INSTRUCTIONS FOR INSTALLATION AND OPERATION

OF

CLASS C-21-HLD PRIMARY FREQUENCY STANDARD

FORM 233

GENERAL RADIO COMPANY
CAMBRIDGE . . MASSACHUSETTS, U. S. A.

INSTRUCTIONS FOR INSTALLATION AND OPERATION OF

CLASS C-21-HLD PRIMARY FREQUENCY STANDARD

ENGINEERING DEPARTMENT
GENERAL RADIO COMPANY
CAMBRIDGE, MASSACHUSETTS, U. S. A.

FORM 233-L

Type 693-B Syncronometer

Type 692-B Multivibrator
1 KC

10 KC

50 KC

100 CYCLES

Type 698-A Duplex Multivibrator
9 - 11 KC

Terminal Strip

Type 676-B Quartz Bar

Type 690-D Piezo Electric
Oscillator

Type 691-C Temperature-Control
Unit

Type 694-C Control Unit

Type 696-C Power Supply

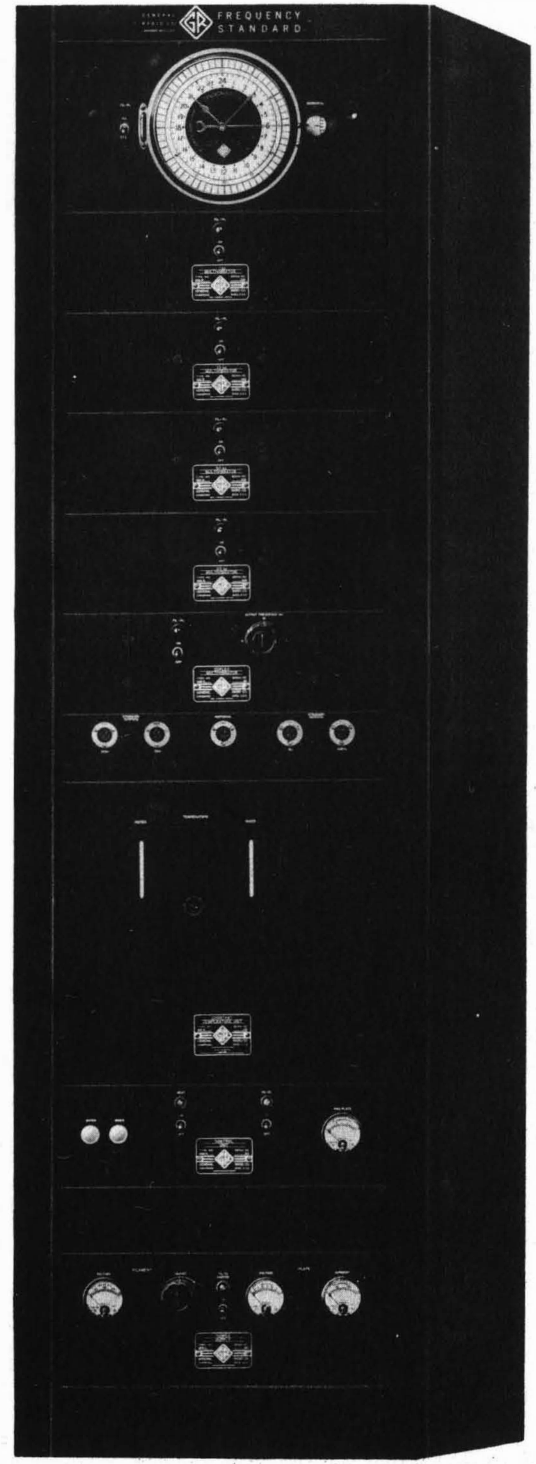

FIGURE 1. **Class C-21-HLD Standard-Frequency Assembly** for complete a-c operation. **For floating-battery operation**, the Type 696-C Power **Supply** and the blank panel are replaced by a Type 695-C Charging Unit.

FOREWORD

This book is an installation and operating manual for a coordinated assembly of individual instruments designed to furnish accurately-known reference frequencies distributed over the entire radio spectrum. The designation "Class C-21-HLD" classifies this assembly in a general way, but for a complete specification the type numbers of the individual instruments are required.

The assembly consists of the following components. There are two possible types of power-supply equipment and this book applies to both:

Type 693-B Syncronometer
Type 692-B Multivibrator (1-kc)
Type 692-B Multivibrator (10-kc)
Type 692-B Multivibrator (50-kc)
Type 692-B Multivibrator (100 cycles)
Type 698-A Duplex Multivibrator
Type 691-C Constant Temperature Unit
Type 690-D Piezo Oscillator
Type 676-B Quartz Bar
Type 694-C Control Unit

COMPLETE A-C OPERATION

When the assembly is intended for operation without batteries from the 60-cycle line a Type 696-C Power Supply is used.

FLOATING-BATTERY OPERATION

Where trickle-charged battery operation is desired, Type 695-C Charging Unit is used. Each of these power-supply units causes minor changes in some of the auxiliaries supplied with the assembly (blank panel, cable, etc.) but these differences are given in full detail on page 35.

The engineering department of the General Radio Company is always glad to help with the solution of problems arising from the use of this primary frequency standard. Reports outlining details of the performance of the assembly are always gratefully received.

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PART I

FUNDAMENTAL PRINCIPLES

PURPOSE The primary frequency standard is designed to supply for laboratory use a large number of standard frequencies, each of which is known with an accuracy of five parts in ten million or better. It provides frequencies over the entire communication spectrum, all of which are derived from and controlled by a single high precision standard of frequency.

DESCRIPTION Since frequency is measured in cycles per second, the element of time enters directly into the determination of frequency. In the final analysis, the exact measurement of frequency consists of counting a number of operations of a given type and dividing by the exact time interval in which they occur. An oscillator or generator may be as uniquely defined in terms of its period (time) as by its frequency, the relation between them being $f = \frac{1}{T}$. The element of time, therefore, is of fundamental importance in the precision determination of frequency. A primary standard of frequency is defined as one whose frequency is determined directly by comparison with mean solar time. The General Radio Class C-21-HLD Primary Frequency Standard comes under this classification.

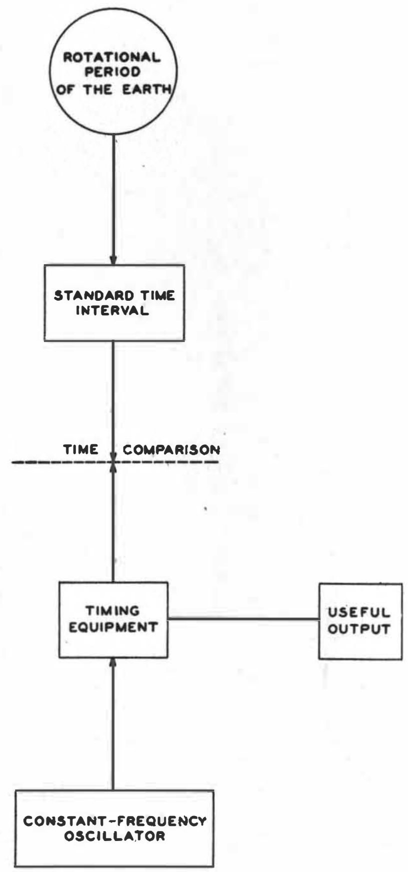


FIGURE 2. Basic principle of a primary standard of frequency

Figure 2 is an outline chart which shows without confusing detail the basic principles of this primary frequency standard. A source of radio-frequency voltage is first established, the frequency of which is nearly enough constant to justify the statement that its instantaneous frequency deviates from its mean frequency by a negligibly small amount. Apparatus is next provided for counting the number of oscillations executed by this frequency standard during a standard time interval, which, for convenience, may take the form of a clock. The time interval usually chosen for measurement is the mean solar day. The total number of oscillations executed by the standard in one mean solar day, divided by the number of seconds in the day, gives its mean frequency in cycles per second.

In order that the output frequencies needed for use in measurements may be secured, the conversion equipment which is necessary for the reduction of the frequency of the working standard to the value employed in operating a synchronous motor-driven clock is utilized. This equipment merely derives the desired frequencies (which may be expressed as harmonics and subharmonics of the frequency of the working standard) by frequency multiplication and division.

FUNCTIONAL ARRANGEMENT Figure 3 shows in more detail the actual primary frequency standard. The working standard is a temperature-controlled piezo-electric quartz-crystal oscillator. The frequency of the working standard is chosen as 50 kilocycles. For special work, other frequencies may be more suitable. Both the timing and conversion functions are performed by two multivibrators operating as frequency dividers, at fundamental frequencies of 10 kc and 1 kc, respectively, under the direct and absolute control of the working-standard oscillator. The 1-kc output voltage of the second multivibrator is amplified to operate a syncronometer which is so geared that when the driving voltage has a frequency of exactly 1 kc, the syncronometer keeps correct time. A means of comparing the indicated syncronometer time with standard time as given by radio or other time signals completes the timing sequence.

The "useful output" is derived from the harmonics of the 10-kc, 1-kc and 100-cycle multivibrators as well as from the harmonics of a third multivibrator which is operated at a fundamental frequency equal to that of the working-standard oscillator. Since each of the "useful output" frequencies is derived from the working standard by harmonic frequency multiplication and division, each is known with the same percentage accuracy as that with which the frequency of the working standard is known.

The assembly contains, in addition to the units mentioned above, an oscillator control panel, a temperature-control unit and a power-supply unit.

The General Radio type numbers of the units are listed in the Foreword. For brief descriptions of the individual units the user is referred to Part II which follows. Figure 1 is a photograph of the assembly

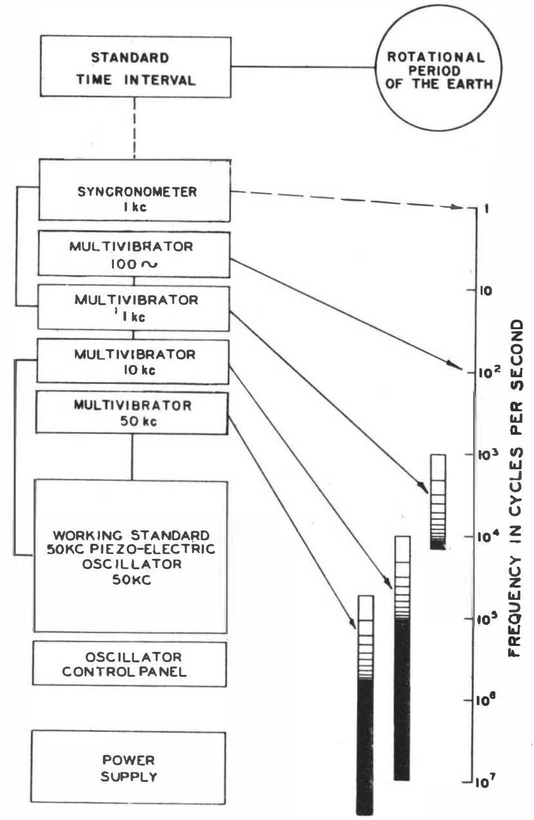


FIGURE 3. Schematic representation of a Class C-21-HLD Primary Frequency Standard showing the frequency distribution of the standard harmonics it makes available for frequency measurements

PART II

DESCRIPTION OF INDIVIDUAL INSTRUMENTS

The following pages give brief descriptions and show the complete wiring diagrams for each of the component instruments of the Class C-21-HLD Primary Frequency Standard. It is intended that these descriptions will serve as a summary of the operating principles for each component and at the same time be complete enough to make possible an intelligent search for trouble should any operating difficulties arise.

It has been previously pointed out that two different types of power supply equipment were available and that a choice between them was made when the order for this primary frequency standard was placed with the General Radio Company. The completely a-c operated assembly uses a Type 696-C Power Supply and the floating-battery-operated assembly uses the Type 695-B Charging Unit. These two instruments are described separately and on page 19 is explained the difference between the two interconnecting cables that each requires.

The alternative type of power-supply equipment can be obtained at any time, if desired, by ordering the new power-supply unit and the new interconnecting cable that its use requires. When changing over from floating-battery operation (with the Type 695-C Charging Unit) to complete a-c operation (with the Type 696-C Power Supply) it is advisable to order a Type 480-P2 Spacer Panel to fill out the rack.

Prices will be quoted on request.

TYPE 694-C CONTROL UNIT

On the Type 694-C Control Unit are mounted the necessary meters and controls for both the oscillator and the constant temperature unit. The wiring for both these pieces of apparatus (See the following pages) should be studied in connection with the wiring diagram for the control unit.

Provision is made for operation of the temperature-control unit from either 115- or 230-volt supply, by change of primary connections to transformer T-1.

PARTS LIST

Resistors	Condensers
R-5 = 10 kΩ	C-4 = 0.025 µf
R-6 = 700 Ω	C-5 = 0.025 µf
R-7 = 10 kΩ	C-7 = 0.25 µf
R-8 = 700 Ω	C-8 = 0.25 µf

Fuses

(Bussmann 7-AG)

F-1 = 5.0 a
F-2 = 0.2 a
F-3 = 2 a
F-4 = 2 a

Lamps

P-1 = 6.3 v 139-939
P-2 = 6.3 v 139-939
P-3 = 115 v 139-430
P-4 = 115 v 139-430

Transformer	Relays
T-1 = 365-407	139-445

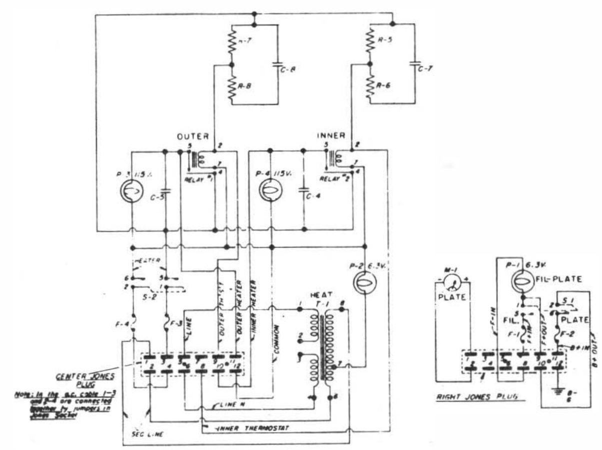


FIGURE 4. Wiring diagram for Type 694-C Control Unit

TYPE 691-C CONSTANT TEMPERATURE UNIT

This unit is the temperature-control unit for the Type 676-B Quartz Bar. The unit consists of two temperature-control boxes, one inside the other.

The two temperature-control boxes are identical in construction, differing only in size. Each box consists of:

(1) A balsa insulating layer.
(2) A layer of distributed heaters.
(3) An aluminum distributing layer.
(4) An asbestos pressboard attenuating layer.
(5) A second aluminum distributing layer.
(6) A second asbestos pressboard attenuating layer.
(7) A third aluminum distributing layer.

The principles of operation and the design considerations will not be discussed here, but are fully covered in an article previously published (see reference 4, page 31.).

It should, however, be pointed out that the use of a two-stage unit makes possible a very precise control of temperature. The inner unit has to operate against only the temperature fluctuations remaining from the operation of the outer unit. If the outer unit reduces the fluctuation in room temperature by a factor, n, then in the inner unit the total reduction is of the order of n^2.

The temperature of the inner box of the temperature-control unit fluctuates less than 0.01°C. for changes in room temperature from -5° to 50° C (20° to 122°F). This is an important factor in determining the ultimate frequency stability of the system. The outer unit controls to better than 0.1°C.

A diagram of the heat-control circuits is shown in Figures 4 and 5. Briefly, the system operates as follows:

When the temperature is below its operating value, the end of the mercury column in the thermostat is below the upper contact, the winding of the relay is energized, the armature of the relay is closed, and current is supplied to the heaters. Under this condition, the heat indicator lamp is lighted.

When the temperature rises to such a value that the mercury column reaches the upper contact, the winding of the relay is short circuited, and the armature circuit opens, breaking the circuit to the heaters turning off the heat indicator lamp. When the temperature at the thermostat drops slightly, the relay again closes, and the cycle is repeated.

Fusible links are placed in the inner, outer and crystal heater circuits as a protection against damage to the temperature-control unit or its contents should the heat-control circuit fail. If the temperature should ever reach about 65° C, the links melt and open the heater circuits.

PARTS LIST

THERMOMETERS

INNER: Type 139-489
OUTER: Type 139-481

THERMOSTATS

INNER: Type 139-503-60°
OUTER: Type 139-503-55°

FUSIBLE LINKS

Type 547-50

LAMPS

W-1 = Mazda 44
W-2 = Mazda 44

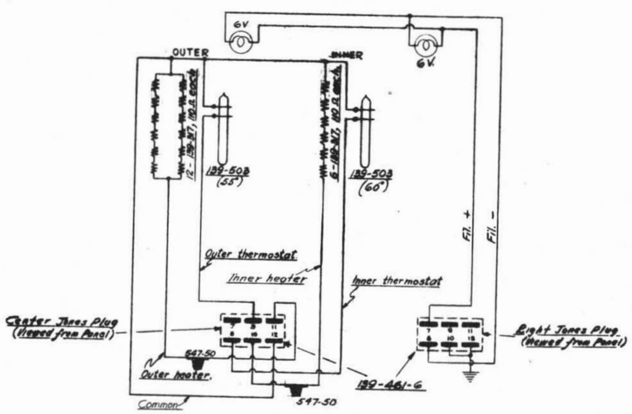


FIGURE 5. Wiring diagram for Type 691-C Constant Temperature Unit

TYPE 690-D PIEZO-ELECTRIC OSCILLATOR

This unit consists of a piezo-electric oscillator, an isolating output amplifier and an elementary vacuum-tube voltmeter for indication of oscillation. The oscillator employs a bridge circuit, in which the crystal operates at, or very near, series resonance. The complete circuit diagram is given in Figure 6.

The oscillator circuit consists of a high-gain tuned amplifier stage, V-1, working into a phase inverter stage, V-2, which drives the bridge, composed of the quartz bar, Q-1, with its series reactance L-2, C-11, C-12, the resistors R-6, R-7 and the lamp, P-1. The output of the bridge is taken to the grid of the amplifier V-1.

On starting up the oscillator, the lamp P-1 is cold and its resistance is low. In consequence, the bridge is badly unbalanced, the bridge output is relatively large and in proper phase to produce oscillation. Oscillation builds up rapidly and as it does so, the lamp resistance begins to increase, bringing the bridge toward balance. As this occurs, the bridge output decreases, decreasing the feedback voltage and decreasing the amplitude of oscillation. Equilibrium is reached when the loss between input and output through the bridge is just equal to the gain from the output to the input of the bridge, through the amplifier. The amplitude of oscillation is thus automatically held at a small and practically constant level, without any limiting or distortion taking place in the tube circuits.

The frequency of oscillation is determined wholly by the quartz crystal, operating at its series resonant frequency, when there is no phase-shift in the amplifier and when the reactance in series with the crystal is zero. The amplifier has been checked for zero phase shift, and the adjustments locked. No appreciable phase shift should occur over long periods of time. The quartz crystal is adjusted to frequency when the series reactance is practically zero. Any minor changes in crystal frequency can then be corrected by moving C-11 from its reference setting. Increasing the dial reading will increase the oscillator frequency. The total change in frequency, over the range of C-11, is approximately plus or minus 5 parts per million. The temperature coefficient of the crystal oscillator is from -0.5 to -1.5 parts per million per degree Centigrade. Changes in supply voltages, or changes in tubes, produce negligible changes in frequency.

TYPE 676-B QUARTZ BAR

This quartz bar and its mounting are the result of considerable study and research in the General Radio laboratories. The design of the holder is such that maximum stability and freedom from external effects is obtained. The bar vibrates along its longest dimension in a direction perpendicular to its electric axis. Under these conditions, the point of minimum motion is at the geometrical center of the plated faces, and the bar is clamped at these points.

The two plates or "baffles" near the end of the bar are designed to minimize the effect of air waves radiated from the ends. These air waves are reflected from nearby surfaces, and, if the reflected waves are not in phase with the motion of the bar, an appreciable reactive component is introduced in the crystal impedance as well as an increase in its damping factor.

The baffles are set at the point which results in maximum crystal amplitude which is the point where quarter-wave air resonance occurs. Under this condition, the operation of the bar is greatly improved, and the effect of changes in atmospheric pressure is minimized.

The air-gap usually existing between the electrodes and the quartz bar is avoided by forming the electrodes directly on the quartz. This not only avoids the frequency variations caused by variations in air-gap (which are very appreciable in most air-gap type mountings) but results also in much improved electrical performance.

PARTS LIST

TYPE 690-D PIEZO OSCILLATOR
(Figure 6)

Condensers

C-1 = 1 μf
C-2 = 100 μμf
C-3 = 0.00025 μf
C-4 = 0.01 μf
C-5 = 0.5 μf
C-6 = 0.5 μf
C-7 = 1 μf
C-8 = 0.01 μf
C-9 = 0.01 μf
C-10 = 0.025 μf
C-11 = 325 μμf
C-12 = 0.00025 μf
C-13 = 0.02 μf

Resistors

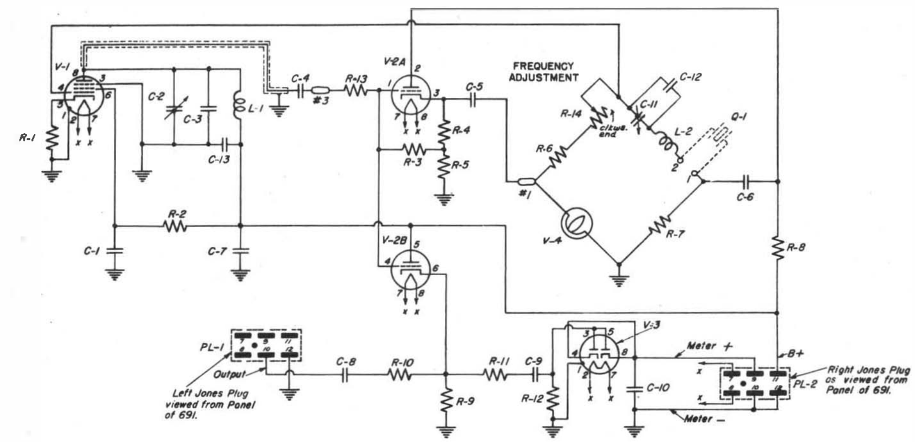
R-1 = 220 Ω
R-2 = 15000 Ω
R-3 = 1 MΩ
R-4 = 560 Ω
R-5 = 2600 Ω
R-6 = 2400 Ω
R-7 = 370 Ω
R-8 = 2700 Ω
R-9 = 2700 Ω
R-10 = 4700 Ω
R-11 = 4700 Ω
R-12 = 15000 Ω
R-13 = 390 Ω
R-14 = 2000 Ω

Quartz Bar

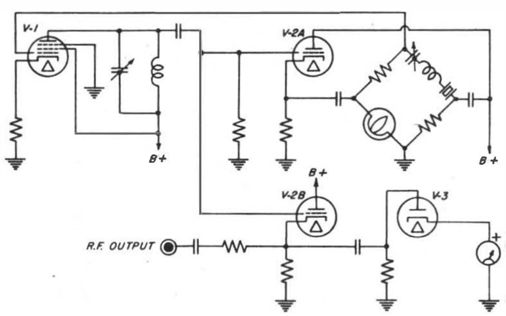
Q = Type 676-B

Tubes

V-1 = RCA Type 6AC7
V-2 = RCA Type 6SN7-GT
V-3 = RCA Type 6H6-GT
V-4 = Lamp 120V, 6W (2 Lap-430)



NOTE: Q-1, PL-1 and PL-2 are mounted on 691-C (not a part of this instrument)



ELEMENTARY SCHEMATIC DIAGRAM

FIGURE 6. Wiring diagrams for Type 690-D Piezo Oscillator

TYPE 692-B MULTIVIBRATORS

The multivibrator is an oscillating system which falls in the general class of "relaxation oscillators". In practice it is essentially a resistance-coupled amplifier with the output coupled back to the input, which causes it to "motor-boat" at a frequency determined by the resistance and capacitance values in the circuit. This type of oscillation has a highly distorted waveform, and the output voltage contains hundreds of harmonics. Although unstable when operated by itself, the multivibrator is readily controlled by introducing into its circuit a small voltage from another oscillator, the frequency of which is in the vicinity of the fundamental or a harmonic of the uncontrolled multivibrator frequency. Under this condition, the fundamental frequency of the multivibrator will then assume a value equal to the frequency of the controlling source or to this frequency divided by an integer. When the multivibrator is in control, small changes in its circuit constants and operating voltages do not change its frequency which is entirely determined by the frequency of the controlling source.

If the frequency of the controlling standard is f_c, then any harmonic frequency derived from the system may be expressed as

$$f_n = \frac{f_c n}{m}$$

where m is the ratio of the standard frequency to the multivibrator fundamental, i.e., the factor by which the crystal frequency is divided, and n is the order of the multivibrator harmonic.

When the frequency division ratio $m = \frac{f_c}{f_m}$ is an odd whole number, best control is obtained if the control voltage is applied to only one of the multivibrator tubes, but, if an even ratio is desired, it is best to introduce the control voltage in both tubes. The Type 692-B Multivibrator is provided with a switch by means of which the control voltage may be applied to one or both multivibrator tubes. The two positions of this switch are engraved ODD and EVEN respectively.

Control from a source whose frequency is a subharmonic of the multivibrator fundamental is, in general, difficult to realize. When, however, the controlling frequency contains an appreciable harmonic whose frequency corresponds to that of the multivibrator fundamental, this harmonic may be filtered and amplified and used as a controlling voltage.

In the Type 692-B Multivibrator an input amplifier is provided, through which the controlling voltage is introduced. This is done so that not only may the input impedance of the unit be high but the reaction of the multivibrator on the controlling source may be kept small. Two output amplifiers are provided, either or both of which may be used as required. One, the CONTROL OUTPUT, is primarily intended for use when several multivibrators are operated in cascade as frequency dividers. The output waveform, while by no means sinusoidal, contains a very strong component of fundamental frequency. The other, or HARMONIC OUTPUT, is purposely arranged to accentuate the higher harmonics of the multivibrator frequency in order that these may be used in frequency measurements. The output impedance is roughly 65 ohms, for use with shielded cables.

In the Class C-21-HLD Primary Frequency Standard four multivibrators are employed. A 50-kc unit is used to obtain a large number of harmonics of the crystal frequency; a 10-kc unit divides the crystal frequency by five and provides a large number of harmonics at multiples of 10 kc, the 1-kc unit divides the 10-kc frequency by ten to obtain an output frequency (1kc) which is 1/50th of the crystal frequency for operation of the syncronometer; the 100-cycle unit divides the 1-kc frequency by 10 and provides output frequencies which are very useful in the audio-frequency range.

The wiring diagram of the Type 692-B Multivibrators is given in Figure 7. The units are similar mechanically for the frequencies used and differ electrically only in the constants as listed in parts list.

PARTS LIST

TYPE 692-B MULTIVIBRATORS
(Figure 7)

Resistors
(Common to all Frequencies)

R-1 = 1 MΩ
R-2 = 47 kΩ
R-3 = 2200 Ω
R-4 = 18 kΩ
R-5 = 5 kΩ
R-12 = 1 MΩ
R-13 = 47 kΩ
R-14 = 2200 Ω
R-15 = 18 kΩ
R-16 = 1500 Ω
R-21 = 5 kΩ

Tubes

V-1 = RCA 6J5G
V-2 = RCA 6J5G
V-3 = RCA 6J5G
V-4 = RCA 6J5G
V-5 = RCA 6J5G

Pilot Lamp

P-1 = 6.3 v 139-939

Condensers
(Common to all Frequencies)

C-1 = 0.002 μf
C-2 = 1.0 μf
C-3 = 1.0 μf
C-4 = 0.02 μf
C-10 = 1.0 μf
C-11 = 1.0 μf
C-15 = 1.0 μf
C-16 = 1.0 μf

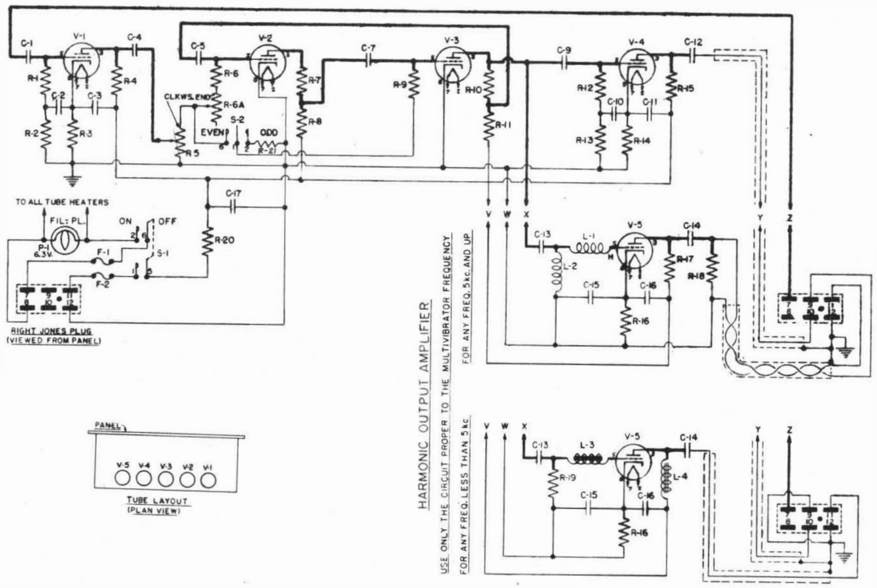
Switches

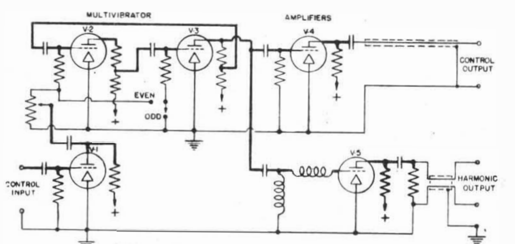
S-1 = DPST 139-333
S-2 = SPDT 139-320

Fuses
(Bussmann 7-AG)

F-1 = 5 a
F-2 = 0.2 a

	100 CYCLES	1 KC	10 KC	50 KC
R-6 =	40 kΩ	25 kΩ	7,500 Ω	5 kΩ
R-6A =	20 kΩ	20 kΩ	10 kΩ	10 kΩ
R-7 =	12,500 Ω	12,500 Ω	20 kΩ	0
R-8 =	30 kΩ	30 kΩ	20 kΩ	20 kΩ
R-9 =	40 kΩ	40 kΩ	7,500 Ω	10 kΩ
R-10 =	12,500 Ω	12,500 Ω	20 kΩ	0
R-11 =	30 kΩ	30 kΩ	20 kΩ	20 kΩ
R-17 =	0	0	4.7 kΩ	4.7 kΩ
R-18 =	0	0	165 Ω	165 Ω
R-19 =	18 kΩ	18 kΩ	0	0
R-20 =	1.8 kΩ	1.8 kΩ	1.8 kΩ	1.8 kΩ
C-5 =	0.05 μf	0.0055 μf	0.0016 μf	0.00035 μf
C-7 =	0.057 μf	0.0055 μf	0.0016 μf	0.00035 μf
C-9 =	0.025 μf	0.025 μf	0.002 μf	0.002 μf
C-12 =	0.5 μf	0.025 μf	0.002 μf	0.002 μf
C-13 =	0.005 μf	0.005 μf	0.0001 μf	0.0001 μf
C-14 =	0.025 μf	0.025 μf	0.002 μf	0.002 μf
C-17 =	3.0 μf	1.0 μf	1.0 μf	1.0 μf
L-1 =	——	——	8 mh	8 mh
L-2 =	——	——	5 mh	5 mh
L-3 =	500 mh	500 mh	——	——
L-4 =	20 h	20 h	——	——





ELEMENTARY SCHEMATIC DIAGRAM

FIGURE 7. Wiring diagram for Type 692-B Multivibrators, (100-cycle, 1-kc, 10-kc, 50-kc)

TYPE 698-A DUPLEX MULTIVIBRATOR

The Type 698-A Duplex Multivibrator provides standard frequency harmonics at multiples of either 9 or 11 kilocycles. Selection of the operating frequency is made by means of a switch. It is used primarily in frequency measurement to overcome the difficulties encountered when very low beat frequencies are obtained between a frequency being measured and the harmonics of the 10-kc multivibrator. For any frequency being measured (except 990 kc and multiples thereof), if a very low beat frequency is obtained against 10-kc harmonics, beats of 1, 2, 3, 4 or 5 kc plus or minus the small frequency difference will be obtained when the duplex multivibrator is used.

The principles of operation of the Type 698-A Duplex Multivibrator are identical with those of the Type 692-B Multivibrators (page 8). The circuit arrangement of the duplex multivibrator differs only in the addition of switching facilities for changing from 9 to 11 kc and for maintaining control. Since this unit is used only in radio frequency measurements, the control output amplifier is omitted. Special selective filters are incorporated in the unit for obtaining 90 kc and 110 kc control voltages (which control, respectively, the 9-kc and 11-kc fundamental frequencies) from the output of the 10-kc multivibrator. In this manner fundamental frequencies which are not integral submultiples of 50 kc are obtainable.

PARTS LIST

Resistors

R-1 = 1 MΩ
R-2 = 47 kΩ
R-3 = 470 Ω
R-4 = 18 kΩ
R-5 = 5 kΩ
R-6 = 2500 Ω
R-6A = 10 kΩ
R-6B = 10 kΩ
R-6C = 10 kΩ
R-7 = 20 kΩ
R-8 = 20 kΩ
R-9 = 12,500 Ω
R-10 = 20 kΩ
R-11 = 20 kΩ
R-16 = 1500 Ω
R-17 = 4.7 kΩ
R-18 = 165 Ω
R-20 = 1.8 kΩ
R-21 = 1 kΩ

Inductors

L-1 = 8 mh
L-2 = 2-139-597 in series
L-101 = 32.5 mh
L-102 = 32.5 mh
L-103 = 40.0 mh

Tubes

V-1 = RCA 6J5G
V-2 = RCA 6J5G
V-3 = RCA 6J5G
V-5 = RCA 6J5G

Condensers

C-1 = 0.002 µf
C-2 = 1.0 µf
C-3 = 1.0 µf
C-4 = 0.02 µf
C-5 = 0.0016 µf
C-7 = 0.0016 µf
C-13 = 0.0001 µf
C-14 = 0.002 µf
C-15 = 1.0 µf
C-16 = 1.0 µf
C-17 = 1.0 µf
C-101 = 40-100 µµf
C-102 = 40-100 µµf
C-103 = 0.002 µf
C-104 = 40-100 µµf
C-105 = 40-100 µµf
C-106 = 0.002 µf
C-107 = 40-100 µµf
C-108 = 40-100 µµf
C-109 = 0.00025 µf
C-110 = 0.0001 µf

Fuses

F-1 = 5 a
F-2 = 0.2 a

Switches

S-1 = 139-333
S-3 = 698-35-2

Pilot Lamp

P-1 = 139-939

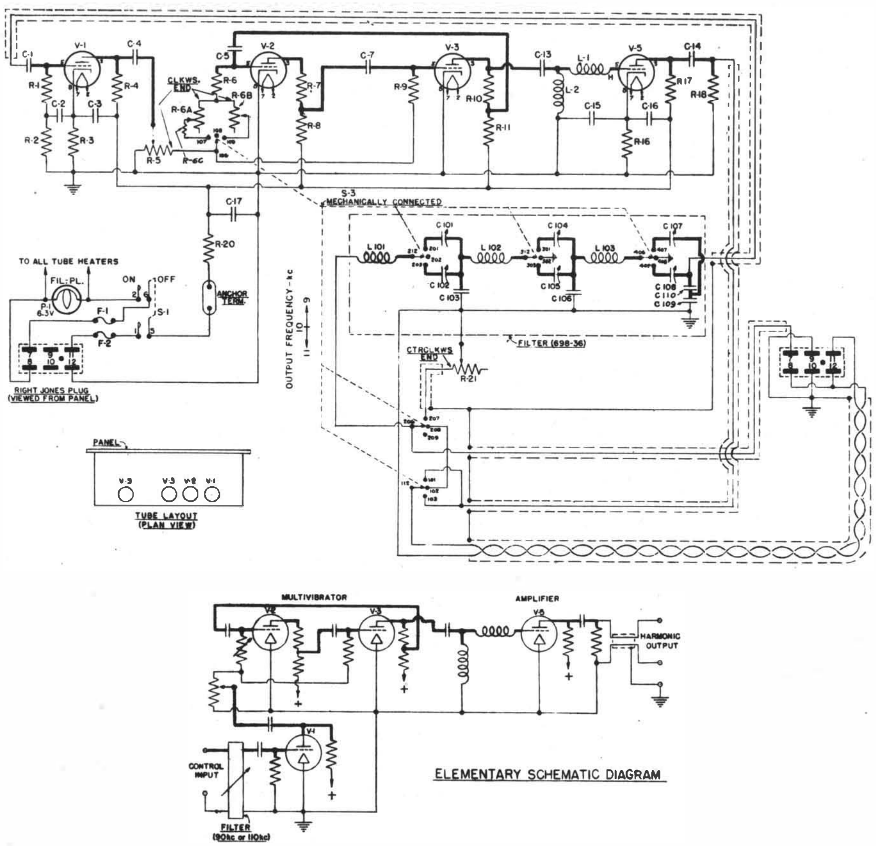


FIGURE 8. Wiring diagram for Type 698-A Duplex Multivibrator

TYPE 693-B SYNCRONOMETER

In this unit the necessary amplifying equipment is provided for the running of the syncronometer on the output voltage available from the multivibrator assemblies. A circuit diagram is given in Figure 9.

The voltage available for driving the clock is generally considerably in excess of the amount required for satisfactory operation, and for this reason a voltage divider is provided for regulating the voltage on the grid of the clock amplifier tube. A second amplifier tube is fed from the harmonic output of the 1-kc multivibrator; the output of this amplifier is connected to the 1-kc outlet on the terminal strip for supplying 1-kc harmonics to external circuits.

The syncronometer is designed and constructed so that when it is operated from a supply frequency of 1 kc, it keeps true time. The number of teeth on the rotor disc is 100; the disc, therefore, makes 10 revolutions per second. The rotation of the disc is stepped down through worm gearing to a countershaft which rotates one revolution per second. This countershaft drives the clock train through a worm and differential gearing giving a reduction of 60 to 1, so that the main shaft of the clock mechanism proper turns at 1 revolution per minute.

Interposed between the driving mechanism and the clock train is a set of planetary differential gears which are normally locked so that the driven shaft rotates at exactly the same speed as the driving shaft.

By means of a crank inserted to the left and above the clock face, the differential train may be unlocked and shifted in either direction with respect to the driving shaft. The shaft carries a gear and a stop-spring engaging the teeth of this gear, so that the position of the shaft on which the crank is mounted may be advanced or retarded by definite steps. Each notch of the gear corresponds to a one-half-second change in the position of the second hand of the clock. If the crank is rotated one tooth to the right, the second-hand of the clock will be advanced one-half second. In this manner it is possible to set the clock while running, to within plus or minus one quarter second of any desired time, without slipping the hands.

To the right of the clock face is mounted the micro-dial, by means of which the time indicated by the clock may be accurately compared with time signals. The contact is driven at one revolution per second as it is mounted on the main countershaft. The contact is closed for about 0.95 of each second. The instant at which the contacts close may be adjusted by turning a crank inserted at the right of the clock face. If the contacts are connected across the telephones or loud-speaker of a time signal receiver (from which any direct current in the output has been filtered) the operation of the cam may be adjusted so as to short-circuit all but the <u>beginning</u> of each pulse of the time signal. The reading of the micro-dial then gives the fraction of a second that the clock differs from the time signal. Each division equals 0.01 second. The micro-dial contacts may be utilized for transmission of second's pulses for laboratory purposes.

A push-button switch for operating the 60-cycle starting motor is mounted to the right of the clock face.

PARTS LIST
(See Figure 9)

Resistors

R-1 = 100 kΩ
R-2 = 47 kΩ
R-3 = 2200 Ω
R-4 = 50 kΩ
R-5 = 22 kΩ
R-6 = 3300 Ω
R-7 = 390 Ω

Condensers

C-1 = 0.01 μf
C-2 = 1.0 μf
C-3 = 1.0 μf
C-4 = 0.025 μf
C-5 = 0.01 μf
C-6 = 1.0 μf

Pilot Lamps

P-1 = 6.3 v. 139-939
P-2 = 6.3 v. 139-939
P-3 = 6.3 v. 139-939
P-4 = 6.3 v. 139-939

Fuses
(Bussmann 7-AG)

F-1 = 5.0 amp.
F-2 = 0.1 amp.

Tubes

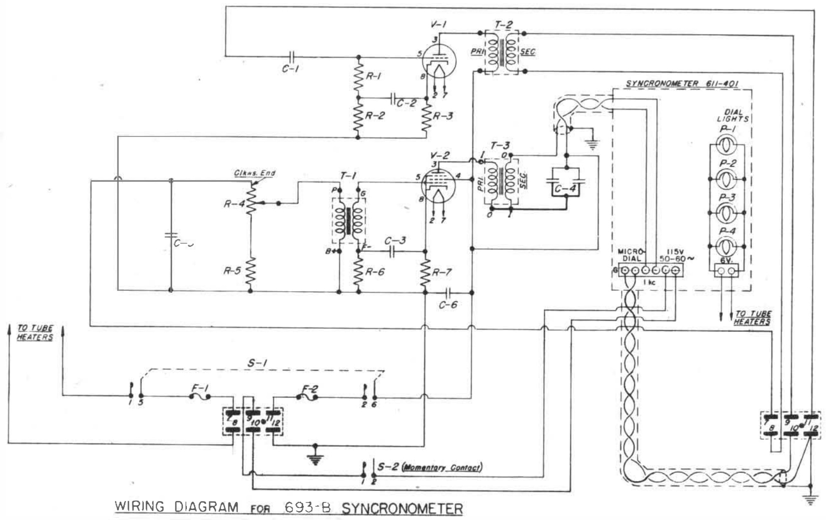
V-1 = RCA 6J5G
V-2 = RCA 6K6G

LUBRICATION The ball bearings are enclosed and do not require lubrication over periods of a few years.

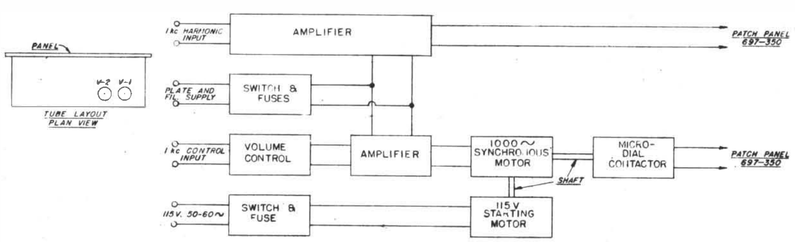
About every three months a drop of light clock oil should be placed at the following points:

(a) Motor spindle worm-gear.
(b) Cross-shaft worm-gear.
(c) Shaft bushing projecting from rear of clock-train, between clock-train and the differential setting mechanism.
(d) Microdial cam surface. If a squeak develops at this point, lubricate as necessary.

Every two to three years, it is advisable, but not always necessary, to disassemble the synchronous motor and clean and lubricate all bearings.



WIRING DIAGRAM FOR 693-B SYNCRONOMETER



ELEMENTARY SCHEMATIC DIAGRAM

FIGURE 9. Wiring diagram for Type 693-B Syncronometer

TYPE 695-C CHARGING UNIT
(FOR OPERATION OF ASSEMBLY
FROM FLOATING BATTERIES)

DESCRIPTION This unit includes transformers and rectifiers for both filament- and plate-battery chargers with a smoothing filter in the latter for use in maintaining batteries on floating charge. The necessary fuses and switches are furnished. Meters are provided in both battery circuits to indicate the charge and discharge currents of the batteries and the voltages of both batteries. Controls are provided in both circuits for regulating the charging current. Relays are provided for automatically transferring the heater circuits of the temperature-control unit to either a reserve battery or auxiliary power supply in case of failure of the a-c supply.

OPERATING CHARACTERISTICS <u>Load Capacity</u>--The voltage and current outputs for the high- and low-voltage circuits, respectively, are:

Voltage	Current
180-200 volts	100 milliamperes
6 volts	12 amperes

<u>Input</u>--The input power supply is 110-115 volts, 50-60 cycles (or 220-230 volts, as ordered).

<u>Circuit</u>--Figure 10 is a complete circuit diagram.

Separate leads are used for the charging and load circuits to avoid introducing any hum into the assembly due to the voltage drop in common leads. An extra filter section is used in the high voltage supply to keep the 1-kc current from the clock and 1-kc multivibrator from entering the other units.

<u>Batteries</u>--When using this power supply, the following batteries are recommended:

For FILAMENT SUPPLY: two 6-volt, 125-ampere-hour storage batteries in parallel.

For PLATE SUPPLY: one 180- to 190-volt, 6 ampere-hour storage battery.

No biasing or other batteries are required.

Operate charging equipment to maintain battery voltages at 2.15 volts per cell.

<u>Auxiliary Heat Reserve</u>--Provision is made for connecting either one of two types of emergency power supply for operating the temperature-control heaters during an interruption in the regular 115-volt a-c service.

a) One pair of wires is provided for connection to a battery, which, when it is "standing by", is under continuous trickle charge from the charging equipment. It is recommended that the battery so used (designated "auxiliary heat reserve battery") be a duplicate of the 180- to 190-volt plate battery so that it can also serve as a spare for plate-circuit service.

b) Another pair of wires is provided for connection to any 115-volt a-c or d-c supply that is independent of the regular 115-volt a-c supply. Such a supply is referred to as "auxiliary heat reserve line." A battery could of course be used here, but it would be necessary to charge it independently of the charging equipment in the assembly.

PARTS LIST

CONDENSERS

C-1 = 0.01 µf
C-2 = 0.01 µf

RESISTORS

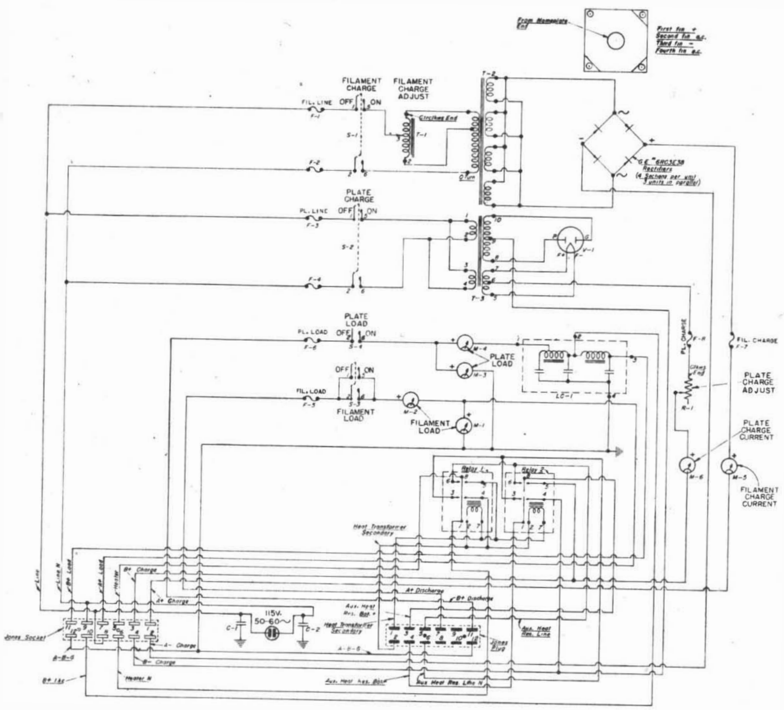
R-1 = 1 KΩ

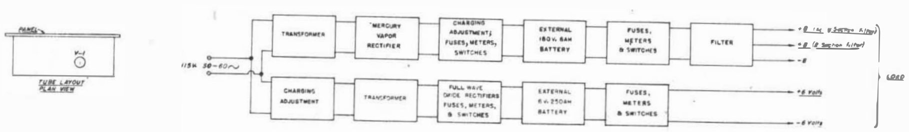
TUBES

V-1 = RCA-83

FUSES
(Bussmann 7-AG)

F-1 = 5 a
F-2 = 5 a
F-3 = 1 a
F-4 = 1 a
F-5 = 15 a
F-6 = 0.2 a
F-7 = 15 a
F-8 = 0.2 a





ELEMENTARY SCHEMATIC DIAGRAM

FIGURE 10. Wiring diagram for Type 695-C Charging Unit

TYPE 696-C POWER SUPPLY
(FOR OPERATION OF ASSEMBLY FROM A-C LINE)

DESCRIPTION The unit includes a transformer for furnishing the proper filament and plate voltages, a rectifier and filter for the plate supply. A manual regulator is provided for regulating the voltages and necessary switches, fuses and meters are included. In cases where interruptions of the supply are infrequent, or are not objectionable, the primary frequency standard may be operated with this supply without batteries of any kind.

OPERATING CHARACTERISTICS <u>Load Capacity</u>--The voltage and current outputs for the high- and low-voltage circuits are respectively:

Voltage	Current
180 volts	150 milliamperes
6 volts	10 amperes (Seven windings)

<u>Input</u>--The unit is designed to operate from 110-115 volt, 50-60 cycles (or 220-230 volts) by change of transformer connections.

<u>Circuit</u>--A complete circuit diagram is given in Figure 11.

Separate transformer windings and leads are provided for the filament circuits of each of the units of the assembly. An extra filter section is used on the high-voltage supply to keep the 1000-cycle current in the clock and 1-kc multivibrator from entering other units.

PARTS LIST

<u>Condensers</u>

C-1 = 0.01 µf
C-2 = 0.01 µf

<u>Tube</u>

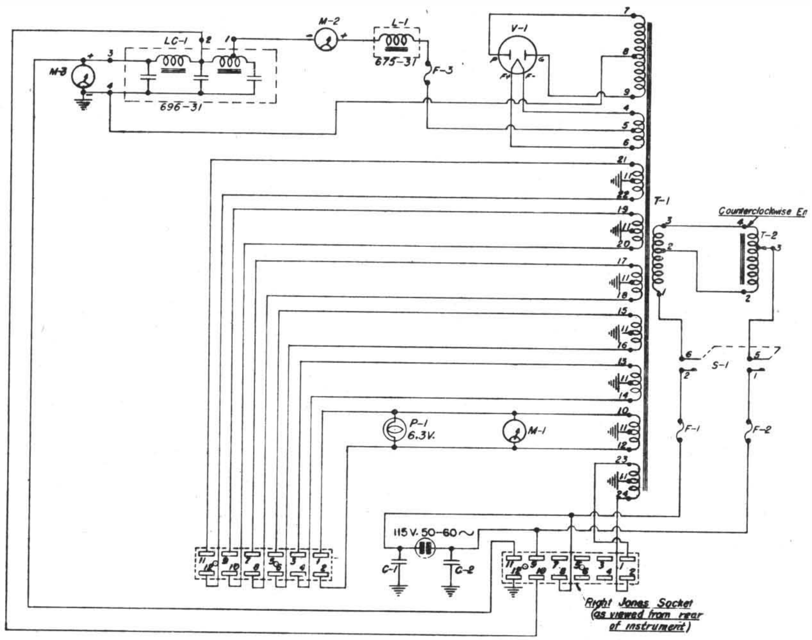
V-1 = RCA 83

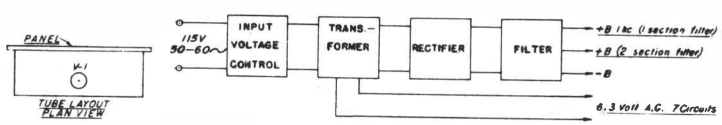
<u>Fuses</u>
(Bussmann 7-AG)

F-1 = 2 a
F-2 = 2 a
F-3 = 0.2 a

<u>Pilot Lamp</u>

P-1 = 6.3 v. 139-939





ELEMENTARY SCHEMATIC DIAGRAM

FIGURE 11. Wiring diagram for Type 696-C Power Supply

TYPE 697 CABLES AND TERMINAL STRIP

Supplied with each assembly are two cables, fully formed, and connected and fitted with plugs making all connections to the units mounted on the rack. When floating-battery operation is employed, one of the cables is provided with 10-foot leads for connection to the batteries and the auxiliary heat reserve. All the necessary attachment cords for making connections to the 115- or 230-volt mains are supplied.

Table I shows the construction of these cables. The terminal strip furnished is fitted with shielded plugs. Outlets are provided for the "Harmonic outputs" of the 50-kc, 10-kc and 100-cycle multivibrators, for the 1-kc output of the clock amplifier and for the micro-dial.

TABLE I

TYPE 697-20C CABLE
Measuring Equipment Signal Cable

NOTE: Sockets of Type 612-C are numbered starting from left as viewed from panel.

ITEM	CODE	WIRE	START INSTR. NO.	START TERMINAL NO.	FINISH INSTR. NO.	FINISH TERMINAL NO.
CIRCUITS INTO TYPE 612-C						
"X"	H	H	Terminal Board	Center Left Socket 11	612-C	4th Socket No. 11
		L		Center Left Socket 12		4th Socket No. 12
		S		Center Left Socket 10		4th Socket No. 10
50 KC Harmonics	E	H	Terminal Board	1st Socket No. 11	612-C	2nd Socket No. 11
		L		1st Socket No. 12		2nd Socket No. 12
		S		1st Socket No. 10		2nd Socket No. 10
9,10,or 11 KC Harmonics	D	H	Terminal Board	1st Socket No. 7	612-C	2nd Socket No. 7
		L		1st Socket No. 8		2nd Socket No. 8
		S		1st Socket No. 9		2nd Socket No. 9
1 KC Harmonics	B	H	Terminal Board	4th Socket No. 11	612-C	3rd Socket No. 11
		L		4th Socket No. 12		3rd Socket No. 12
		S		4th Socket No. 10		3rd Socket No. 10
100~ Harmonics	A	H	Terminal Board	4th Socket No. 7	612-C	3rd Socket No. 7
		L		4th Socket No. 8		3rd Socket No. 8
		S		4th Socket No. 9		3rd Socket No. 9
Microdial	C	H	Terminal Board	3rd Socket No. 11	612-C	6th Socket No. 11
		L		3rd Socket No. 12		6th Socket No. 12
		S		3rd Socket No. 10		6th Socket No. 12
616-C Output	J	H	616-C	Left Socket No. 7	612-C	4th Socket No. 7
		L		Left Socket No. 8		4th Socket No. 8
		S		Left Socket No. 9		4th Socket No. 9
*617-C Output	P	H	617-C	Left Socket No. 11	612-C	5th Socket No. 7
		L		Left Socket No. 12		5th Socket No. 8
		S		No connection		5th Socket No. 12

CABLE DATA

ITEM	CODE	WIRE	START INSTR. NO.	START TERMINAL NO.	FINISH INSTR. NO.	FINISH TERMINAL NO.
**619-E Output (Phones)	R	H L S	619-E	Left Socket No. 11 Left Socket No. 12 No Connection	612-C	5th Socket No. 9 5th Socket No. 10 5th Socket No. 12
614-B Output	S	H L S	614-B	Left Socket No. 8 Left Socket No. 12 No connection	612-C	5th Socket No. 11 5th Socket No. 12 5th Socket No. 12
				CIRCUITS OUT OF TYPE 612-C		
617-C Input	N	H L S	612-C	6th Socket No. 9 6th Socket No. 10 6th Socket No. 12	617-C	Left Socket No. 7 Left Socket No. 8 No connection
619-E Input	L	H L S	612-C	1st Socket No. 11 1st Socket No. 12 1st Socket No. 10	619-E	Left Socket No. 7 Left Socket No. 8 Left Socket No. 9
Speaker Input	M	H L S	612-C	6th Socket No. 7 6th Socket No. 8 6th Socket No. 12	Speaker	One side of Type 274-M Plug Other side of Type 274-M Plug No connection
				TYPE 699-A INPUT CIRCUITS		
1-KC Harmonics	G	H L S	612-C	3rd Socket No. 11 3rd Socket No. 12 3rd Socket No. 10	699-A	Left Socket No. 11 Left Socket No. 12 Left Socket No. 10
100~ (Control)	F	H L S	Terminal Board	3rd Socket No. 7 3rd Socket No. 8 3rd Socket No. 9	699-A	Left Socket No. 7 Left Socket No. 8 Left Socket No. 9
*617-C Output	T	H L S	617-C	Left Socket No. 11 Left Socket No. 12 No connection	699-A	Center Socket No. 7 Center Socket No. 8 Center Socket No. 12
**619-E Output	U	H L S	619-E	Left Socket No. 11 Left Socket No. 12 No connection	699-A	Center Socket No. 9 Center Socket No. 10 Center Socket No. 12
614-B Output	V	H L S	612-C	5th Socket No. 11 5th Socket No. 12 5th Socket No. 12	699-A	Center Socket No. 11 Center Socket No. 12 Center Socket No. 12
				MISCELLANEOUS CIRCUITS		
1-KC Harmonics into 614-B	K	H L S	612-C	3rd Socket No. 11 3rd Socket No. 12 3rd Socket No. 10	614-B	Left Socket No. 7 Left Socket No. 12 No connection
614-B Output into 617-C	W	H L S	614-B	Left Socket No. 8 Left Socket No. 12 No connection	617-C	Left Socket No. 9 Left Socket No. 12 Left Socket No. 12
616-C R.F. Output	X	H L S		Left Socket No. 7 Left Socket No. 8 Left Socket No. 9	616-C	Free end of cable labeled "616" H L S

* Shields of these two cables connected together at Type 617-C (left socket).
** Shields of these two cables connected together at Type 619-E (left socket). And insulate from ground in both cases.

CABLE DATA

TYPE 697-40C POWER CABLE
for Floating Battery Operation

ITEM	COLOR CODE	START INSTR. NO.	START TERMINAL NO.	FINISH INSTR. NO.	FINISH TERMINAL NO.
A+(Charge) A-(Charge) B+(Charge) B-(Charge)	Red No. 12 Black No. 12 Slate(Yellow) Yellow(Black)	695-C 695-C 695-C 695-C	Right Plug No. 1 Right Plug No. 2 Right Plug No. 3 Right Plug No. 4		Battery A+ Battery A- Battery B+ Battery B-
A+(Discharge) A- & G (Discharge) B+(Discharge) B- & G (Discharge)	Red No. 12 Black No. 12 Slate(Yellow) Yellow(Black)		Battery A+ Battery A- Battery B+ Battery B-	695-C 695-C 695-C 695-C	Center Socket No. 7 Center Socket No. 12 Center Socket No. 11 Center Socket No. 12
A+(Load)	Red No. 12	695-C	Right Plug No. 7	694-C 698-A 692-B (100~) 692-B (50 KC) 692-B (10 KC) 692-B (1 KC) 693-B 695-C	Right Socket No. 7 Right Socket No. 7 Right Socket No. 7 Right Socket No. 7 Right Socket No. 7 Right Socket No. 7 Right Socket No. 7 Right Plug No. 7
A+(691-C) A-(Load)	Orange No. 14 Black No. 12	694-C 695-C	Right Socket No. 9 Right Plug No. 12	691-C 694-C 691-C 698-A 692-B (100~) 692-B (50 KC) 692-B (10 KC) 692-B (1 KC) 693-B 695-C	Right Socket No. 7 Right Socket No. 8 Right Socket No. 8 Right Socket No. 8 Right Socket No. 8 Right Socket No. 8 Right Socket No. 8 Right Socket No. 8 Right Socket No. 8 Right Plug No. 8
B+(1 KC)	Slate (Red)	695-C	Right Plug No. 10	692-B (100~) 692-B (1 KC) 693-B	Right Socket No. 11 Right Socket No. 11 Right Socket No. 11
B+(Load)	Slate	695-C	Right Plug No. 11	694-C 698-A 692-B (50 KC) 692-B (10 KC)	Right Socket No. 11 Right Socket No. 11 Right Socket No. 11 Right Socket No. 11
B+(691-C)	Slate(Black)	694-C	Right Socket No. 10	691-C	Right Socket No. 11

CABLE DATA

ITEM	COLOR CODE	START INSTR. NO.	START TERMINAL NO.	FINISH INSTR. NO.	FINISH TERMINAL NO.
B- & G(Load)	Yellow	695-C	Right Plug No. 12	694-C 691-C 698-A 692-B (100~) 692-B (50 KC) 692-B (10 KC) 692-B (1 KC) 693-B	Right Socket No. 12 Right Socket No. 12 Right Socket No. 12 Right Socket No. 12 Right Socket No. 12 Right Socket No. 12 Right Socket No. 12 Right Socket No. 12

HEATER CIRCUITS

Line Line N (115 or 230 v (Trans. Pri.)	Red (Blue) Red	695-C 695-C	Right Plug No. 8 Right Plug No. 9	694-C 694-C	Center Socket No. 5 Center Socket No. 6
Line Line N (Trans. Sec.) 115 v.	Green(Black) Green	694-C 694-C	Center Socket No. 1 Center Socket No. 2	695-C 693-B 695-C 693-B	Center Socket No. 1 Right Socket No. 9 Center Socket No. 2 Right Socket No. 10
Heater Heater N	Green(Yellow) Green	695-C 695-C	Right Plug No. 5 Right Plug No. 6	694-C 694-C	Center Socket No. 3 Center Socket No. 4
Inner Heater Outer Heater Common	Red(Green) Red(Yellow) Green(Red)	694-C 694-C 694-C	Center Socket No.10 Center Socket No.11 Center Socket No.12	691-C 691-C 691-C	Center Socket No.10 Center Socket No.11 Center Socket No.12
Bat.+ Bat.- Line Line N (Aux. Heat. Re-serves)	Blue(Brown) Yellow(Blue) Black(Red) Black		External Battery + External Battery- External Line External Line N	695-C 695-C 695-C 695-C	Center Socket No. 3 Center Socket No. 4 Center Socket No. 5 Center Socket No. 6

MISCELLANEOUS CIRCUITS

Meter + Meter - Inner Thermo-stat Outer Thermo-stat	Blue(Red) Blue(Yellow) Black(Green) Black(Yellow)	691-C 691-C 691-C 691-C	Right Socket No. 9 Right Socket No.10 Center Socket No.8 Center Socket No.9	694-C 694-C 694-C 694-C	Right Socket No. 1 Right Socket No. 2 Center Socket No. 8 Center Socket No. 9

TYPE 697-41C POWER CABLE
for Complete A-C Operation

ITEM	COLOR CODE	START INSTR. NO.	START TERMINAL NO.	FINISH INSTR. NO.	FINISH TERMINAL NO.
Fil.(694-C)	2 Red No. 14 (Twisted)	696-C	Center Plug No. 3 Center Plug No. 4	694-C	Right Socket No. 7 Right Socket No. 8
Fil.(691-C)	2 Yellow No.14 (Twisted)	694-C	Right Socket No.9 Right Socket No.8	691-C	Right Socket No. 7 Right Socket No. 8
Fil.(698-A)	2 Slate No. 14 (Twisted)	696-C	Right Plug No. 1 Right Plug No. 2	698-A	Right Socket No. 7 Right Socket No. 8
Fil.(692-B) 100~	2 Blue No. 4	696-C	Center Plug No. 5 Center Plug No. 6	692-B (100~)	Right Socket No. 7 Right Socket No. 8
Fil.(692-B) 50 KC	2 Orange No.14 (Twisted)	696-C	Center Plug No.11 Center Plug No.12	692-B (50 KC)	Right Socket No. 7 Right Socket No. 8

CABLE DATA

ITEM	COLOR CODE	START INSTR. NO.	START TERMINAL NO.	FINISH INSTR. NO.	FINISH TERMINAL NO.
Fil.(692-B) 10 KC	2 Brown No. 14 (Twisted)	696-C	Center Plug No. 9 Center Plug No.10	692-B (10 KC)	Right Socket No. 7 Right Socket No. 8
Fil.(692-B) 1 KC	2 Green No. 14 (Twisted)	696-C	Center Plug No. 7 Center Plug No. 8	692-B (1 KC)	Right Socket No. 7 Right Socket No. 8
Fil.(693-B)	2 Black No. 14 (Twisted)	696-C	Center Plug No. 1 Center Plug No. 2	693-B	Right Socket No. 7 Right Socket No. 8
B+(1 KC)	Slate (Red)	696-C	Right Plug No. 10	692-B (100~) 692-B (1 KC) 693-B	Right Socket No.11 Right Socket No.11 Right Socket No.11
B+	Slate	696-C	Right Plug No. 11	694-C 698-C 692-B (50 KC) 692-B (10 KC)	Right Socket No.11 Right Socket No.11 Right Socket No.11 Right Socket No.11
B+(691-C)	Slate (Black)	694-C	Right Socket No.10	691-C	Right Socket No.11
B- & G	Yellow	696-C	Right Plug No. 12	694-C 691-C 698-A 692-B (100~) 692-B (50 KC) 692-B (10 KC) 692-B (1 KC) 693-B	Right Socket No.12 Right Socket No.12 Right Socket No.12 Right Socket No.12 Right Socket No.12 Right Socket No.12 Right Socket No.12 Right Socket No.12

HEATER AND MOTOR CIRCUITS

Line Line N (115 or 230 v (Trans. Pri.)	Red (Blue) Red	696-C	Right Plug No. 8 Right Plug No. 9	694-C 694-C	Center Socket No. 5 Center Socket No. 6
Line Line N (Trans. Sec. 115 v	Green(Black) Green	694-C 694-C	Nos. Center Socket 1 & 3 Center Socket 2 & 4 1-3 2-4 Connected in socket.	693-B 693-B	Right Socket No. 9 Right Socket No.10
Inner Heater Outer Heater Common	Red (Green) Red (Yellow) Green (Red)	694-C 694-C 694-C	Center Socket No.10 Center Socket No.11 Center Socket No.12	691-C 691-C 691-C	Center Socket No.10 Center Socket No.11 Center Socket No.12

MISCELLANEOUS CIRCUITS

Meter + Meter -	Blue (Red) Blue (Yellow)	691-C 691-C	Right Socket No. 9 Right Socket No. 10	694-C 694-C	Right Socket No. 1 Right Socket No. 2
Inner Thermostat	Black(Green)	691-C	Center Socket No.8	694-C	Center Socket No.8
Outer Thermostat	Black(Yellow)	691-C	Center Socket No.9	694-C	Center Socket No.9

TYPE 697-42C CABLE
Frequency Standard Signal Cable

CONTROL CIRCUITS

ITEM	CODE	WIRE	START INSTR. NO.	START TERMINAL NO.	FINISH INSTR. NO.	FINISH TERMINAL NO.
50 KC	A	H	691-C	Left Socket No. 10	692-B (50 KC)	Left Socket No. 7
		L		Left Socket No. 12		Left Socket No. 12
		S		Left Socket No. 12		No connection
50 KC	B	H	692-B (50 KC)	Left Socket No. 7	692-B (10 KC)	Left Socket No. 7
		L		Left Socket No. 12		Left Socket No. 12
		S		Left Socket No. 12		No connection
10 KC	C	H	692-B (10 KC)	Left Socket No. 10	692-B (1 KC)	Left Socket No. 7
		L		Left Socket No. 12		Left Socket No. 12
		S		Left Socket No. 12		No connection
1 KC	D	H	692-B (1 KC)	Left Socket No. 10	693-B	Left Socket No. 7
		L		Left Socket No. 12		Left Socket No. 12
		S		Left Socket No. 12		No connection
1 KC	E	H	692-B (1 KC)	Left Socket No. 10	692-B (100~)	Left Socket No. 7
		L		Left Socket No. 12		Left Socket No. 12
		S		Left Socket No. 12		No connection
100~	J	H	692-B (100~)	Left Socket No. 10	Terminal Board	Center Plug No. 7
		L		Left Socket No. 12		Center Plug No. 8
		S		Left Socket No. 12		Center Plug No. 9

HARMONIC OUTPUT CIRCUITS

ITEM	CODE	WIRE	START INSTR. NO.	START TERMINAL NO.	FINISH INSTR. NO.	FINISH TERMINAL NO.	
50 KC	N						And Shielded Plug - 50 KC
		H	692-B (50 KC)	Left Socket No. 11	Terminal Board	1st Plug No. 11	1
		L		Left Socket No. 9		1st Plug No. 12	2
		S		Left Socket No. 12		1st Plug No. 10	3
10 KC*	R	H	692-B (10 KC)	Left Socket No. 11	698-A	Left Socket No. 7	
		L		Left Socket No. 9		Left Socket No. 8	
		S		Left Socket No. 12		Left Socket No. 9	
9,10 or 11 KC	M						And Shielded Plug - 10 KC
		H	698-A	Left Socket No. 11	Terminal Board	1st Plug No. 7	1
		L		Left Socket No. 12		1st Plug No. 8	2
		S		Left Socket No. 10		1st Plug No. 9	3

* Also serves as control for Type 698-A.

ITEM	CODE	WIRE	START INSTR. NO.	START TERMINAL NO.	FINISH INSTR. NO.	FINISH TERMINAL NO.	
1 KC	F	H	692-B (1 KC)	Left Socket No. 11	693-B	Left Socket No. 11	
		L		Left Socket No. 9		Left Socket No. 12	
		S		Left Socket No. 12		No connection	
1 KC	H						And Shielded Plug - 1 KC
		H	693-B	Left Socket No. 9	Terminal Board	4th Plug No. 11	1
		L		Left Socket No. 8		4th Plug No. 12	2
		S		Left Socket No. 12		4th Plug No. 10	3
100~	G						And Shielded Plug - 100~
		H	692-B (100~)	Left Socket No. 11	Terminal Board	4th Plug No. 7	1
		L		Left Socket No. 9		4th Plug No. 8	2
		S		Left Socket No. 12		4th Plug No. 9	3
Micro-dial	L						And Shielded Plug, Microdial
		H	693-B	Left Socket No. 10	Terminal Board	3rd Plug No. 11	1
		L		Left Socket No. 12		3rd Plug No. 12	2
		S		Left Socket No. 12		3rd Plug No. 10	3

PART III

RACKING UP The equipment is designed to be mounted in the General Radio Type 480-P Relay Rack. The units should be mounted in the relative positions given below and illustrated in Figure 1.

*Type 693-B Syncronometer Type 692-B Multivibrator (1 kc) Type 692-B Multivibrator (10 kc) Type 692-B Multivibrator (50 kc) Type 692-B Multivibrator (100 cycles) Type 698-A Duplex Multivibrator (9-11 kc) Type 697 Terminal Strip (Attached to cable) Type 691-C Constant Temperature Unit Type 694-C Control Unit	Instruments common to both "a-c operation" and "floating-battery operation."

Complete a-c	Floating-battery
Type 480-P2 Blank Panel Type 696-C Power Supply (a-c operated)	Type 695-C Charging Unit (a-c operated)

*Before mounting the Type 693-B Syncronometer, remove the two clamping screws projecting through the bottom of the unit midway between the clock mountings at each end of the clock. These are used to clamp the clock firmly during shipment. On installation, the clock should be free on the air-craft type mountings. These screws are identified by having lock terminals under the heads, on bottom of case.

POWER CONNECTIONS Connect the a-c power line to the junction box mounted in the rear of the cabinet.

INSTALLING CABLES ON A-C ASSEMBLY In the case of a-c operation, all connections, with the exception of those to the 115- or 230-volt, 50- to 60-cycle mains, are made by plug-in cables furnished with the equipment (See Figure 1).

INSTALLING CABLES ON FLOATING-BATTERY OPERATED ASSEMBLY In the case of floating-battery operation, the cables are fitted with 10-foot leads for connections to the plate and filament batteries and to the "auxiliary heat reserve battery" and the "auxiliary heat reserve supply" (See page 15). All connections to the equipment on the rack, with the exception of the connections to the 115- or 230-volt, 50- to 60-cycle mains, are made by plug-in cables furnished with the equipment.

The long leads mentioned in the preceding paragraph are coded for connection as follows:

3-Red #12 wires to positive (+) *3-Black #12 wires to negative (-)	6-volt Battery
2-Slate (Yellow Tracer) to positive (+) 2-Yellow (Black Tracer) to negative (-)	180-Volt Plate Battery
1-Blue (Brown Tracer) to positive (+) 1-Yellow (Blue Tracer) to negative (-)	Auxiliary Heat Reserve Battery †
1-Black (Red Tracer) to high side 1-Black to neutral or ground side	Auxiliary Heat Reserve Line †

*Can be distinguished from the other black wire by their larger size.

†CAUTION: In order to prevent an accidental short circuit of the supply in use as auxiliary heat reserve, the ends of the two unused auxiliary-heat-reserve wires should be taped. All four wires should be taped if no auxiliary heat reserve is used.

TUBES A complete set of vacuum tubes is furnished with the equipment. A complete list of the tubes supplied is given in the shipping list for the assembly, page 35. These should be installed as shown in the wiring diagrams for the individual instruments, as given in pages 3 to 18.

Six-volt pilot lights are shipped in place in all units. (See also list of spares on shipping list, page 35.)

ADJUSTMENTS Before heating the temperature-control unit, the Type 676-B Quartz Bar should be placed in the inner compartment and the three wires soldered to the terminals provided on the base. Inspection of the thermostats should be made for broken mercury columns. If broken, warm up the thermostat in hot water until the broken parts are joined together in the expansion chamber at the top of the thermostat. The inner thermostat operates at 60°C., the outer at 55°C.

Inspection should also be made to see that the thermostat and thermal fuse connections are all firmly made. These connections appear on the terminal strips at the top of both inner and outer boxes. Insert the thermometers through the door on the front panel. The outer thermometer is graduated in 0.5° steps; the inner in 0.1°C. steps. DO NOT force the thermometers into place. If there seems to be any obstruction, a rod or a drill may be used to clear the hole for the thermometer.

PART IV

INSTRUCTIONS FOR OPERATING COMPLETE A-C ASSEMBLY

(See Part V for Floating-Battery Operation)

The following paragraphs give all the information necessary for starting up an assembly in which power is derived from a Type 696-C Power Supply. If difficulties are encountered, turn to Part VI for suggestions.

In placing the equipment in operation, the temperature control should be started at least twelve and preferably twenty-four hours before the apparatus is to be used. It is recommended, even though the equipment as a whole may not be operated continuously, that the temperature control be left on at all times.

The temperature-control circuits are turned on and off by the HEAT switch mounted at the left on the Type 694-C Control Unit. Leave the MASTER switch on the Type 696-C Power Supply in the OFF position.

On first closing the HEAT switch, both "inner" and "outer" relays should operate, and both heat-indicator lamps should light. The thermostats will not operate until the heat has been applied for roughly one-half to one hour. The temperature in the crystal compartment does not reach its final value until a period of six to twelve hours has elapsed.

The final inner temperature should be 60°C. within $\pm\ 0.5^{\circ}$ and it should remain constant to within 0.01°C. The outer thermometer should read approximately 57°C.

To place the assembly in operation, proceed as follows:

1. Throw MASTER switch on Type 696-C Power Supply to ON. Pilot should light and FILAMENT and PLATE meters should read. Set ADJUST control to give 6.3 volts on filament voltmeter, at red line.

2. Throw FIL-PL switch on the Type 694-C Control Unit to ON. The filament pilot lamp should light and, after a few moments, the PLATE meter should read. If the meter reading is 20-30 microamperes, the crystal oscillator is NOT oscillating. When oscillating the reading should be from 75 to 110 microamperes. When first starting, the meter will show a reading of 200 microamperes momentarily, decreasing quickly to the normal current.

Turn on the various multivibrators and the syncronometer in order, from the bottom toward the top of the rack. The voltage and current readings of the power supply unit are given in the test data, page 32.

3. Unless adjustments have been disturbed in shipment, the multivibrators should be operating at the correct frequencies and be in control. Details on checking the multivibrators are given in Part VI.

4. To start the clock motor, press the push-button on panel, thus turning on the 60-cycle supply to the starting motor. Due to the pull of the steady plate current the motor will not turn until the FIL-PL switch is thrown to OFF <u>momentarily.</u> Return this switch to ON immediately. The clock rotor will now turn and pick up speed.

The motor reaches synchronous speed in about two seconds as indicated on the clock face. In most cases the 1000-cycle motor will take hold and prevent the 60-cycle motor from any further increase in speed. The switch on the clock panel may then be released. If the 60-cycle motor carries the rotor through synchronous speed, simply release the switch. The 1000-cycle motor may fall into step while coasting. If not, simply press the starting motor switch and bring the 1000-cycle motor up to synchronous speed again.

PART V

INSTRUCTIONS FOR OPERATING FLOATING-BATTERY ASSEMBLY

(See Part IV for Complete A-C Operation)

The following paragraphs give all the information necessary for starting up an assembly in which power is derived from a Type 695-C Charging Unit. If difficulties are encountered, turn to PART VI for suggestions.

In placing equipment in operation, the temperature control should be started at least twelve, and preferably twenty-four hours before the apparatus is to be used. It is recommended that even though the equipment as a whole may not be operated continuously, that the temperature control be left on at all times.

As soon as the 115-volt supply to the Type 695-C Charging Unit is turned on, the auxiliary heat reserve relays should close.

The temperature control circuits are turned on and off by the HEAT switch mounted at the left on the Type 694-C Control Unit. On first closing this switch, both inner and outer relays should operate, and both heat indicator lamps should light. The thermostats will not operate until the heat has been applied for roughly one-half to one hour. The temperature in the crystal compartment does not reach its final value until a period of from six to twelve hours has elapsed. The final inner temperature should be 60°C. ± 0.5° and should remain constant to approximately 0.01°C. The outer thermometer should read approximately 57°C.

To place the assembly in operation, proceed as follows:

1. On throwing on both the FILAMENT CHARGE and PLATE CHARGE switches on the Type 695-C Charging Unit, the filament and plate charging current meters should indicate. On throwing the FILAMENT-LOAD and PLATE-LOAD switches to LOAD, the filament and plate load current meters should indicate the total load current in each circuit taken by the assembly. To maintain the batteries in a charged condition, adjust the charging current to slightly exceed the load current. The excess must be determined to maintain the batteries at 2.15 volts per cell.

If all the FIL-PL and FILAMENT switches on each instrument are OFF when the equipment is first started, then the filament and plate load current meters should give no readings.

2. Throw FIL-PL switch on the Type 694-C Control Unit to ON. The filament pilot lamp should light and, after a few moments, the PLATE meter should read. If the meter reading is 20-30 microamperes, the crystal oscillator is NOT oscillating. When oscillating the reading should be from 75 to 110 microamperes. When first starting, the meter will show a reading of 200 microamperes momentarily, decreasing quickly to the normal current.

Turn on the various multivibrators and the syncronometer in order, from the bottom toward the top of the rack. The voltage and current readings of the power supply unit are given in the test data, page 32.

3. Unless adjustments have been disturbed in shipment, the multivibrators should be operating at the correct frequencies and be in control. Details on checking the multivibrators are given in Part VI.

4. To start the clock motor, press the switch on the syncronometer panel, thus turning on the 60-cycle supply to the starting motor. Due to the pull of the steady plate current, the motor will not turn until the FIL-PL switch is thrown to OFF momentarily. Return this switch to ON immediately. The clock rotor will now turn and pick up speed.

The motor reaches synchronous speed in about two seconds, as indicated on the clock face. In most cases the 1000-cycle motor will take hold and prevent any further increase in speed. The switch on the clock face may then be released. If the 60-cycle motor carries the rotor through synchronous speed, simply release the switch. The 1000-cycle rotor may fall in step while coasting. If not, simply press the starting motor switch and bring the 1000-cycle motor up to synchronous speed again.

PART VI

OPERATING SUGGESTIONS

After the assembly has been installed and put in operation as described in either PART IV or PART V, a check upon the various adjustments is desirable.

1. CRYSTAL OSCILLATOR If the oscillator does not operate, make certain that the lamp, P-1, (Figure 6) is screwed firmly into the socket. If the oscillator still does not operate, inspect the filament of the lamp, P-1, for breakage or test the lamp with an ohmmeter. Finally, inspect the quartz bar for displacement in the mounting due to shipment. The bar should be in alignment in the holder, with the baffles parallel to the ends. The two air-gaps should be equal. The crystal should be clamped firmly enough so that shaking the holder does not cause any displacement of the bar. The clamping points should be at the geometric centers of the two plated faces.

CAUTION: Handle crystal with great care so as not to break off the connecting leads.

2. MULTIVIBRATORS The Type 692-B Multivibrators should operate at very nearly their rated frequency when no control voltage is applied, that is, when the control voltage adjustment is set at zero (left-hand control). If this control is advanced slightly, the multivibrator should go into control and remain at the controlled frequency as the control voltage is increased over quite a range. If sufficient control voltage is applied, the multivibrator frequency may be pulled up to the next higher value. Set the control voltage adjustment at about 80% of the value where this jump occurs.

If only a very small control voltage is used, it will be found that as the frequency control is varied (by removing the snap cover on the panel and adjusting the control with a screw driver) control may be obtained over a narrow range. Set the control in the middle of this range.

If the multivibrators require entire readjustment, proceed as follows:

Use a heterodyne receiver or heterodyne-frequency meter covering a range of preferably 100 kc to 150 kc (any 50-kc interval covering two crystal harmonics can be used, but it should be taken at as low a frequency as possible).

First, identify the settings for two crystal harmonics, suchas 100 kc and 150 kc, by coupling the receiver to the crystal oscillator RF OUTPUT terminal at the rear of the temperature-control unit.

Next, turn on the 50-kc multivibrator. The settings where beats are heard should agree with those previously obtained, and the beat tones should be as clear and steady as when listening to the crystal oscillator directly. Control should be obtained over a wide range on the control voltage adjustment (left-hand control). Turn off the multivibrator.

Turn on the 10-kc multivibrator using the settings given in test data. Starting at 100 kc count the zero beat points found on the receiver between this point and the next crystal harmonic. If the first point 100 kc, is called zero, then the last point should be five. The multivibrator is then operating at 50/5 = 10 kc. If the count gives four, the frequency is 50/4 = 12.5 kc, etc. If the multivibrator frequency is too low, adjust the frequency control toward the right until the proper frequency is obtained; if the frequency is too high, turn it to the left. Make the final setting by reducing the control voltage to a small value and adjusting the frequency to the middle of the control range. These adjustments are best made when listening to a multivibrator harmonic which is not a crystal harmonic, such as 110 kc, 120 kc, etc.

To check the 1-kc multivibrator, compare the output frequency with a calibrated audio-frequency oscillator, tuning fork, etc., of 1 kc. If none are available start the clock and compare with a watch. If the clock keeps time, the frequency is 1 kc. It it gains or loses by about 10% the multivibrator frequency must be readjusted. Obtain the final setting of the control by reducing the control voltage and setting the frequency control in the middle of the control range.

In checking the adjustments of the Type 698 Duplex Multivibrator, the following procedure is suggested.

Set the Type 619 Heterodyne Detector to 90 kc. Turn switch on Type 698 Duplex Multivibrator to 9 kc. If the duplex multivibrator is in adjustment, zero beat should be obtained. Now offset the heterodyne detector to obtain a low beat tone.

Turn the input control of the Type 698 Duplex Multivibrator, upper left on panel, toward the left until the beat tone just becomes unsteady, or changes to a different tone. Slightly readjust the 9-kc frequency adjustment, lower right on panel, to obtain original beat tone. Again reduce input, following with frequency adjustment until the input voltage has been reduced to a low value and the frequency control gives the correct frequency over a narrow range. Set frequency control at center of this range and leave it at this point. Advance input control about three-quarters of the way to the right. Check frequency of multivibrator to be certain it is 9 kc. This can be done by calibration of the Type 619 Heterodyne Detector or by the direct-reading dial of the Type 616 Heterodyne Frequency Meter.

The 11-kc position is checked by setting the Type 619 Heterodyne Detector to 110 kc, throwing the switch on the Type 698 Duplex Multivibrator to 11 kc and proceeding as above. The same input control, upper left on panel, is used; the frequency adjustment is the upper right control on panel. Check frequency to be certain it is 11 kc.

When viewed from the rear, the arms of the frequency control resistors should point almost towards each other; the upper one about straight down, the lower about straight up.

Since the output of the selective filter is greater on 90 kc than on 110 kc, the lower left-hand control provides for equalizing the outputs. This adjustment does not need to be changed after setting at the factory.

DETERMINATION AND ADJUSTMENT OF CRYSTAL FREQUENCY The frequency of the system is self-determining and can be corrected for errors and deviations. The timing equipment provides a means for counting the number of cycles executed by the crystal, so, to determine the average frequency over any time interval, we have only to divide the number of cycles occurring during that interval by the length of the interval in seconds. The reading of the syncronometer is a measure of the number of cycles executed by the crystal, so, if we set the syncronometer to standard time, and, after an appreciable interval (say 24 hours), we compare its reading with standard time, the amount by which its reading differs from the standard time is a measure of the deviation of the crystal frequency from its assigned value. In practice this can be applied as follows:

Suppose we compare the syncronometer with standard time signals as transmitted by radio and find the syncronometer to be 0.12 second fast. The next day (24 hours later) the syncronometer is found to be 0.46 second fast. Then the time interval read on the syncronometer is 24 hours plus (0.46 - 0.12) second and the frequency of the crystal oscillator is

$$\frac{86{,}400 + (0.46 - 0.12)}{86{,}400} \times 50{,}000$$

or 50,000.195 cycles per second.

It is generally more convenient to consider the <u>deviation</u> of the frequency from its assigned value, expressed in parts per million, or other convenient percentage terms. Since there are 86,400 seconds in one day, one part in a million deviation in the average frequency means that the syncronometer will gain or lose 0.0864 seconds in twenty-four hours. If, then, the seconds gained or lost by the syncronometer per 24 hours are divided by 0.0864, the deviation of the average frequency is obtained, expressed in parts per million. <u>This figure is convenient since it applies to any and all of the frequencies derived from the assembly.</u>

Obviously, the accurate determination of the frequency depends on the time signals being correct. Actually there are small errors in the transmission, and correction for these will be supplied on request to the observatory or transmitting station.

COMPARISON OF SYNCRONOMETER WITH TIME SIGNALS The following instructions for making comparisons between time kept by the assembly and time signals are based on the transmissions of the U. S. Naval Observatory through NAA and NSS. There are at present eight different frequencies used for transmissions at various times during 24 hours, and although occasional changes are made, there are probably few, if any, places where one or more transmissions cannot be received satisfactorily. It is suggested that, if possible, these transmissions be used until the operating engineer has become thoroughly familiar with the operation of the assembly.

To the right of the syncronometer face is mounted the micro-dial, by means of which the time indicated by the syncronometer may be accurately compared with time signals. The contact is driven at 1 revolution per second by the main counter-shaft. The contacts are connected to the output terminals on the terminal strip marked MICRO-DIAL. The contacts are closed for about 0.95 second. The instant at which the contacts close may be adjusted by turning the knurled wheel by inserting the key in the opening just to the right of the syncronometer face. If the contacts are connected across the telephones or loud-speaker of a time receiver (from which any direct current in the output has been filtered) the operation of the cam may be adjusted so as to short-circuit all but the beginning of each pulse of the time signal as transmitted by the U. S. Naval Observatory. This adjustment is made by advancing the wheel from "zero" on the scale <u>toward lower readings</u> until just a very short pulse remains of each transmitted time dot. This adjustment may generally be made to better than 0.01 second. The arrangement requires,

if the readings are to be taken directly from the figures on the scale, that fractions of a second be expressed as <u>positive increments</u> from the last whole second. For example, if the clock were 0.30 seconds slow, the reading would be 11 h. 59 m. 59.70 seconds on the syncronometer and micro-dial scales. Each division on the micro-dial scale corresponds to 0.01 second.

The micro-dial contacts may be utilized for transmission of second's pulses for laboratory purposes. This is helpful, for instance, if time kept by the assembly is to be compared with time signals from a station using the so-called rhythmic type of transmission in which 61 pulses or dots are sent out in 60 seconds. This requires that the method of coincidences be used. It is thus merely necessary to compare, by aural or other means, the seconds pulses from the standard with the pulses of the transmission.

GREATER PRECISION Where the reliability of the time signals is great enough to justify a closer comparison than the 0.01 second provided by the micro-dial, the General Radio Company is prepared to furnish a syncronometer that can be compared with time signals to better than 0.001 second. Stroboscopic means are utilized. Prices and other details will be supplied on request.

ADJUSTMENT OF FREQUENCY After the frequency of the system has been determined by means of time signals for several days, readjustments may be made to bring the frequency to exactly 50 kilocycles. If the adjustment to be made is small, the ADJUST dial on the unit may be used.*

*An increase in dial reading corresponds to an increase in frequency.

<u>REFERENCES</u>

The following references can be consulted for more information about the Class C-21-HLD Primary Frequency Standard.

1. "'Universal' Frequency Standardization from a Single Frequency Standard", by J. K. Clapp: Journal of the Optical Society of America and Review of Scientific Instruments, Vol. 15, No. 1, July, 1927. Of historical interest because this paper is the first to disclose the use of the multivibrator for frequency division.

2. "A Convenient Method for Referring Standard Frequency Standards to a Standard Time Interval", by L. M. Hull and J. K. Clapp: Proceedings of the Institute of Radio Engineers, Vol. 17, No. 2, February, 1929. This paper is also of historical interest. It describes the operation of the first experimental equipment from which the present primary frequency standard has evolved.

3. "Interpolation Methods for use with Harmonic Frequency Standards", by J. K. Clapp: Proceedings of the Institute of Radio Engineers, Vol. 18, No. 9, September, 1930. Describes in general terms methods for interpolating between standard harmonic frequencies from a Class C-21-H Standard-Frequency Assembly.

4. "Temperature Control for Frequency Standards" by J. K. Clapp: Proceedings of the Institute of Radio Engineers, Vol. 18, No. 12, December, 1930. Describes the design considerations behind General Radio temperature-control boxes.

TEST DATA

Approximate total plate current taken by each unit. Taken by turning off each unit and noting plate current increase on power supply meter when turned on again.

TYPE 693-B SYNCRONOMETER

Serial No.______ ______ma

TYPE 692-B MULTIVIBRATORS

Frequency	Serial No.	Control Switch (Inside)	
1 kc	______	EVEN	______ma
10 kc	______	ODD	______ma
50 kc	______	ODD	______ma
100 ~	______	EVEN	______ma

TYPE 698-A DUPLEX MULTIVIBRATOR

Serial No.____________
Frequency: 9 or 11 kc ______ma

TYPE 690-D PIEZO OSCILLATOR

Serial No._________
Frequency Adust_______div.

TYPE 691-C CONSTANT TEMPERATURE UNIT

Serial No._______
INNER Temperature_______ °C.
OUTER Temperature_______ °C.

TYPE 676-B QUARTZ BAR

Serial No. _______
Frequency________ kc.

TYPE 694-C CONTROL UNIT

Serial No.________
Plate Meter Reading ____________ μa ______ma

TYPE 695-C CHARGING UNIT

Serial No.__________
FILAMENT LOAD_________a
FILAMENT VOLTAGE______v
PLATE LOAD__________ma
PLATE VOLTAGE_________v

TYPE 696-C POWER SUPPLY

Serial No.__________
FILAMENT VOLTAGE______v
PLATE VOLTAGE________v
PLATE CURRENT________ma

GENERAL RADIO COMPANY

VACUUM-TUBE DATA

Voltages are measured between terminals shown with meter of 20,000 ohms per volt (d-c); 1,000 ohms per volt (a-c).
Currents are measured in series with terminal shown.

INSTRUMENT	SOCKET TERMINAL NOS.	RIGHT V-1	V-2	V-3	V-4	→ LEFT as seen from REAR V-5	NOTES
693-B		6J5G	6K6G				A
	2-7 v a-c	5.6	5.6				
	8-Gnd v d-c	22.5	17.5				
	8-5 v d-c	22.5	17.5				
	3-8 v d-c	142	123				
	3 ma d-c	11.5	38				
	4-8 v d-c	—	155				
	4 ma d-c	—	6.5				
692-B 1 KC		6J5G	6J5G	6J5G	6J5G	6J5G	A,B
	2-7 v a-c	5.8	5.8	5.8	5.8	5.8	
	8-Gnd v d-c	12.5	0	0	11	23	
	8-5 v d-c	10	0	0	10	23	
	3-8 v d-c	78	55	60	80	147	
	3 ma d-c	4.7	3.0	2.8	4.3	15	
692-B 10 KC		6J5G	6J5G	6J5G	6J5G	6J5G	A,B
	2-7 v a-c	5.8	5.8	5.8	5.8	5.8	
	8-Gnd v d-c	10	0	0	10	12	
	8-5 v d-c	7.5	0	0	8	12	
	3-8 v d-c	70	56	57	67	95	
	3 ma d-c	3.8	2.2	2.5	3.8	7.3	
692-B 50 KC		6J5G	6J5G	6J5G	6J5G	6J5G	A,B
	2-7 v a-c	5.6	5.6	5.6	5.6	5.6	
	8-Gnd v d-c	10	0	0	10	12	
	8-5 v d-c	8	0	0	8	12	
	3-8 v d-c	118	75	77	77	112	
	3 ma d-c	2.1	4.8	4.6	4.2	8.4	
692-B 100~		6J5G	6J5G	6J5G	6J5G	6J5G	A,B
	2-7 v a-c	6.0	6.0	6.0	6.0	6.0	
	8-Gnd v d-c	10	0	0	10	16	
	8-5 v d-c	8	0	0	8	16	
	3-8 v d-c	70	50	55	70	120	
	3 ma d-c	3.8	2.6	2.4	3.9	11	
698-A		6J5G	6J5G	6J5G	Omitted	6J5G	A,B,C
	2-7 v a-c	6.0	6.0	6.0	—	6.0	
	8-Gnd v d-c	10	0	0	—	11	
	8-5 v d-c	8	0	0	—	11	
	3-8 v d-c	63	50	50	—	97	
	3 ma d-c	4.0	2.7	2.7	—	7.6	
690-D		6AC7	6SN7-GT	6H6-GT			D
	2-7 v a-c	6.2					
	7-8 v a-c		6.2	6.2			
	5-Gnd v d-c	1.5					
	3-Gnd v d-c		24				
	6-Gnd v d-c		22				
	3-4 v d-c		0.25				
	4-5 v d-c	1.5					
	8-Gnd v d-c	165					
	2-Gnd v d-c		142				
	5-Gnd v d-c		165				
	6-Gnd v d-c	150					
	8 ma d-c	5.8					
	6 ma d-c	2.7					
	2 ma d-c		8.6				

INSTRUMENT	SOCKET TERMINAL NOS.	RIGHT ——> V-1	V-2	V-3	V-4	LEFT as seen from REAR V-5	NOTES
696-C		83					E
	1-4 v a-c	4.6					
	2-Gnd v a-c	232					
	3-Gnd v a-c	232					
	1,4-Gnd v d-c	190					
	2 ma d-c	57					
	3 ma d-c	57					

NOTES

A. Remove signal cable plug when making readings.
B. Remove V-2 when readings for V-1, V-3, V-4 or V-5 are taken. Insert V-2, and remove V-3, when making readings for V-2.
C. V-4 is omitted in Type 698-A.
D. Disconnect connections to quartz bar when taking readings. In Type 690-D Oscillator tubes are in order V-1, P-1, V-2, V-3, seen from REAR, left to right. Radio-frequency output measured with 20,000-ohm oxide-rectifier voltmeter between multipoint plug terminals 10-12, averages about 0.5 volt.
E. Data taken with full load on power supply unit.

SHIPPING LIST

The following is a list of the instruments, accessories, and spare parts shipped with the Class C-21-HLD Primary Frequency Standard for which this book is the instruction manual.

1 - Instruction Book
1 - Type 480-P Relay Rack
1 - Type 693-B Syncronometer
1 - Type 692-B Multivibrator (1 kc)
1 - Type 692-B Multivibrator (10 kc)
1 - Type 692-B Multivibrator (50 kc)
1 - Type 692-B Multivibrator (100 cycles)
1 - Type 698-A Duplex Multivibrator
1 - Type 691-C Constant Temperature Unit
1 - Type 690-D Piezo Oscillator (Inside Type 691-C)
1 - Type 676-B Quartz Bar (Inside Type 691-C)
1 - Type 139-503 Thermostat (55°) - OUTER } Shipped in place.
1 - Type 139-503 Thermostat (60°) - INNER }
1 - Type 139-489 Thermometer - INNER
1 - Type 139-481 Thermometer - OUTER
1 - Type 694-C Control Unit
1 - Type 697-42C High-Frequency Connecting Cable and Terminal Strip
5 - Type X3-12 Cannon Shielded Plugs
48 - Panel Screws

TUBES

1 - 6K6G
1 - 6AC7
1 - 6SN7-GT
1 - 6H6-GT
25 - 6J5G
1 - 83
1 - 6-watt, 120-volt Mazda Candelabra base

FOR FLOATING-BATTERY OPERATED ASSEMBLY

1 - Type 695-C Charging Unit
1 - Type 697-40C Power-Supply Cable (with 10-ft. leads)
1 - 115-volt Attachment Cord

FOR COMPLETELY A-C OPERATED ASSEMBLY

1 - Type 696-C Power Supply
1 - Type 697-41C Power-Supply Cable
1 - 115-Volt Attachment Cord
1 - Type 480-P2 Blank Panel

SPARE PARTS

FOR FLOATING-BATTERY OPERATED ASSEMBLY

4 - Type 691-P5 Fusible Links
28 - Mazda 44 Lamps
5 - 120-v, 6-w, candelabra-base lamps
1 box - 0.1-a fuses
7 boxes - 0.2-a fuses
2 boxes - 1.0-a fuses
1 box - 1.5-a fuses
1 box - 2.0-a fuses
1 box - 2.5-a fuses
6 boxes - 5.0-a fuses
1 box - 15.0-a fuses

FOR COMPLETELY A-C OPERATED ASSEMBLY

4 - Type 691-P5 Fusible Links
28 - Mazda 44 Lamps
5 - 120-v, 6-w, candelabra-base lamps
1 box - 0.1-a fuses
7 boxes - 0.2-a fuses
1 box - 1.0-a fuses
1 box - 1.5-a fuses
1 box - 2.0-a fuses
1 box - 2.5-a fuses
5 boxes - 5.0-a fuses

GENERAL RADIO COMPANY

PATENT NOTICE

This equipment is manufactured and sold under the following U. S. Patents and license agreements:

Patents of the American Telephone and Telegraph Company, solely for utilization in research, investigation, measurement, testing, instruction and development work in pure and applied science, including industrial and engineering fields.

Patents and patent applications of Dr. G. W. Pierce pertaining to piezo-electric crystals and their associated circuits.

Patent No. 1,967,185
Patent No. 2,009,013
Patent No. 1,967,184
Patent No. 2,029,358