermostat and thermometer in the crystal oven; turn on the instrument and observe oven temperature and operation of the oven indicator lamp.

3-2-50 100C Serial 31 to

INSTRUCTIONS

MODEL 100C

SECONDARY FREQUENCY STANDARD

SPECIFICATIONS

Output Rating--

Output Frequency	Volts into 5000 ohms load
100 cycles per second	5 minimum
1000 cycles per second	5 minimum
10,000 cycles per second	5 minimum
100,000 cycles per second	5 minimum

Distortion--

4% at all frequencies with 5000 ohms load.

Internal impedance - 200 ohms load.

Quartz Crystal--

100 kc

Quartz Crystal Oven--

Heater voltage 6.3v

Oven temperature 65°C

Power Supply Rating--

Voltage - - - 105 to 125 volts

Frequency - - 50 to 60 cycles

Wattage - - - 140 watts

Overall Dimensions--	Weight
Cabinet Model - 23¼" lg x 12¼" h x 14-7/16" d	38 lbs.
Rack Model- - - 19" lg x 10½" h x 14-7/16" d	28 lbs.

Tube Complement--

V1	6BH6	Oscillator
V2a, b	6AL5	Rectifier
V3	6AS6	Frequency Divider
V4	6AS6	Frequency Divider
V5a	6AL5	Rectifier
V6	6AS6	Frequency Divider
V7	6AH6	100 kc isolating amplifier
V8	6AH6	10 kc output isolating amplifier
V9	6AH6	1000 cycles output isolating amplifier
V10	6AH6	100 cycles output isolating amplifier
V11	5R4GY	Power Supply Rectifier
V12	6L6G	Voltage Regulator
V13	6L6G	Voltage Regulator
V14	6AQ6	Voltage Regulator
V15	OA2	Voltage Regulator

OPERATING INSTRUCTIONS

Inspection--

This instrument has been thoroughly tested and inspected before being shipped and is ready for use when received.

After the instrument is unpacked, the cover should be removed (See Maintenance Section) so that the instrument may be carefully inspected for damage received in transit. While the cover is off, the tubes should be checked to see that they are firmly seated in their sockets. If any shipping damage is found, follow the procedure outlined in the "Claim for Damage in Shipment" page at the back of this instruction book.

Initial Installation--

Before installing the Model 100C, make sure that the tubes and relay are secure in their sockets.

The instrument should be situated so that there is adequate ventilation. Lack of proper ventilation may cause the ambient temperature in the instrument to rise high enough so that the oven thermostat will lose control.

Observe the "Caution" regarding the crystal oven, in the front of this book, before turning on the power.

After the power is on, several hours will elapse before the crystal oven temperature becomes constant. The instrument should be run continuously so that the temperature of the components reaches a steady state and constant output frequencies will be maintained. Continuous operation of the instrument will also improve the stability of the crystal.

Low capacity shielded wire should be used to distribute the output voltages to the equipment under test as it will prevent the pick-up of extraneous voltages. The shield braid on the wire is connected to the "G" binding posts of the instrument. To maintain a minimum output voltage of 5 volts, at each frequency, a load of not less than 5000 ohms impedance may be connected across the output terminals. The following table gives the maximum capacity that can be tolerated without exceeding the above conditions.

Frequency	Capacity for Capacitive Reactance = 5000 ohms
100 KC	.0003 mf
10 KC	.003 mf
1 KC	.03 mf
100 cycles	.3 mf

$$\frac{\text{Maximum capacity across output terminals}}{\text{Capacity (mf per foot) of wire}} = \text{Max. length of shielded wire}$$

The length of the shielded line, carrying the 100KC may be extended by connecting a 100 KC tuned circuit across the line. This tuned circuit consists of an inductance in parallel with a variable capacitor. Tune the capacitor for maximum output.

Controls and Terminals--

FREQ. ADJ. - See section on "Standardization with WWV" for the use of this control.

POWER - This switch controls all power supplied to the instrument from the power line.

OUTPUT SELECTOR - This switch connects any one of the four frequencies to the "output" binding posts on the front panel.

FUSE - the fuseholder, located on the back of the chassis, contains a 1.5 ampere cartridge fuse. The fuse may be replaced by unscrewing the fuse holder cap and inserting a new fuse.

Power Cable - The power cable consists of three conductors. Two of these conductors carry power to the instrument while the third conductor (green wire) is connected to the instrument chassis. The third wire projects from the cable near the plug end of the cable and may be connected to a ground when it is desirable to have a grounded instrument chassis.

Output Binding Posts - The four sets of binding posts on the back of the chassis are the output terminals for the four frequencies generated by the instrument. The binding posts marked "G" are connected to the chasses.

GENERAL INFORMATION

The Hewlett-Packard Low Frequency Standard Model 100C is an accurate and stable secondary frequency standard. It may be standardized with the Bureau of Standards transmissions from WWV at intervals to maintain a high order of accuracy.

The Model 100C consists of a crystal-controlled oscillator operating at 100KC which controls the stability of all frequencies generated by the instrument. The frequencies of 10KC, 1KC and 100 cps are produced by 10:1 cascaded frequency dividers which are driven by the 100KC precision oscillator. Each divider operates its own isolating amplifier so that all sine waves generated by the instrument are independently availalbe for external use.

A regulated power supply delivers all necessary voltages to the instrument and maintains a constant voltage which contributes to the excellent stability of the instrument.

<u>100KC Oscillator Circuit</u>--

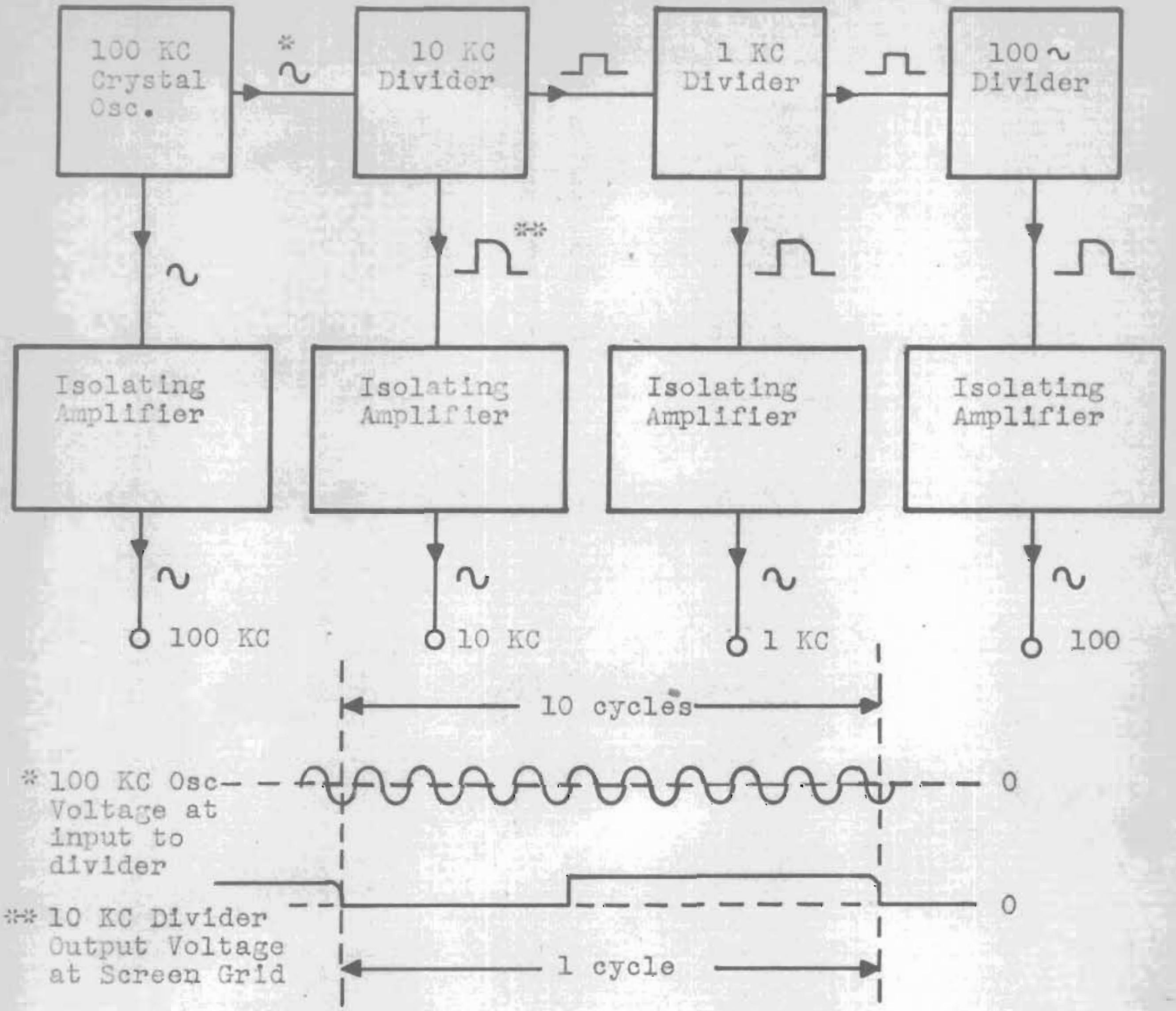
The 100KC oscillator is a modified Pierce circuit. This circuit allows the frequency to be changed ±1 cps by changing the capacity across the crystal. A very low temperature coefficient crystal held at a constant temperature controls the frequency to within 10 parts per million at normal room temperature.

<u>Frequency Divider Circuit</u>--

The frequency divider circuit is composed of (see Fig. 2) tubes V2, V3 and associated components. Tube V3 is the actual frequency divider, operating as a controlled one-shot multivibrator. The time constants of the circuit are adjusted so that the circuit is triggered by every tenth cycle of the oscillator.

Assuming for a moment that the oscillator is not operating, the operation of the circuit can be described as follows: In a quiescent state tube V3 operates in such a manner that the plate is at a higher voltage than the screen grid but draws no current. This is explained by the fact that the suppressor grid is sufficiently negative with respect to the cathode to cut off the plate current. Therefore the screen grid acts as a plate for the space current. The control grid is at cathode potential and is thus drawing heavy current. The cathode of Diode V2 is connected to a higher dc voltage than its plate so that V2 is an open circuit to positive voltages and to small negative voltages applied to its cathode. The negative portion of the oscillator is large enough to pass through diode V2 and trigger a multivibrator action in V3: The negative voltage is passed from the plate of V3 to the control grid through C1. The negative control grid reduces the space current, causing the screen voltage to rise and the cathode voltage to fall. This action reduces the suppressor bias with respect to the cathode sufficiently that current passes through the suppressor grid to the plate. The plate voltage therefore drops rapidly, reinforcing the original negative voltage on the control grid. Because the plate voltage on V3 is now low, the plate of V2 is at a lower voltage than its cathode and no negative trigger voltages can pass through diode V2.

FIG. 1 BLOCK DIAGRAM OF MODEL 100C



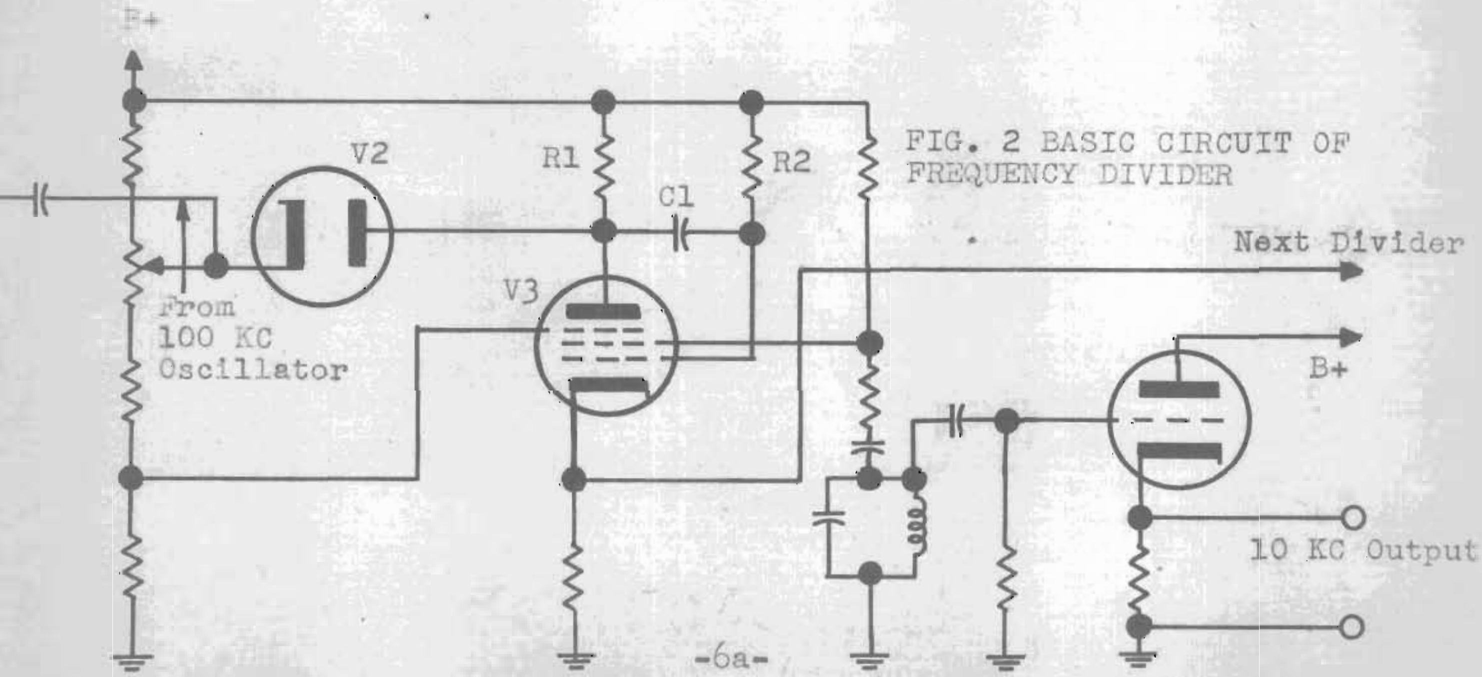


FIG. 2 BASIC CIRCUIT OF FREQUENCY DIVIDER

3/2/50 1000 Serial 31 to

The circuit remains in this condition as the negative charge on the control grid leaks off through resistor R2. As the grid voltage slowly rises, the space current in the tube slowly increases, causing the plate voltage to drop somewhat more. At the same time the cathode voltage slowly rises, increasing the bias on the suppressor grid. Finally, a critical point is reached where the screen has more attraction for the space current than the plate.

When this critical point is reached, the second portion of the multivibrator action occurs: The screen voltage falls rapidly and plate current ceases. This action transfers a positive voltage to the control grid, resulting in more space current and reinforcing the drop in screen voltage. The circuit then becomes quiescent and is prepared for the next negative pulse through Diode V2a. The time constants in the circuit are adjusted so that the total multivibrator action requires slightly more than nine cycles of the oscillator frequency, the circuit being again ready for triggering on the tenth cycle. Thus, a frequency-dividing action has occurred.

This divider circuit is highly stable and will operate for long periods of time without correction.

The sinusoidal output from the divider is obtained from a tuned circuit that is connected to the screen grid of V3 through a large isolating resistor. This sinusoidal wave is relatively harmonic-free, having less than 4% distortion.

The remaining divider circuits are connected in cascade and are driven from the cathode circuit of V3. A rectangular wave is present at the cathode and this wave, after differentiation, triggers the following divider. The remaining divider circuits operate in a manner similar to the circuit of V3, the major difference being that the time constants are adjusted to accomodate the lower repetition rates involved.

Each divider is connected to its own isolating amplifier. This amplifier isolates the divider from variable external loads and provides a low impedance output.

Power Supply and Voltage Regulator Circuit--

The power supply consists of a transformer to supply the necessary voltages and a conventional full-wave rectifier and filter system to convert alternating current to direct current.

STANDARDIZATION WITH WWV

The 100KC oscillator circuit of the Model 100C is set to 100KC at the factory and it will maintain this frequency within ±.001% (10 parts per million) on the range of normal room temperatures. This degree of accuracy is sufficient for many purposes. For a greater degree of accuracy the 100KC oscillator should be standardized with a primary frequency standard at frequent intervals.

The most accessible primary frequency standard is the standard frequencies broadcast by the National Bureau of Standards Station WWV at Washington, D.C. This service may be utilized to check the Model 100C by employing a short wave radio receiver and a frequency multiplier.

Station WWV broadcasts standard frequencies twenty-four hours a day on the following frequencies: 2.5, 5, 10, 15, 20, 25, 30 and 35 megacycles. For the latest information on using this service a Bureau of Standards Circular "Methods of Using Standard Frequencies Broadcast by Radio" may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C. A detailed announcement of WWV broadcast services, LC886 will be provided upon request from the National Bureau of Standards, Washington 25, D.C.

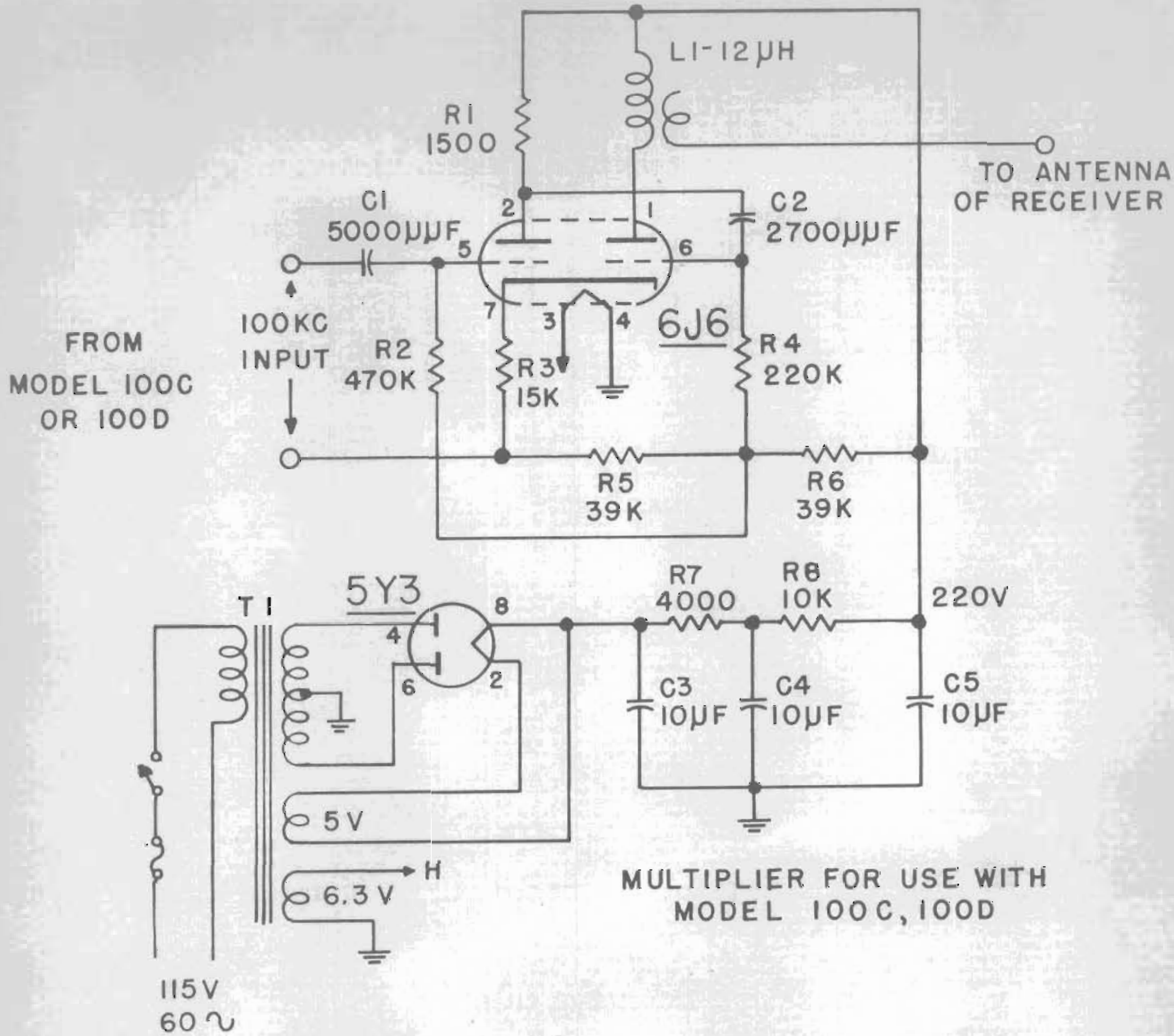
A schematic wiring diagram for a suitable multiplier is shown in the accompanying illustration. This circuit will give multiples of 100KC so that a signal is obtained on all the WWV transmission frequencies. A wire from the antenna terminal of the short wave receiver loosely coupled to Coil L1 provides a signal to mix with the signal from WWV. This coupling should be varied until it is approximately the same strength as WWV.

The adjustment of the 100KC oscillator on the Model 100C is performed as follows:

1. Feed the 100KC oscillator output through the multiplier to the radio receiver tuned to the highest WWV frequency providing the best signal. The higher the WWV frequency used, the greater the accuracy obtained in calibrating the 100KC oscillator. Headphones or loudspeaker may be used to indicate the presence of a beat between the 100KC oscillator and WWV.

2. If a beat note is present the 100KC oscillator has drifted from its correct frequency. To return the Model 100C oscillator to exactly 100KC it is necessary to tune the "FREQ. ADJ." capacitor in the lower left corner of the front panel. Turn this control in the direction that produces a decrease in the pitch until the zero beat point is reached and then increase in pitch as rotation is continued. At the zero beat point the 100KC oscillator will be standardized with WWV.

3. Should it be impossible to reach zero beat with the "FREQ. ADJ." control, then set the control to approximately onehalf capacity. Next rotate the screwdriver adjustments C2 and C4 located on the chassis in rear of crystal oven, together and in the same direction until the zero beat point is reached.



MULTIPLIER FOR USE WITH
MODEL 100C, 100D

C1 Capacitor: fixed; mica; 5000 mmf; 300 vdcw

C2 Capacitor: fixed; mica; 2700 mmf; 300 vdcw

C3, 4,5 Capacitor: fixed; electrolytic; 10 mf; 450 vdcw

R1 Resistor: fixed; composition; 1500 ohms; ±10%; 1 watt

R2 Resistor: fixed; composition; 470,000 ohms; ±10%; 1 watt

R3 Resistor: fixed; composition; 15,000 ohms; ±10%; 1 watt

R4 Resistor: fixed; composition; 220,000 ohms; ±10%; 1 watt

R5, R6 Resistor: fixed; composition; 39,000 ohms; ±10%; 2 watts

R7 Resistor: fixed; wirewound; 4000 ohms; ±10%; 20 watts

R8 Resistor: fixed; wirewound; 10,000 ohms; ±10%; 20 watts

L1 12 Microhenry coil: winding-34 turns #24 enamelled wire on 5/8" diam. bakelite form, winding 3/4" long.

T1 Power Transformer: pri. 115 v. 60 cycles; H.V. Sec. 550 V CT@ 20 MA See 5V @ 2A; 6.3 @1A.

Tubes:
1 5Y3GT
1 6J6

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The accuracy of the 10KC, 1KC and 100 cycles outputs may be determined by comparing them with the 100KC output by means of an oscilloscope.

APPLICATION

The Low Frequency Standard is applicable to most frequency measurements from very low audio frequencies up to about twenty megacycles. It may be used as a source of constant frequency voltage to operate timing circuits and modulate radio frequency generators.

The Model 100C is most useful for the calibration of audio, supersonic and radio frequency generators. Also as a comparison device to determine the frequency stability of all kinds of radio equipment.

A typical arrangement for the use of the standard in low-frequency measurements is shown in Figure 4. Low frequencies are most conveniently measured by means of Lissajous figures on an oscilloscope. However for very complex Lissajous figures it is desirable to use a large-screen oscilloscope.

An external oscillator can be used to advantage to increase the ease of identification of the more complex patterns. For example, when measuring "inconvenient" frequencies such as 210 cps, the oscillator can be adjusted to 200 cps against the 100 cps output of the standard, resulting in a simple figure-eight pattern on the oscilloscope. By then switching the standard to 10 cps and adjusting the oscillator to the first frequency above 200 cps that results in a sinusoidal pattern, a frequency of 210 cps can be accurately obtained on the oscillator. The oscillator frequency is then compared with the unknown frequency.

High frequency measurements are best made with the aid of a suitable receiver. The transition point between low and high frequency measurements is determined by the characteristics of the equipment at hand, by the stability of the unknown frequency, and by the complexity of the ratio of the unknown frequency to the standard frequency. With modern oscilloscopes and stable frequencies the transition point is above 1 megacycle. The relatively pure sine wave output of the Model 100C may have to be distorted to produce harmonics for some of the predeeding applications. This may be accomplished by inserting a germanium crystal in the output circuit of the Model 100C or by using an amplifier which draws grid current.

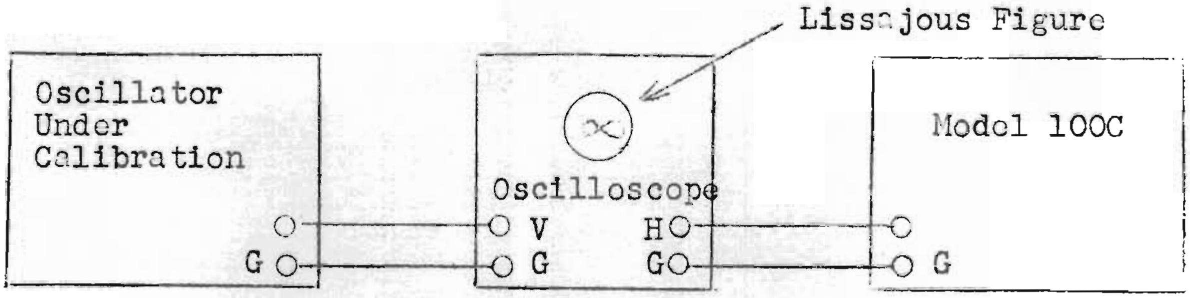
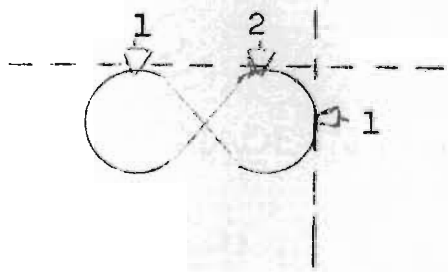


Figure 4.

Lissajous figures are produced on the screen of cathode ray tube when an alternatingcurrent voltage is corrected to both the horizontal and vertical deflecting plates of the tube. When a standard frequency voltage is fed to one set of plates and a voltage of unknown frequency is connected to the other set, the resultant figure identifies the ratio between the standard and unknown frequencies

TYPICAL LISSAJOUS FIGURE SHOWING POINTS OF TANGENCY



Unknown Frequency (connected to vertical plates of oscilloscope)

10KC (connected to horizontal plates of oscilloscope)

$$\frac{\text{No of horizontal tangencies}}{\text{No. of vertical tangencies}} \times \text{Frequency of standard} = \text{Unknown Frequency}$$

$$\frac{2}{1} \times 10\text{kc} = 20\text{ kc}$$

MAINTENANCE

Periodically the Model 100C should have the dust blown from the chassis and the tubes should be checked to see they are firmly seated in their sockets.

The following is a listing of possible symptoms and their remedies:

SYMPTOM:	REMEDY:
Fuse Failure	Inspect the instrument for a short circuit in the power circuits and clear the short before replacing fuse.
Low Output Voltage: (100KC output)	1. Check for too low an impedance load or a short circuit across the 100KC output terminals.
	2. Check V1 and V7 by replacing with new tubes. Also tune C5 for peak voltage.
	3. Measure voltage from pin 8 of V13 to chassis. Should be +225V. If voltage is too low, check power circuit for short circuit.
Low Output Voltage: (100KC output normal)	1. Determine which frequencies have subnormal output and check for too low an impedance load for a short circuit across the output terminals.
	2. Check the tubes and voltages in the divider and isolating amplifier of the highest frequency with subnormal output.
	3. Adjust the proper divider adjustment for synchronism. These adjustments are screwdriver adjustments located on top of the chassis near the panel and are labeled "10KC Divider", 1KC Divider" and "100~ Divider".
Lack of Synchronism:	1. Connect 10KC output to oscilloscope vertical plates and 100KC output to horizontal plates. Adjust R6 ("10 KC divider") so that a Lissajous figure for a 10 to 1 ratio is obtained.
	2. Follow the above procedure for 10KC and 1KC, 1KC and 100 cycles. Adjust R14 (1KC Divider) and R23 ("100~ Divider) respectively.
Crystal Oven Not Heating:	1. While the instrument is in operation, remove crystal oven from its socket. If relay is operating correctly, the crystal oven pilot lamp should burn. Clean relay contacts if relay is defective.
	2. If relay is correct, follow procedure of "Caution" section in front of this book.
Crystal Oven overheating:	1. See "Caution" Section.

Cover and Bottom Plate Removal--

The cover may be removed from the instrument without taking the instrument out of the wooden cabinet. The instrument must be removed from the cabinet when it is necessary to remove the bottom plate.

To remove the cover, unscrew the four screws holding the cover to the back of the instrument, This releases the cover so that it can be drawn out the back of the cabinet.

The bottom plate is removed by unscrewing the four screws, one in each corner of the plate.

Crystal Oven Disassembly--

The following is the step-by-step procedure necessary to disassemble the crystal oven to the point that the heater and socket connections are exposed. See Figure 1 for parts numbers referred to in this procedure.

1. Remove the four wing nuts (#1), the cover, and the insulating pad.

2. Remove the four spade screws and ring on top of the oven.

3. Remove the two nuts holding the thermometer (#2) and the thermometer.

4. Disconnect the thermostat wires at point #3.

5. Remove the two screws (#4) and the thermostat guard. Draw out the thermostat.

6. Remove the four screws (#6) at the bottom edge of the oven and slide clamp (#7) off of the housing. The housing will unwrap from around the bottom casting.

7. Unwrap the insulation and the heat wires and socket are exposed.

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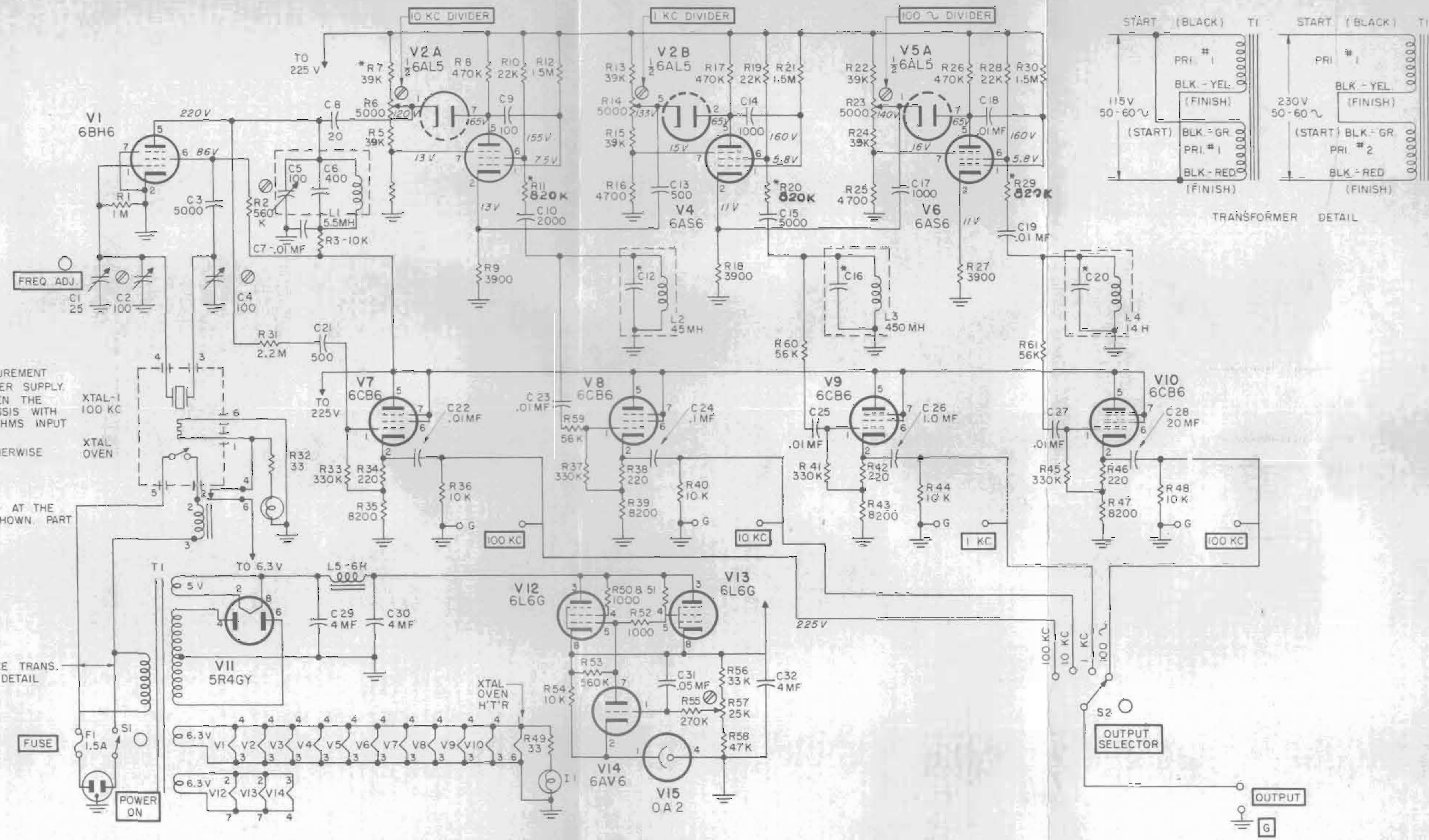

SCHMATIC DIAGRAM OF MODEL 100C SECONDARY FREQUENCY STANDARD

SERIAL 60 TO

NOTES

CONDITIONS OF DC VOLTAGE MEASUREMENT

1. 115 VOLTS, 50-60 CYCLE POWER SUPPLY.
2. MEASUREMENT TAKEN BETWEEN THE INDICATED POINTS AND CHASSIS WITH A VOLTMETER OF 100 MEGOHMS INPUT RESISTANCE.

CAPACITY IN µµF UNLESS OTHERWISE NOTED.

K = 1000 OHMS

M = 1 MEGOHM

* = ELECTRICAL VALUE ADJUSTED AT THE FACTORY. AVERAGE VALUE SHOWN. PART MAY BE OMITTED.

○ PANEL CONTROL

⊘ SCREWDRIVER ADJ.

⏚ CHASSIS

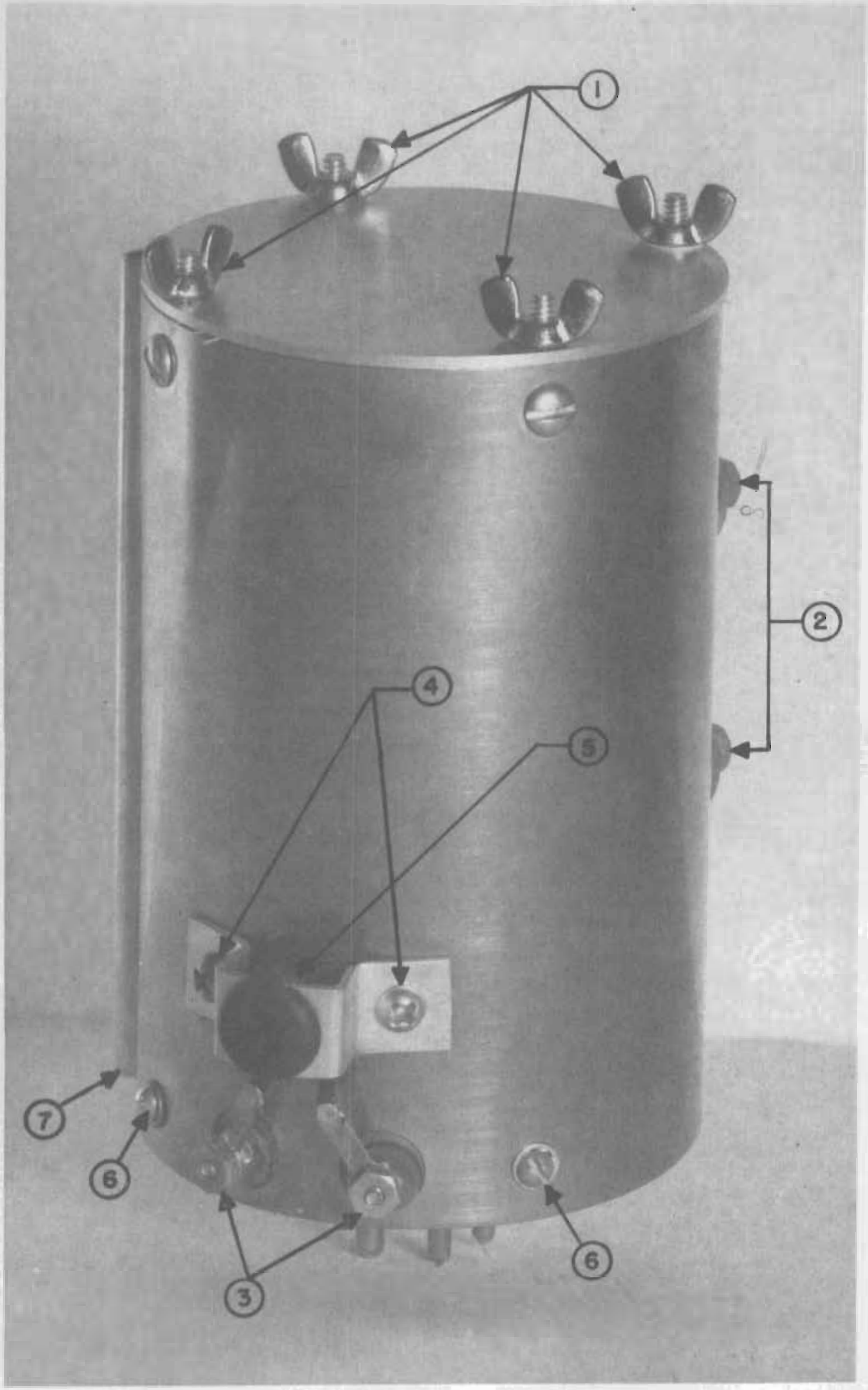

FIGURE 1
MODELS 100C, 100D
CRYSTAL OVEN ASSEM.
STK.# M-69A

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Mfr. & Mfrs. Designation
R1	Resistor: fixed; composition; 1 megohm ±10%; 1 watt	24-1M	Allen-Bradley GB-1051
R2	Resistor: fixed; composition: 560,000 ohms; ±10%; 1 watt	24-560K	A-B GB-5641
R3	Resistor: fixed; composition; 10,000 ohms; ±10%; 1 watt	24-10K	A-B BG-1031
R4	Resistor: fixed; composition; 4,700 ohms; ±10%; 1 watt	24-4700	A-B GB-4721
R5	Resistor: fixed; composition; 33,000 ohms; ±10%; 1 watt	24-33K	A-B GB-3331
R6	Resistor: variable; wirewound; 5,000 ohms; ±10%	210-8	Clarostat Type 58
R7	Resistor: 39,000 ohms; ±10%; 1 watt; Factory Adjustment	24-39K	A-B GB-3931
R8	Resistor: fixed; composition 47,000 ohms; ±10%; 1 watt	24-470K	A-B GB-4741
R9	Resistor: fixed; composition; 3,300 ohms; ±10%; 1 watt	24-3300	A-B GB-3321
R10	Resistor: fixed; composition; 22,000 ohms; ±10%; 2 watts	25-22K	A-B HB-2231
R11	Resistor: fixed; composition; 1.2 megohms; ±10%; 1 watt	24-1.2M	A-B GB-1251
R12	Resistor: fixed; composition 1.5 megohms; ±10%; 1 watt	24-1.5M	A-B GB-1551
R13	Resistor: 39,000 ohms; Factory Adjustment	24-39K	A-B GB-3931
R14	Resistor: variable; wirewound; 5,000 ohms	210-8	Clarostat Type 58
R15	Resistor: fixed; composition; 33,000 ohms; ±10%; 1 watt	24-33K	A-B GB-3331
R16	Resistor: fixed; composition; 4,700 ohms; ±10%; 1 watt	24-4700	A-B GB-4721
R17	Resistor: fixed; composition; 470,000 ohms; ±10%; 1 watt	24-470K	A-B GB-4741
R18	Resistor: fixed; composition; 3,300 ohms; ±10%; 1 watt	24-3300	A-B GB-3321

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Mfr. & Mfrs. Designation
R19	Resistor: fixed; composition; 22,000 ohms; ±10%; 2 watts	25-22K	A-B GB-2231
R20	Resistor: fixed; composition; 750,000 ohms; ±5%; 1 watt; Factory Adjustment	24-90	A-B GB-7545
R21	Resistor: fixed; composition; 1.5 megohm; ±10%; 1 watt	24-1.5M	A-B GB-1551
R22	Resistor: fixed; composition; 39,000 ohms; ±10%; 1 watt; Factory Adjustment	24-39K	A-B GB-3931
R23	Resistor: variable; wirewound; 5,000 ohms	210-8	Clarostat Type 58
R24	Resistor: fixed; composition; 33,000 ohms; ±10%; 1 watt	24-33K	A-B GB-3331
R25	Resistor: fixed; composition; 4,700 ohms; ±10%; 1 watt	24-4700	A-B GB-4721
R26	Resistor: fixed; composition; 470,000 ohms; ±10%; 1 watt	24-470K	A-B GB-4741
R27	Resistor: fixed; composition; 3,300 ohms; ±10%; 1 watt	24-3300	A-B GB-3321
R28	Resistor: fixed; composition; 22,000 ohms; ±10%; 2 watts	25-22K	A-B HB-2231
R29	Resistor: fixed; composition; 1 megohm; ±10%; 1 watt; Factory Adjustment	24-1M	A-B GB-1051
R30	Resistor: fixed; composition; 1.5 megohms; ±10%; 1 watt	24-1.5M	A-B GB-1551
R31	Resistor: fixed; composition; 2.2 megohms; ±10%; 1 watt	24-2.2M	A-B GB-2251
R32	Resistor: fixed; composition; 33 ohms; ±10%; 1 watt	24-33	A-B GB-3301
R33	Resistor: fixed; composition; 330,000 ohms; ±10%; 1 watt	24-330K	A-B GB-3341
R34	Resistor: fixed; composition; 220 ohms; ±10%; 1 watt	24-220	A-B GB-2211
R35	Resistor: fixed; composition; 8,200 ohms; ±10%; 2 watts	25-8200	A-B HB-8231

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	- hp- Stock No.	Mfr. & Mfrs. Designation
R36	Resistor: fixed; composition; 10,000 ohms; ±10%; 1 watt	24-10K	A-B GB-1031
R37	Resistor: fixed; composition 330,000 ohms; ±10%; 1 watt	24-330K	A-B GB-3341
R38	Resistor: fixed; composition; 220 ohms; ±10%; 1 watt	24-220	A-B GB-2211
R39	Resistor: fixed; composition; 8,200 ohms; ±10%; 2 watt	25-8200	A-B HB-8231
R40	Resistor: fixed; composition; 10,000 ohms; ±10%; 1 watt	24-10K	A-B GB-1031
R41	Resistor: fixed; composition; 330,000 ohms; ±10%; 1 watt	24-330K	A-B GB-3341
R42	Resistor: fixed; composition; 220 ohms; ±10%; 1 watt	24-220	A-B GB-2211
R43	Resistor: fixed; composition; 8,200 ohms; ±10%; 2 watt	25-8200	A-B HB-8231
R44	Resistor: fixed; composition; 10,000 ohms; ±10%; 1 watt	24-10K	A-B GB-1031
R45	Resistor: fixed; composition; 330,000 ohms; ±10%; 1 watt	24-330K	A-B GB-3341
R46	Resistor: fixed; composition; 220 ohms; ±10%; 1 watt	24-220	A-B GB-2211
R47	Resistor: fixed; composition; 8,200 ohms; ±10%; 2 watt	25-8200	A-B HB-8231
R48	Resistor: fixed; composition; 10,000 ohms; ±10%; 1 watt	24-10K	A-B GB-1031
R49	Resistor: fixed; composition; 33 ohms; ±10%; 1 watt	24-33	A-B GB-3311
R50	Resistor: fixed; composition; 1,000 ohms; ±10%; ½ watt	23-1000	A-B EB-1021
R51	Resistor: fixed; composition; 1,000 ohms; ±10%; ½ watt	23-1000	A-B EB-1021
R52	Resistor: fixed; composition; 1,000 ohms: ±10%; ½ watt	23-1000	A-B EB-1021
R53	Resistor: fixed; composition; 560,000 ohms; ±10%; 1 watt	24-560K	A-B GB-5641

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TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Mfr. & Mfrs. Designation
R54	Resistor: fixed; composition; 10,000 ohms; ±10%; 2 watts	25-10K	A-B HB-2531
R55	Resistor: fixed; composition; 270,000 ohms; ±10%; 1 watt	24-270K	A-B GB-2741
R56	Resistor: fixed; composition; 33,000 ohms; ±10%; 1 watt	24-33K	A-B GB-3331
R57	Resistor: variable; 25,000 ohms; Composition	210-11	Centralab: BA1-010-1990
R58	Resistor: fixed; composition; 47,000 ohms; ±10%; 1 watt	24-47K	A-B GB-4731
R59	Resistor: 56,000 ohms; ±10%; ½ watt; fixed; composition	23-56K	A-B EB-5631
R60	Resistor: 56,000 ohms; ±10%; ½ watt; fixed; composition	23-56K	A-B EB-5631
R61	Resistor: 56,000 ohms; ±10%; ½ watt; fixed; composition	23-56K	A-B EB-5631
C1	Capacitor: variable; air; 10 mmf	12-9	Sarkes-Tarzian #A-25L
C2	Capacitor: variable: air	12-17	S-T J103L
C3	Capacitor: fixed; mica; 5000 mmf; ±10%; 300 vdcw	14-14	Micamold Type W
C4	Capacitor: variable; air; 100 mmf	12-17	S-T J103L
C5	Capacitor: variable; air; 100 mmf	12-11	S-T J103L
C6	Capacitor: fixed; mica; 400 mmf; 500 vdcw	14-400	Micamold Type OXM
C7	Capacitor: fixed; paper; .01 mf; ±20%; 600 vdcw	16-41	Solar Mfg. Corp. ST-6-01
C8	Capacitor: fixed; mica; 20 mmf; ±10%; 500 vdcw	14-20	Micamold Type OXM
C9	Capacitor: fixed; mica; 100 mmf; ±10% 500 vdcw	14-100	Micamold Type OXM
C10	Capacitor: fixed; mica; 2000 mmf; ±10%; 500 vdcw	14-13	Micamold: Type W
C11	This reference symbol not assigned		
C12	Part of Tuned Circuit Assembly		

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TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Mfr. & Mfrs. Designation
C13	Capacitor: fixed; mica; 500 mmf; ±10%; 500 vdcw	14-500	Micamold Type OXM
C14	Capacitor: fixed; mica; 1000 mmf; ±10%; 500 vdcw	14-11	Micamold Type W
C15	Capacitor: fixed; mica; 5000 mmf; ±10%; 300 vdcw	14-14	Micamold Type W
C16	Part of Tuned Circuit Assembly		
C17	Capacitor: fixed; mica; 2000 mmf; ±10%; 500 vdcw	14-13	Micamold Type W
C18	Capacitor: fixed; mica; .01 mf; ±10%; 300 vdcw	14-23	Micamold Type W
C19	Capacitor: fixed; mica; .01 mf. ±10%; 300 vdcw	14-23	Micamold Type W
C20	Part of Tuned Circuit Assembly		
C21	Capacitor: fixed; mica; 500 mmf; ±10%; 500 vdcw	14-500	Micamold Type OXM
C22	Capacitor: fixed; paper; .01 mf; -10% +30%; 600 vdcw	16-11	Aerovox Type 684
C23	Capacitor: fixed; paper; .01 mf; -10% +30 %; 600 vdcw	16-11	Aerovox Type 684
C24	Capacitor: fixed; paper; .1 mf; -10 +20%; 600 vdcw	16-1	Aerovox Type 684
C25	Capacitor: fixed paper; .01 mf; -10 +30%; 600 vdcw	16-11	Aerovox Type 684
C26	Capacitor: fixed; paper; 1 mf; ±10%; 600 vdcw	17-12	General Elec. 23F467G103
C27	Capacitor: fixed; paper; .01 mf; 600 vdcw	16-11	Aerovox Type 684
C28	Capacitor: fixed; electrolytic; 20 mf; 450 vdcw	18-20	P.R.Mallory FPS-144
C29	Capacitor: fixed; paper; 4 mf; ±10%; 600 vdcw	17-10	Cornell-Dubilier TLA6040
C30	Capacitor; fixed; paper; 4 mf; ±10%; 600 vdcw	17-10	Cornell-Dubilier TLA6040
C31	Capacitor: fixed; paper; .05 mf; ±10%; 600 vdcw	16-15	Aerovox Type P6888

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Mfr. & Mfrs. Designation
C32	Capacitor: fixed; paper; 4 mf; ±10%; 600 vdcw	17-10	Cornell-Dubilier TLA6040
	Binding Post	312-3	Hewlett-Packard
	Crystal Oven: (Less crystal)	M-69A	H-P
	Replaceable Parts in Crystal Oven:		
	Crystal, Quartz: 100 kc	41-13	Jas. Knight H-18-55
	Thermometer, Contact:	41-5	Precision Inst. 40
	Thermometer:	41-6	Jensen Inst. Co. S. F.
F1	Fuse: 1.6 amp; 3AG type	211-15	Bussman Mfg. Co. MDLI.6
	Fuseholder:	312-8	Littelfuse #342001
I1, I2	Lamp:	211-47	G.E. Supply #47
	Knob:	37-11	H-P
	Power Cable:	812-56	H-P
	Power Transformer:	910-43	H-P
L1	Coil, R.F: 5.5 mh	48-3	Maguire Ind. Inc. 19-4551
L2, L3, L4 C12, C16, C20	Tuned Circuit Assembly:	911-22	H-P
L5	Reactor: 6H @ 125 ma; 240 ohms	911-12	H-P
REL-1	Relay: SPST normally closed	49-6	Sigma Inst. Type 41R07-10,000-5
S-1	Toggle Switch: SPST	310-11	Arrow-Hart & Hegeman 20994-HW
S-2	Rotary Switch:	310-39	Oak Mfg. Co. 36072-H2

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Mfr. & Mfrs. Designation
	TUBES: See NOTE below		
V1	6BH6, Oscillator	212-6BH6	See Note
V2	6AL5, Rectifier	212-6AL5	See Note
V3	6AS6, Frequency Divider	212-6AS6	Western Elec.
V4	6AS6, Frequency Divider	212-6AS6	Western Elec.
V5a	6AL5, Rectifier	212-6AL5	See Note
V6	6AS6, Frequency Divider	212-6AS6	Western Elec.
V7	6AH6, 100 kc isolating amplifier	212-6AH6	See Note
V8	6AH6, 10 kc output isolating amplifier	212-6AH6	See Note
V9	6AH6, 1000 cycles output isolating amplifier	212-6AH6	See Note
V10	6AH6, 100 cycles output isolating amplifier	212-6AH6	See Note
V11	5R4GY, Power Supply Rectifier	212-5R4GY	See Note
V12	6L6G, Voltage Regulator	212-6L6G	See Note
V13	6L6G, Voltage Regulator	212-6L6G	See Note
V14	6AQ6, Voltage Regulator	212-6AQ6	See Note
V15	OA2, Voltage Regulator	212-OA2	See Note
	NOTE: Any tube with RMA standard characteristics may be used except as listed for V3, V4, and V6.		

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LIST OF MANUFACTURERS CODE LETTERS FOR REPLACEABLE PARTS TABLE

Code Letter	Manufacturer
A	Aerovox Corp.
B	Allen-Bradley Co.
C	Amperite Co.
D	Arrow, Hart and Hegeman
E	Bussman Manufacturing Co.
F	Carborundum Co.
G	Centralab
H	Cinch Manufacturing Co.
I	Clarostat Manufacturing Co.
J	Cornell Dubilier Electric Co.
K	Electrical Reactance Co.
L	Erie Resistor Corp.
M	Federal Telephone and Radio Corp.
N	General Electric Co.
O	General Electric Supply Corp.
P	Girard-Hopkins
HP	Hewlett-Packard
Q	Industrial Products Co.
R	International Resistance Co.
S	Lectrohm, Inc.
T	Littelfuse, Inc.
U	Maguire Industries, Inc.
V	Micamold Radio Corp.
W	Oak Mfg. Co.
X	P.R. Mallory Co., Inc.
Y	Radio Corp. of America
Z	Sangamo Electric Co.
AA	Sarkes Tarzian
BB	Signal Indicator Co.
CC	Sprague Electric Co.
DD	Stackpole Carbon Co.
EE	Sylvania Electric Products, Inc.
FF	Western Electric Co.
GG	Wilkor Products, Inc.
HH	Amphenol
II	Dial Light Co. of America
JJ	Leecraft Manufacturing Co.
ZZ	Any tube having RMA standard characteristics