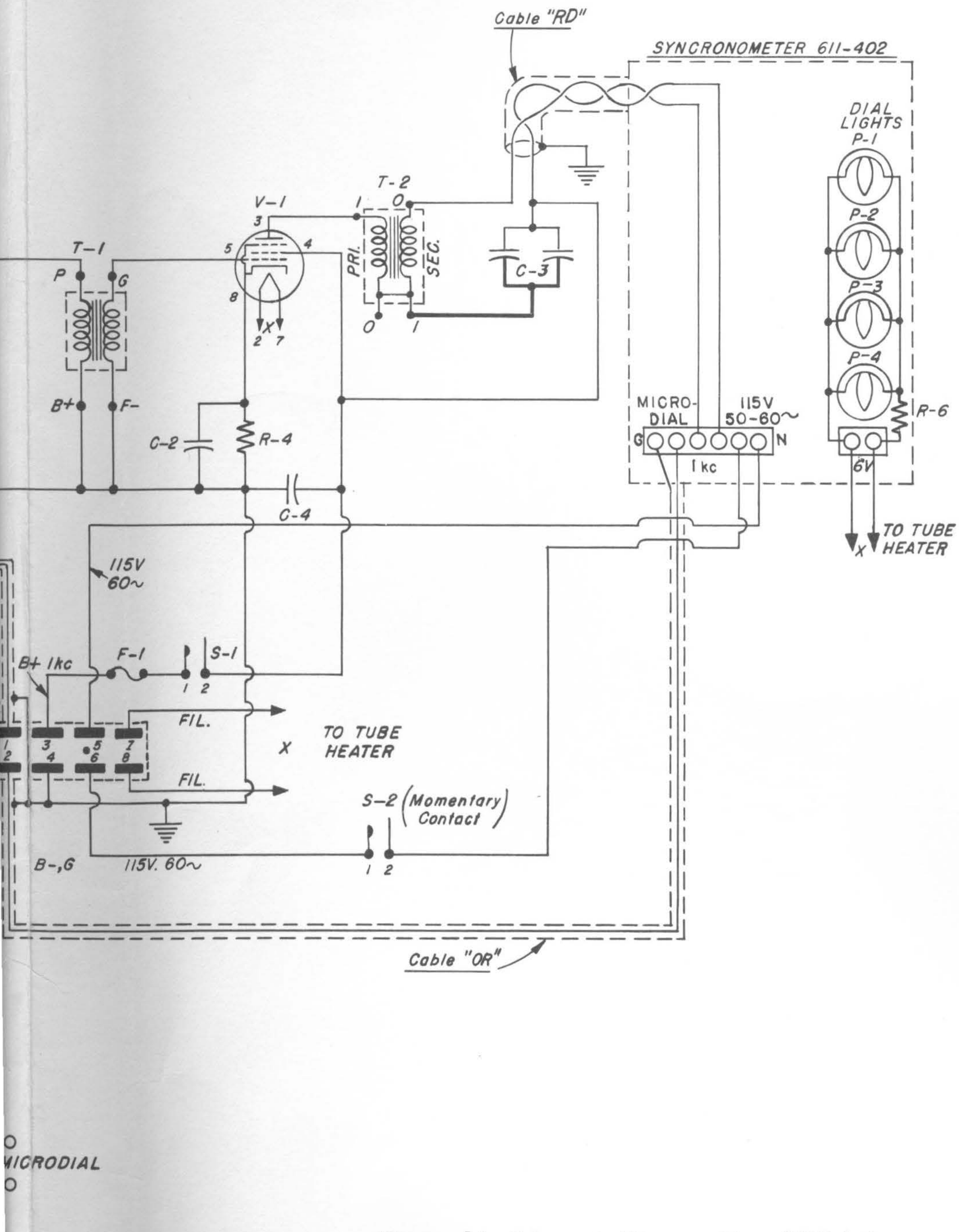

Figure 14. Schematic Diagram, Type 1103-A Syncronometer.

OPERATING INSTRUCTIONS

WGW

TYPE 1100-A

FREQUENCY STANDARDS

1100-A

GENERAL RADIO COMPANY

664-H

OPERATING INSTRUCTIONS

TYPE 1100-A

FREQUENCY STANDARDS

Form 664-H
May, 1960

GENERAL RADIO COMPANY
WEST CONCORD, MASSACHUSETTS, USA

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TEST DATA

on

TYPE 1100-_______FREQUENCY STANDARD

Type 1103-A Syncronometer Serial No. __________

Type 1102-A Multivibrator and Power Supply Unit Serial No. __________

Type 1101-B Piezo-Electric Oscillator

Serial No. __________

Frequency Adjustments, COARSE: ______ div; FINE: ______ div.

Temperature ______ °C.

Diode Meter Reading ______ μa.

Type 1190-B Quartz Bar Serial No. __________

Type 1112-A Standard Frequency Multiplier Serial No. __________

Type 1112-B Standard Frequency Multiplier Serial No. __________

Type 1116-A Emergency Power Supply Serial No. __________

Type 1570-A _____Automatic Voltage Regulator Serial No. __________

TYPE 1105-A FREQUENCY MEASURING EQUIPMENT

Type 1107-A Interpolation Oscillator Serial No. __________

Type 1109-A Comparison Oscilloscope Serial No. __________

Type 1106-A Frequency Transfer Unit Serial No. __________

Type 1106-B Frequency Transfer Unit Serial No. __________

Type 1106-C Frequency Transfer Unit Serial No. __________

Type 1108-A Coupling Panel Serial No. __________

DATE: ____________________ No. ____ OBSERVER: __________

SPECIFICATIONS

Frequency Range: Standard frequencies ranging from one pulse per second to frequencies of several megacycles can be obtained from this equipment.

The output frequencies are as follows: The upper frequency limit depends upon the method used to detect and utilize the harmonics. The values here quoted are easily reached when using the TYPE 1106 Frequency Transfer Units.

From 100-kc multivibrator, 100 kc and its harmonics up to 50 megacycles.

From 10-kc multivibrator, 10 kc and its harmonics up to 10 megacycles.

From 1-kc multivibrator, 1 kc and its harmonics in the audio-frequency range.

From 100-cycle multivibrator, 100 cycles and its harmonics in the lower audio range.

From the syncronometer unit, one-second contactor. The time of occurrence of the contact may be phased to occur at any instant over a range of one second.

This contact is open for about 50 and closed for 950 milliseconds.

If a suitable high-frequency receiver is used to detect them, 100-kc harmonics up to 75 or more megacycles can be utilized directly. For work at higher frequencies, harmonics of an auxiliary oscillator whose fundamental is monitored against the standard at a lower frequency can be used.

Output Voltage: The harmonic outputs of the 100 and 10 kc are at low impedance (65 ohms). The r-m-s voltages, measured at the terminals of the frequency standard, across a 65-ohm load, are: at 100 kc, 0.2 volt; and 10 kc, 1.2 volts. The audio-frequency outputs are at low impedance (600 ohms). The r-m-s voltages measured at the terminal strip of the standard, across a 10,000-ohm load, are: 10 kc, 20 volts; 1 kc, 25 volts; 100 cycles, 20 volts. These voltages are representative only; they are not guaranteed values.

Frequency Adjustment: The frequency of the quartz bar in its oscillator circuit is adjusted to within 1 part in ten million of its specified frequency in terms of standard time. Slight changes in frequency may occur during shipment, but a control is provided for adjusting the frequency after installation.

Long-Term Stability: When the assembly is operated in accordance with instructions, and after an aging period of a month, the rate of drift of the frequency will remain below 5 parts in 10^8 per day averaged over 10 days and this will decrease with time to about 0.5 part in 10^8 per day at the end of one year's operation.

Short-Term Stability: The standard is designed so that ordinary changes in air pressure, ambient temperature, and line voltage have practically no effect on the frequency. The temperature coefficient of frequency of the quartz bar is less than 1 part in 10^7 per degree C. The temperature variation of the oven is less than $1/250$ of the ambient temperature variation. The voltage coefficient of frequency of the crystal-controlled oscillator is less than 2 parts in 10^8 for line voltage changes of 10%. The voltage regulator eliminates fluctuations from this source.

The fluctuations of frequency of the standard over short periods, such as those required in making frequency measurements, are less than 1 part in 10^9.

Output Terminals: The various output frequencies are made available at TYPE 874 Coaxial Connectors at the rear of the assembly. Since all necessary wiring, for all interconnections between units of the assembly, is provided in the form of cables, no connections need be made by the user other than power-supply connections, and a connection to the point where the standard frequencies are to be used.

Tube Complement:

1—6AC7	1—5R4-GY	1—6K6-GT/G
10—6SN7-GT	1—1N34A	

Power Supply: 105 to 125 (or 210 to 250) volts, 60 cycles.

Power input receptacle will accept either 2-wire (TYPE CAP-35) or 3-wire (TYPE CAP-15) power cord. Two-wire cord is supplied.

Power Input: For the TYPE 1100-AQV Secondary Standard, the power *demand* from the supply line is approximately 190 watts; with heaters off, the power required is approximately 160 watts. For the TYPE 1100-APV Primary Standard, the corresponding figures are 210 and 180 watts, respectively.

Accessories Supplied: Complete set of tubes, spare sets of fuses, fusible links, pilot lights. All connecting cables, including power-supply leads, servicing cable, and complete operating instructions,

Mounting: All units are mounted on standard 19-inch relay-rack panels finished in crackle lacquer, dress panel construction. A floor-type cabinet rack, wrinkle finish, is supplied for mounting the units of the assembly. Blank panels are supplied to fill unused portion of rack.

Dimensions: The over-all dimensions of the assembly in floor-type cabinet rack are (height) 76⅛ × (width) 22 × (depth) 20½ inches, over-all. The available panel space is 40 rack units or 70 inches.

Net Weight: In floor-type racks, TYPE 1100-APV, 392 pounds, TYPE 1100-AQV, 357 pounds.

U. S. Patent No. 2,548,457

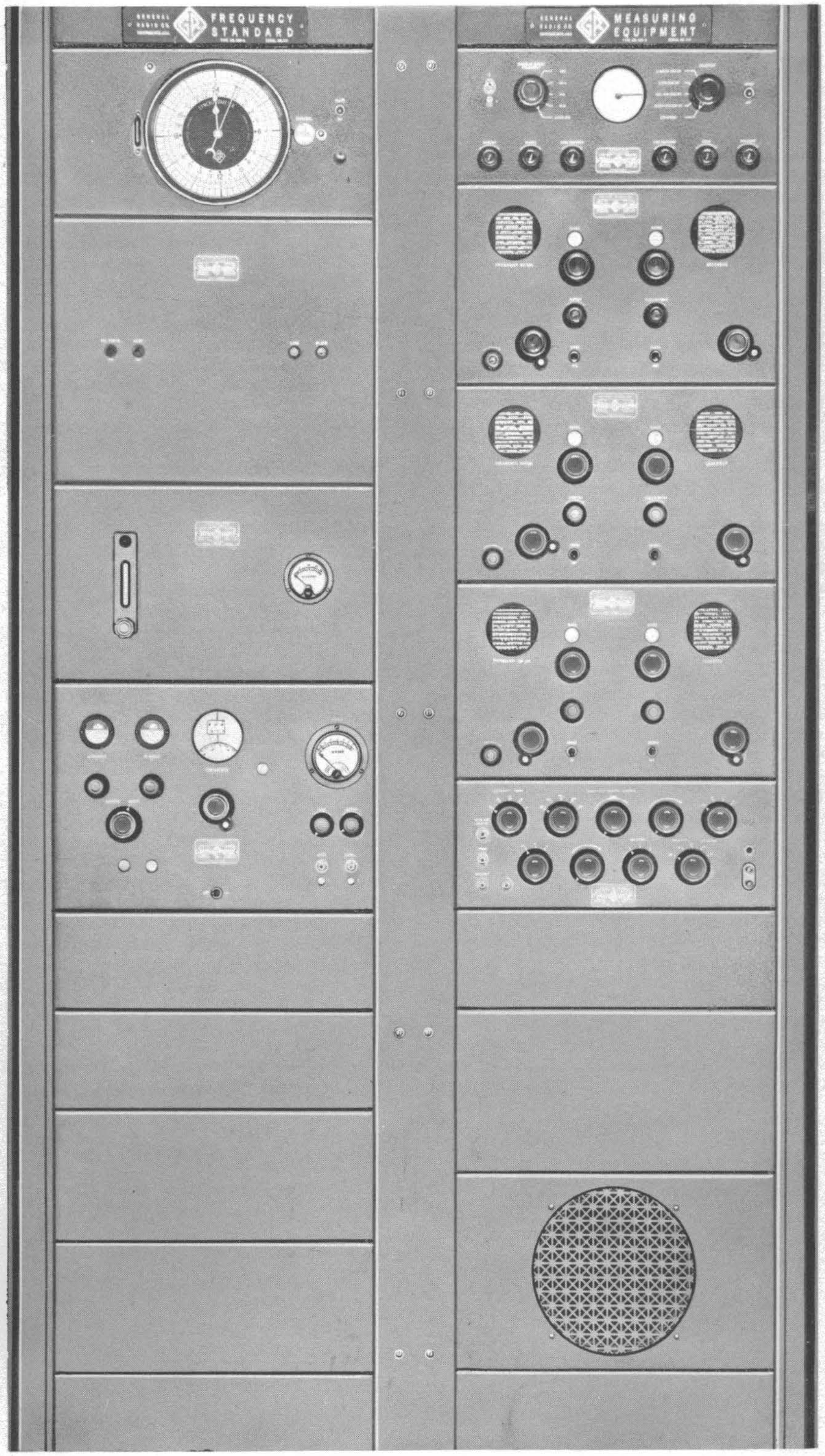


Figure 1. Type 1100-APV Primary Frequency Standard with Type 1105-A Frequency Measuring Equipment.
Left, top to bottom: Type 1103-A Syncronometer, Type 1102-A Multivibrator and Power Supply Unit, Type 1101-B Piezo-Electric Oscillator, Type 1107-A Interpolation Oscillator.
Right, top to bottom: Type 1109-A Comparison Oscilloscope, Type 1106-A, -B, -C Frequency Transfer Units, Type 1108-A Coupling Panel.

TYPE 1100-A
FREQUENCY STANDARDS

Section 1

PRINCIPLES OF FREQUENCY MEASUREMENT

1.1 FREQUENCY AND TIME. Frequency measurement is, by definition, based on time measurement; conversely, time measurement can be based on frequency measurement. The interrelation between frequency and time interval is so fundamental that a highly accurate and precise measurement of one is necessarily an equally accurate and precise measurement of the other. If 100 events, equally spaced in time, occur within, say, a minute, we know that (a) the frequency of occurrence is 100 per minute, and (b) the time interval between the beginning of one event and the beginning of the next is 1/100 minute, or 3/5 second. In this illustration, a succession of regularly occurring events was necessary. As a basis of time measurement, man has always sought the most dependably regular events available - historically, the movements of the stars and planets.

1.2 KINDS OF TIME. The basis of all time measurements, then, has long been astronomical observation. The lengths of the year and of the day, after certain corrections have been applied, are among our most reliable standards of time. The tropical year - that is, the time taken by the earth to orbit about the sun from vernal equinox to vernal equinox - is the basis of the time denoted as "Ephemeris Time", and the second has been defined as a very small fraction (1/31,556,925.975) of the tropical year 1900.

Our commonly used Universal Time - known also as Greenwich Mean Time - is based on the length of the "mean solar day". A solar day is the time taken by the earth to rotate once about its own axis with respect to the sun, assuming that the sun is a fixed reference point. Or, looking at it another way, a solar day is the time taken by the sun to make its apparent transit around the earth. Because the earth's equator is tilted with respect to its orbital plane, and because the earth's orbit is elliptical, the length of the solar day varies throughout the year. The average length of a solar day over the course of a year is called the "mean solar day".

Sidereal time is also based on the earth's rotation about its own axis, this time with respect to distant stars. Because of the great distances from the earth to these stars, rendering the stars virtually fixed reference points, the measurement of sidereal time can be carried out very precisely. Sidereal-time measurements are in fact used by astronomers in the calculation of solar time.

Ephemeris Time, based on the tropical year, and Universal Time, based on the mean solar day, can be intercompared by means of simultaneous observations of the moon and stars, and precise conversion of one to the other is possible.

1.3 THE SUBDIVISION OF TIME. Once the length of the day has been rigorously defined, it remains only to subdivide it into equal parts. A source of rapidly and regularly recurring events is needed for this purpose. The period of a pendulum can be made fairly constant, and pendulum clocks were long used as our most reliable timing devices. The period of even the best pendulum depends on the acceleration of gravity, and hence will show variations if the earth's gravity varies. The development of quartz-crystal oscillators for radio use in the 1920's gave us our first time-frequency standards relatively independent of gravity. These oscillators, designed as stable frequency references, were also time-interval determinants of exceptional accuracy and stability.

1.4 THE QUARTZ CRYSTAL. Two outstanding qualities of crystalline quartz make it especially attractive as a control element for an oscillator: the possibility of obtaining resonators of high Q (frequency sensitivity), and the outstanding stability of the quartz itself over long periods of time. The variation of frequency of a quartz crystal resonator with temperature is a function of the shape of the crystal element, its dimensions, and its angle of cut from the mother crystal.

Quartz crystal resonators are produced in the form of bars, rings, and plates for various applications.

1.5 CRYSTAL OSCILLATORS. Crystal-oscillator circuits are designed for many purposes. Some produce relatively large amounts of power at the expense of considerable dissipation in the crystal element. Others yield little power but high frequency stability. The principal crystal-oscillator circuits used in frequency standards are known as (a) the Meacham bridge-stabilized oscillator[1], (b) the Gouriet-Clapp[2] or modified Pierce oscillator, and (c) the quartz servo-controlled oscillator[3]. The General Radio frequency standards use a development of the Meacham bridge oscillator, described in paragraph 2.3.

1.6 STANDARD TIME TRANSMISSION. Every time/frequency standard must be checked periodically against a standard of higher accuracy, right up to the most accurate standards in the world, which are basically checked against astronomical observations. Checking one standard against another usually requires some sort of transmission of time-frequency information between the two standards. Appropriate governmental bureaus often assume the task of checking time directly against celestial movements, and of transmitting standard signals by radio. In the United States, the National Bureau of Standards operates radio station WWV, which transmits standard time signals on several radio frequencies, as does the U. S. Naval Observatory, over several stations of the Naval radio service. The power and frequencies of these signals are such that the time and frequency data measured at the U. S. Naval Observatory and at the Bureau of Standards are generally available over much of the world throughout the day. Other government agencies operate similar transmitters in England, Canada, Japan, Africa, Italy, and Belgium, and WWV has a Hawaiian auxiliary, WWVH. (Refer to paragraph 4.4.)

As a general policy, the Bureau of Standards' stations transmit both constant standard carrier frequencies and constant time intervals, while many of the other agencies transmit only standard time signals.

1.7 FREQUENCY DRIFT WITH TIME. For various reasons, crystal oscillators generally drift upward in frequency of oscillation as time elapses. The shape of this frequency-vs-time curve is usually exponential, with the frequency drifting rapidly at first and then at a decreasing rate. Crystal characteristics change slowly with time, and eventually reach a relatively low, constant drift rate. However, most quartz crystals continue to drift slowly upward indefinitely. Although this drift rate becomes approximately linear after several years, and can be considered as such without discernible error, the standard must be recalibrated frequently in order to insure output of the nominal standard frequency (refer to paragraph 4.4).

[1] L. A. Meacham, "The Bridge-Stabilized Oscillator", PROCEEDINGS OF THE IRE, Vol 26, pp 1278-1294; October, 1938.

[2] U. S. Patent Number 2,012,497

[3] N. Lea, "Quartz Resonator Servo - A New Frequency Standard", MARCONI REVIEW, Vol 17, pp 65-73, 3rd Quarter, 1954.

Section 2
GENERAL RADIO FREQUENCY STANDARDS

2.1 NOMENCLATURE. The Type 1100 Frequency Standard is available in the following models:

Type 1100-APV Primary Frequency Standard (115/230 v, 60 cps)

Type 1100-AQV Frequency Standard (115/230 v, 60 cps)

Type 1100-APVQ6 Primary Frequency Standard (115 v, 50 cps)

Type 1100-AQVQ6 Frequency Standard (115 v, 50 cps)

Type 1100-APVQ11 Primary Frequency Standard (230 v, 50 cps)

Type 1100-AQVQ11 Frequency Standard (230 v, 50 cps)

The only difference between the Type 1100-AP Primary Frequency Standard and the Type 1100-AQ Frequency Standard is that the former includes a Type 1103-A Syncronometer to permit direct comparison against standard time, and the latter does not. The other components of the Frequency Standard (both Types 1100-AP and 1100-AQ) are as follows:

Type 1101-B Piezo-Electric Oscillator
Type 1102-A Multivibrator and Power-Supply Unit
Type 1190-B Quartz Bar
Type 1570-A Automatic Voltage Regulator
Relay Rack, Blank Panels, Connecting Cables.

2.2 TYPE 1190-B QUARTZ BAR. The Type 1190-B Quartz Bar (Figure 2) is an X-cut bar operated at its

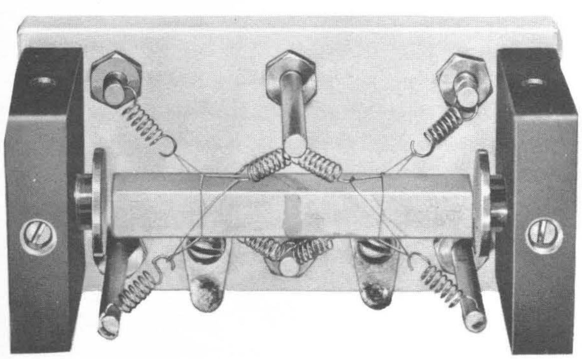


Figure 2.
Quartz Bar and Suspension.

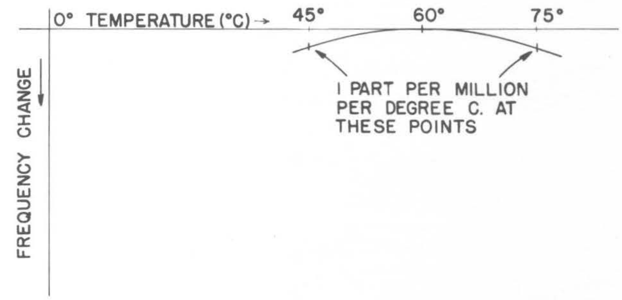


Figure 3.
Typical Temperature vs Frequency Curve.

second overtone at 100 kc. Its two half-wave extensional mode sections operate in push-pull. That is, the half from the center to one end expands as the other half contracts. The bar is suspended at its two nodal planes by a nylon monofilament string, which is in turn kept in tension by coil springs. Adjustable baffles at the end of the bar are used to reflect ultrasonic radiation and thus to reduce damping and frequency change caused by changes in air pressure. Plated electrodes are applied directly to the surface of the bar on its sides, and are interconnected for second-overtone excitation in the extensional mode. The Q of the bar is about 120,000 in this mounting.

The frequency-vs-temperature curve for this quartz bar is an inverted parabola (see Figure 3). At the vertex, where the slope of the curve is zero, zero temperature coefficient is obtained. The temperature at which this point occurs in the Type 1190-B Quartz Bar is at or slightly below 60 °C.

2.3 TYPE 1101-B PIEZO-ELECTRIC OSCILLATOR. The Type 1101-B Piezo-Electric Oscillator contains the crystal oscillator, output amplifier, elementary vacuum-tube voltmeter (to indicate oscillation) and temperature-control unit.

The derivation of the Meacham Bridge oscillator used in the Type 1100 Frequency Standard is shown in Figure 4. Figure 4A is a general oscillator diagram. In Figure 4B, the addition of a resistive bridge network stabilizes the gain and phase shift of the amplifier. In Figure 4C, a lamp is inserted in one arm of the bridge to serve as an amplitude regulator. Now the oscillator

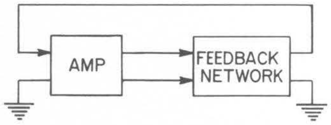


Figure 4A.

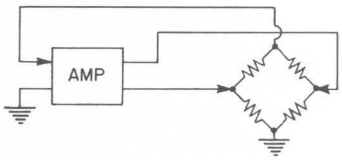


Figure 4B.

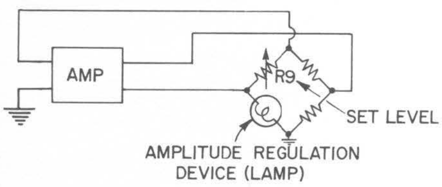


Figure 4C.

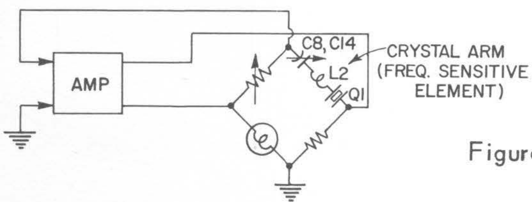


Figure 4D.

Figure 4. Derivation of Meacham-Bridge Oscillator. (A) General Oscillator Diagram. (B) Resistive Bridge Network, Stabilizing Gain and Phase Shift. (C) Addition of Lamp and Level Adjustment; Circuit Now Stabilized in Gain, Phase Shift and Level. (D) Meacham-Bridge Circuit, Stabilized in Gain, Phase Shift of Amplifier, Level, and Frequency of Oscillation.

is stabilized in gain, phase shift, and level. Finally, in Figure 4D, the frequency-sensitive element – the crystal arm – is added, and the oscillator is stabilized in gain, phase shift, level, and frequency. (Component designations used in diagrams are those used in the schematic diagrams at the rear of the manual.)

In the oscillator bridge circuit, a tungsten-filament produces a resistance that varies as the voltage across it changes. When the oscillator is first turned on, this lamp is cold and its resistance is low. Consequently, the bridge is unbalanced, and the bridge output voltage is large and phased to produce positive feedback, which builds up oscillation amplitude. As the oscillation amplitude builds up rapidly, the lamp warms up and its resistance increases, bringing the bridge toward balance. This causes decreased bridge output voltage, and decreases the amplitude of oscillation. Equilibrium is reached when the attenuation through the bridge is just equal to the gain through the amplifier. The frequency of oscillation is fixed principally by the quartz bar operating at its series-resonant frequency, as long as there is no phase shift in the amplifier and no reactance is added in series with the crystal. The amplifier is checked at the factory for zero phase shift, and the adjustment is locked. No appreciable phase shifts should occur over long periods of time. The point of zero reactance in series with the crystal is marked on the coarse frequency adjustment dial, with the fine frequency dial set at midscale (50).

The temperature control box consists of an aluminum casting, forming the inner controlled space in which the quartz bar is mounted, an asbestos-board attenuating layer, an outer aluminum casting, a balsa wood insulating container, and, finally, a metal housing. The thermostat itself is a sensitive mercury-in-glass contacting thermometer, mounted in a thermostat heater of very low heat capacity, on the top face of the outer aluminum casting. A small amount of heat (adjustable by R105) controls the thermal position of the thermostat. The adjustment provides a rate of temperature rise in the mercury thermostat equal to that in the oven proper. Rotating R105 clockwise raises the temperature of the controlled space by adjusting this rate of rise with respect to that in the oven. When properly adjusted, this compensated temperature control unit keeps the temperature of the controlled space independent of ambient-temperature changes. Even if the control unit is not adjusted for minimum variation, the effects of changes in ambient temperature are reduced by a factor of about 250. Considering the low temperature coefficient of frequency of the Type 1190-B Quartz Bar and its heat flow characteristic, the variation in frequency due to the changes in ambient temperature is negligible. Frequency variation caused by on-off cycling of the temperature control thermostat is not observable.

Two output connections are provided on the oscillator: one in the cable to the Type 1102-A Multivibrator Unit, and the other at J1 on the oscillator shelf for driving frequency multipliers such as the GR Type 1112-A Standard Frequency Multiplier.

2.4 MULTIVIBRATORS. In order to divide the single-frequency output of the piezo-electric oscillator into a low enough frequency to operate a synchronous clock motor, and also in order to provide many standard radio-frequency outputs, four multivibrators are used in the frequency standard. These multivibrators (or controlled relaxation oscillators) are mounted in the Type 1102-A Multivibrator and Power Supply Unit.

The four multivibrators (100 cps, 1 kc, 10 kc, and 100 kc) are mounted on the rear panel of the Type 1102-A Unit, with two sets of output connections available: one pair to connect the 100-kc and 10-kc harmonic outputs to the Type 1106 Frequency Transfer Units (refer to paragraph 4.7) or to other frequency measuring equipment.

Each multivibrator is a two-stage resistance-capacitance-coupled amplifier with its output fed back to its input. Its uncontrolled frequency of oscillation is determined mainly by the time constant of the R-C coupling, but depends also upon tubes, supply voltages, and level of operation.

If a voltage is injected into the multivibrator circuit at a frequency equal to a multiple of the free-running multivibrator frequency, the multivibrator may be synchronized and thus provide a frequency divider. The input frequency from the Type 1101-B 100-kc Oscillator is thus reduced in successive steps to 1 kc to operate the Type 1103-A Syncronometer (refer to paragraph 2.5).

Multivibrators, besides acting as frequency dividers, are excellent harmonic generators, and this property is used in the frequency standard to provide from each divider stage a very large number of harmonics of each multivibrator's fundamental frequency.

For frequency measurement purposes, the combined division-multiplication action of the multivibrators produces many standard frequencies, each known with the same precision as that of the constant-frequency controlling signal. These standard frequencies are distributed over the spectrum from low audio to very high radio frequencies.

2.5 SYNCRONOMETER. The Type 1103-A Syncronometer, supplied only with the Type 1100-AP Standard, comprises a 1-kc synchronous motor and clock to display the integral of the number of cycles executed by the standard-frequency oscillator as a standard time interval. By means of the microdial, the "second" as indicated by the synchronous motor driven by the standard can be compared with the standard second as received from standard time radio transmissions (e.g., from WWV). A contactor in the microdial opens for about 0.05 second, once each second (i.e., once each 10 revolutions of the synchronous motor). The time of opening can be adjusted with respect to the incoming time signals so that, for instance, only the start of each time signal is heard. The amount of adjustment necessary to achieve synchronization is indicated on the calibrated microdial; in this manner the performance of the frequency standard can be checked against standard time, offering a means of calibration accurate to one part in ten million over a 24-hour period. When the Syncronometer is used with the Type 1109-A Comparison Oscilloscope, time comparisons can be made to one millisecond or one part in 10^8 for 24 hours. Variations in radio propagation may reduce the over-all accuracy of this time-interval comparison slightly.

2.6 POWER SUPPLY. The power supply for the entire frequency standard is contained in the Type 1102-A Multivibrator and Power Supply Unit. The power supply consists of two sections: the transformer-rectifier-filter circuit that supplies power to the multivibrators, syncronometer, and oscillator; and the transformer-rectifier-relay circuit used in conjunction with the thermostat and crystal oven in the Type 1101-B Piezo-Electric Oscillator. These two sections are controlled by the front-panel FIL-PLATE and HEAT switches, respectively. LINE and PLATE fuses are also accessible from the front panel for replacement.

2.7 VOLTAGE REGULATOR. Supplied with the frequency standard is a Type 1570-A Automatic Voltage Regulator. This regulator, when installed between the power line and the frequency standard's power supply, holds the supply voltage constant to within 0.25 percent, with resultant increase in frequency stabilization of the crystal oscillator.

Section 3
INSTALLATION

3.1 MOUNTING. The components of the frequency standard are shipped already mounted in a standard relay rack, complete with blank panels needed to fill the available rack space of 70 inches. Depending upon the specifications of the individual order, it may be necessary for the user to make a few minor 115-volt connections from the power-line terminals to the Type 1570-A Voltage Regulator. Once power is connected to the frequency standard, it is ready for operation.

The Type 1103-A Syncronometer motor is mounted on shockproof mountings to reduce vibration of the chassis in operation. In shipment, these shockproof mountings are restrained by clamping screws to prevent damage. Clamping screws should be removed before operation.

Section 4
OPERATING PROCEDURE

4.1 PLACING THE STANDARD IN OPERATION. To turn on the main power supply, snap the FIL-PLATE and HEAT switches (on the Type 1102-A unit) to ON. After the tubes have warmed up, all circuits are ready for use. The temperature control unit requires at least four or five hours to reach its final temperature of 60°C. At normal room temperatures the thermostat cycle is about 20 seconds, the heat being on about six seconds, as indicated by the pilot lamp on the Type 1101-B Oscillator.

At the start, the meter on the panel of the Type 1101-B Oscillator may swing to full scale momentarily. After stabilization, the meter reading should be 90 ±5 microamperes. (If not, refer to paragraph 5.2.2.)

4.2 STARTING AND SETTING SYNCRONOMETER. To start the Syncronometer motor, press the start button on the panel of the Type 1103-A Syncronometer and momentarily throw the PLATE switch to OFF until the motor starts. Then leave the PLATE switch ON. When the Syncronometer motor comes up almost to synchronous speed, give the start button successive short pushes to bring the motor into synchronism. When starting the motor, open the door covering the clock face in order to hear the beating of the motor with the 1000-cycle driving signal. When the motor "locks in", the tone will become stable.

To set the syncronometer, insert the crank into the opening at the upper left of the clock face. Each "click" advances or retards the second hand by 0.5 second. If it is necessary to reset by a considerable amount, open the door and use the finger to advance or retard the clock hands. When the adjustment is finished, be sure that the minute and sweep second hands are synchronized. Make the final fine setting with the crank. The crank adjustment sets the second, minute, and hour hands.

4.3 USE OF THE MICRODIAL FOR TIME CHECKS. Several agencies throughout the world operate standard frequency and time radio stations whose signals can be used to check the frequency standard. The principal stations in North America are WWV (Washington, D.C.), NSS (Annapolis, Md), NBA (Balboa, Canal Zone), and CHU (Ottawa, Ont). Time signals from WWV are usually available in North America on at least one of the six standard frequencies used. For more information on transmitted time signals, write to the National Bureau of Standards, Boulder, Colo.; the U.S. Naval Observatory, Washington 25, D.C.; or the Dominion Observatory, Ottawa, Ont.

The microdial on the Syncronometer allows the user to check time as a function of the oscillator frequency against time as received from a source such as WWV. To make such a comparison, first connect the microdial contactor leads (the cable marked A4, at the rear of the Synchronometer) across the audio-frequency output of a communications receiver. Then tune the receiver to the time-signal frequency. The microdial contactors open for only 0.05 second each second, and at all other times the receiver output will be shorted, and the time signals muted. The times of opening can be brought into coincidence with the very beginning of each time tick by means of the key adjustment to the right of the microdial scale. For a time diagram of this operation, see Figure 5. Turn the key so that the microdial setting decreases, until only the noise of the time tick is audible as a very short click.

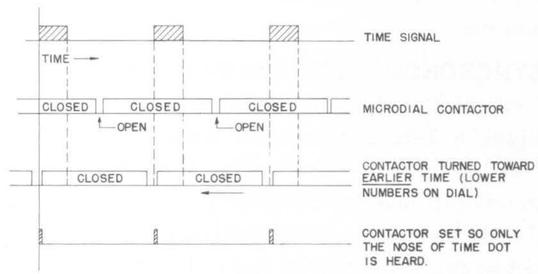
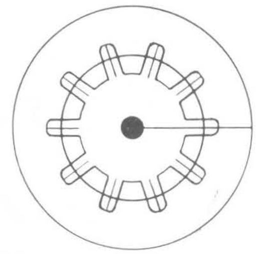


Figure 5
Diagram of Time Comparison Using the Microdial.

A more precise and more reliable check of frequency against time signals is afforded by use of the Type 1109-A Comparison Oscilloscope, a component of the Type 1105-A Frequency Measuring System. This system, which uses a visual display of the time signals on the circular-sweep oscilloscope, is described in the *General Radio Experimenter* for June, 1958, and details are available on request. The use of this oscilloscope provides an accurate time-of-arrival indicator driven directly by the standard oscillator and independent of variations in the microdial contactor.

The user who lacks the Type 1105-A Frequency Measuring System can nevertheless use an oscilloscopic display. A 60-cps sine-wave sweep is applied to the horizontal plates of a conventional oscilloscope, and a small amount of 60-cps sine wave plus the time-signal input is applied to the vertical plates. Adjust the oscilloscope controls for a presentation similar to that shown in Figure 6a. (The modulated time signals of

Figure 6a
Oscilloscopic Display, Showing Signals Received from CHU.



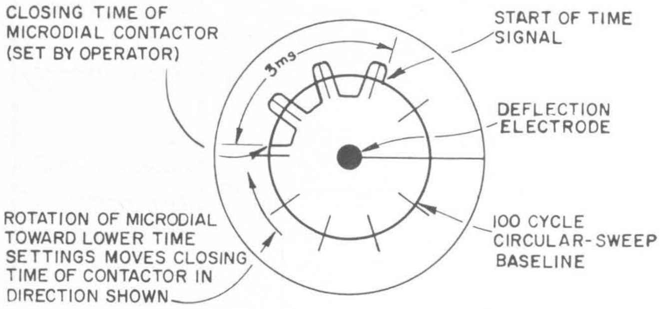


Figure 6b
Time-Signal Display on Type 1109-A Comparison Oscilloscope, with Microdial Set to Close 3 Milliseconds after Start of Time Signal.

WWV and CHU are easier to use here than are the cw-pulse signals.) Then the microdial contactor can be set to chop off part of the display (see Figure 6b).

Once the microdial is synchronized with the time signals, any subsequent deviation is represented by the number of divisions the dial must be readjusted to restore synchronization. (One division equals 0.01 second.) For instance, if the microdial is synchronized with time signals at a setting of 75 and, 24 hours later, had to be reset to 25 to restore synchronization, the 24-hour deviation is 75 - 25 x (0.01 second), or 0.5 second. Since there are 86,400 seconds in a day, this one-half second indicates a deviation of about 5.8 parts per million. Since the clock had been losing, the frequency standard was low in frequency.

The following table will be found useful in correlating microdial divisions with parts per million (based on a 24-hour time interval):

PPM	MICRODIAL DIVISIONS PER DAY
0.5	4.3
1	8.6
1.5	13
2	17.3
2.5	21.6
3	25.9

Since one can easily read half divisions on the microdial scale, comparisons can be made to better than 0.5 part in 10^7. The ultimate accuracy of the time-signal transmissions may be realized only by the use of an oscilloscope.

4.4 LOGGING PERFORMANCE. A good log is indispensable to the user who desires a continuous check on the accuracy of his frequency standard. Such a log may be a running account of frequency comparisons (refer to paragraph 4.5) or a chronicle of daily microdial resettings.

Time signals are generally available from WWV throughout the United States; however, for maximum reliability, it is recommended that the microdial be checked daily against as many time-signal stations as can ordinarily be received. The primary frequency standard at General Radio is checked daily against WWV, CHU, and NSS.

In this way, not only will checks be less dependent on vagaries of radio transmission paths, but a correction applied at one of the standard transmitters will be recognized as such and not misinterpreted as instability in the Type 1100-A.

It should be noted that a fixed day-to-day microdial adjustment indicates that the frequency standard is high or low in frequency - but not that the standard is drifting. If microdial settings for successive days are 50.0, 49.9, 49.8, 49.7, etc., there is a constant error of one-tenth division, or 1 millisecond per day. Thus the frequency error is about -1 part in 10^8, but the standard is not drifting in frequency. It is merely set low in frequency and can be corrected by adjustment of C14 only a few divisions upward. It is important to remember that, even if the frequency remains rock-steady, there will be a constantly increasing time deviation as long as the frequency is the slightest bit high or low.

Figure 7 shows the effects of a constant oscillator drift rate. In this plot, ω_0 is the nominal oscillator frequency, ω_1 is a frequency setting initially high by an amount A (i.e. A is positive), and ω_2 is a setting initially low by an amount A (A is negative). B is the amount the frequency has drifted after one day. After two days, the total drift is 2B, etc. The frequency error, ω_T, may be expressed as:

$$\omega_T = 2\pi f = A + BT$$

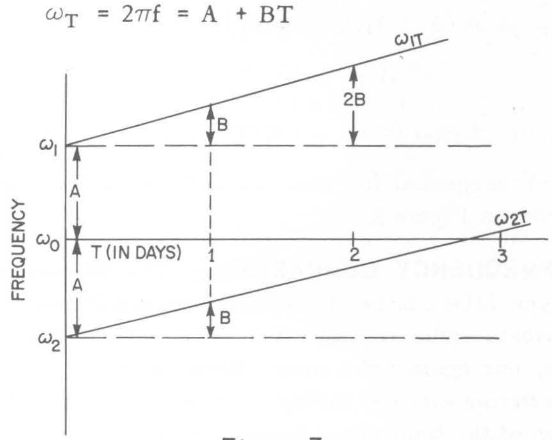


Figure 7.
Effects of Constant Oscillator Drift.

FREQUENCY-STANDARD LOG

DATE	TIME (EST)	MICRODIAL READINGS						REMARKS
		WWV	Δt(ms/day)	NSS	Δt(ms/day)	CHU	Δt(ms/day)	
8/14/59	0900	5 mc 49.7		9425 kc 50.1		7335 kc 49.6		Fading on all signals
8/15	0900	49.9	+2	50.1	0	49.7	+1	
8/16	0900	50.1	+2	50.3	+2	49.9	+2	Propagation
	1300	50.2	(+1)	missed		50.1	(+2)	(daily change)
	1500	50.2−	(−½)			50.0	(−1)	
8/17	0900	50.3+	+2½					Reset FINE
	0905	→						adj from 40 to 35

Figure 8. Suggested Microdial Log Form.

where: $A = \omega_1$, or ω_2 = initial setting of oscillator frequency

B = change in frequency per day

T = time in days

The time error due to this frequency drift is expressed as follows:

$$t = \int_{T_1}^{T_2} \omega_T dT = \left[AT + \frac{BT^2}{2} + C \right]_{T_1}^{T_2}$$

where t = integral of oscillations of frequency standard

C = constant of integration

$$t = A(T_2 - T_1) + \frac{B}{2}(T_2{}^2 - T_1{}^2) + (C_{T2} - C_{T1})$$

$$\Delta t = t - T_{ref} = t - A_O(T_2 - T_1)$$

$$= (A - A_O)(T_2 - T_1) + \frac{B}{2}(T_2{}^2 - T_1{}^2) + (C_{T2} - C_{T1})$$

where $A_O = \omega_{ref}$ (e.g., $2\pi \times 100$ kc)

A suggested log form for daily microdial checks is shown in Figure 8.

4.5 FREQUENCY COMPARISONS. The frequency of the Type 1100 can be checked against the frequency of a standard radio transmission by a simple system of beating one against the other. Because of the presence of interfering signals, fading, or other difficulties in reception of the transmitted frequency, comparison against time is usually a more convenient and reliable method of checking the standard.

The standard frequencies supplied by the Type 1100 coincide with those transmitted by the U.S. Bureau of Standard's Station WWV. If a communications receiver is turned to a frequency on which both WWV and the Type 1100 are audible, any slight difference in the two frequencies will produce a "beat", a periodic waxing and waning in intensity. The rate of this waxing and waning is the difference in frequency, which can be counted against a stop watch or against the sweep second hand of the Type 1103-A Syncronometer.

4.6 FREQUENCY ADJUSTMENT OF THE OSCILLATOR. After the frequency standard has been found high or low in frequency by either time or frequency comparison, it is possible to adjust the frequency of the quartz-crystal oscillator to compensate for the error. There are two frequency adjustments on the rear panel of the Type 1101-B Oscillator Unit, one coarse (C8) and one fine (C14). Large changes in frequency are made by C8, with C14 used as a trimming adjustment.

In the frequency-comparison procedure described in paragraph 4.5, C14 and C8 may be adjusted to bring the standard to zero-beat with the standard-frequency transmissions. If a series of zero-beat points results, the quartz crystal may be short-circuited and the oscillator may be operating on only the tuned circuit L2, C8, and C9. If it is not possible to adjust C14 and C8 for zero beat, the 100-kc multivibrator is probably out of control. This may be because of absence of control voltage, which can be caused by (1) malfunction of the crystal oscillator, (2) malfunction of the 100-kc multivibrator's input amplifier, or (3) faulty wiring or improper adjustment in the control-voltage circuits to the input amplifier. An improper setting of the frequency control adjustment of the 100-kc multivibrator may also produce this effect.

If the standard is adjusted by reference to standard time signals, the fine frequency adjustment (C14) will permit accurate setting to about 1 part in 10^8. If the microdial settings are increasing, the frequency is high and C14 should be turned to a lower reading. If the microdial settings are decreasing, the frequency is low and C14 should be turned to a higher reading.

Each dial division of the coarse adjustment (C8) corresponds to 20 times the capacitance change (and hence effect on frequency) of one division of the fine dial (C14). Note that on C8 the frequency change per dial division is less at the low-frequency (0) end of the dial than at the high-frequency (100) end. The rate of tuning therefore becomes less as the capacitor is more fully meshed, since the percent variation is less per division that at the low-capacitance end of the dial.

The total adjustment range of capacitors C8 and C14 is about 12 parts per million (1.2 cps at 100 kc). If time comparisons are to be used, it may be desirable to establish, at the start of operation, a rough calibration of oscillator frequency versus C8 dial reading. This can be done by use of a WWV signal, as follows: Set the C8 dial at several check points, including 0 and 100 divisions, and at each setting note the frequency by counting the beats against WWV (refer to paragraph 4.5). Plot the graph of frequency versus dial setting. Thereafter, the graph may be used to determine an approximate setting whenever the oscillator frequency must be adjusted.

4.7 FREQUENCY MEASURING EQUIPMENT. The General Radio Type 1105-A Frequency Measuring Equipment contains all the auxiliary equipment necessary for the accurate measurement of unknown frequencies in terms of standard frequencies from the Type 1100. Use of the Type 1105 with any model of the Type 1100 permits measurements of frequencies up to 25 Mc, and higher by means of the transfer-oscillator method. The Type 1105 contains the following instruments, each available separately:

Type 1106-A, -B, -C Frequency Transfer Units
Type 1107-A Interpolation Oscillator
Type 1108-A Coupling Panel
Type 1109-A Comparison Oscilloscope
Type 480-MA Relay Rack

Full descriptions of this equipment are given in the current General Radio Catalog.

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 insure proper handling and identification. For instruments not covered by the warranty, a purchase order should be forwarded to avoid unnecessary delay.

5.2 TYPE 1101-B PIEZO-ELECTRIC OSCILLATOR.

5.2.1 FREQUENCY ADJUSTMENT. Refer to paragraph 4.6.

5.2.2 AMPLITUDE ADJUSTMENT. The amplitude of the crystal oscillator is factory-set to 90 ±5 microamperes as indicated on the front-panel meter. If the resistance of the quartz crystal changes because of aging, the amplitude of oscillation will change. If the meter indication is outside of the range from 85 to 95 μa, adjust R9, a screw-driver adjustment on the rear panel, to bring the indication to 90 μa.

The open-circuit output voltage of the crystal oscillator should normally be about 1.7 volts, as measured by a vacuum-tube voltmeter between the shielded-lead connection (pin 1) and ground at plug PL1.

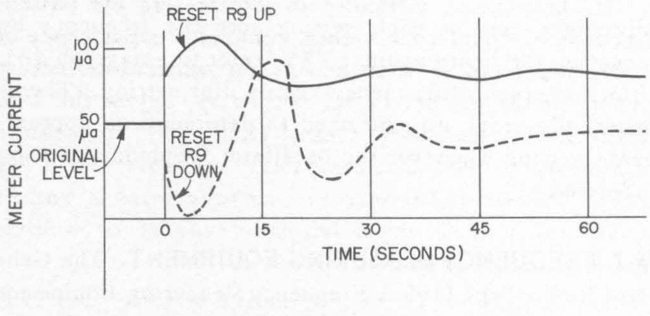


Figure 9.
Meter Current vs Time, after Adjustment of R9.

Typical effects of resetting the level adjustment, R9, are shown in Figure 9. The solid line shows a typical excursion of oscillation amplitude when R9 is set upward, and the broken line indicates the effects of a downward setting.

5.2.3 THERMOSTAT ADJUSTMENT. The amount of power supplied to the compensating thermostat heater is adjusted by means of R105, a screw-driver adjustment behind the thermometer cover plate on the front panel. This factory-set control should normally require very slight, if any, adjustment to make the thermometer read 60.0° ±0.1°C. Turning R105 clockwise raises the operating temperature. After adjusting R105, wait several hours for temperature to stabilize before making further adjustment.

If the temperature drops, the cause is probably a burned-out fusible link, F101, in the oven. The neon pilot light signals the operation of the thermostat and control relay, and at normal room temperature lights every 20 seconds, after the temperature control box has reached normal operating temperature. If the light stays off and the temperature drops, check the fusible link. If it is necessary to replace the light, remove the thermometer cover plate, remove the burned-out unit, and replace with a Type NE-51 neon bulb.

If the temperature control system does not function properly after a new fusible link (F101) has been installed, the mercury contact thermometer (thermostat S101) may be faulty. Do NOT use an ohmmeter to check this device, without first placing a current-limiting resistor in series with the contacts to limit the current to less than 10 ma. Replace the thermostat (S101) if necessary.

5.3 TYPE 1102-A MULTIVIBRATOR UNIT.

5.3.1 MULTIVIBRATOR FREQUENCY ADJUSTMENTS.

5.3.1.1 General. The proper adjustment of the multivibrators can be checked with the multivibrator panel in the normal operating position. These checks should be made with all normal multivibrator output connections in place. Control voltage adjustments are usually at maximum when fully clockwise.

5.3.1.2 100-kc Multivibrator. The 100-kc multivibrator is in the lower right-hand corner of the multivibrator panel as seen from the rear (tube side of chassis). The two adjustments are a frequency adjustment (R6 and R10) marked 100 kc, near the right-hand edge of the panel, and a control voltage adjustment (R1), near the center of the panel. Both are screw-driver controls.

Using a Type 1106-A Frequency Transfer Unit (part of the Type 1105 Frequency Measuring Equipment) or a communications receiver that can be tuned to a harmonic of the 100-kc multivibrator (preferably at 200 kc), beat the multivibrator harmonic with the receiver's beat-frequency oscillator to obtain a convenient beat frequency, say 500 cps. Turn the 100-kc screw-driver control in one direction until the beat tone suddenly becomes unsteady or jumps in frequency. Then turn the control the other way for the same effect. Note the spread between the two points at which instability occurs, and set the 100-kc adjustment midway between them. Check that the input control (R1) is set fully clockwise.

The open-circuit voltage of the 100-kc multivibrator, as measured with a vacuum-tube voltmeter between the output terminal (PL4) and ground, is about 8 volts.

5.3.1.3 10-kc Multivibrator. Using a Type 1106-A Frequency Transfer Unit or a communications receiver, check for two adjacent harmonics of the 100-kc multivibrator – say at 300 and 400 kc. Then disconnect the 100-kc multivibrator from the receiver and connect the 10-kc multivibrator. Listen for a steady beat tone at 310 kc (assuming that 300 and 400 kc were chosen). If the tone is unsteady, adjust the 10-kc multivibrator frequency control slightly counterclockwise (at the upper right-hand edge of the multivibrator panel) for a steady beat tone. Starting at 300 kc, and calling this point zero, count the number of beat points passed through as the receiver is tuned from 300 to 400 kc. If the number is 10, the multivibrator is set correctly. Make sure that the multivibrator input control (R16) is fully clockwise.

If the number of beat points is 9 or 11, adjust the frequency control (R21, R26) until the correct number is obtained.

When the frequency has been checked to be correct, adjust the receiver for an audible beat tone with a harmonic other than a multiple of 100 kc, say 310 kc. Adjust the frequency control in both directions until the beat note suddenly changes. Note the spread between these two points on the frequency control and set the control slightly counterclockwise from the point midway between them.

If the Type 1109-A Comparison Oscilloscope (part of the Type 1105-A Equipment) is available, check the 10-kc multivibrator as follows:

a. Connect the 100-kc multivibrator output to the X terminals on the panel of the oscilloscope.

b. Throw CIRCULAR SWEEP FREQUENCY switch to 10 kc. Throw SELECTOR switch to X vs STANDARD CIRCULAR SWEEP. Adjust sweep diameter as necessary.

c. If the multivibrator frequency is locked in, a stationary pattern, somewhat like a gear wheel, will appear. If the pattern is correct, there will be 10 teeth on the wheel. If the pattern is not stationary, adjust the 10-kc multivibrator frequency control (R21, R26) to obtain a stationary pattern, and if necessary adjust to obtain 10 teeth.

d. Adjust the frequency control in both directions until the 10-tooth pattern blurs or disappears. Note the spread between these two points and set the control slightly counterclockwise from the point midway between them.

The open-circuit output voltage of the 10-kc multivibrator, measured with a vacuum-tube voltmeter between the output terminal (PL3) and ground, should be about 60 volts. The voltage at terminal PL4 is approximately 25 volts open-circuit.

5.3.1.4 1-kc Multivibrator. If the Type 1109-A Comparison Oscilloscope (part of the Type 1105 Equipment) is available, check the 1-kc multivibrator as follows:

a. Connect the 10-kc multivibrator output PL3 (or PL4) to the oscilloscope X terminals.

b. Throw CIRCULAR SWEEP FREQUENCY switch to 1 kc. Throw SELECTOR switch to X vs STANDARD CIRCULAR SWEEP. Adjust sweep diameter as necessary.

c. Check that the 1-kc input control, R33, is fully clockwise. Then proceed as described in paragraph 5.3.1.3, adjusting the 1-kc multivibrator frequency control (R38, R43) as necessary. The frequency control is marked 1 KC, and is at the upper left-hand edge of the multivibrator panel as seen from the rear.

The 1-kc multivibrator can also be checked with an audio-frequency oscillator (such as the Type 1107-A Interpolation Oscillator) and an ordinary cathode-ray oscilloscope, as follows:

aa. Connect the 10-kc multivibrator output, PL4 (left rear), to the vertical-deflection amplifier of the oscilloscope.

bb. Connect the audio-frequency oscillator to the horizontal-deflection amplifier.

cc. Check that the 1-kc input control, R33, is fully clockwise.

dd. Adjust the oscillator to 2 kc, where a 5:1 Lissajous figure will appear. Adjust the oscillator carefully to make the pattern stand still.

ee. Replace the 10-kc vertical-deflector input by the 1-kc multivibrator output. A 2:1 stationary Lissajous figure will appear if the 1-kc multivibrator is locked in and is adjusted to correct frequency.

ff. In case of difficulty in interpreting the pattern because of distorted waveform, connect a capacitance of 0.05 microfarad or more across the vertical-deflection input. If the pattern is not stationary, adjust the 1-kc multivibrator frequency control (R38, R43) to obtain a stationary pattern, and readjust if necessary for a 2:1 ratio. The 1-kc multivibrator frequency control is marked 1 KC and is at the upper left-hand edge of the multivibrator panel as seen from the rear.

gg. Adjust the frequency control in both directions until the pattern blurs or disappears. Note the spread between these two points on the frequency control, and set the control midway between them.

The open-circuit output voltage of the 1-kc multivibrator, as measured with a vacuum-tube voltmeter between the output terminal (PL5) and ground, should be about 45 volts.

5.3.1.5 100-Cycle Multivibrator. If the Type 1109-A Comparison Oscilloscope (part of Type 1105 Equipment) is available, check the 100-cycle multivibrator as follows:

a. Connect the output of the 1-kc multivibrator, PL5, to the oscilloscope X terminals.

b. Throw CIRCULAR SWEEP FREQUENCY switch to 100~. Throw SELECTOR switch to X vs STANDARD CIRCULAR SWEEP. Adjust sweep diameter as necessary.

c. Check that the 100-cycle multivibrator input control, R50, is fully clockwise.

d. Proceed as described in paragraph 5.3.1.3, adjusting the 100-cycle multivibrator frequency control (R55, R60) as necessary. The frequency control is marked 100 ~, and is at the lower left-hand edge of the multivibrator panel as seen from the rear.

The 100-cycle multivibrator can also be checked with an audio-frequency oscillator (such as the Type 1107-A Interpolation Oscillator) and an ordinary cathode-ray oscilloscope, as follows:

aa. Connect the 1-kc multivibrator (PL5) to the vertical-deflection amplifier of the oscilloscope.

bb. Connect the audio-frequency oscillator to the horizontal-deflection amplifier.

cc. Check that the 100-cycle input control, R50, is fully clockwise.

dd. Set the oscillator to 200 cycles, where a stationary Lissajous figure should appear. Then proceed as outlined in paragraph 5.3.1.4, step ee to end, noting that the 100-cycle multivibrator frequency control is R55, R60 (marked 100~).

The open-circuit output voltage of the 100-cycle multivibrator, as measured with a vacuum-tube voltmeter between the output terminal (PL6) and ground, should be about 40 volts.

5.3.2 ACCESS TO COMPONENTS. For access to the components of the Multivibrator and Power Supply Unit, proceed as follows:

a. Remove the four wing nuts from the rear panel.

b. Withdraw the rear panel from the cabinet, breaking the connections at the plug under the handle at the top of the panel.

c. Attach the four spacer studs supplied with the multivibrator unit (Part No. SPFM-1414-7) to the four corner posts.

d. Plug the servicing cable supplied with the multivibrator (Part No. 1102-24) into the connector under the top of the case, and let the cable hang over one of the upper spacer studs.

e. Reverse the multivibrator panel so that the tube side is toward the cabinet, and mount the panel on the studs, using the wing nuts.

f. Plug the loose end of the service cable into the connector at the top of the panel. The multivibrator circuits are now entirely exposed and can be operated in the normal manner. Tests with voltmeter, oscilloscope or ohmmeter may be made easily at any point in the circuit.

5.4 TYPE 1103-A SYNCRONOMETER. The Syncronometer requires little or no attention. The bearings are all sealed ball bearings requiring no lubrication. A very small amount of light oil may be placed on the vertical and horizontal worm gears about once a year. If the cam shoe of the microdial squeaks, apply a little light oil at the cam face.

If it is necessary to adjust the level of the input signal to the 1-kc amplifier tube (V1), set the voltage from the arm of potentiometer R1 to ground to approximately 0.9 volt. Use a vacuum-tube voltmeter.

In case of trouble, check that the voltage from the arm of potentiometer R1 to ground is 0.9 volt. This insures proper input to the 1-kc tuned amplifier.

If it is desired to use the microdial contactor with a high-impedance audio-signal source, it may be necessary to shunt the microdial contacts with a resistor of a few thousand ohms (4700 ohms is usually low enough), to avoid the effects of stray induced voltages on this lead.

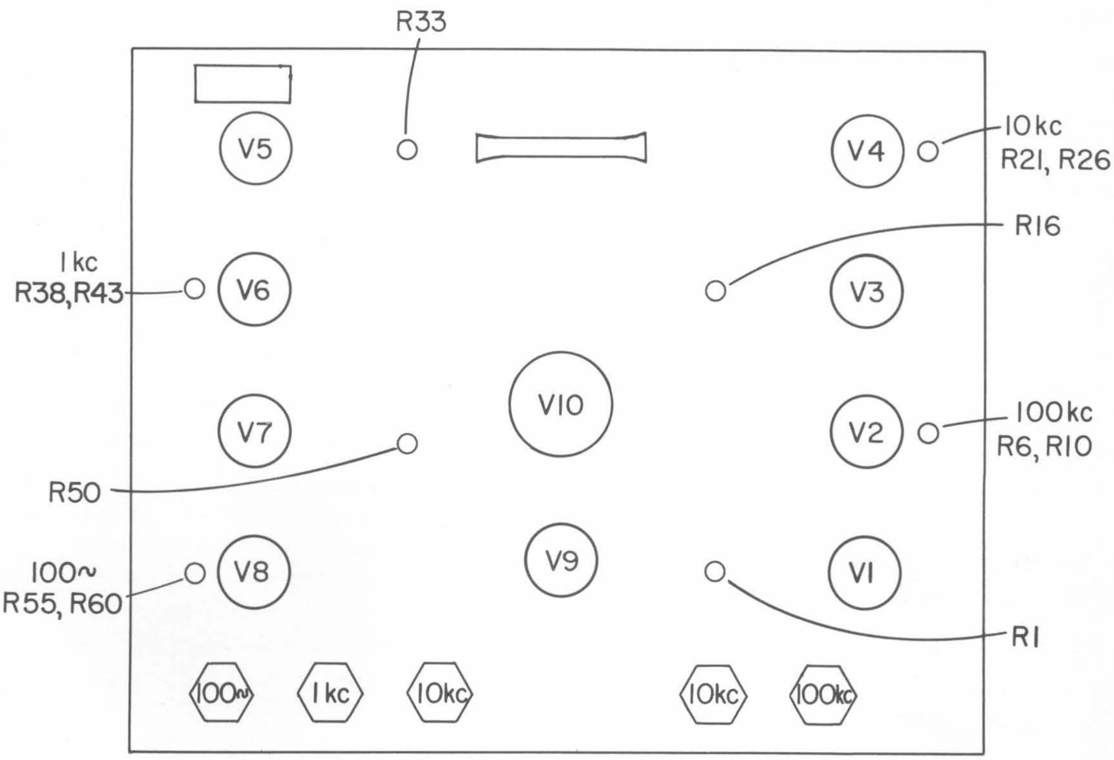


Figure 10. Tube and Connector Location Diagram,
Type 1102-A Multivibrator Unit.

TABLE OF VOLTAGES AND RESISTANCES

TYPE 1101-B OSCILLATOR

TUBE (TYPE)	PIN	VOLTS	RES TO GROUND
V1 (6AC7)	1	0	0
	2-7	6.3 ac	—
	3	0	0
	4	0	1.2 k
	5	2.65	220
	6	165	47.5 k
	7-2	6.3 ac	—
	8	255	1.7 k
V2 (6SN7GT)	1	16	1 M
	2	235	3.5 k
	3	26.5	2.7 k
	4	16	1 M
	5	265	680
	6	27.5	2.7 k
	7-8	6.3 ac	—

TYPE 1102-A MULTIVIBRATOR AND POWER SUPPLY UNIT

TUBE (TYPE)	PIN	VOLTS	RES TO GROUND
V1 (6SN7GT)	1	19	1 M
	2	220	2.2 k
	3	30	3.2 k
	4	-0.2	1 M
	5	102	22 k
	6	1.5	1 k
V2 (6SN7GT)	1	-10.6	8.5 k
	2	80	22.2 k
	3	0	0
	4	-6.2	3.5 k
	5	54	22.2 k
	6	0	0
V3 (6SN7GT)	1	20	1 M
	2	230	2.2 k
	3	31	3.2 k
	4	-30	1 M
	5	230	2.2 k
	6	6.5	510
V4 (6SN7GT)	1	-13.5	17 k
	2	100	42.2 k

TYPE 1102-A MULTIVIBRATOR AND POWER SUPPLY UNIT (Cont)

TUBE (TYPE)	PIN	VOLTS	RES TO GROUND
V3 (6SN7GT) (Cont)	3	0	0
	4	-12.0	17 k
	5	100	42.2 k
	6	0	0
V5 (6SN7GT)	1	21	1 M
	2	235	2.2 k
	3	33.5	3.2 k
	4	0	1 M
	5	235	2.2 k
	6	43	10 k
V6 (6SN7GT)	1	-27	45 k
	2	118	42.2 k
	3	0	0
	4	-25	45 k
	5	116	42.2 k
	6	0	0
V7 (6SN7GT)	1	21.5	1 M
	2	220	2.2 k
	3	34	3.2 k
	4	0	1 M
	5	220	2.2 k
	6	40	10 k
V8 (6SN7GT)	1	-29.5	45 k
	2	115	42.2 k
	3	0	0
	4	-29.5	45 k
	5	113	42.2 k
	6	0	0
V9 (6SN7GT)	1	0	1.2 M
	2	220	2.2 k
	3	19.5	10 k
	4	0	1 M
	5	220	2.2 k
	6	42.0	10 k
V10 (5R4GY)	2	335	0
	4	800 ac	55
	6	800 ac	55
	8	335	0

(Continued on next page)

TABLE OF VOLTAGES AND RESISTANCES (Cont)

TYPE 1102-A MULTIVIBRATOR AND POWER SUPPLY UNIT (Cont)

VOLTAGES AT POWER TRANSFORMERS T101, T102

	TERM.	AC VOLTS
T101	1-2	117
	3-4	117
	5-6	6.3
	7-8	6.3
	9-10	6.3
	13-14	400
	14-15	400
	16-18	5.0
T102	1-2	117
	3-4	117
	6-7	10.5
	7-8	100

VOLTAGES AT OUTPUT JACKS

JACK	RMS (VTVM)	P-P (CRO)
J1	8.3	15.0
J2	66	230
J3	19.5	48
J4	46.5	108
J5	41	100

TYPE 1103-A SYNCRONOMETER

TUBE (TYPE)	PIN	VOLTS	RES TO GROUND
V1 (6K6GT)	2	fil	
	3	260	1.2 k
	4	280	270
	5	0	0
	7	fil	
	8	23.5	1 k

NOTES:

Voltage measurements made with vacuum-tube voltmeter, except where otherwise indicated.

All resistance measurements made with respect to ground, with B+ short-circuited to ground at terminal 17 of T101. Resistances are in ohms unless otherwise indicated.

Voltages are dc and to ground, except where otherwise indicated.

PARTS LIST

REF	PART NO. (NOTE A)			
RESISTORS (NOTE B)				
R1	220	±5%	1/2 w	REC-20BF
R2	47 k	±5%	1 w	REC-30BF
R3	390	±10%	1/2 w	REC-20BF
R4	1.0 M	±10%	1/2 w	REC-20BF
R5	560	±5%	1/2 w	REC-20BF
R6	2.2 k	±5%	1 w	REC-30BF
R7	2.7 k	±5%	1 w	REC-30BF
R8	680	±1%		REF-70
R9	1 k			973-411
R10	370	±1%		REF-70
R11	2.7 k	±5%	1 w	REC-30BF
R12	2.7 k	±10%	1 w	REC-30BF
R13	5.6 k	±5%	1 w	REC-30BF
R14	2.7 k	±10%	1 w	REC-30BF
R15	47	±10%	1/2 w	REC-20BF
R16	2.7 k	±10%	1 w	REC-30BF
R17	1 k	±10%	2 w	REC-41BF
R18	470	±10%	2 w	REC-41BF
R19	10 k			POSW-3
R101	1 k			REPO-4
R102A thru R102L	1 k (11 resistors)			REPO-6
R103A thru R103F	1 k (6 resistors)			REPO-7
R104	260	±5%		1101-26
R105	2 k			POSW-3
R106	1 k	±10%	IRC Type	BW-1/2
R107	82 k	±10%	1/2 w	REC-20BF
CAPACITORS (NOTE C)				
C1	1.0			COL-5
C2	0.6			COL-4

REF	PART NO. (NOTE A)		
CAPACITORS (NOTE C)			
C3	7-140 $\mu\mu$f		COA-5-2
C4	0.0003	±2%	COM-45C
C5	0.02	±10%	COM-50B
C6	0.01	±10%	COM-45B
C7	0.5		COW-3
C8	13-320 $\mu\mu$f		COA-6-2
C9	0.00025	±2%	COM-45C
C10	0.5		COW-3
C11	0.02	±10%	COM-50B
C12	0.01	±10%	COM-45B
C13	0.01	±10%	COM-35B
C14	0.5-15 $\mu\mu$f		368-K
C15	0.01	±10%	COM-45B
C16	0.01	±1%	COC-63
MISCELLANEOUS			
F101	FUSIBLE LINK		547-50
J1	CABLE ASSY		1101-305
J2	JACK		CDSJ-8
L1	INDUCTOR		379-39-2
L2	INDUCTOR		379-39-2
M1	METER, 0-200 μa		MEDS-101
P101	LAMP		NE-51
PL1	PLUG		CDMP-463-6
PL2	PLUG		CDSP-15
PL101	PLUG		CDMP-12-4
Q1	QUARTZ BAR		1190-B
S101	THERMOSTAT		TH-503
V1	TUBE		6AC7
V2	TUBE		6SN7-GT
V3	CRYSTAL DIODE		1N34A
V4	LAMP, 6 w, 120 v Mazda Type S-6		2LAP-430

For NOTES, refer to page 21.

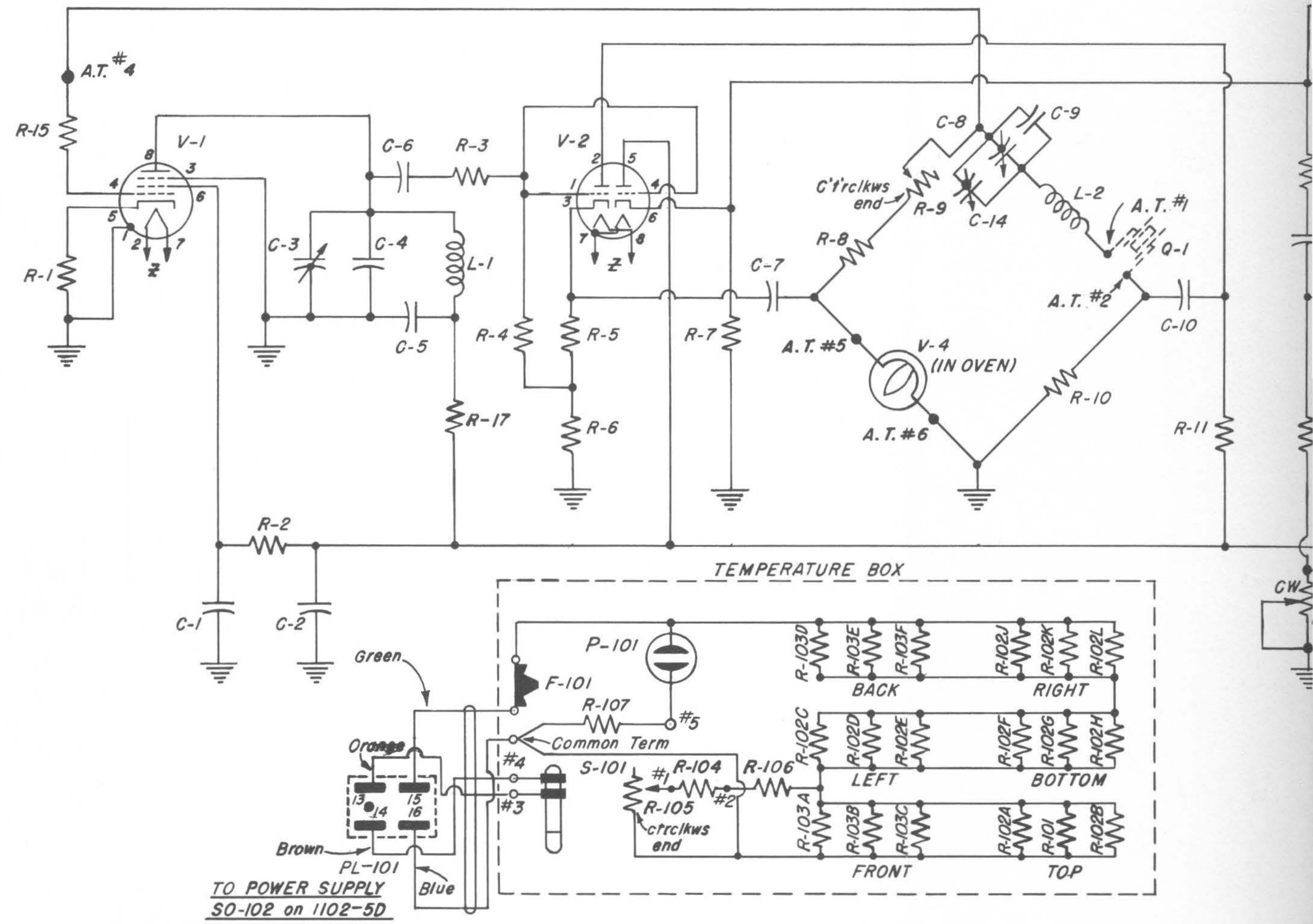
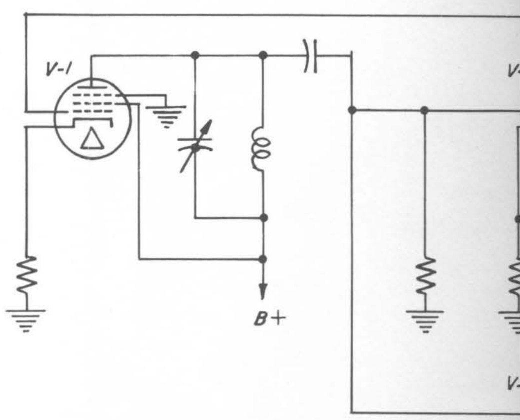
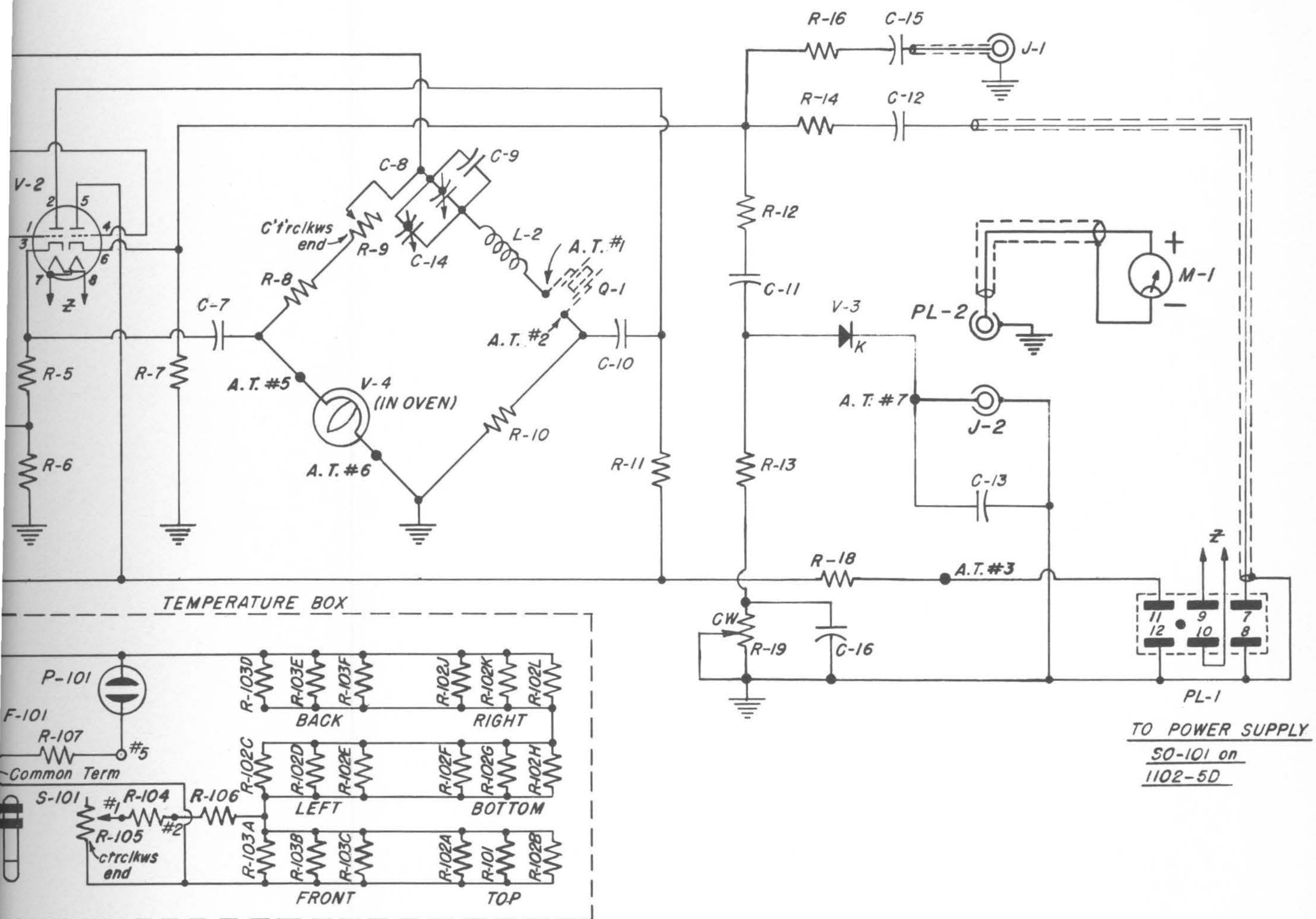


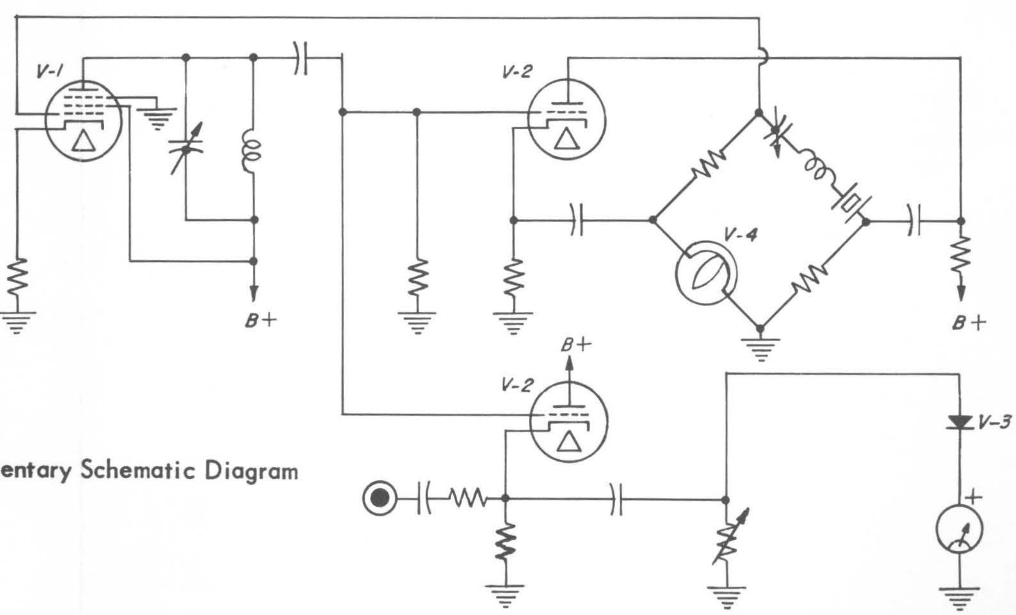
Figure 11. Schematic Diagram, Type 1101-B Oscillator.



Elementary Schematic Diagram



scillator.



Elementary Schematic Diagram

PARTS LIST

REF	PART NO. (NOTE A)			
RESISTORS (NOTE B)				
R1	50 k			301-465
R2	1 M	±10%	1 w	REC-30BF
R3	470	±10%	1/2 w	REC-20BF
R4	2.7 k	±10%	1 w	REC-30BF
R5	2.5 k	±1%	1/3 w	REPR-16
R6	2 k			Part of 1102-305
R7	3 k	±1%	1/3 w	REPR-16
R8	20 k	±1%	1/3 w	REPR-16
R9	2.5 k	±1%	1/3 w	REPR-16
R10	2 k			Part of 1102-305
R11	20 k	±1%	1/3 w	REPR-16
R12	1 M	±10%	1 w	REC-30BF
R13	1 k	±10%	1 w	REC-30BF
R14	2 k	±5%		REPO-16
R15	47 k	±10%	1 w	REC-30BF
R16	50 k			301-465
R17	1 M	±10%	1 w	REC-30BF
R18	470	±10%	1/2 w	REC-20BF
R19	2.7 k	±10%	1 w	REC-30BF
R20	10 k	±1%	1/3 w	REPR-16
R21	5 k			Part of 1102-306
R22	5 k	±1%	1/3 w	REPR-16
R23	20 k	±1%	1/3 w	REPR-16
R24	20 k	±1%	1/3 w	REPR-16
R25	10 k	±1%	1/3 w	REPR-16
R26	5 k			Part of 1102-306
R27	20 k	±1%	1/3 w	REPR-16
R28	20 k	±1%	1/3 w	REPR-16
R29	1 M	±10%	1 w	REC-30BF
R30	470	±10%	1 w	REC-30BF
R31	2 k	±5%		REPO-16
R32	47 k	±10%	1 w	REC-30BF
R33	20 k			301-465
R34	1M	±10%	1 w	REC-30BF
R35	470	±10%	1/2 w	REC-20BF
R36	2.7 k	±10%	1 w	REC-30BF
R37	30 k	± 1%	1/3 w	REPR-16
R38	20 k			Part of 1102-307
R39	5 k	±1%	1/3 w	REPR-16
R40	10 k	±1%	1/3 w	REPR-16
R41	30 k	±1%	1/3 w	REPR-16
R42	30 k	±1%	1/3 w	REPR-16
R43	20 k			Part of 1102-307
R44	10 k	±1%	1/3 w	REPR-16
R45	30 k	±1%	1/3 w	REPR-16
R46	1 M	±10%	1 w	REC-30BF
R47	10 k	±10%	1 w	REC-30BF
R48	2 k	±5%		REPO-16
R49	47 k	±10%	1 w	REC-30BF
R50	20 k			301-465
R51	1 M	±10%	1 w	REC-30BF
R52	470	±10%	1/2 w	REC-20BF
R53	2.7 k	±10%	1 w	REC-30BF
R54	30 k	±1%	1/3 w	REPR-16
R55	20 k			Part of 1102-307
R56	5 k	±1%	1/3 w	REPR-16
R57	10 k	±1%	1/3 w	REPR-16
R58	30 k	±1%	1/3 w	REPR-16
R59	30 k	±1%	1/3 w	REPR-16
R60	20 k			Part of 1102-307
R61	10 k	±1%	1/3 w	REPR-16
R62	30 k	±1%	1/3 w	REPR-16
R63	1 M	±10%	1 w	REC-30BF
R64	10 k	±10%	1 w	REC-30BF
R65	10 k	±10%	1 w	REC-30BF
R66	2 k	±5%		REPO-16
R67	10 k	±10%	1 w	REC-30BF
R68	33 k	±10%	1 w	REC-30BF
R69	47 k	±10%	1 w	REC-30BF
R70	1.0 M	±10%	1 w	REC-30BF
R71	220 k	±10%	1/2 w	REC-20BF
R72	100 k	±10%	1/2 w	REC-20BF
CAPACITORS (NOTE C)				
C1	0.001	±10%		COM-45B
C2	0.002	±10%		COM-45B
C3	0.000325	±10%*		COM-45B
C4	0.000325	±10%*		COM-45B
C5	0.0001000	±10%		COM-45B
C6	0.000020	±10%		COM-45B
C7	0.004	±10%		COM-45B
C8	1.0			COC-5
C9	0.001	±10%		COM-45B
C10	0.01	±10%		COM-50B
C11	0.001520	±10%*		COM-45B
C12	0.001520	±10%*		COM-45B
C13	0.000500	±10%		COM-45B
C14	0.000200	±10%		COM-45B
C15	0.004	±10%		COM-45B
C16	2.0			COL-6
C17	0.001	±10%		COM-45B
C18	0.02	±10%		COM-50B
C19	0.005115	±10%*		COM-45B
C20	0.005115	±10%*		COM-45B
C21	0.01	±10%		COM-45B
C22	0.002	±10%		COM-45B
C23	4.0 (two 2.0 in 11)			COL-6
C24	0.002	±10%		COM-45B
C25	0.025	±10%		COM-50B
C26	0.0627	±10%*		COM-50B
C27	0.0627	±10%*		COM-50B
C28	0.025	±10%		COM-50B
C29	0.5			COL-4
C30	0.5			COL-4
C31A	50			
C31B	25	450 dcwv		COE-10
C31C	25			
C32	0.03	±10%		COM-50B
C33	1			COL-5
C34	0.0002	±10%		COM-45B

REF	PART NO. (NOTE A)	
MISCELLANEOUS		
J1	JACK	874-P62
J2	JACK	874-P62
J3	JACK	874-P62
J4	JACK	874-P62
J5	JACK	874-P62
L1	INDUCTOR	379-35-2
PL1	PLUG	CDMP-461-12
SO1	SOCKET	CDMS-5-8

TUBES		TUBES	
V1	6SN7-GT	V6	6SN7-GT
V2	6SN7-GT	V7	6SN7-GT
V3	6SN7-GT	V8	6SN7-GT
V4	6SN7-GT	V9	6SN7-GT
V5	6SN7-GT		

For NOTES, refer to page 21.

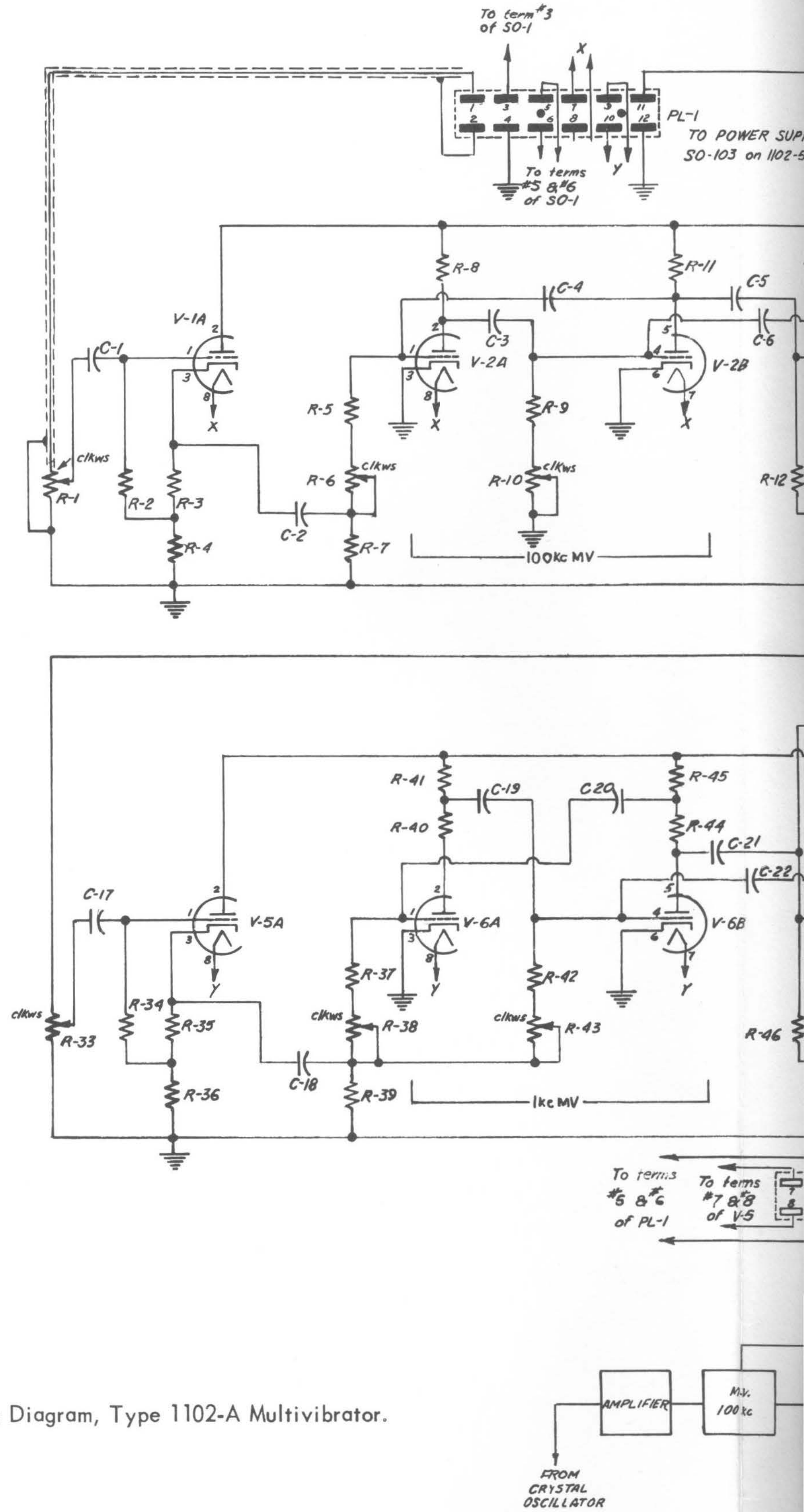
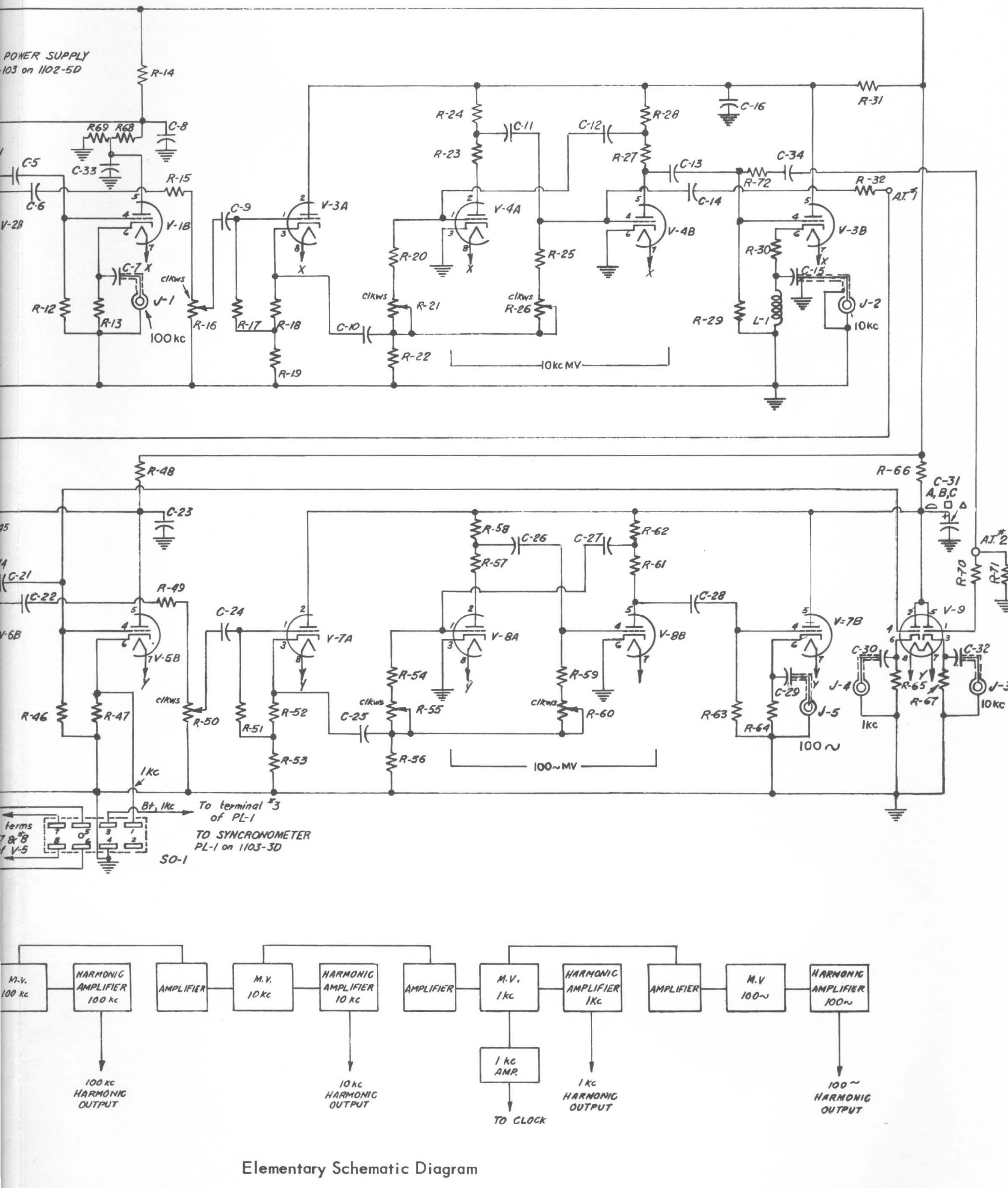


Figure 12. Schematic Diagram, Type 1102-A Multivibrator.



Elementary Schematic Diagram

PARTS LIST

REF	PART NO. (NOTE A)			
	RESISTORS (NOTE B)			
R101	1800	±10%	1 w	REW-4C
R102	100	±10%	1/2 w	REW-3C
R103	1 M	±10%	1 w	REC-30BF
	CAPACITORS (NOTE C)			
C101	16			COE-4
C102	0.1			COL-2
C103	0.01	±10%	600 dcwv	COL-71
C104	0.01	±10%	600 dcwv	COL-71
C105	4.0	±10%		COL-8
C106	4.0	±10%		COL-8
C107	4.0	±10%		COL-8
C108A	50 }			
C108B	25 }		400 dcwv	COE-10
C108C	25 }			
	FUSES			
F101	115 v; 50-60 cps: 2-amp Slo-Blo 3AG			FUF-1
	230 v, 50-60 cps: 1-amp Slo-Blo 3AG			FUF-1
	115 v, 40 cps: 3.2-amp Slo-Blo 3AG			FUF-1
	230 v, 40 cps: 1.6-amp Slo-Blo 3AG			FUF-1
F102	0.5-amp Slo-Blo 3AG			FUF-2
	MISCELLANEOUS			
L101	INDUCTOR			485-476
L102	INDUCTOR			1102-26
PL101	PLUG			ZCDPP-10
RX101	RECTIFIER			2RE-1400-3
S101	SWITCH, dpst			SWT-333, NP
S102	SWITCH, dpst			SWT-333, NP
S103	RELAY			3RE-5
SO101	SOCKET			CDMS-5-6
SO102	SOCKET			CDMS-5-4
SO103	SOCKET			CDMS-467-12
T101	TRANSFORMER			565-407-2
T102	TRANSFORMER			485-462
V10	TUBE			5R4GY

For NOTES, refer to page 21.

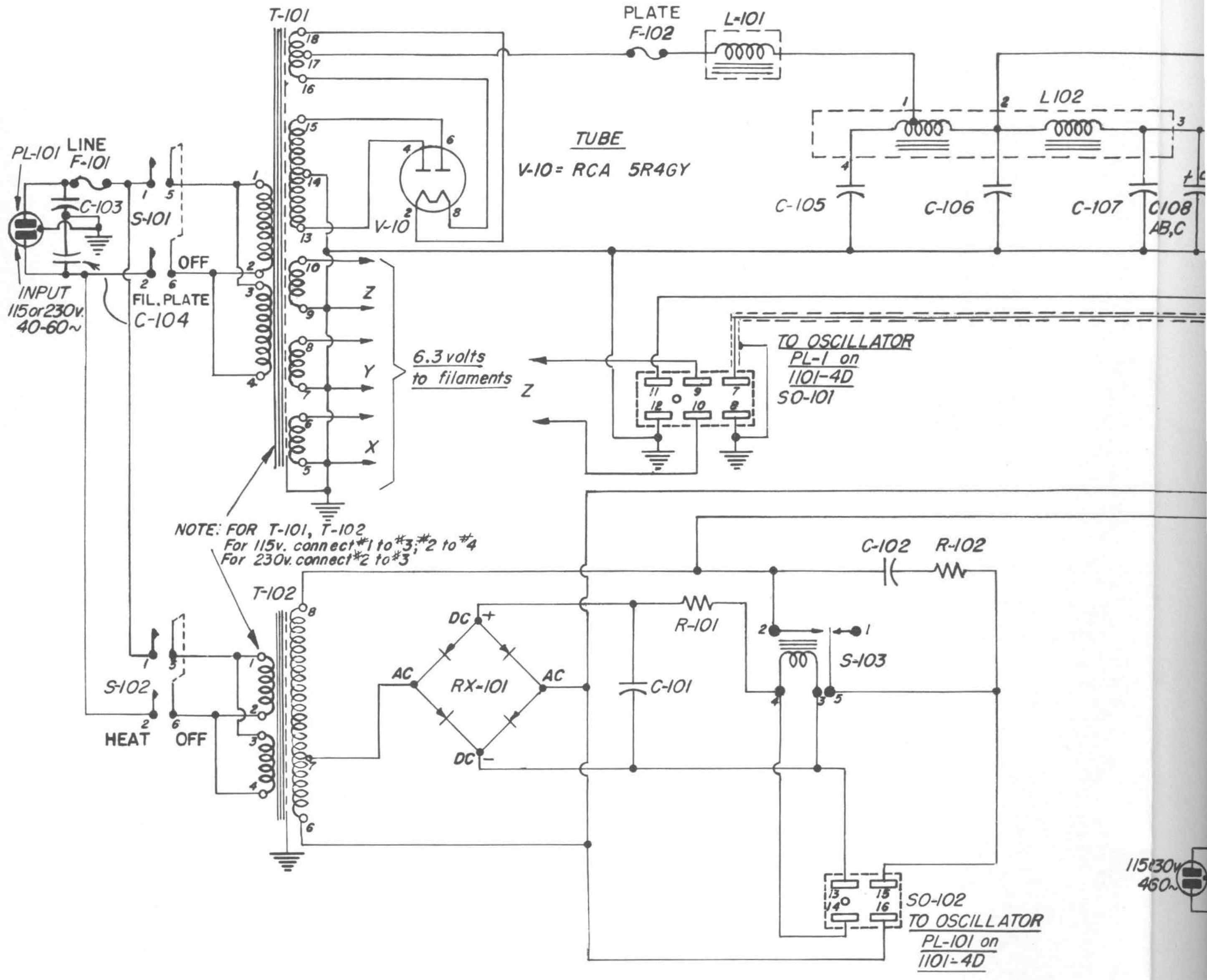
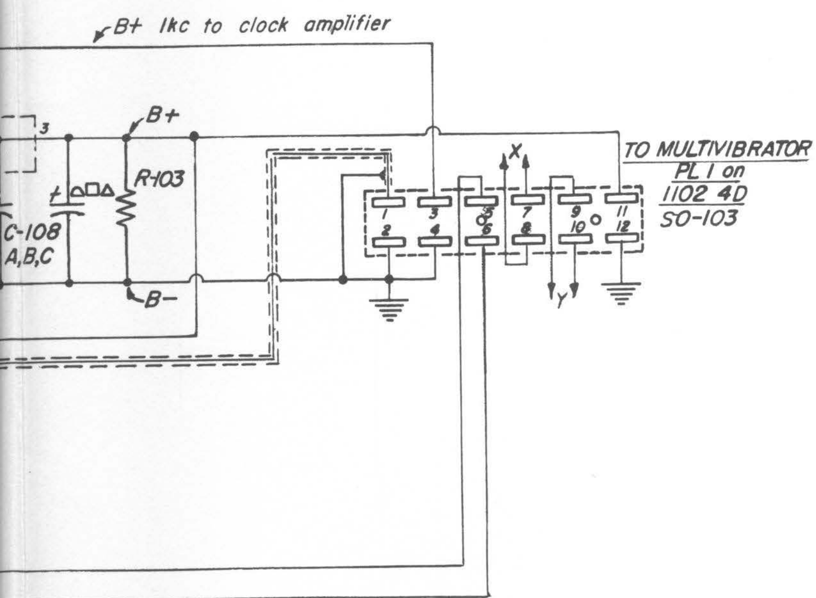
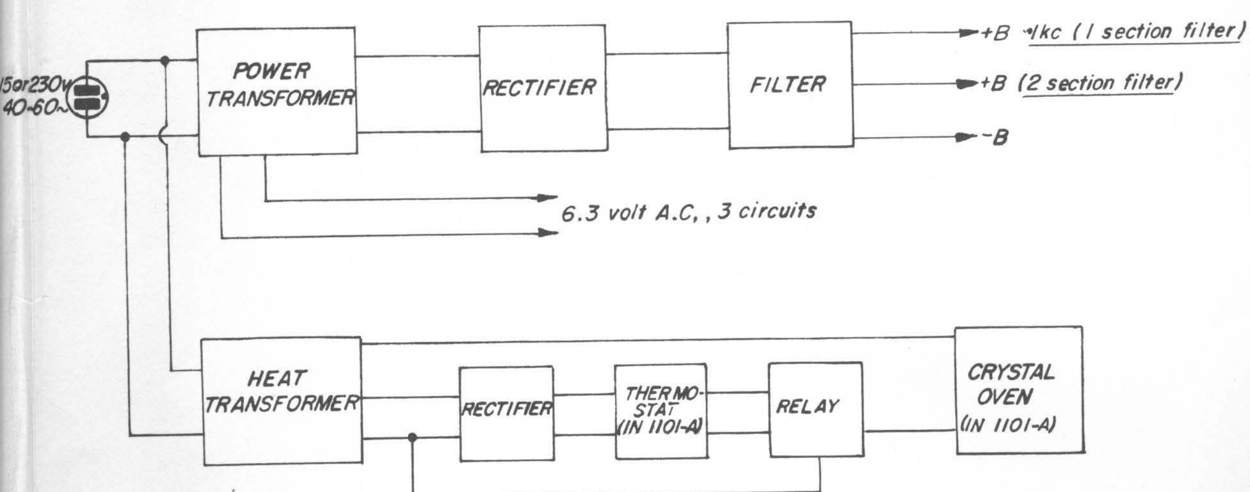


Figure 13. Schematic Diagram, Type 1102-A Power Supply.





Elementary Schematic Diagram

PARTS LIST

REF	PART NO. (NOTE A)				
RESISTORS (NOTE B)					
R1	50 k	±5%			973-412
R2	27 k	±10%	1 w		REC-30BF
R4	1 k	±10%	1 w		REW-4C
R5	0.1 M	±10%	1 w		REC-30BF
R6	1.5	±5%	10 w		REPO-22
CAPACITORS (NOTE C)					
C1	0.05	±10%			COM-50B
C2	2	±10%			COL-6
C3	0.025	±10%	1200 dcwv		COM-50B
	(2 0.0125 in parallel)				
C4	1	±10%			COL-5
MISCELLANEOUS					
F1	FUSE, 0.2-amp Slo-Blo 3AG				FUF-2
P1	LAMP, 6.3 v Mazda 44				2LAP-939
P2	LAMP, 6.3 v Mazda 44				2LAP-939
P3	LAMP, 6.3 v Mazda 44				2LAP-939
P4	LAMP, 6.3 v Mazda 44				2LAP-939
PL1	PLUG				CDMP-461-8
S1	SWITCH, spst				SWT-323,NP
S2	SWITCH, spst				SWP-809
T1	TRANSFORMER				345-H
T2	TRANSFORMER				693-30
V1	TUBE				6K6-GT

NOTES: (A) - Part No. designations for resistors and capacitors are as follows:

COA - Capacitor, air
COC - Capacitor, ceramic
COE - Capacitor, electrolytic
COL - Capacitor, oil
COM - Capacitor, mica
COW - Capacitor, wax

POSW - Potentiometer, wire wound
REC - Resistor, composition
REF - Resistor, film
REPO - Resistor, power
REPR - Resistor, precision
REW - Resistor, wire-wound

(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 $\mu\mu$f (micromicrofarads).

* -- Tolerance on sum of pairs (C3 and C4, C11 and C12, C19 and C20, C26 and C27) is ±2%.

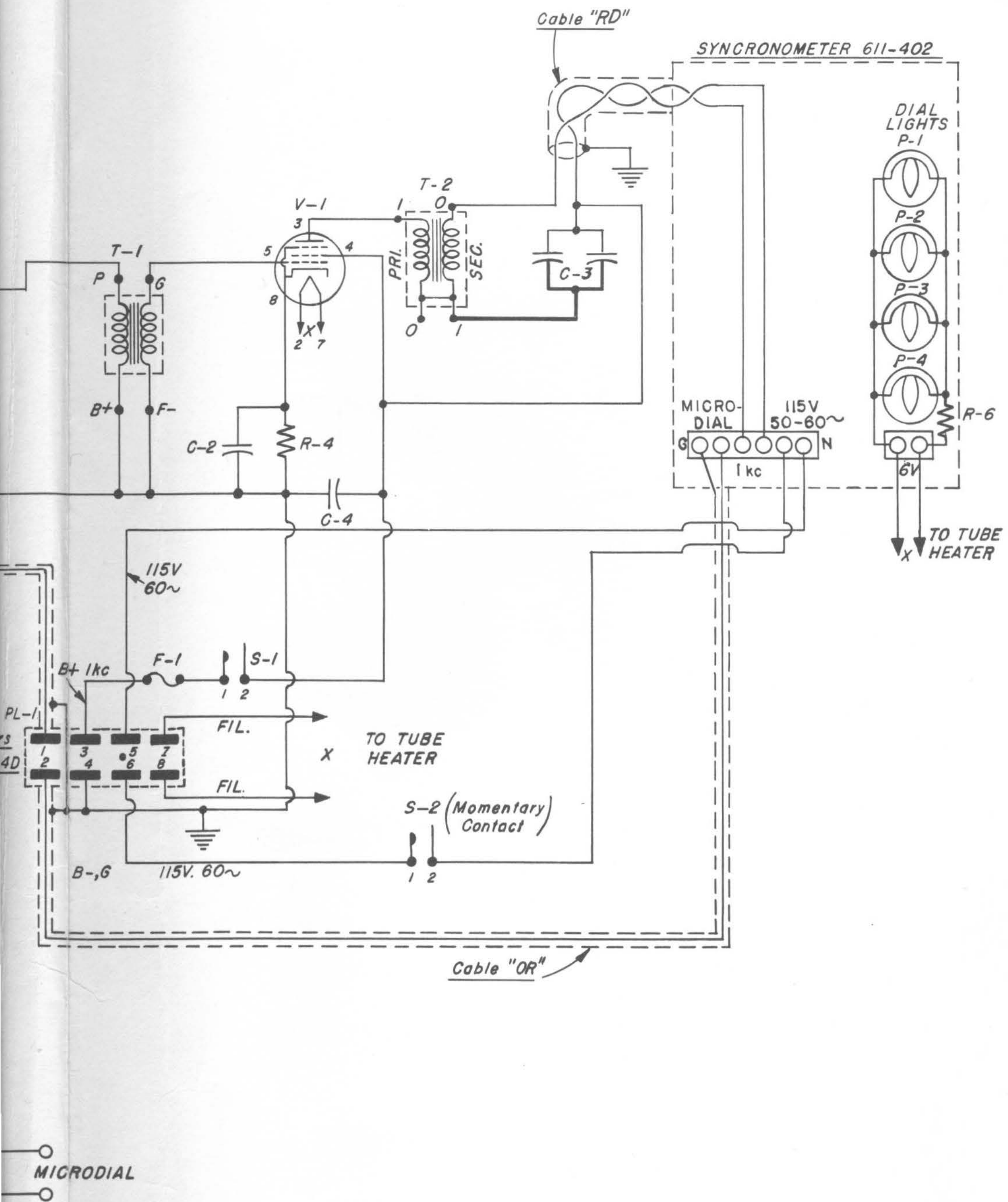
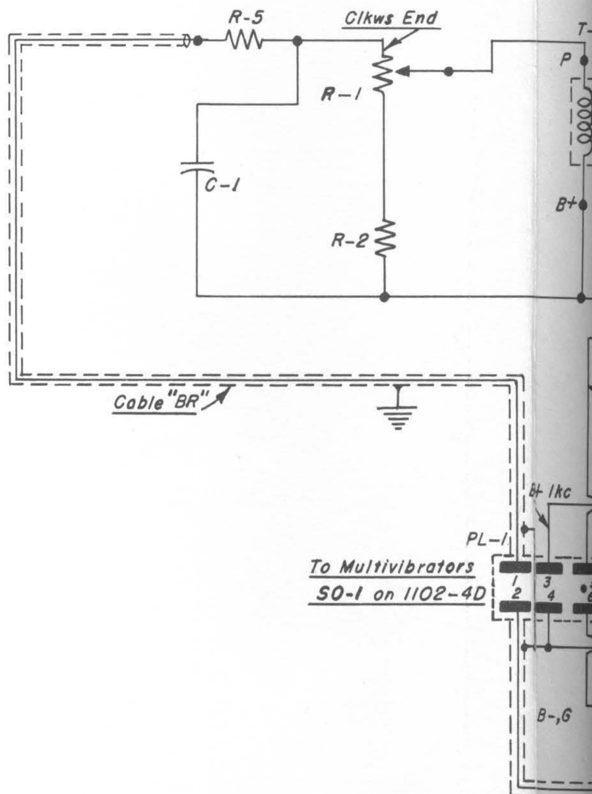
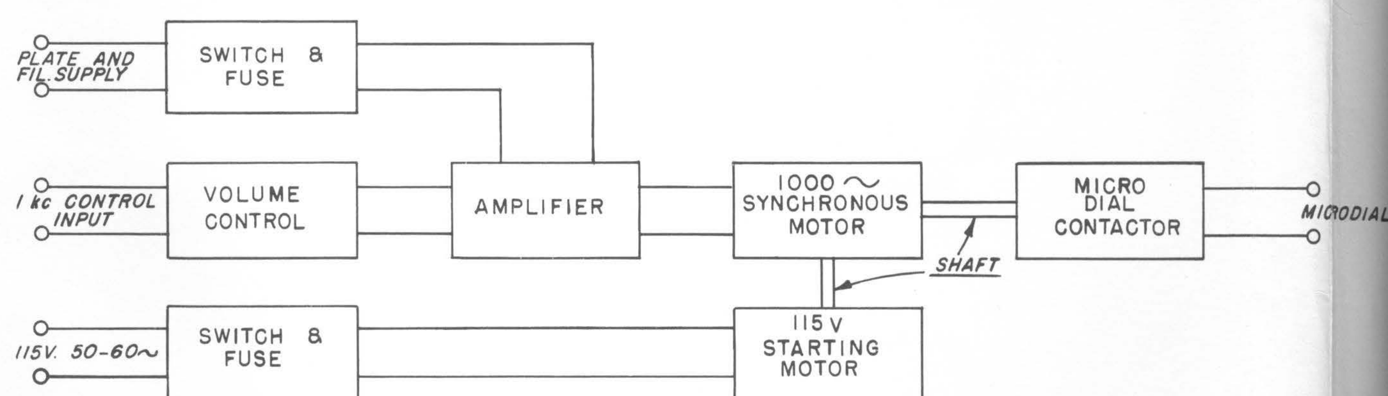


Figure 14. Schematic Diagram, Type 1103-A Syncronometer.





Elementary Schematic Diagram

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