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# INSTRUCTION BOOK FOR TIME STANDARD AN/FSM-5A


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Radio Division II


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# INSTRUCTION BOOK
# FOR
# TIME STANDARD
# AN/FSM-5A

**NAVAL RESEARCH LABORATORY**

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## PREFACE

To isolate and eliminate the various causes of errors in the determination and distribution of Navy time signals, the Naval Research Laboratory has been carrying out theoretical and experimental investigations of techniques useful in the precise determination of standard time and time intervals including the evaluation of their relative merits.

The basic techniques in the AN/FSM-5A equipments were developed at NRL to provide a means of evaluating and resolving various errors in the present Navy time system. The equipment contains a 100-kc oscillator, a five-channel electronic keyer with fixed program sequence, and a measuring system for rapidly comparing and setting the equipment to the Naval Observatory time signals as transmitted by radio or landline. The oscillator is capable of maintaining a constant rate of better than one part in $10^8$ The measuring system resolution is better than one millisecond.

## PROBLEM STATUS

This is an interim report; work on the problem is continuing.

## AUTHORIZATION

NRL Problem R10-73
BuShips Problem S1570
RDB Project NE-021-240

Manuscript submitted June 1, 1953



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Figure 1-1. Front View of Time Standard AN/FSM-5A



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# SECTION 1
# GENERAL DESCRIPTION

## 1. BASIC CONSIDERATIONS

### Purpose

Time Standard AN/FSM-5A (Figure 1-1 and Table 1-1), a fixed radio-station instrument consisting of a series of rack-mounted assemblies, is used to supply and maintain time information and standard frequency. When set up and properly checked, this instrument is capable of supplying time information correct to within one millisecond and frequency accurate to one part in 50 million.*

TABLE 1-1
Equipment Supplied

| Shipping Box No. | Quantity Per Equipment | Name of Unit | Navy Designation | Over-all Dimensions | | | Volume (cu ft) | Weight (lb) |
|---|---|---|---|---|---|---|---|---|
| | | | | Height (in.) | Width (in.) | Depth (in.) | | |
| 5 | 1 | R-F Oscillator | 0-76/U | 10-1/4 | 19 | 20-1/4 | 2.30 | 95 |
| 6 | 1 | Frequency Divider | CV-87A/FSM-5A | 7 | 19 | 18-3/4 | 1.45 | 29 |
| 9 | 1 | Clock | TD-31/FSM-5A | 21 | 19 | 12-1/2 | 2.90 | 65 |
| 7 | 1 | Time Comparator | CV-88A/FSM-5A | 10-1/2 | 19 | 18-1/2 | 2.14 | 40 |
| 3 | 1 | Power Supply | PP-455A/FSM-5A | 10-1/2 | 19 | 19-1/4 | 2.22 | 86-1/2 |
| 4 | 1 | Power Supply | PP-456A/FSM-5A | 7 | 19 | 16-1/4 | 2.16 | 41 |
| 8 | 1 | Oscilloscope | OS-13/UA | 8-3/4 | 19 | 20-1/4 | 1.95 | 44 |
| 10 | 1 | Binary Tester | CV-88A6/FSM-5A | 8-1/4 | 9-7/8 | 8-7/8 | 0.42 | 9-3/4 |
| 1 | 1 | Cabinet | CY-597/G | 87-1/2 | 22-3/8 | 26 | 29.5 | 322 |
| 2 | 1 | Voltage Stabilizer* | -- | 13-27/32 | 8-7/8 | 14-5/32 | 1.01 | 50 |
| 10 | 1 | Spare Parts | -- | -- | -- | -- | -- | -- |
| 10 | 1 | Test Prod. | Mx-1015/U | 50 (length) | -- | -- | -- | -- |
| 10 | 1 | R-F Cable | CG-55/U | 180 (length) | -- | -- | -- | -- |

*General Electric; Cat. No. 91G150

### Description

The basic unit of the time standard is a precision oscillator, O-76/U (Figure 1-2), which operates at a frequency of 100,000 cps. The signal from this oscillator is used to

*To operate with the specified accuracy, the time standard should be installed in a room air-conditioned at 25° ± 2° C.

drive a frequency divider which, in turn, supplies a 1000-cycle signal to drive the synchronous motor of Clock TD-31/FSM-5A. The motor is geared to visible hands which indicate the seconds, minutes, and hours on a 24-hour face. It is also geared to a transparent disc, which rotates one revolution per second. The disc is marked along its circumference in milliseconds from 0 to 1000. A strobotron, which is placed behind the disc, is viewed through a microscope eyepiece located adjacent to the face of the clock. The strobotron is flashed every second for a period of time sufficient to view the disc.

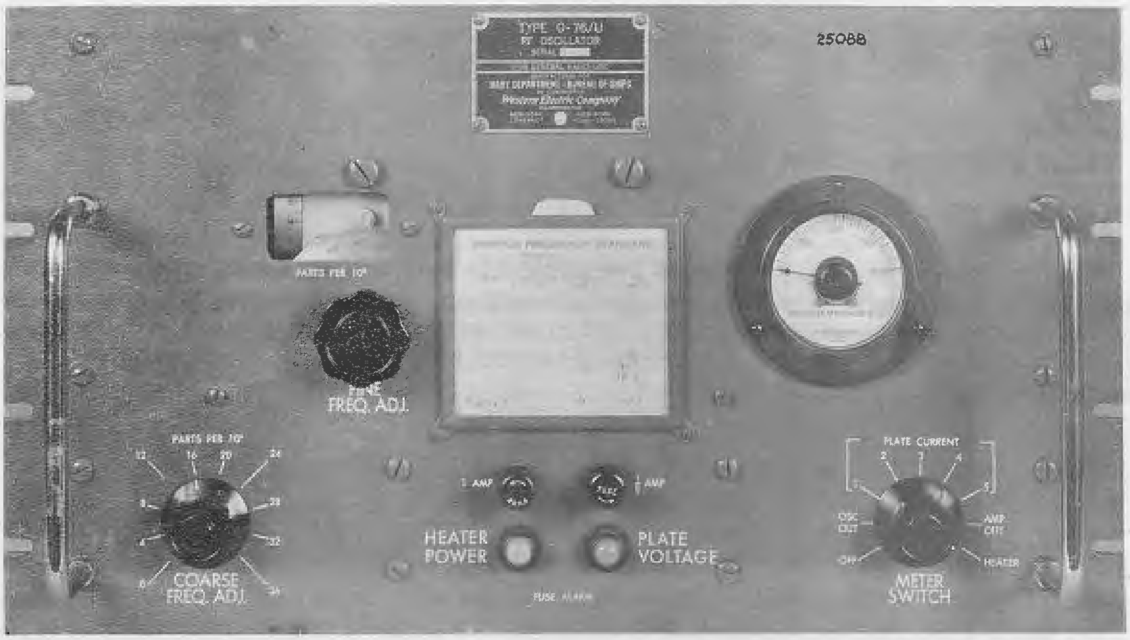


Figure 1-2. R-F Oscillator O-76U

The repetition rate of the strobotron signal is one second, and the signal is obtained from the output counter-decade unit in the time-comparator assembly, CV-88A/FSM-5A. By means of delay switches, the time of occurrence of this strobotron signal may be delayed by 0-999 milliseconds relative to the one-second output from the keyer unit in the time comparator. If the keyer output, which is controlled by the clock, is in synchronism with the one-second signal from the time comparator, the strobotron will light the disc at the exact instant the zero marker is aligned with the hairline of the microscope. This system is used to check the operation of the time comparator. Proper adjustment of the time comparator permits a signal such as NSS or WWV to be presented on the oscilloscope, OS-13/U, and provides a means for comparing the clock with standard time transmissions.

## Features

A and B storage batteries are employed to supply power for those units of the time standard which are used in running the clock. If the ac source should fail, the batteries would furnish power to the driving parts of the clock. The batteries are charged by rectified ac line power, and a means is provided to control the rate of charge. A self-contained oscilloscope with coaxial patch plugs and cords is incorporated into the time standard for quickly monitoring the waveshapes of the various units.

## 2. UNITS OF COMPLETE ASSEMBLY

### R-F Oscillator

The source of the precise 100-kc signal in the time standard is the crystal-controlled oscillator, which consists of a "GT-cut" temperature-controlled quartz crystal, a driving amplifier for the crystal, an isolating amplifier, and a heater oscillator. The output frequency of the oscillator may be changed within small limits by a coarse frequency adjustment and a fine frequency adjustment located on the front panel. After stabilization, which may take a month or longer, the oscillator will maintain its frequency to within one part in $10^8$ per day (100,000 ± 0.001 cps). A meter on the unit may be switched into various parts of the circuit to check operation. Fuses for the oven heater and plate supply are installed on the front panel, and fuse alarm lights indicate the failure of either fuse.

### Frequency Divider

By means of two regenerative loops, Frequency-Divider Assembly CV-87A/FSM-5A (Figure 1-3) steps the 100-kc voltage from the r-f oscillator down to 1000 cycles for the operation of the clock motor, TD-31/FSM-5A. The divider also provides 1000-cycle square waves to the time comparator. The divider stages are fixed-tuned and do not require adjustment from the front panel. The 1000-cycle signal to the clock motor and time comparator has the same degree of accuracy as the original 100-kc signal.

A one-kc phase-shift circuit is provided in the frequency divider to set the time of the clock contact opening.

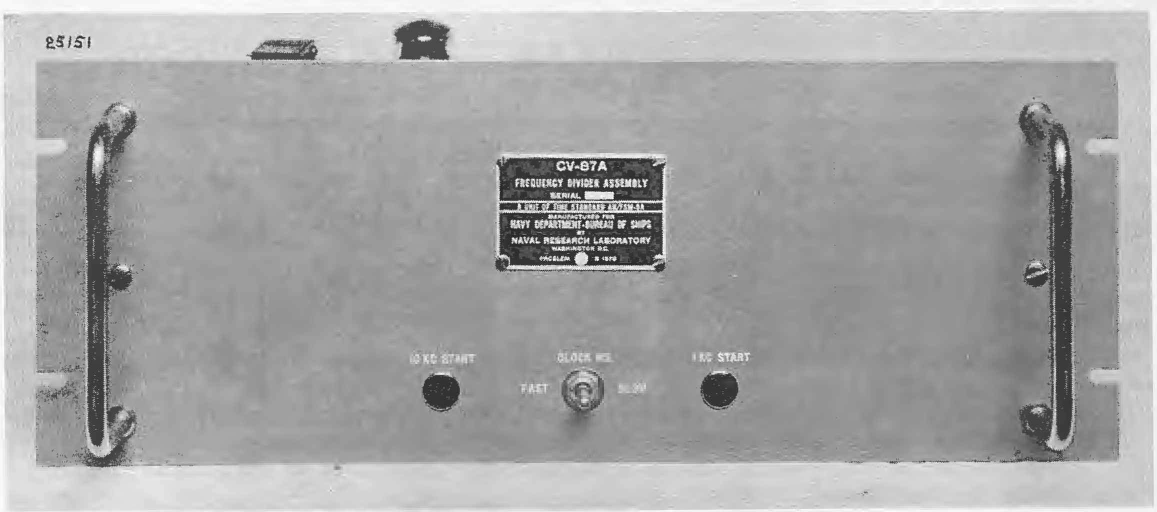


Figure 1-3. Frequency Divider CV-87A/FSM-5A

### Clock

The shaft driving the transparent spinning disc (Figure 1-4) also drives a one-second contact and a block of coding cams. This block is arranged so that beginning at five minutes before each hour the 29th second of each minute and those seconds of each minute, as

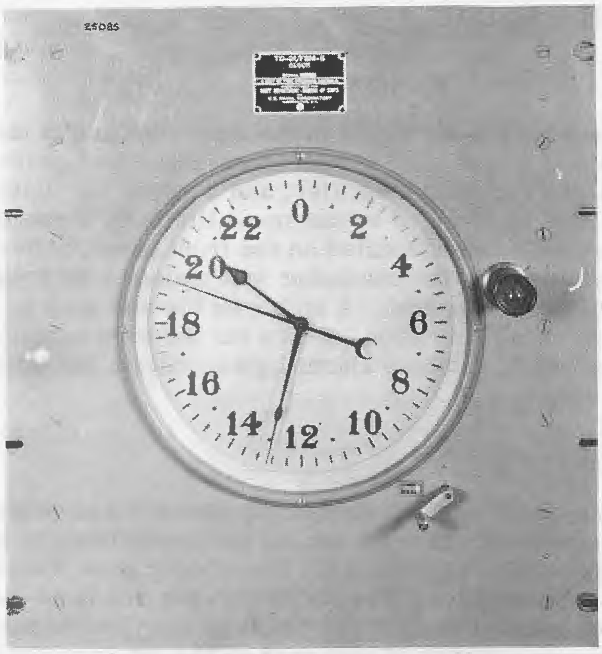

Figure 1-4. Clock TD-31/FSM-5A

shown in Table 1-2, are omitted. Here, a dash indicates a keyed signal, and a blank space indicates an omitted signal.

TABLE 1-2
Code Program

| Minutes | Seconds | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 |
| 54 | -- | * | * | * | * | * | * | * | * | * | -- |
| 55 | -- | | -- | -- | -- | -- | | | | | -- |
| 56 | -- | -- | | -- | -- | -- | | | | | -- |
| 57 | -- | -- | -- | | -- | -- | | | | | -- |
| 58 | -- | -- | -- | -- | | -- | | | | | -- |
| 59 | -- | | | | | | | | | | —† |

*Transmitter keying switch should be turned ON during this interval.
†Transmitter keying switch should be turned OFF from 2 to 15 seconds following the long dash.

The termination of the signal has no significance. The 60th second following the 59th minute is represented by a long dash, and its beginning marks the beginning of the hour. A crank is provided on the clock panel to adjust the one-second contact so that it properly gates the keying pulses supplied to the time comparator.





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### Time Comparator

The time comparator (Figure 1-5) is used to compare the time of occurrence of a one-second keyer signal synchronized by the clock with that of NSS or WWV standard radio time signals applied to the Y-axis of the oscilloscope. A three-position switch on the front panel is used to select either a 440- or 600-cycle rejection filter for WWV reception. In the second position, both filters are bypassed and straight-through operation is permitted; such a system is recommended for all other types of time comparison. When a radio time signal appears on the oscilloscope face, its time of occurrence relative to the time-comparator keyer signal is indicated by the delay dials and oscilloscope markers.


Figure 1-5. Time Comparator CV-88A/FSM-5A

### Power Supply PP-455A/FSM-5A

The power necessary to operate the time comparator is supplied by Power Supply PP-455A/FSM-5A (Figure 1-6). Regulated power is furnished at +300, +450, -105 volts dc and at 6.3 volts 60-cycle ac.


Figure 1-6. Power Supply PP-455A/FSM-5A

Power Supply PP-456A/FSM-5A

Plate power at 150 volts is furnished by Power Supply PP-456A/FSM-5A (Figure 1-7) to the oscillator and to those parts of the frequency divider which are essential for continuous operation of the clock. The power supply also provides a trickle charge for the B battery. A second rectifier and transformer in this power unit supply 360-volt dc plate power and 6.3-volt 60-cycle ac filament power to operate the auxiliary parts of the frequency divider. An ATR Battery Eliminator, Model 620C ELIP, mounted on the bottom of the cabinet, supplies 6.3-volt dc filament power to the r-f oscillator and to those tubes of the frequency divider which are essential for continuous operation of the clock. This power supply also furnishes current to charge the A battery.

Cathode-Ray Oscilloscope

The oscilloscope (Figure 1-8) is used as an indicator in conjunction with the time comparator; it is also utilized in testing and servicing the equipment. The oscilloscope consists of a three-inch cathode-ray tube, power supplies, amplifiers for vertical and horizontal deflection, and a linear time-base sweep generator. The unit can be connected to any of the circuits in the time standard by means of patch cords. As an aid in observing complex patterns, provision is made to intensity modulate signals from an external source. Since the oscilloscope is not needed for operation of the clock, no provision is made to operate it under emergency conditions, and the unit may be turned off when not actually in use. The output terminals of the time comparator are connected to input jacks provided at the rear of the oscilloscope.

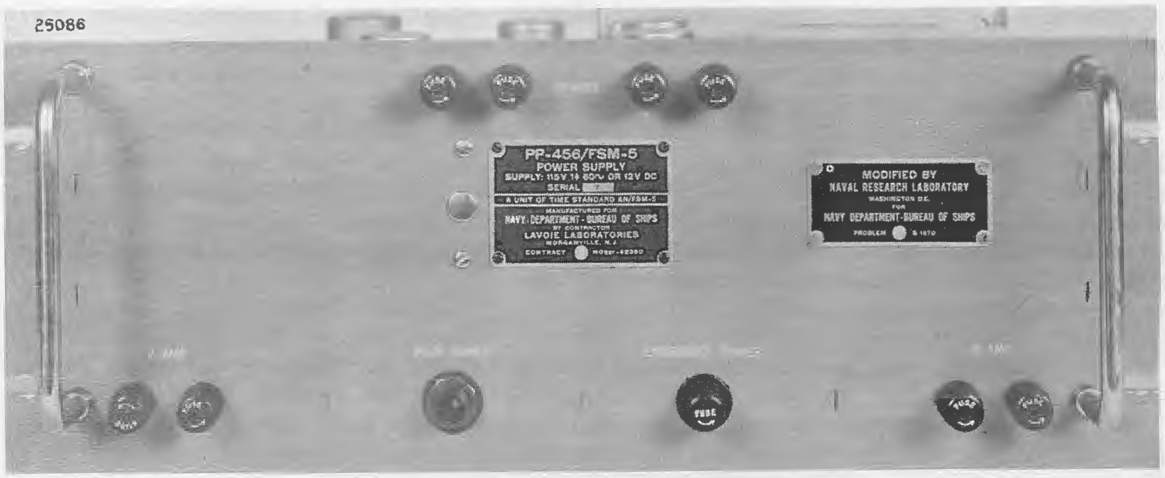


**Figure 1-7. Power Supply PP-456A/FSM-5A**

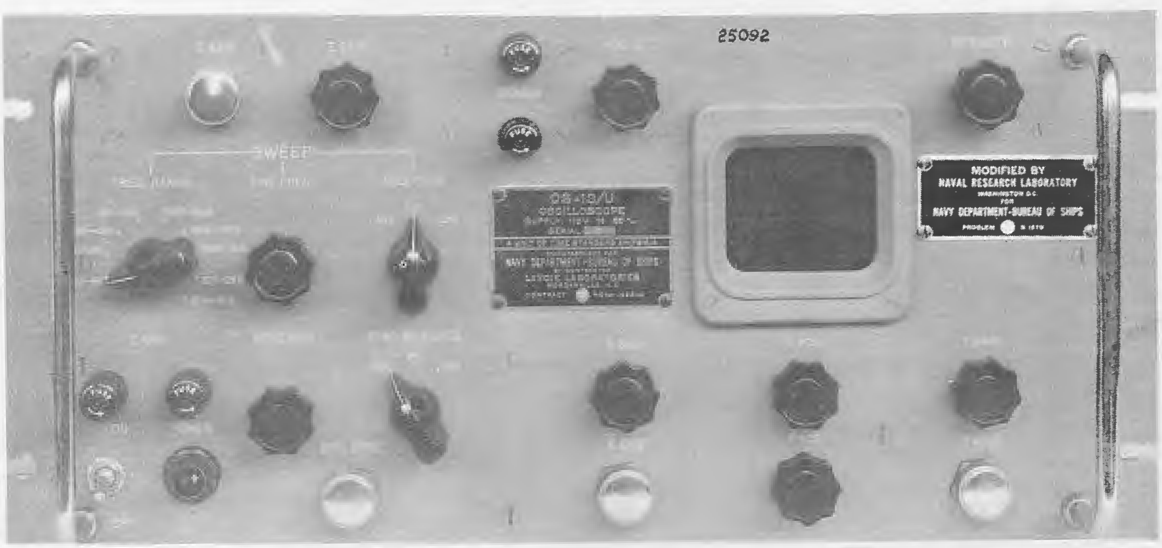


Figure 1-8. Oscilloscope OS-13/UA

Mounting Cabinet

Cabinet CY-597/G is made of steel and strengthened throughout by an arrangement of supporting cross members and corner-angle gussets. The unit, consisting of a switch panel and an accessory compartment, was designed to accommodate components of the time standard. The front mounting panels are 19 inches in width.

The panel mounting angles, which provide 77 inches of vertical mounting space, are drilled and tapped alternately on 1-1/4 and 1/2 inch centers for No. 10-32 screws and are movable in 1/2-inch steps from the front to the rear of the cabinet.

The sides of the cabinet are closed by removable panels; small removable filler panels are included at the top and bottom. The rear of the cabinet is fitted with a steel door to allow access to the mounted units. The door and top of the cabinet are fitted with adjustable louvers which provide controlled ventilation.

The switches on the panel control the primary power input to the cabinet and are mounted in the bottom rear of the unit. The switch panel is wired and fused for 115-volt 15-ampere alternating current. A trouble light, which is fused separately with two one-ampere fuses, is also included. It is controlled by a "bat" handle double-pole single-throw switch. The main-power double-pole single-throw switch disconnects all circuits except the two convenience outlets and trouble lamp.

The power input cable, in 1/2- or 3/4-inch conduit, enters the switch panel through a knockout in the bottom.

Two covered boxes, used to enclose the terminal strips for the A and B battery connections, are located at the lower right-hand side of the cabinet (looking from the rear).

An accessory compartment is mounted on the upper right-hand side of the inside of the cabinet. The various oils and tools provided with the clock should be transferred to this compartment when the time standard is installed.

## 3. REFERENCE INFORMATION

BuShips Problem Letter:
67-(29)(832) Ser 832-358, 7 Nov 1950

Manufactured by:
Naval Research Laboratory, Washington, D. C.

Electrical Power Service:
115-volt 60-cycle alternating current

Power Consumed:
500 watts

Number of Boxes in a Complete Shipment:
10

Total Cubical Content:
46 cubic feet

Total Weight:
782 pounds



 [redacted]

[redacted]



TABLE 1-3
Auxiliary Equipment Required

| Number of Units | Name | Use | Characteristics |
|---|---|---|---|
| 1 | Radio Receiver | Receives standard time signals to check the clock | Output is 1 to 11 volts; Tunes to NSS or WWV |
| 3 | "A" Storage-Battery Cells | Furnish emergency filament power | Low-gravity long-life 2.15-volt lead-acid cells (Similar to Exide type EME-17) |
| 69 | "B" Storage-Battery Cells | Furnish emergency plate power | Low-gravity long-life 2.15-volt lead-acid cells (Similar to Exide type CME-5) |
| 1 | Pull-Type 70A Fuse | Protects and disconnects A batteries | Connected in series with ungrounded A battery charging line |
| 1 | Pull-Type 10A Fuse | Protects and disconnects B batteries | Connected in series with ungrounded B battery charging line |
| 1 | Battery Rack | Supports A and B batteries | Similar to those shown in the battery-rack drawing and photograph furnished with this instruction book |

TABLE 1-4
Vacuum-Tube Complement

| Unit | Tubes - Number and Type | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OA2 | OB2 | 3JP1 | 6AS6 | 6AS7 | 6AQ5 | 5686 | 6C4 | 12AU7 | 5R4G | 6SN7G | 6SL7G | 6X5GT | 5963 | 6AL5 | 884 | 5696 | 5R4 | 6X4 | 12AX7 | 5651 | 6W4 | 631P1 | 6AC7 | 6V6GT | Total Number |
| Frequency-Divider Assembly | | | | 8 | 1 | 1 | 3 | 1 | 2 | | | | | | | | | | | | | | | | | 16 |
| Oscilloscope | 1 | | 1 | | | | | | | 2 | 6 | 1 | 1 | | | 1 | | | | | | | | | | 13 |
| Time-Comparator Assembly | | | | | 3 | | | 1 | 8 | | | | | 14 | 1 | | 5 | | | | | | | | | 32 |
| Power Supply PP-455A/FSM-5A | | 1 | | | 3 | | | | | | | | | | | | | 3 | 1 | 2 | 2 | | | | | 12 |
| Power Supply PP-456A/FSM-5A | | | | | | | | | | | | | 1 | | | | | | | | | 4 | | | | 5 |
| Clock | | | | | | | | | | | | | | | | | | | | | | | 1 | | | 1 |
| R-F Oscillator | | | | | | | | | | | | | | | | | | | | | | | | 4 | 1 | 5 |
| Total Number of Each Type | 1 | 1 | 1 | 8 | 7 | 1 | 3 | 2 | 10 | 2 | 6 | 1 | 2 | 14 | 1 | 1 | 5 | 3 | 1 | 2 | 2 | 4 | 1 | 4 | 1 | 84 |



[redacted]

# SECTION 2
# THEORY OF OPERATION

## 1. EXPLANATION OF BLOCK DIAGRAM

### Frequency Source

The r-f oscillator[1] (Figures 2-1 and 2-2), which consists of a 100-kc GT-cut crystal (Y-1410) mounted in a temperature-controlled oven, is the primary source of frequency in the time standard. Precise temperature control is accomplished by means of a temperature-sensitive 800-cycle bridge-controlled oscillator consisting of a two-stage feedback amplifier, V1404 and V1405. This resistance bridge also provides the source of heat. The crystal oscillation is controlled by another bridge-type two-stage feedback amplifier, V1401 and V1402. Part of the output of this amplifier is fed into an amplifier, V1403, which isolates or prevents external influences from affecting the oscillator frequency. This output is connected to the frequency divider.

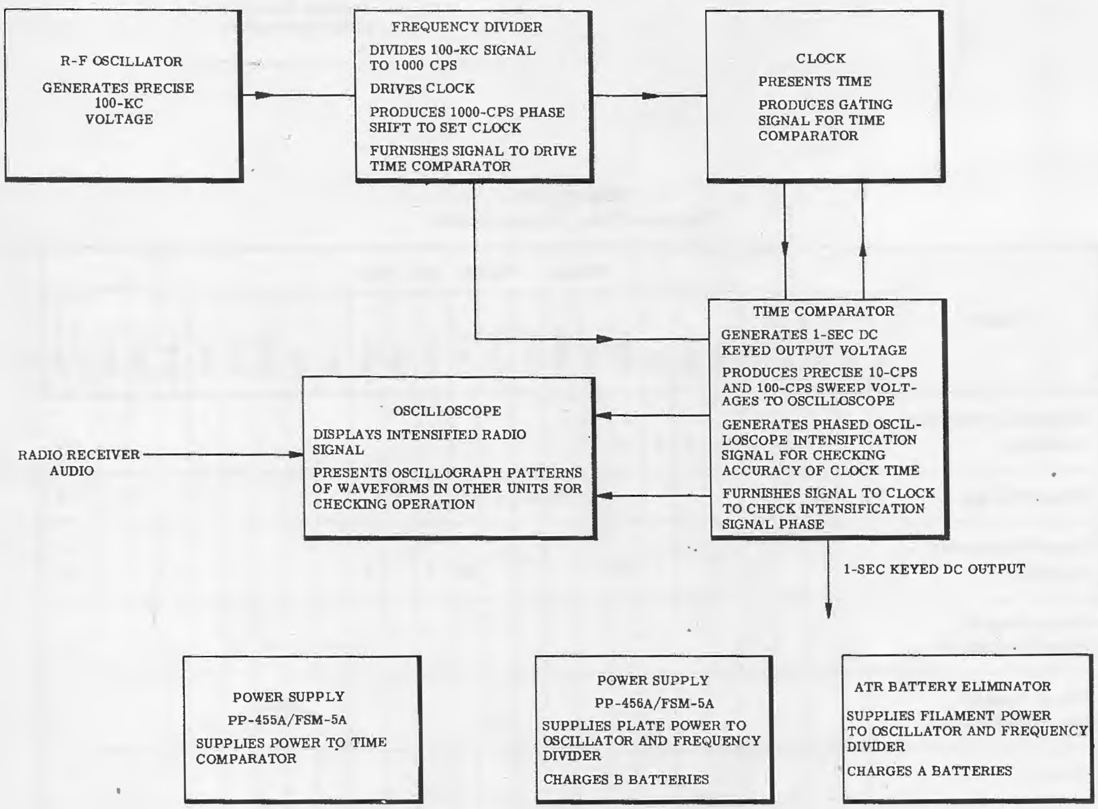


Figure 2-1. Over-all Block Diagram of Time Standard

[1] Bell Telephone Laboratories, "D-175730 Frequency Standard," Instruction Bulletin No. 1198, Issue No. 1



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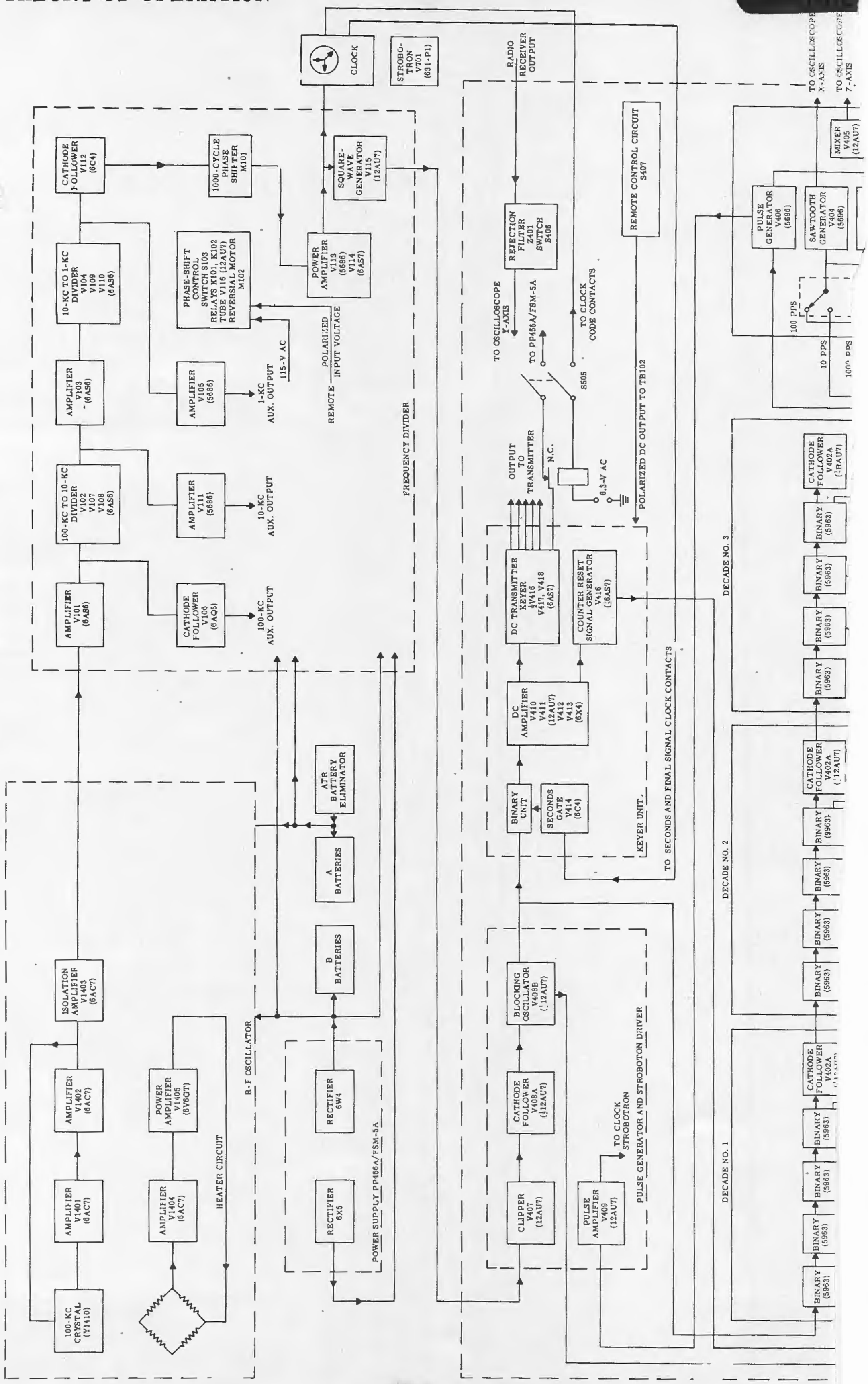


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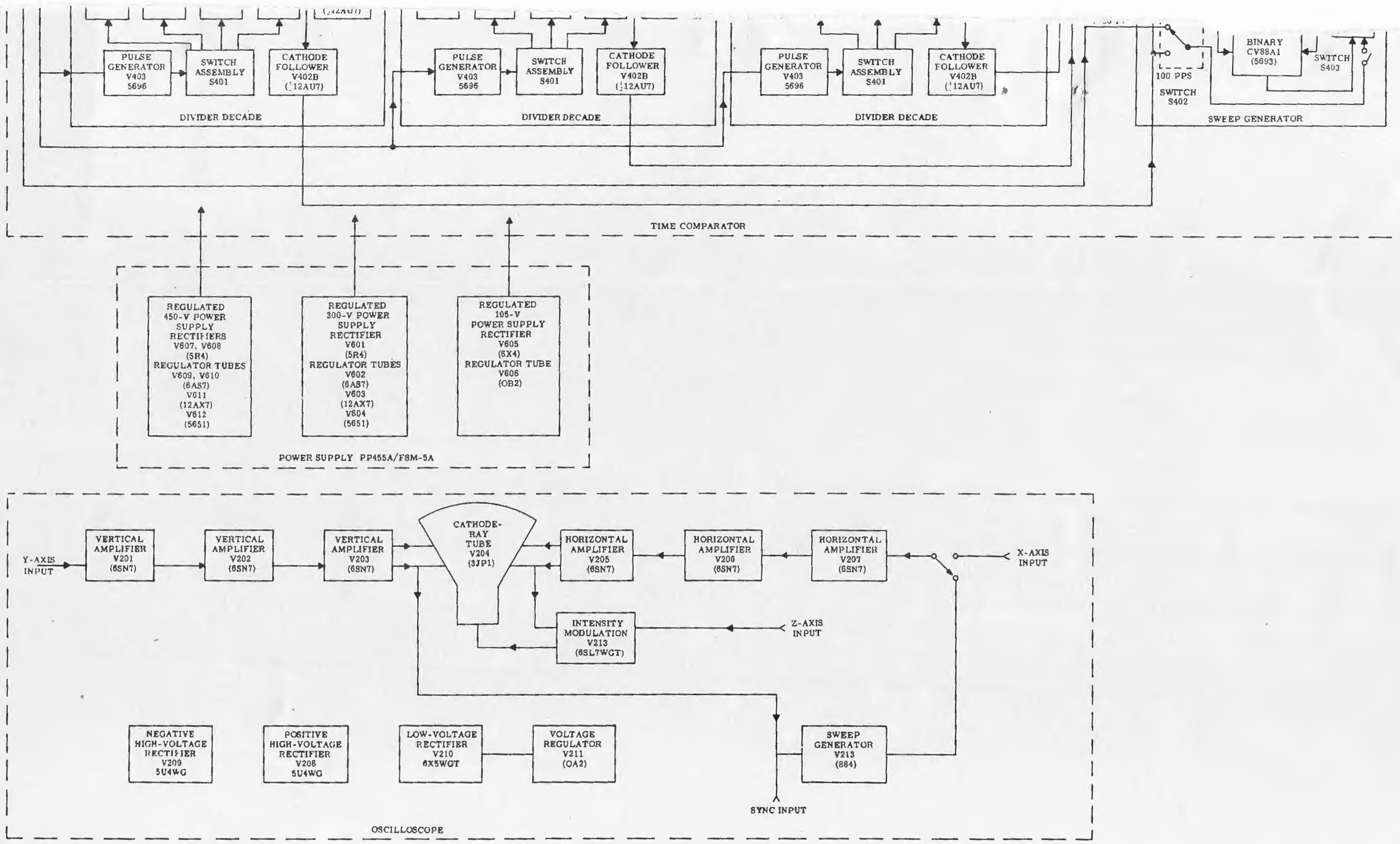


Figure 2-2. Functional Block Diagram of Time Standard

Frequency Divider

Amplifier V101 is connected to the first 10:1 frequency-divider chain which consists of the tubes V102, V107, V108 and to the cathode follower, V106. A 100-kc signal is available for auxiliary equipment from the output of V106, and a 10-kc signal is available at the output of the isolation amplifier, V111. The 10-kc signal is also fed to a second isolation amplifier, V108, which drives another 10:1 divider chain consisting of V104, V109, and V110. The 1-kc signal from the second divider chain is coupled to the cathode follower, V112, and applied to the power amplifier, V114 and V113, through a phase shifter, M101. This signal drives the clock motor and the square-wave generator, V115. The phase-shift mechanism is used to synchronize the one-second signals from the clock with standard observatory time signals. It may be controlled either locally or remotely.

Time Comparator

This assembly consists of a pulse generator and strobotron driver, CV-88A4/FSM-5A, three counter-decade units, CV-88A2/FSM-5A, a keyer unit, CV-88A5/FSM-5A, and a sweep generator, CV-88A3/FSM-5A. It generates six synchronized but independently keyed one-second dc signals gated by the seconds contact in the clock and provides a means to make time-comparison measurements. Clock time can be compared with Naval Observatory time to the nearest millisecond by applying an NSS time signal to the Y-axis of the oscilloscope and by adjusting the time-comparator decade dials so that the leading edge of the signal can be seen on the trace. Figure 2-2 illustrates, in block form, the relationship between the units comprising this assembly. Figure 2-3 is a graphical display of the signals generated by the units and the phase relationship between them. Square waves of 1 kc are fed from the frequency divider to the pulse-generator and strobotron-driver clipper which serves to sharpen the square-wave input. A blocking oscillator, V408B, is driven by the positive pulses from the differentiated square wave coupled to it through a cathode follower, V408A. Negative pulses occurring at the plate of the blocking oscillator are fed to the binary unit, CV-88A1, in the keyer unit. These negative pulses are gated once each second by the clock and V414 to generate a positive voltage of 0.3-second duration and a one-cycle repetition rate. The leading edge of the positive rectangular voltage is determined by the first pulse after the gate opens. This rectangular voltage is amplified by the tubes V410, V411, V412, V413 and then applied to the grids of the transmitter keyer tubes, V416, V417, and V418. Each triode section of these tubes generates a positive dc output of approximately +125 volts, and all sections are synchronized. The signal from one half of V416 is used to reset the counter decades. The remaining output signals from these tubes are available for transmitter keying. A relay in series with the clock code contact opens the plate circuits of the five transmitter keyer tubes so that certain selected seconds signals are omitted during the coding period.

The 1-kc pulses at the plate of the blocking oscillator are fed through the counter-decade dividers 1, 2, and 3 which scale this frequency down to 100, 10, and 1 cps, respectively. The positive one-second rectangular pulse generated by the keyer tube, V416, is fed to a differentiating circuit in each of the decade units. The pulse resulting from the differentiation fires the thyratron, V403, in each decade and resets the binary units through the switch assemblies labeled S401. Setting these switches varies the output phase of the one-second pulses from the third decade. This pulse can be delayed from 0 to 999 milliseconds in one-millisecond steps with respect to the leading edge of the output signal from the keyer tube, V416.

If Switch S402, which is located in the sweep generator, is turned to Positions 1 or 2, either 100-cycle or 10-cycle pulses will be selected from the cathode follower, V402B, in decades 1 or 2. These signals drive the sawtooth generator, V404, at 100 or 10 cps, and this sawtooth voltage is fed to the X-amplifier in the oscilloscope.

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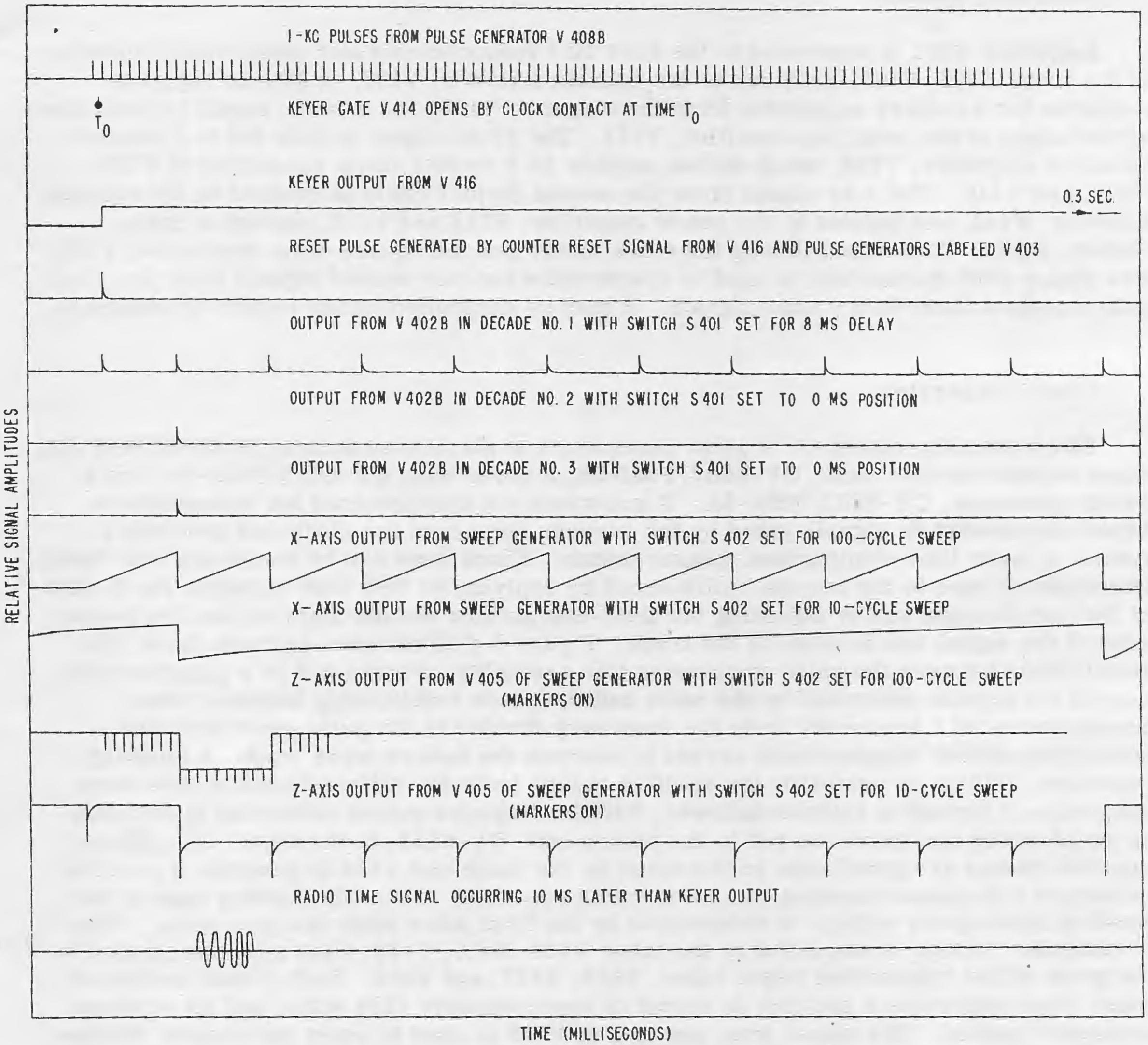
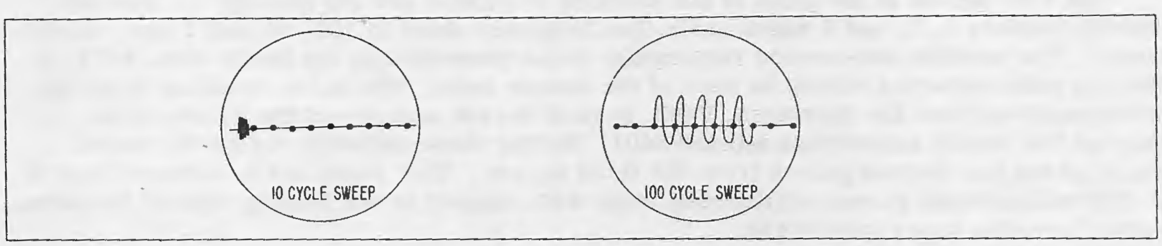



(A) PHASE RELATIONSHIPS BETWEEN SIGNALS




(B) SCOPE PRESENTATION RESULTING FROM TIME COMPARATOR AND WWV RADIO TIME SIGNALS

Figure 2-3. Graphical Presentation of Time Comparator Operation

The output from the cathode follower, V402B, in decade 3 fires the thyratron, V406. The output from V406, together with the 100-cycle or 10-cycle pulses selected by Switch S402, is fed to the binary unit in the sweep generator. These input signals generate a positive rectangular pulse from the binary unit, the leading edge of which is coincident with the 1-cycle delayed output from V402B of decade 3 and one cycle of the sawtooth voltage. The duration of this signal is equal to the sweep period selected by the Switch, S402. In Position 1, 1000-cycle marker pulses are selected from the tertiary winding of the blocking oscillator. In Position 2, 100-cycle marker pulses are selected from decade 1. These signals and the delayed rectangular voltage from the binary unit are fed to the mixer, V405.

The mixer output, which is the superposition of the rectangular pulse and marker pulses, is fed to the oscilloscope Z-amplifier. The rectangular pulse results in intensification during a particular cycle of the sweep every second. The marker pulses appear as intensified points which divide the sweep into ten equal time intervals. (The observation of time signals in the presence of noise is facilitated by throwing the marker switch, S403, to the "off" position.) The left-hand edge of the intensified sweep is delayed from 0 to 999 ms as determined by the settings of the switches labeled S401.* The leading edge of a radio time signal applied to the oscilloscope Y-axis is observed only if it occurs sometime during the intensified sweep. For the phase relationship shown in Figure 2-3, the switches labeled S401 are set for a delay of 8 ms. Since the leading edge of the radio time signal is coincident with the second time-interval marker from the left-hand end on the 100-cycle sweep, the delay of the radio time signal with respect to the leading edge of the transmitter keyed output is 10 ms.

The output of the thyratron, V406, is also fed to the pulse amplifier, V409, the output of which fires the strobotron located in the clock; as a result, the strobotron illuminates one of the graduations on the 1-rps graduated disc geared to the clock motor. If the decade units are operating properly, the graduation read on the disc will correspond to the delay-switch readings to within ±1.0 ms. (The clock-motor worm drive introduces this uncertainty.)

### Power Supply PP-456A/FSM-5A

In Power Supply PP-456A/FSM-5A, the 6W4 rectifiers furnish plate power to the r-f oscillator and to those parts of the frequency divider which must operate continuously. The supply also furnishes a trickle charge to the 150-volt B batteries which maintain clock operation during power-line failure. Rectifier 6X4 and its associated transformer supply plate and filament power to those tubes (V106, V111, V105, and V115) of the frequency divider which are not essential for clock operation. The ATR Battery Eliminator, Model 610C-ELIP, furnishes rectified filament current to the tubes essential for continuous clock operation; it also charges the A batteries which furnish filament power during emergency periods.

### Power Supply PP-455A/FSM-5A

In Power Supply PP-455A/FSM-5A, regulated plate current at 450 volts, derived from the rectifiers, V607 and V608, and the regulator tubes, V609, V610, V611, and V612, is furnished to the keyer output tubes. Regulated plate power is furnished for the remaining tubes of the time comparator by the 300-volt regulated supply, which is derived from the rectifier tube, V601, and the regulator tubes, V602, V603, and V604.

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*Actually, the leading edge is delayed a few microseconds by the sweep fly-back time.

Negative bias voltage is furnished by the regulated -105-volt dc output derived from the rectifier, V605, and the voltage regulator, V606.

## 2. FREQUENCY-DIVIDER ASSEMBLY

### Operational Function

The frequency divider, shown in block form in Figure 2-4 and schematically in Figure 8-18, generates 10-kc and 1-kc signals by means of two regenerative 10:1 divider loops. Auxiliary signals available from the frequency divider are (a) 10 kc and 1 kc at the output jacks, J102 and J104, respectively, (b) 100 kc at the output jack, J103, and (c) 1-kc square waves at the output jack, J106. The output from the power tubes, V113 and V114, is applied to the jack, J105; this signal is used to drive the clock motor. The phase of the 1-kc output driving the clock may be controlled either locally or remotely; a means for setting the clock is provided in this way. Auxiliary circuits not used in driving the clock are energized by ac power from the 60-cycle line; circuits directly connected with driving the clock are supplied from the storage-battery charging circuit.

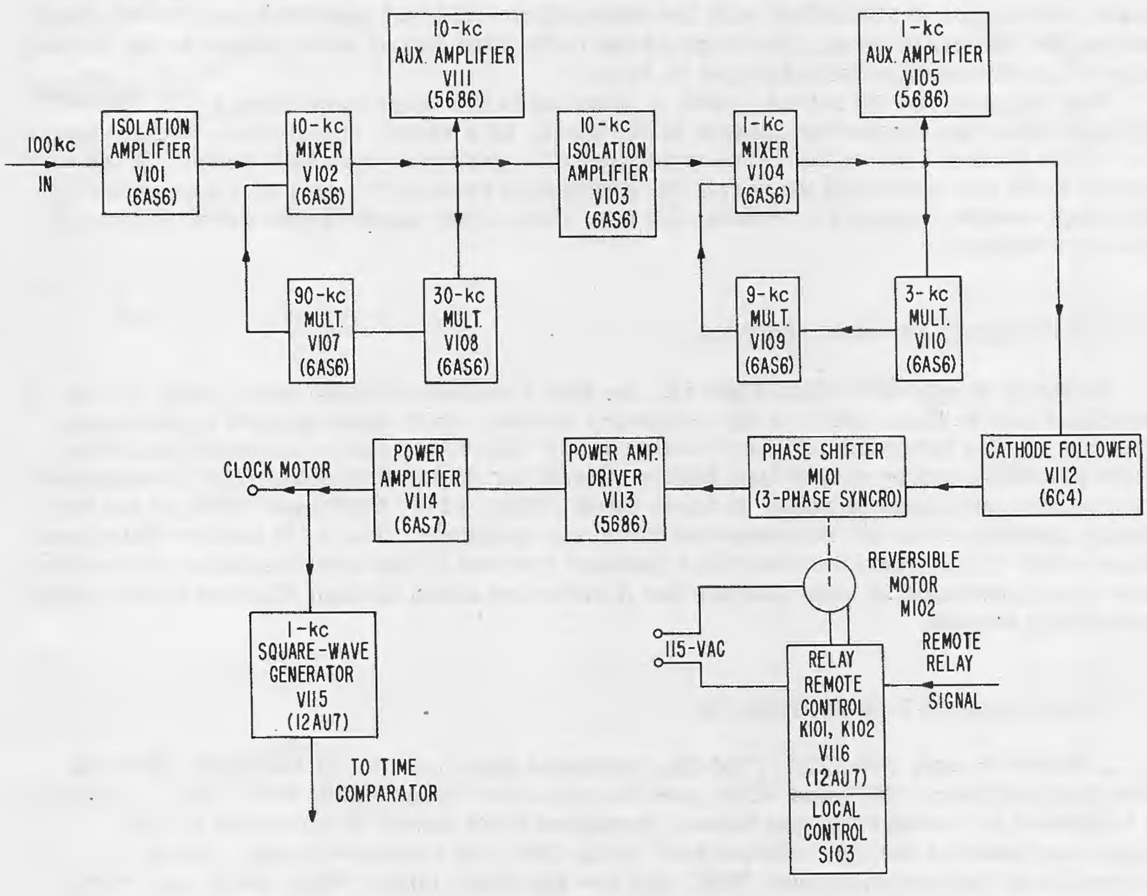


Figure 2-4. Schematic Diagram of Frequency Divider

### Regenerative Divider Action

Figure 2-5, a block and simplified schematic diagram of the 100:10 kc divider, will serve to illustrate the process by which frequency division is accomplished. The basic circuit which divides 100 kc to 10 kc is exactly the same as that from 10 kc to 1 kc except for the change in L and C for the frequencies involved. The 100-kc output from the oscillator is coupled to the grid of the isolation amplifier, V101. To remove unwanted frequencies, the isolation-amplifier plate impedance, Z101, is tuned to 100 kc. The output from Z101 is fed to the control grid of V102 which is a mixer whose plate load, Z102, is tuned to 10 kc. This 10-kc output is coupled to the harmonic generator, V108, which multiplies the frequency by three. To amplify the third harmonic and reject any other frequencies present, Z106, the plate impedance of V108, is tuned to 30 kc. This signal is applied to grid 1 of the harmonic generator, V107, which generates 90 kc across its plate impedance, Z105, which is tuned to 90 kc. This 90-kc signal is coupled to grid 3 of the mixer, V102, which beats the 90 kc with the 100 kc, thus supporting the 10-kc output. The gain around this loop is so low that oscillation cannot be sustained except while being started by shorting out the cathode resistor of V108. When the resistor is shorted out, a transient is introduced to "ring" the 30-kc coil, which in turn, is multiplied to 90 kc by V107; the 90 kc then beats with 100 kc to produce the starting 10 kc. The process is continued by the 10-kc signal, thus causing the circuit to regenerate. As long as the 100-kc input is present, regeneration continues, but it stops when the 100 kc disappears and does not start until the 100 kc is resupplied and the cathode shorted.

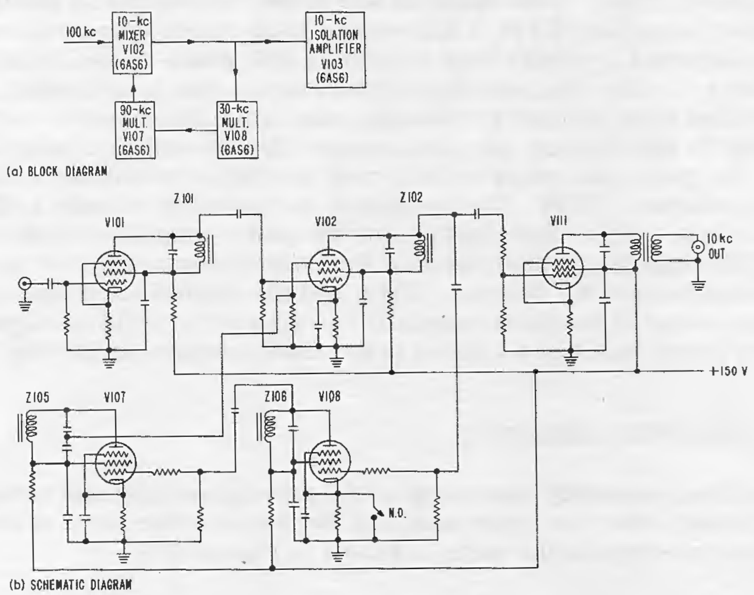


Figure 2-5. Block and Simplified Schematic of the 100:10 kc Frequency-Divider Loop

### Phase Control

Since the phase shifter used in the 1-kc output circuit has a low input impedance, a cathode follower, V112, is necessary to match this low impedance and to isolate the high impedance output of the 1-kc divider loop. The phase shifter, M101, is a 3-phase synchro repeater, which is loaded so that a rotating field is obtained. By moving the rotor in the direction of field rotation, the phase of the output decreases by 1 cycle or 1 ms per revolution; moving the rotor in the opposite direction increases the phase by 1 cycle or 1 ms per revolution.

The armature shaft of the reversible motor, M102, is directly coupled mechanically to the rotor of M101. Single-phase 115-volt 60-cycle is used to drive this motor; relative $90^o$ phase shift between the current through the stator windings (thus direction of rotation of the motor) is controlled by inserting a 0.1-$\mu$f condenser in series with one or the other of these windings. In the divider assembly, Switch S103 controls the direction of rotation locally; the relays, K101 and K102, in conjunction with the tube, V116, control the direction of rotation remotely. Normally, V116 is cut off by means of the voltage-divider action of the resistors, R153 and R156. A dc signal, which is generated remotely making terminal 2 of the terminal board, TB101, positive, causes the right-hand section of V116 to conduct and relay K102 to close. As a result, the condenser is inserted in series with stator winding 1. An opposite polarity signal at the terminals of TB101 inserts the condenser in series with stator winding 2, thus causing an opposite rotation.

A 1-kc tone may also be received on the remote-control line for oscillator comparison. Chokes L109 and L110 and the condenser, C153, act as a 1-kc rejection filter to isolate the phase-control driving circuit from the 1-kc signal.

### Power Amplifier for Clock Motor

The output of the phase shifter, M101, is coupled directly to the power amplifier which drives the clock motor and the 1-kc square-wave generator. The power amplifier consists of two stages of power amplification; the first, V113, is a relatively low-power single-ended pentode driver. The output of this driver is coupled by the transformer, T103, to the power amplifier, V114, a high-power twin-triode operated class-B. The clock motor is connected in series with a choke, L109, which is tied to the cathodes of the push-pull tubes. In this way, one side of the clock motor is grounded, and the shock hazard is eliminated from the outer collecting ring; also, the dc plate current from both triodes is allowed to flow through the clock motor, thus providing a polarizing current of about 150 ma. The push-pull output of the power amplifier is matched to the clock motor by the output transformer, T104. The secondary is connected through a dc blocking capacitor to the clock motor. Bias voltage for the power amplifier is derived from the cathode current through the dc resistance of the choke and clock motor and from the grid-leak bias developed across the resistor, R149, and the condenser, C146, from the driving signal. The 1-kc output of the power amplifier is also fed to V115, a clipper that generates 1-kc square waves which are applied to the time comparator through J106.

## 3. TIME-COMPARATOR ASSEMBLY

This is a unitized assembly consisting of the pulse generator and strobotron driver, three counter-decade units, the keyer unit, and the sweep generator. A schematic diagram of the interconnection of the units is shown in Figure 2-6.

### Pulse Generator and Strobotron Driver

The 1-kc square-wave output from the frequency divider is fed to the grid of the clipper, V407 (Figure 2-7). The square-wave voltage at the plate of V407B is differentiated by the condenser, C424, and the resistor, R445, and applied to the grid of the cathode follower, V408A. Tubes V408A and V408B are biased to cutoff by the negative voltage developed across R449. Positive 1-kc pulses from V408A are coupled to the grid of the blocking oscillator, V408B, and 1-kc negative pulses (approximately 150 volts) of 2-$\mu$sec duration are generated at its plate to drive the keyer unit and the counter-decade units. Positive marker pulses generated in the tertiary winding of the blocking-oscillator

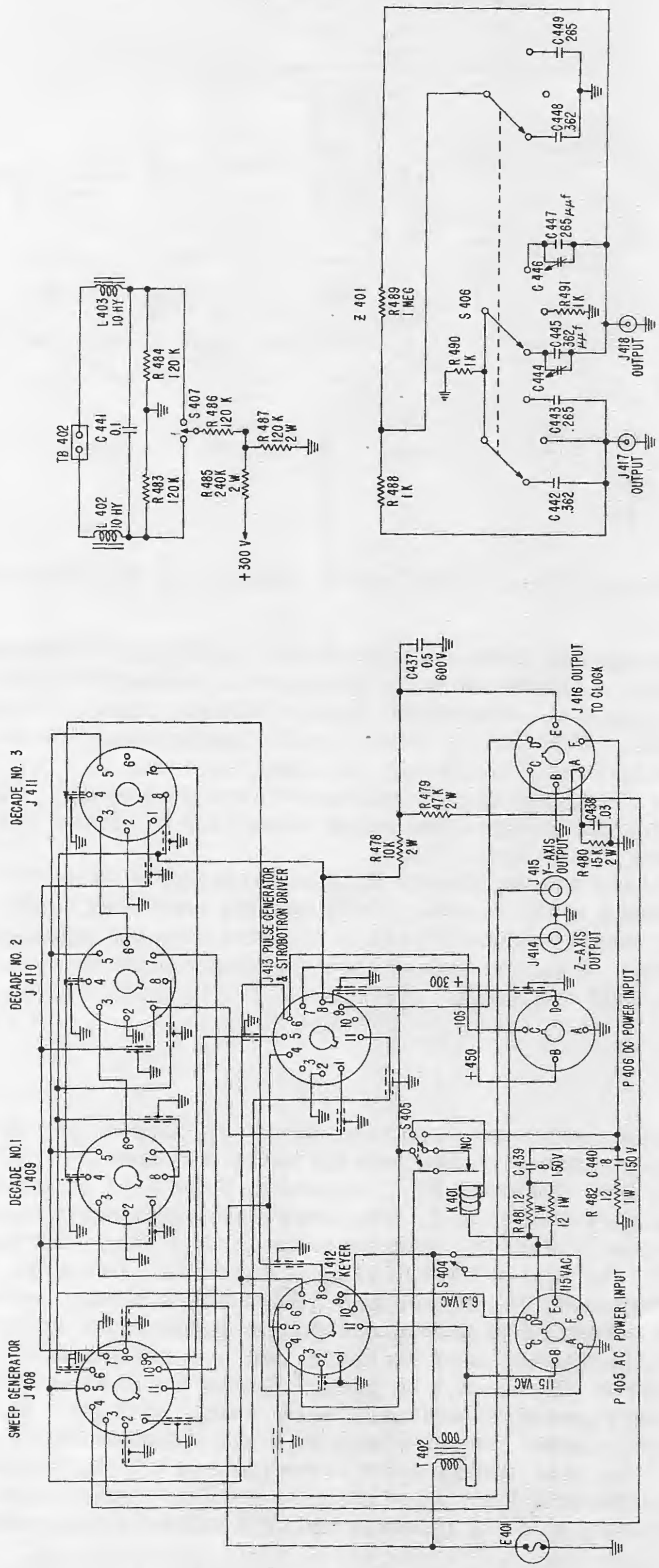


Figure 2-6. Schematic Diagram Showing Interconnection Between Units of Time Comparator

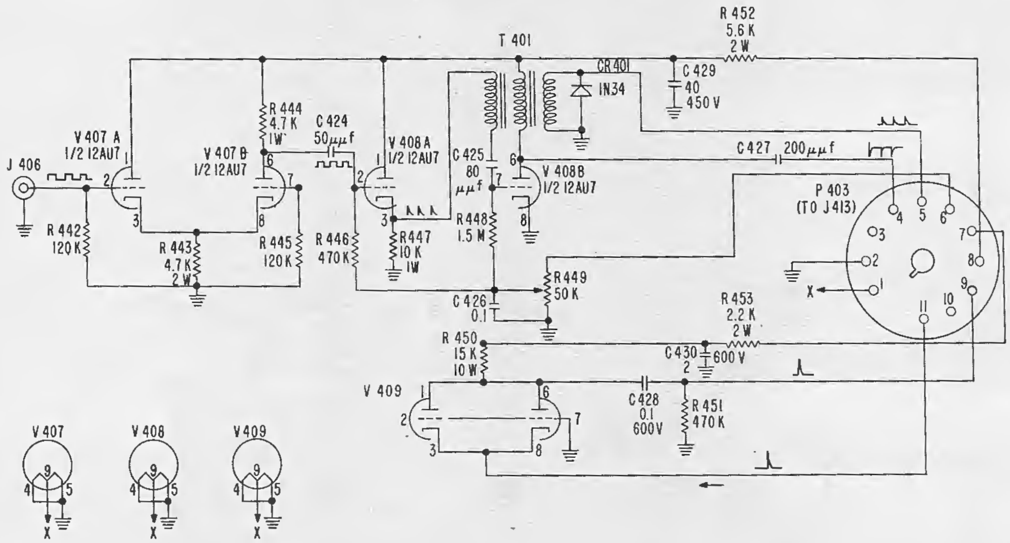


Figure 2-7. Schematic Diagram of Pulse Generator and Strobotron Driver

transformer, T401, are supplied to the selector switch, S402, in the sweep generator. Here, the cathode of V406, a strobotron pulse generator, is connected to the cathode of V409, a grounded-grid amplifier. When V406 fires, a 160-volt pulse is developed across the cathode resistor, R441, which drives V409 to cutoff and develops a large positive pulse across its plate-load resistance, R450. To obtain sufficient gain for firing the strobotron, V701, in the clock assembly, a relatively large plate-supply voltage is required; hence 450 volts was chosen. The output from V409 is coupled to the grid of V701 through the coupling condenser, C428.

Anode and screen power are supplied to the strobotron, V701, from the output jack, J416. The filter, consisting of the resistor, R478, and the condenser, C437, decouples V701 from the 300-volt supply. Anode voltage is obtained from the voltage developed across the resistor, R480. A screen bias of about 65 volts results from the dividing action of the resistors, R479 and R480.

### Keyer Unit

In the pulse generator and strobotron driver, the sharp negative pulses developed at the plate of the blocking oscillator, V408B, are fed to the left-hand grid of the binary plug-in unit in the jack, J407 (Figure 2-8). The plate of Tube V414 is connected to the right-hand grid of the binary plug-in unit. The clock's seconds contact connected in series with the final-signal contact is connected to the grid of V414. During the time that both contacts are closed, the grid of V414 is at ground potential; therefore, V414 conducts and holds the binary tube, V401B, to cutoff. When either contact opens, V414 is cut off by the negative bias developed by the voltage-divider action of the resistors, R466 and R467. In this way, the flip-flop action of the binary unit is made sensitive to negative pulses on the grid of V401A. The first 1-kc pulse following the opening of the seconds contact triggers the binary into the condition in which V401B conducts. This state of conduction remains until the seconds contact is closed, thus cutting off V401B. This action results in a negative rectangular voltage pulse at the plate of V401B, the leading edge of which is coincident with the first 1-kc pulse after the seconds contact opens. The duration of the rectangular output pulse is approximately 0.3 second and its repetition rate

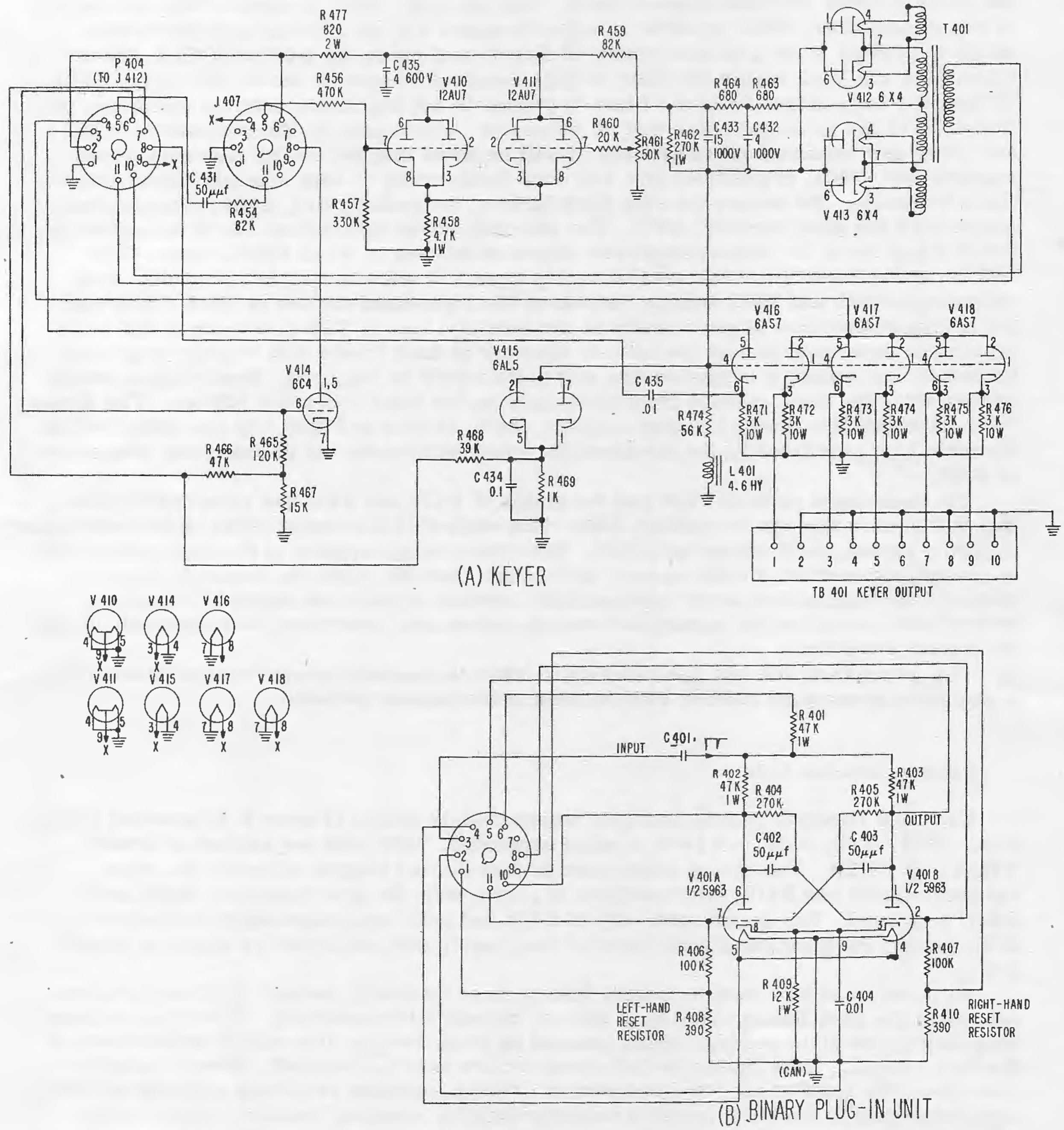


Figure 2-8. Schematic Diagram of Keyer and Binary Plug-in Unit



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is one second. The accuracy of the beginning of this signal is the same as that of the standard 1-kc pulses and its duration depends on the time the seconds contact of the clock is open.

This rectangular pulse is coupled directly to the dc amplifier, V410, which amplifies the pulse to about 280 volts peak-to-peak. The clamper, V411, is used to bias the cathode of the dc amplifier, V410, positive in order to cancel out the residual positive voltage which is present at its grid as a result of direct coupling to the plate of V401B. Rectifiers V412 and V413 supply the plate voltage required to operate the dc amplifier, V410. If the stray capacitance from the filter to ground is not kept to an absolute minimum, the rise time of the dc output pulse will be excessive. Consequently, the condensers, C432 and C433, are insulated above ground. It will be noted that the center tap of the power transformer, T401, is positive; this was done deliberately to help minimize stray capacitance to ground. To reduce the rise time further, the peaking coil, L401, is connected in series with the grid resistor, R474. The 280-volt output signal from the dc amplifier is fed to the grids of six cathode-follower stages consisting of three 6AS7G tubes, V416, V417, and V418 which are biased alternately from -10 volts to well below cutoff. Both cathodes of V417 and V418 and the cathode of the right-hand section of V416 are brought out to five independent keyer circuits at the terminal board, TB401, and about 125 volts positive is developed across the cathode resistor of each triode with respect to ground. To obtain this output, a regulated 450-volt plate supply is required. Regulation is necessitated since the plate current from the supply varies from 0 to about 300 ma. The diode, V415, is connected across the grid resistor, R474, to bias and thus clip any undesired ac 60-cycle hum generated by the electrostatic coupling between the primary and secondary of T401.

The right-hand plate of V416 and the plates of V417 and V418 are connected to the 450-volt source through the switch, S405. The contact of the coding relay, K401, which is normally closed, is in series with S405. When the coding contacts of the clock are closed to ground, the contact of K401 opens. As a result, the 450 volts are removed from the plates of the transmitter keyer tubes and the seconds signals are omitted (Table 1-2). Switch S405 energizes the transmitter keying system and, therefore, is closed only during the transmitting time.

The output from the left-hand section of V416 is coupled through the condenser, C435, to the pulse generators labeled V403 located in the counter decades.

### Counter-Decade Unit

Each unit consists of four identical binary plug-in stages (Figure 2-9) inserted in the jacks, J401, J402, J403, and J404, a pulse generator, V403, and two cathode followers, V402A and V402B. The binary stages are Eccles-Jordan trigger circuits; the reset resistors, R408 and R410, are connected in series with the grid resistors, R406 and R407, to ground. The ungrounded ends of R408 and R410 are connected to the switch, S401, so that the position of application of the reset pulse can be set as shown in Figure 2-9.

To understand how each individual binary stage operates, assume that the right-hand section of the first binary (V401B) of counter decade 1 is conducting. There is a voltage drop across the plate resistor, R403, caused by plate-current flow which, with the aid of the bias resistor, R406, holds the left-hand section well below cutoff. Since no plate current flows, the plate of the left-hand section, V401A, remains relatively positive and the right-hand grid is held at a positive value through the coupling resistor, R404. In this way, stable conduction is maintained through the right-hand section. The one-kc negative driving pulses derived from the blocking oscillator, V408B, in the pulse generator and strobotron driver are coupled to the input stage through the condenser, C401, and the common plate-supply resistor, R401. The first pulse through the plate resistor, R402,



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and the condenser, C402, cuts off V401B, the conducting section. The grid of the nonconducting section is simply made more negative. With both sections nonconducting, the only information left concerning the former conducting state is the voltage across the condensers, C402 and C403. The greatest charge and voltage are carried by C402 because of the higher initial voltage and potential difference due to the flow of grid current at the lower end. Upon termination of the negative driving pulse, both grids approach a more positive value determined by their respective resistance networks, but owing to the greater charge on C402, the grid connected to C403 is the first to go above cutoff. By coupling through C402, conduction in this section causes a regenerative switch over to the left-hand conduction condition. Each successive input pulse reverses the state and gives a binary action. By coupling from the plate of V401B through C401 of the following stage, a negative pulse is supplied to the following stage when the right-hand section goes into conduction. Since positive pulses through C401 do not trigger a stage, the following stage receives only half as many switching pulses and thus a scale of two is formed. The four similar stages thus provide a scaling factor of 16. To obtain decimal scaling, a triggering pulse derived from the fourth stage is fed through the cathode follower, V402A, the coupling resistor, R412, and the condenser, C406, to the second stage. In a similar manner, a triggering pulse from the fourth stage is fed back to the third through the coupling resistor, R411, and the condenser, C405. These feedback pulses are applied in such a manner that switch over in stages two and three only occurs once during a counting cycle of 10.

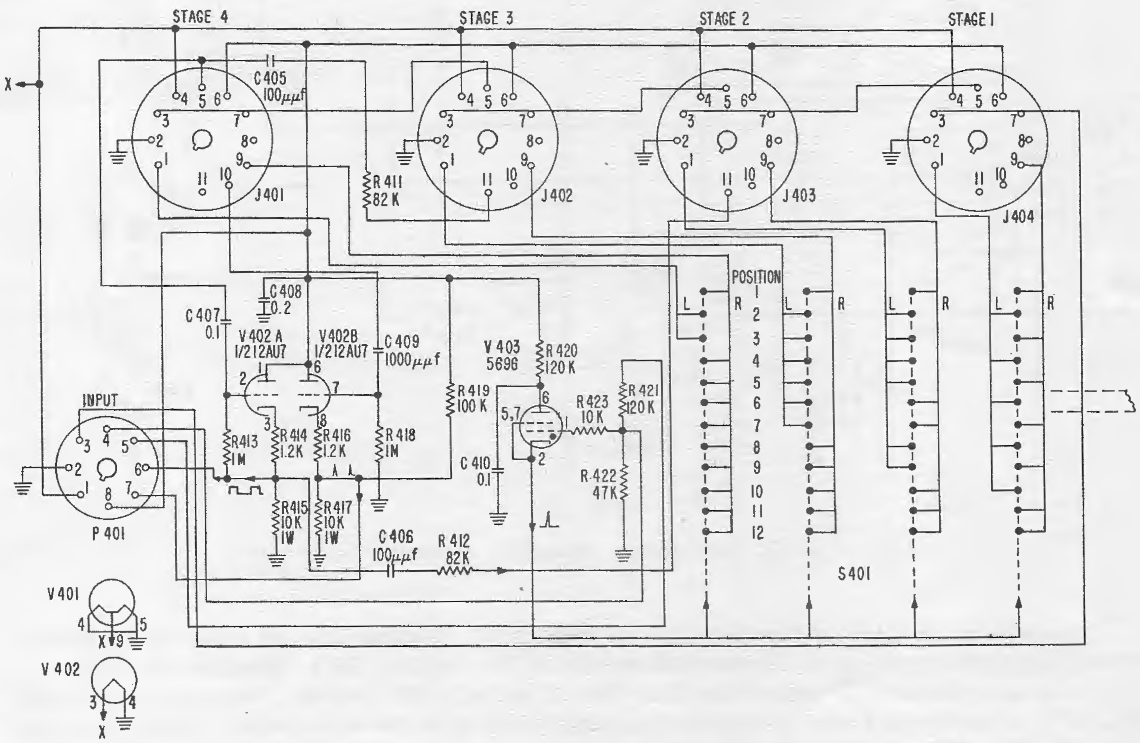


Figure 2-9. Schematic Diagram of Counter Decade

Since two input pulses are required to switch the second stage and four input pulses are necessary to switch the third stage, the feedback is equivalent to adding six pulses for every ten input pulses to the decade. In other words, 100-cycle pulses are obtained from the 1-kc input by dividing 1600 counts by 16; 10-cycle pulses are obtained from 100 cycles by dividing 160 counts by 16; a one-cycle pulse is obtained from 10 cycles by dividing 16 counts by 16. To minimize the effect of the shunt capacitance of connecting leads, each decade unit is coupled to the following by the cathode follower, V402A.

The output from the left-hand section of the fourth binary stage of each decade unit is differentiated by the condenser, C409, and the resistor, R418, and applied to the grid of V402B, which is clamped to cutoff by the voltage divider composed of the resistors, R419 and R417. From V402B, the repetition rate of the positive pulses in decade 1 is 100 cps; in decade 2 it is 10 cps; and in decade 3 it is 1 cps. These pulses are fed to the sweep selector switch, S402, in the sweep generator (Figure 2-10).

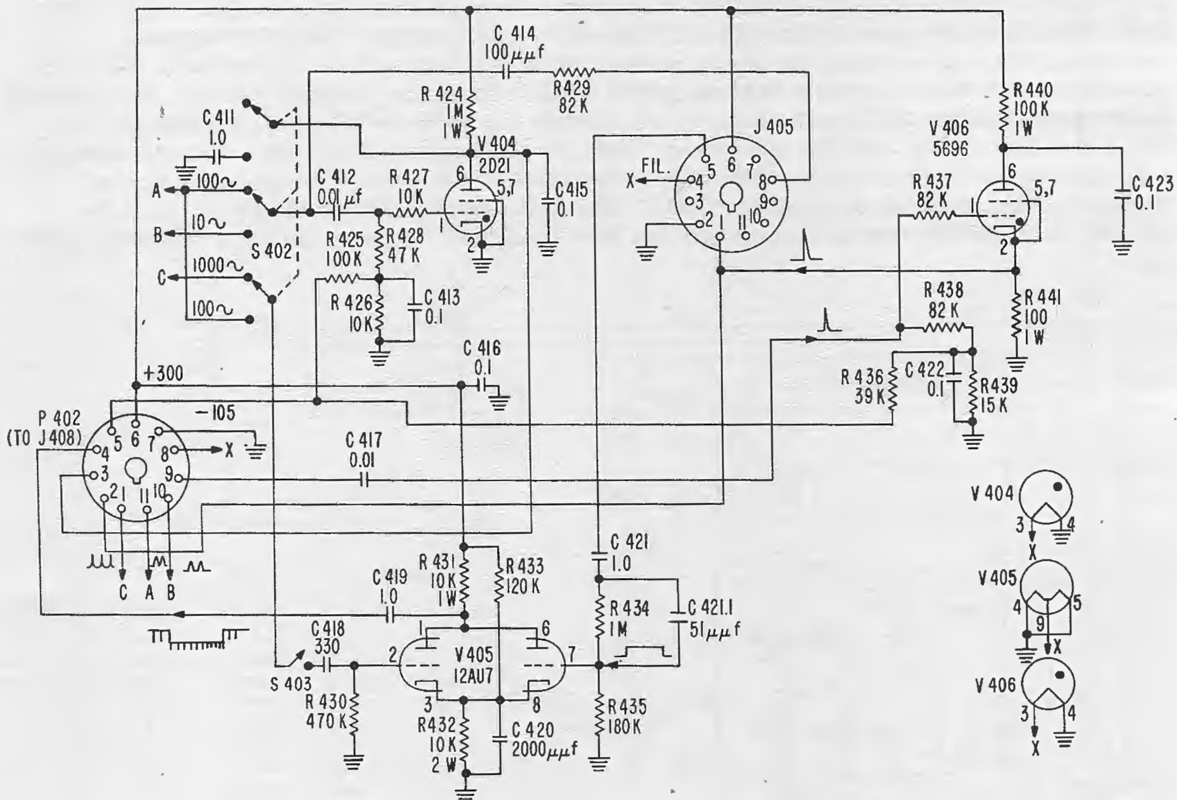


Figure 2-10. Schematic Diagram of Sweep Generator

The cathode of V403, a thyratron pulse generator, is connected to each selector arm of the 4-ganged single-pole 12-position wafers of the switch, S401. Each of the four wafers is associated with one of the four binary units in the decade. Resistors R408 and R410 in the binary unit are connected to specific contacts on each wafer. Thus, the cathode of V403 is connected to R408 or R410, depending on the position of the selector arms of S401. A nonconducting stable state of the thyratron, V403, is maintained by the negative grid bias developed by the voltage across the resistor, R422. The leading edge of the rectangular pulse generated by the keyer unit is differentiated by the condenser, C435, and the resistor, R421, and thus a positive pulse is generated at the grid of V403. This pulse, which, of course, occurs coincident with the leading edge of the keyer rectangular pulse, fires V403, and the position of the switch, S401, determines whether the discharge current flows through the resistor, R408, or the resistor, R410, in each binary stage. As a result of this current, there is a large positive voltage of short duration developed across these resistors.

The conducting sequence* of the three-decade units is shown in Table 2-1; here R refers to the right-hand section conducting and L to the left-hand section conducting. The "zero count" conducting sequence is designated as RRRR (all right-hand sections are conducting).

The output signal from V402 of each decade occurs when the fourth stage of that decade switches from the L to R conducting state. If the reset pulse were not applied when the unit is first energized, the conducting sequence of the binary stages at the time the reset pulse occurs may be any one of those shown in Table 2-1.

If all switches labeled S401 are set in Position 1, which corresponds to zero delay, then the reset pulse is applied to all right-hand binary sections. Now, the 1000-cycle decade input signal and the input to the keyer are derived from the same source. Therefore, the reset pulse (coincident with the leading edge of the keyer rectangular voltage) and one pulse of the 1000-cycle decade input occur simultaneously. The amplitude of the reset pulse, however, is so large that it overwhelms the effect of the 1000-cycle binary input pulse occurring simultaneously and forces conduction in all right-hand sections.† It should be noted that the conducting sequence of all binaries is repeated for every 1000 pulses fed to the decades. Hence, every 1000th pulse of the 1000-cycle decade input pulses following the first and the nth reset pulse switch to the zero-count state, with a resulting output pulse from each decade. Thus, the output one-second pulses from decade 3 are coincident with the reset pulse, and hence a one-cycle output is provided with zero delay relative to the keyer output.

For a delay of N milliseconds in the output from decade 3, switches labeled S401 are set so that the reset pulse forces a conducting sequence that corresponds to 1000 -N counts relative to the zero-count conducting sequence. Because of the cyclic recurrence of the conducting sequences of the binary stages, every 1000th (n = 1, 2, _ _ _) 1-kc input pulse and the nth reset pulse switch to the 1000 -N conducting sequence. An output results from all decades N counts (N milliseconds) following the corresponding reset pulse. This reset process provides a one-cycle output pulse from decade 3 which is delayed by N milliseconds with respect to the keyer output. It will be noted that the phase of the 100-cycle and 10-cycle pulses from decades 1 and 2 is delayed by the same amount as the one-cycle output from decade 3. The reset switches labeled S401 are connected to force conducting sequences (Table 2-1) which provide a delay in the decade 3 output ranging from 0 to 999 milliseconds in one-millisecond steps. Since the conducting sequence of the binaries is cyclic, it would be possible (after the first reset) to remove the reset pulse altogether and still maintain the same phase relation between the reset pulse and the one-second output signal from decade 3. Counts introduced by transients, however, could change this phase relationship. Since it is advantageous to continue applying the reset pulse every second in order to correct the phase continually, this method of reset is used.

### Sweep Generator

The principal functions of the sweep generator (Figure 2-10) are to produce a sawtooth sweep voltage, to generate a gating pulse of proper delay and duration, and to mix

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*The conducting-sequence stage is reversed when the previous stage changes from the L to R conducting state.

†If the reset pulse is applied to the right-hand grid resistor, conduction is forced in the right-hand section; if it is applied to the left-hand section, conduction is forced in the left-hand section.



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the gating pulse with proper marker pulses. In these functions provision is made for two sets of conditions; and Switch S402 is used to select the desired set.

The sweep voltage, which has either a 100- or a 10-ms period, is derived from periodically occurring pulses from the counter-decade units; thus, the sweep period is 100 or 10 ms, depending on the choice.

TABLE 2-1
Conducting Sequence of Decades

| Decade Number | Number of Pulses Following Zero-Count State | Position of Reset Switch S401 | Delay-Dial Reading (milliseconds) | Stages | | | |
|---|---|---|---|---|---|---|---|
| | | | | 1 | 2 | 3 | 4 |
| | 0 | 12 | OFF | R | R | R | R |
| | 0 | 11 | 10 | R | R | R | R |
| | 1 | 10 | 9 | L | R | R | R |
| | 2 | 9 | 8 | R | L | R | R |
| | 3 | 8 | 7 | L | L | R | R |
| | 4 | 7 | 6 | R | R | L | R |
| 1 | 5 | 6 | 5 | L | R | L | R |
| | 6 | 5 | 4 | R | L | L | R |
| | 7 | 4 | 3 | L | L | L | R |
| | 8 | 3 | 2 | (R | L | L | L)* |
| | 9 | 2 | 1 | L | L | L | L |
| | 0 | 1 | Z | R | R | R | R |
| | 0 | 12 | OFF | R | R | R | R |
| | 0 | 11 | 90 | R | R | R | R |
| | 10 | 10 | 80 | L | R | R | R |
| | 20 | 9 | 70 | R | L | R | R |
| | 30 | 8 | 60 | L | L | R | R |
| | 40 | 7 | 50 | R | R | L | R |
| 2 | 50 | 6 | 40 | L | R | L | R |
| | 60 | 5 | 30 | R | L | L | R |
| | 70 | 4 | 20 | L | L | L | R |
| | 80 | 3 | 10 | (R | L | L | L)* |
| | 90 | 2 | 0 | L | L | L | L |
| | 0 | 1 | Z | R | R | R | R |
| | 0 | 12 | OFF | R | R | R | R |
| | 0 | 11 | 900 | R | R | R | R |
| | 100 | 10 | 800 | L | R | R | R |
| | 200 | 9 | 700 | R | L | R | R |
| | 300 | 8 | 600 | L | L | R | R |
| | 400 | 7 | 500 | R | R | L | R |
| 3 | 500 | 6 | 400 | L | R | L | R |
| | 600 | 5 | 300 | R | L | L | R |
| | 700 | 4 | 200 | L | L | L | R |
| | 800 | 3 | 100 | (R | L | L | L)* |
| | 900 | 2 | 0 | L | L | L | L |
| | 0 | 1 | Z | R | R | R | R |

*This state of conduction results from feedback.



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These driving pulses are coupled to the grid of the thyratron, V404, connected in parallel with a condenser which is charged positively through a resistor connected to the plate supply. In the operation of the circuit, the voltage across the condenser, C415 (or C415 in parallel with C411 in Position 2 of S402), reaches the plate-supply voltage if no input driving pulses are present at the grid. Since V404 is in parallel with C415, the voltage at the plate also reaches the plate-supply voltage. However, since the grid is biased sufficiently negative, the tube remains nonconducting. When positive driving pulses of sufficient amplitude are applied to the grid, the first pulse will cause V404 to conduct heavily for a short time and C415 will be discharged. At the completion of the discharge, V404 extinguishes, and the voltage across C415 rises exponentially toward the plate-supply voltage. However, if another pulse is applied to the grid of V404 long before the voltage across C415 reaches plate-supply voltage, V404 will conduct again and discharge C415, thus repeating the cycle. For pulses with a period T, the output voltage at the plate of V404 is a sawtooth voltage with a period T. In the operation of this unit, driving pulses are always present; so a continuous sawtooth voltage is present at the plate of V404 which is connected to the jack, J415. When the Switch S402 is turned to Position 1, the period, T = 100 ms; when turned to Position 2, T = 10 ms. When T is varied, the discharge condenser must be changed by nearly a proportionate amount in order to maintain the same degree of sweep linearity. Consequently, the switch, S402, which is used to select the input driving pulses is also used to select the discharge condenser in order to maintain the same degree of linearity.

The same pulses fed to the sawtooth generator are fed to the grid of the right-hand section of the binary unit in J405. These pulses normally hold the right-hand section of the binary in the conducting state. The positive delayed one-second pulse from decade 3 is connected to the grid of the pulse generator, V406. The cathode of V406 is connected to the left-hand reset resistor, R408, in the binary unit and also to the cathode of the amplifier, V409, in the pulse generator and strobotron driver. Each time a delayed pulse is applied to the grid of V406, a 160-volt positive pulse of short duration appears at its cathode and switches the binary unit to the left-hand conducting state where it remains until the next sawtooth driving pulse (T seconds later) is applied to the right-hand grid. The opposite state of conduction is forced by this pulse, and this state of conduction continues until the next delayed one-second pulse occurs. A positive, rectangular output-voltage pulse of duration T (T = 100 ms or 10 ms depending on the position of S402), which is delayed by the amount introduced by the counter decades, appears at the right-hand plate of the binary. This voltage is applied to grid 7 of the mixer, V405. Marker pulses, which have a period, T/10, selected by S402, are applied to grid 2 of V405 through the marker Switch, S403. The output signal derived from V405 is fed to the oscilloscope Z-amplifier through the jacks, J414 and J205A. The rectangular pulse intensifies during the selected cycle of the sweep once per second; the marker pulses appear as intensified points, dividing the sweep into ten equal intervals.

### Tone-Rejection Filter

When Switch S406 is in Position 1, Filter Z401, a parallel-T type, is tuned to reject 440 cycles; in Position 3, it is tuned to reject 600 cycles. Straight-through operation is provided when S406 is set in Position 2.

### Code Relay

By closing Switch S405 the clock code contact is connected in series with the relay holding coil, K401, and the filament transformer, T603. It also connects the relay contact to the 450-volt output from Power Supply PP-455A/FSM-5A. The relay armature contact is connected to the plates of the keyer tubes. Thus, since the relay is normally closed, plate voltage is removed from the keyer tubes when the code contact is closed. When S405 is open, power is removed from the relay and keyer tubes. The resistors, R481 and R482, and the condensers, C439 and C440, are connected as a filter to prevent excessive arcing across the clock code contact. The transformer, T603, also supplies filament power to the keyer unit. Filament power to all other units of the time comparator is supplied by the transformer, T401, which is located on the time-comparator chassis.

### Remote Control

The remote-control switch, S407, is connected to the 300-volt source; by means of the resistance network composed of the resistors, R485, R486, and R487 this switch supplies a polarized output at the terminals of TB402 to control the phase of a remotely located time standard.

A 1000-cycle signal, simultaneously impressed at the terminals of TB402, is isolated from the 300-volt source by the filter consisting of the inductances, L402 and L403, and the condenser, C441.

## 4. CATHODE-RAY OSCILLOSCOPE

### Purpose

An oscilloscope (Figure 2-11), included in the time standard, is used in conjunction with the comparator to make time-comparison measurements; it is also used to check the operation of the other assemblies. Jacks are provided on the panel and by means of the supplied cables, the oscilloscope can be connected to any of the assemblies. Connectors on the oscilloscope permit signals to be applied to the vertical or horizontal axis, to the intensity grid, or to the synchronizing grid of the sweep circuit. A linear sweep built into the oscilloscope and variable from 20 to 25,000 cps allows the waveform of the test signal to be observed. This sweep can be synchronized with the signal under test, with the line frequency, or with still another external frequency. By applying one test signal to the Y-axis, and another to the X-axis, the frequency ratio between the two signals may be determined from the resulting Lissajous pattern. To analyze complex Lissajous patterns or provide timing markers, a signal may be applied to the Z-axis, thereby modulating the intensity of the image. As the pattern is traced by the beam, this modulation will show as alternate bright and dark spots.

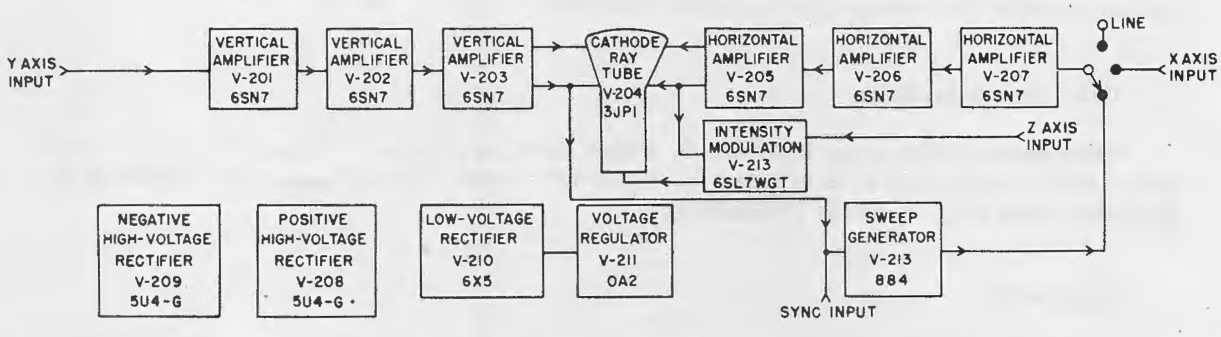


Figure 2-11. Block Diagram of Oscilloscope



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### X-Axis and Y-Axis Amplifiers

Signals applied to the vertical deflection channel are impressed on the grid of V201A, which is connected as a cathode follower (Figure 2-12). A potentiometer in the cathode circuit allows the amplitude of the signal to be varied without appreciable effect on the frequency response. The signal is then applied to the grid of V201B; this tube and tube V202A are connected in cascade and act as triode amplifiers. The signal is then fed into V202B which acts as a split-load phase inverter. Half the signal is developed across the cathode resistor, R212, and half across the plate-load resistor, R211. These voltages, which are equal and 180 degrees out of phase, are impressed on the grids of V203A and V203B. The resulting push-pull deflection minimizes defocusing of the electron beam in the cathode-ray tube since the algebraic sum of the voltages impressed on the deflection plates is always approximately the same and the acceleration of the electron beam is not affected. Inductances L201, L202, and L203 are connected in series with the plate-load resistors of V202A, V203A, and V203B in order to compensate for the shunting effect of stray capacitances in the circuit and to keep the gain of the amplifier uniform even at high frequencies. The operation of the X-axis amplifier is identical to that of the Y-axis amplifier except that a selector switch in the input circuit allows the signal to be selected from an external source, an internal linear sweep generator, or the 60-cycle line. The first X-amplifier stage is connected push-pull to obtain a more linear sweep.

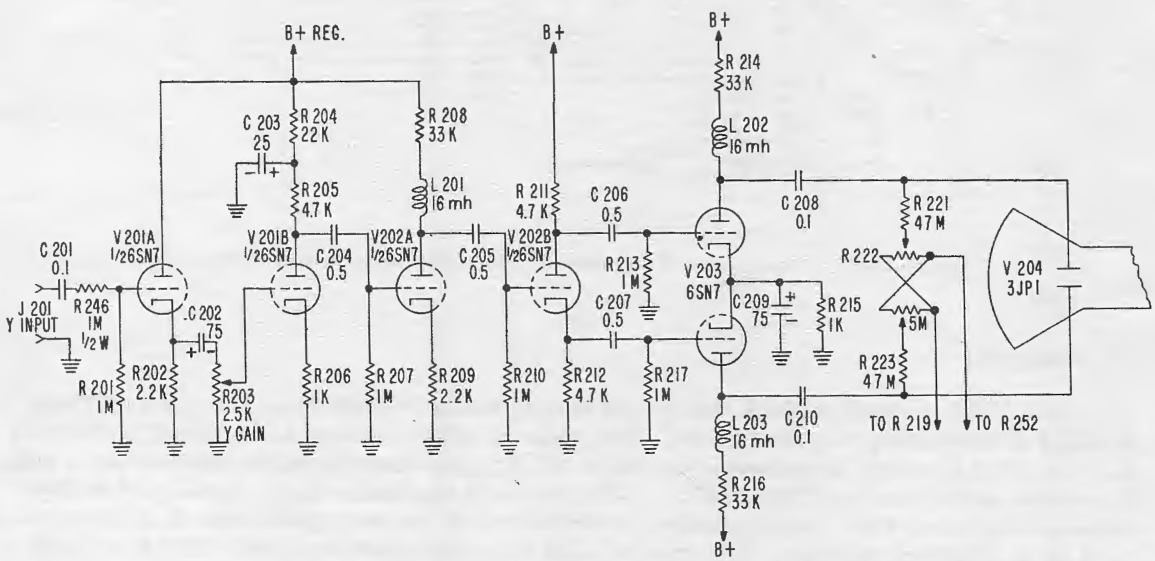


Figure 2-12. Schematic Diagram of Oscilloscope Vertical Amplifier

### Sweep Generator

The purpose of the sweep generator, the circuit of which is shown in simplified form by Figure 2-13, is to produce a linear change in voltage which will be amplified and used to deflect the beam horizontally at uniform speed. Thyratron V214 is in a normally non-conducting state so that a sweep capacitor selected by Switch S203 charges through the resistors, R263 and R264. When the voltage reaches the breakdown potential of V214, the gas in Tube V214 ionizes (it is thus rendered conducting), and the sweep capacitor is discharged through the resistor, R268, and the tube, V214. The purpose of the resistor is to limit the current through the tube. If a positive pulse is applied to the grid of the tube while the sweep capacitor is charging, the breakdown potential of the tube is lowered and the tube conducts sooner than it would normally. In this way, a means is provided to synchronize the sweep with an external signal. When the sweep capacitor is discharged to about 10 volts, the gas in the tube will no longer remain ionized, the tube resumes its non-conducting state, and charging of the sweep capacitor starts again. When conduction through the tube is resumed, the sweep capacitor has been charged to only a small percentage of the supply voltage. Utilization of such a limited portion of the charge-voltage characteristic provides a nearly linear rate of rise for the basic sweep voltage passed by the X-axis amplifier. Fine control of the sweep time is provided by a continuously adjustable rheostat, R264, which is used to govern the charging rate of the sweep capacitor. Coarse setting is provided by the switch, S203, which selects the proper sweep capacitor for the frequency range desired.

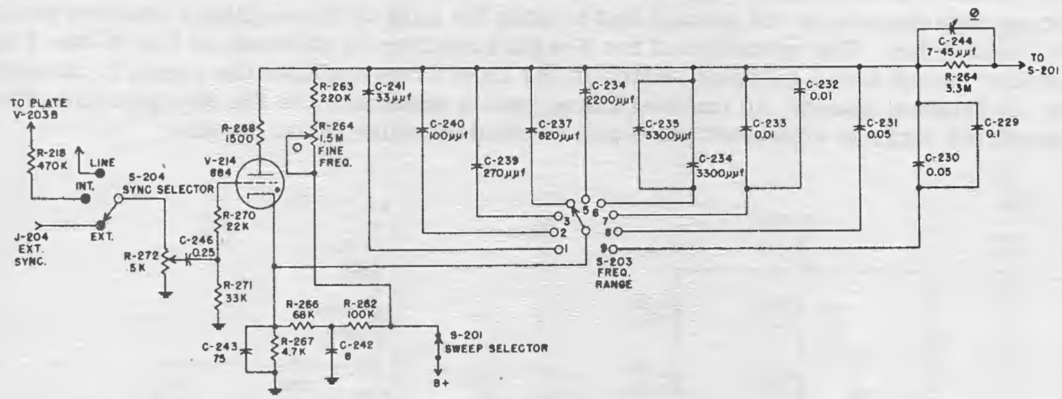


Figure 2-13. Schematic Diagram of Oscilloscope Sweep Generator

### Blanking

Tube V213 is used to blank the return trace, which is present on the plate of Tube V214 as a fast-acting negative pulse. The pulse is differentiated and applied to the grid of Tube V213A, which is cathode-coupled to V213B; the blanking pulse appears as a negative pulse on the plate of Tube V213B. This pulse is applied to the control grid of the cathode-ray tube, V204, and the beam is therefore cut off during the time it is being swept back to its starting position. The grid of V213B is connected to a jack, J205A, so that external intensity modulation may be employed.

### Cathode-Ray Tube

Cathode-ray tube V204 is a type 3JP1, which is provided with an intensifier or post-deflection electrode used to accelerate the electron beam after it has been deflected, thereby providing high intensity without decreasing the deflection sensitivity. The positive 1450 volts applied to the intensifier electrode is obtained from the rectifier V208, a type 5U4WG (Figure 2-14). The deflection plates and accelerating anode are operated near ground potential, and the cathode potential is supplied by a negative high-voltage rectifier, V209. Actually, the control grid is operated at the most negative potential; the cathode and focusing anode are tapped off a voltage divider between the negative supply

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and ground. The potential applied to the grid is variable so that the intensity of the spot may be varied. The focusing anode potential can be changed to sharpen the focus of the spot, and the midposition of the spot may be changed by varying the dc potential applied to either the horizontal or vertical deflection plates. Plate voltage to operate the various amplifiers is supplied by the rectifier, V210, a type 6X5WGT, and regulation for the input-amplifier tubes is provided by the type-OA2 voltage-regulator tube, V211.

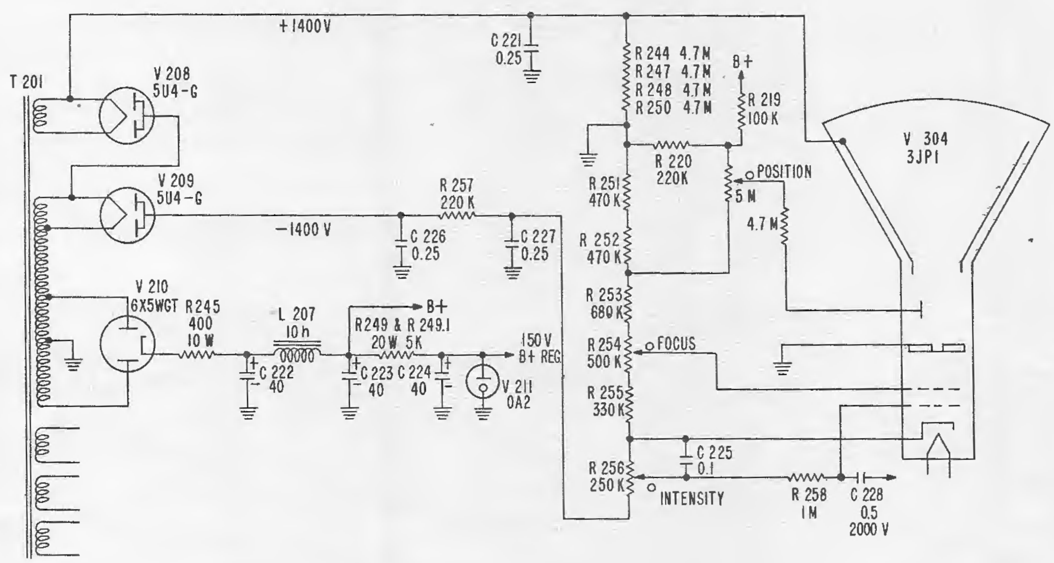


Figure 2-14. Schematic Diagram of Oscilloscope Power Supply

## 5. POWER SUPPLY PP-455A/FSM-5A

This power supply, shown schematically in Figure 2-15, supplies plate power, bias voltage, filament voltage, and 115-volt ac to the units of the time comparator. The regulated dc outputs from this supply are 300, 450, and -105 volts; 6.3 volts are also supplied.

A type 5R4 rectifier, V601, operates in a full-wave circuit and changes the alternating-current output of the regulated transformer, T601, to direct current. The capacitance input filter, consisting of the choke, L601, and the condensers, C601 and C602, furnishes a smoothed dc input to the regulating circuit. Here the tube, V602, a type 6AS7, acts as a variable resistance. If, for any reason, the voltage increases at the output, the voltage at the plate of the amplifier, V603B, increases as a result of the additional potential on its cathode. This increase results since its grid is held substantially constant by the voltage reference tube, V604, which is a type 5651. The increase in voltage at the plate of V603B is applied to the grid of V603A, and as a result, the voltage at the plate of V603A is decreased. This, in turn, increases the bias on V602 and hence the resistance; this action tends to lower the output voltage. If the output voltage drops for any reason, this effect causes the resistance of V602 to decrease and the output voltage tends to rise. Feedback continues until the voltage differential at the output furnishes the proper bias on V602 to maintain the output voltage. The differential depends directly on the feedback factor and results in a voltage regulation of about 0.5 percent. The output is adjusted to 300 volts by the potentiometer, R506.

Two 5R4 rectifiers, V607 and V608, connected in a full-wave circuit, furnish a regulated current of 450 volts dc by rectification of the output of the transformer, T602.



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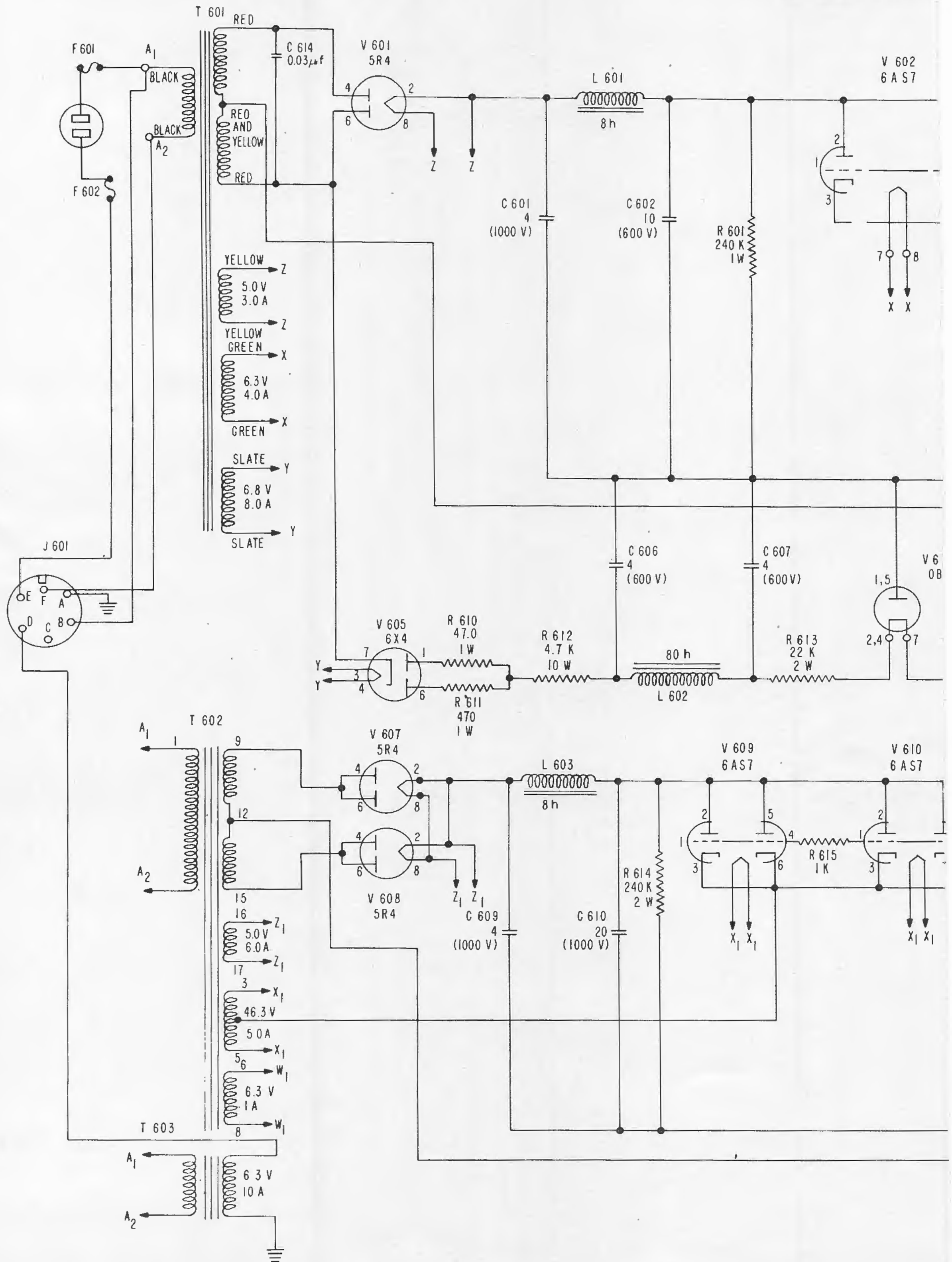


Figure 2-15. Schematic Diagram of Pow



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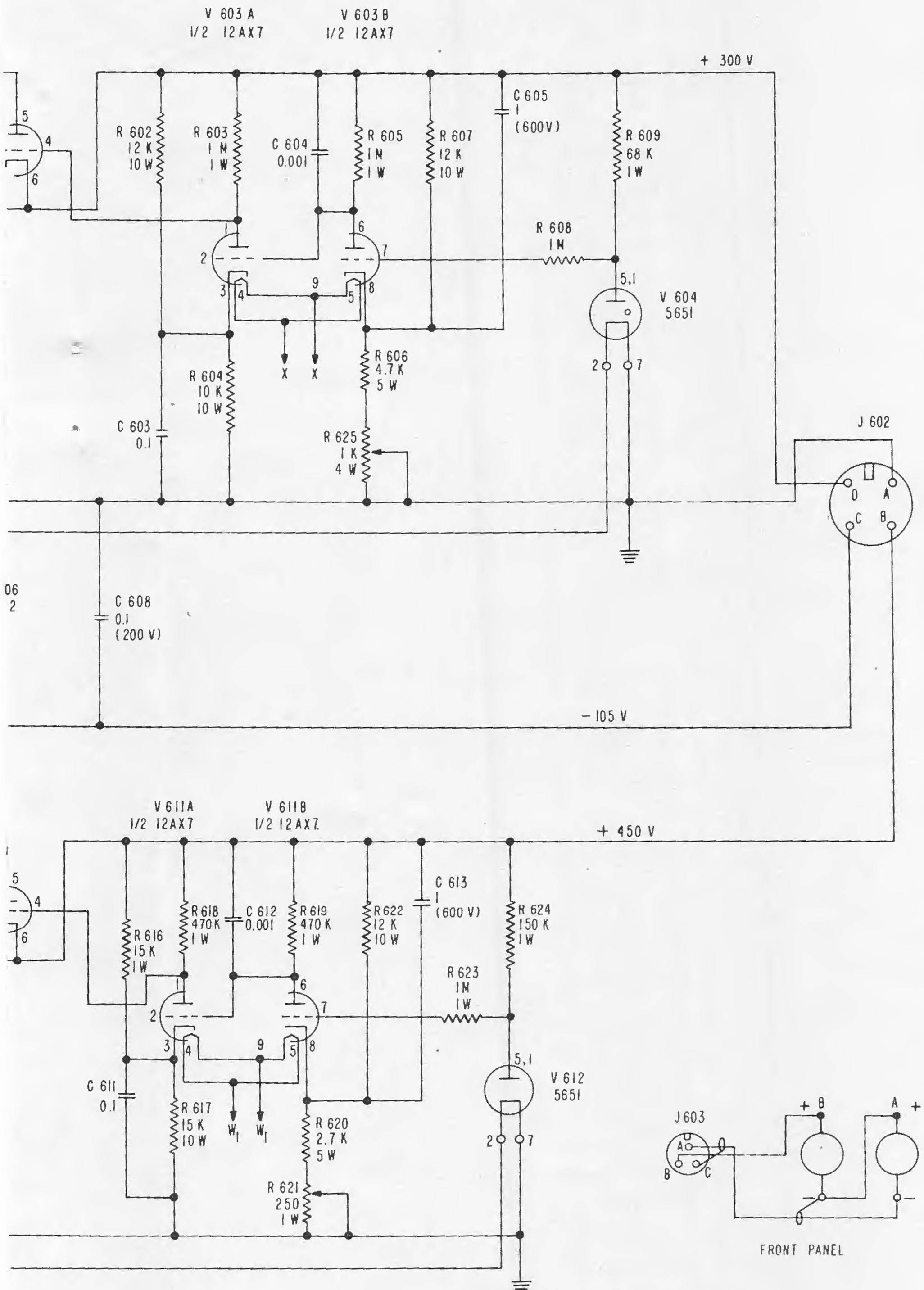
V 603 A
1/2 12AX7
V 603 B
1/2 12AX7
+ 300 V
C 605
1
(600V)
R 602
12 K
10 W
R 603
1 M
1 W
C 604
0.001
R 605
1 M
1 W
R 607
12 K
10 W
R 609
68 K
1 W
R 608
1 M
V 604
5651
R 604
10 K
10 W
R 606
4.7 K
5 W
X
X
C 603
0.1
R 625
1 K
4 W
J 602
D
A
C
B
C 608
0.1
(200 V)
06
2
− 105 V
V 611A
1/2 12AX7
V 611B
1/2 12AX7
+ 450 V
C 613
1
(600 V)
R 618
470 K
1 W
C 612
0.001
R 619
470 K
1 W
R 622
12 K
10 W
R 624
150 K
1 W
R 616
15 K
1 W
R 623
1M
1W
C 611
0.1
R 617
15 K
10 W
W1
W1
V 612
5651
R 620
2.7 K
5 W
R 621
250
1 W
J603
+ B
A +
FRONT PANEL



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The capacitance input filter, consisting of the choke, L605, and the condenser, C605 and C606, furnishes a smoothed dc input to the regulating circuit which is composed of Tubes V609, V610, V611, and V612. Stabilization is affected in a manner similar to that of the 300-volt output. Because of the large load current, parallel operation of the rectifiers and series triodes, V609 and V610, is required. The output voltage is adjusted to +450 volts by the potentiometer, R620. Rectifier V605, a 6X4 type, supplies a bias of -105 volts by the half-wave rectification of the output of one side of the power transformer, T601. The voltage-regulator tube, V606, is an OB2 type which stabilizes this output at -105 volts.

An ac output of 115 volts is available at the jack, J601; the filament transformer, T603, furnishes 6.3 volts ac to J601.

## 6. POWER SUPPLY PP-456A/FSM-5A

Output currents at 360 and 150 volts dc and at 6.3 volts ac are furnished by Power Supply PP-456A/FSM-5A, which is shown schematically in Figure 2-16. This power supply receives 60-cycle 115-volt current from the voltage stabilizer located on top of the cabinet.

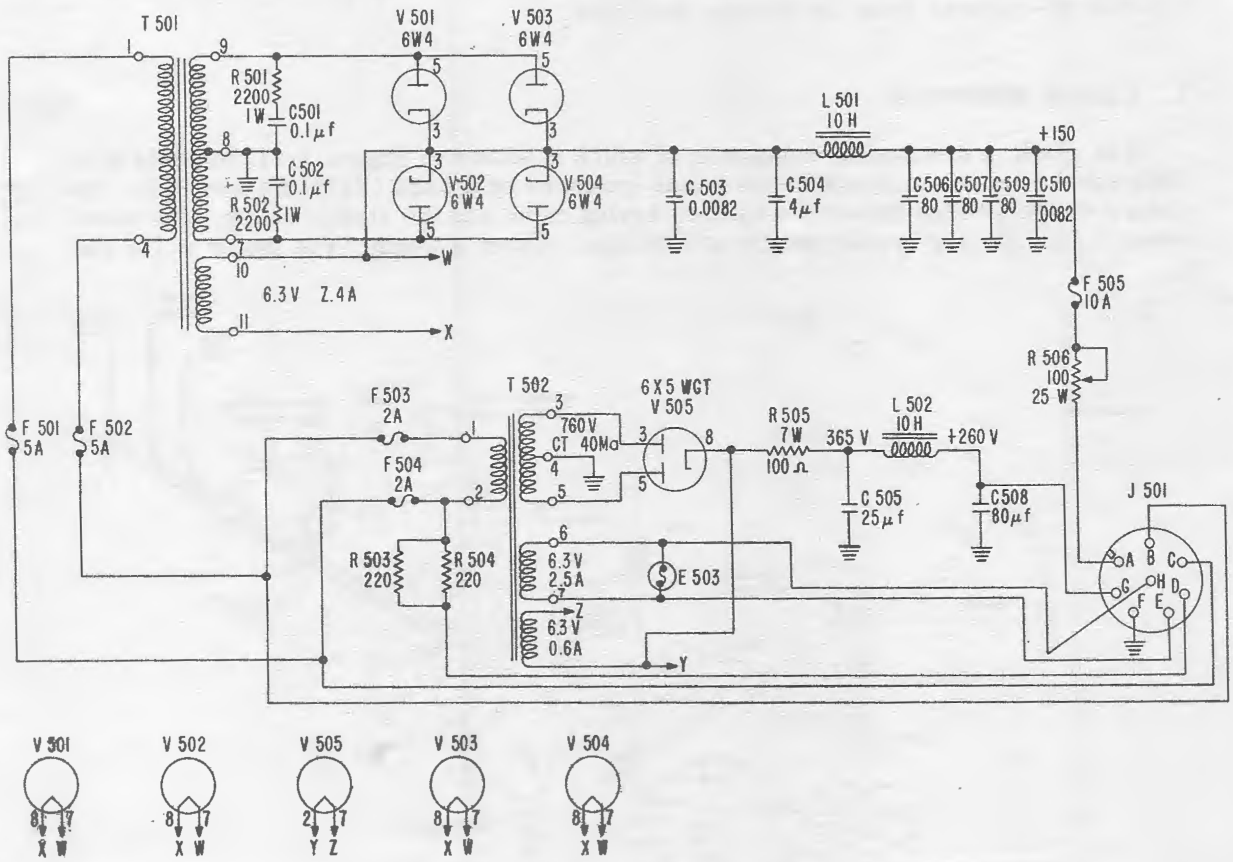


Figure 2-16. Schematic Diagram of Power Supply PP-456A/FSM-5A

The 150-volt dc output, developed by the full-wave rectification of the secondary current of T501 from four type-6W4 rectifiers, V501, V502, V503, and V504, furnishes:



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a. Plate power for the oscillator,

b. Plate power to those tubes of the frequency divider which are essential for operation of the clock, and

c. A trickle charge to the B batteries which are floated across the 150-volt output. The charging rate is controlled by means of a dropping rheostat, R506, and the developed voltage is indicated by the B voltmeter located on the front panel of Power Supply PP-455/FSM-5A.

The 260-volt output developed by rectification of the output current from the power transformer, T502, by a type 6X5 rectifier, V505, connected for full-wave operation, supplies plate power to the auxiliary tubes of the frequency divider. Filament power is supplied to these tubes by the 6.3-volt 2.5-amp filament winding on T502. The 115-volt ac output from the jack, J501, supplies power to the clock heater.

Rectified 6.3-volt dc from an ATR Battery Eliminator, Model 620C ELIP furnishes (a) filament power to the oscillator, (b) filament power to those tubes of the frequency divider essential for operating the clock, and (c) a trickle charge to the A batteries. Battery charging rate is controlled by varying the input ac voltage to the battery eliminator by the GR-type V-5 Variac mounted inside the cabinet. The input power to the Variac is 115-volt 60-cycle ac from the voltage stabilizer.

## 7. CLOCK ASSEMBLY

The clock, a mechanical schematic of which is shown in Figure 2-17, consists of a 1000-cycle tone-wheel synchronous motor (powered by a 6AS7 (V114) located in the frequency divider) which drives the various keying cams and the visible hands. The tone-wheel rotor, running synchronously at 1200 rpm, drives a worm. The motor worm and

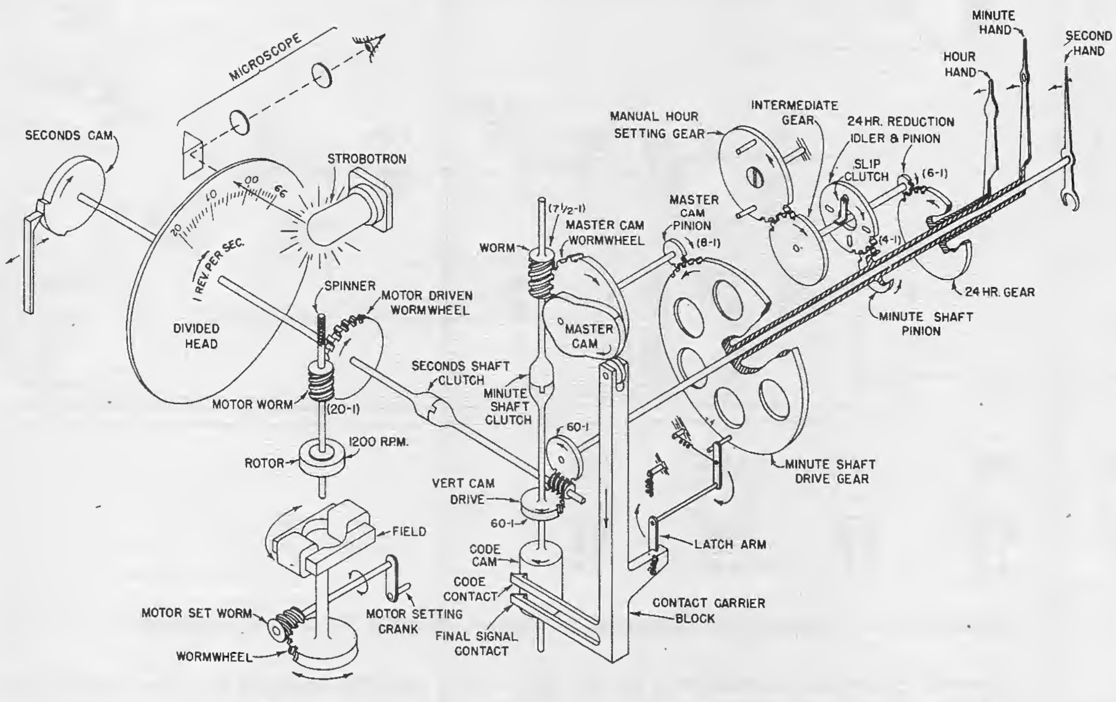


Figure 2-17. Schematic Diagram of Clock Mechanism



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worm wheel provide a step-down ratio of 20:1, thereby rotating the seconds shaft at 60 rpm or one revolution per second. The seconds shaft drives a seconds contact cam, a transparent divided head, and a seconds-hand drive worm which can be disconnected by means of a clutch used to set the seconds hand.

The seconds contact cam operates a spring contact arm through a quartz point. Quartz is used on all three contact arms in the clock to minimize wear and to facilitate contact adjustment. As the cam rotates, the contact arm is raised and lowered, alternately grounding and ungrounding a contact plate which is connected to the keyer tube, V414, in the time comparator.

The divided head is made of glass and has 1000 graduations scribed at regular intervals about its circumference. Every tenth mark is numbered, and each fifth mark is accentuated. Thus, since the shaft rotates once per second, each mark corresponds to a time of one millisecond. A microscope is fastened to the front panel of the clock in such a manner that the graduations and numbers on the divided head are visible and readable. If a light is flashed through the glass disc, the motion of the disc will appear to be stopped, and the angular position of the seconds shaft may be determined from the graduations visible through the microscope. In practice, a strobotron tube, V701, located behind the divided head, is flashed exactly once per second by the delayed signal from the time comparator. The divided head is observed through the microscope, and the time comparator dials are set for a particular delay. The graduation read on the glass head should be the number of milliseconds delay (to ±1 millisecond) indicated on the delay dials. This process shows whether or not the time-comparator assembly is operating properly.

A drive worm is geared directly to the seconds hand through a worm wheel. A 60:1 step-down ratio is provided between the worm and the worm wheel so that the seconds hand rotates at its proper speed of one rpm. This drive worm also powers a worm wheel connected to the code contact cams and the master cam worm, which can be disconnected by means of a clutch used to set the minute hand.

The code contact cams rotate once per minute, and at five minutes before the hour, they actuate the code contact arms. These arms are connected electrically to the relay, K401, in the time comparator and perform the function of eliminating the transmitter keying signal at certain seconds of each minute.

The master cam rotates once every 7-1/2 minutes and moves the code contact arms to their proper positions on the code contact cams, which are normally held at the bottom of their travel by a latch arm. The minute-shaft drive gear releases the latch arm once every hour. The master cam allows the assembly carrying the code contact to rise quickly to the top of the code contact cam, and then (in one-minute steps) to push the code contact arms down for the proper coding sequence. When the code contact arms reach the bottom of their travel, the final signal contact is actuated, and the latch arm holds the assembly down until the next hour has passed.

The master cam shaft drives the minute shaft through an 8:1 step-down gear. The minute-shaft drive gear has a pin which unlocks the latch arm for the contact carrier block. The minute hand on the face of the clock is connected to this shaft and rotates once per hour.

The minute shaft drives the 24-hour reduction idlers through a 4:1 step-down gear. The 4:1 hour gear is set on the shaft with a slip-clutch arrangement which allows the shaft to be turned by a hand wrench used to set the hour hand without turning the minute shaft. A 6:1 step-down gear train drives the hour hand at one revolution each 24 hours.

# SECTION 3
# INSTALLATION

## 1. LOCATION

The time standard must be considered as a permanent installation designed for continuous operation. The cabinet should be supported by a firm foundation and removed from vibration, excessive ambient temperature changes, drippage, dust, and dirt. At least 36, but preferably 42 inches, should be allowed between the rear of the cabinet and the nearest object so that maintenance personnel can work with the rear door fully open. Primary power is brought into the cabinet through knockouts in the bottom of the switch panel. These knockouts will accommodate one-half or three-quarter inch conduit (not furnished). A cableway in the floor beneath the cabinet is necessary for primary-power cables and signal cables. Figure 3-1 shows outline dimensions, space requirements, and floor cutout.

## 2. MOUNTING SURFACE

Since the equipment is heavy (Table 1-1), it is necessary for the installing activity to determine that the mounting surface is sufficiently reenforced and that the surface is true and level. Certain drilling and cutting is required but, in placing the unit, care must be taken that no supporting members of the floor are cut.

## 3. UNPACKING

The manner in which the various units are packed and the approximate weights and dimensions are given in Table 1-1.

To eliminate confusion, the cases should be unpacked one at a time and each unit should be set in place before opening the next case.

The proper sequence for unpacking and setting up the units (Figures 3-2 and 3-3) is as follows:

Cabinet

Voltage Stabilizer

Power Supply PP-455A/FSM-5A

Power Supply PP-456A/FSM-5A

R-F Oscillator

Frequency-Divider Assembly

Time-Comparator Assembly

Oscilloscope

Clock





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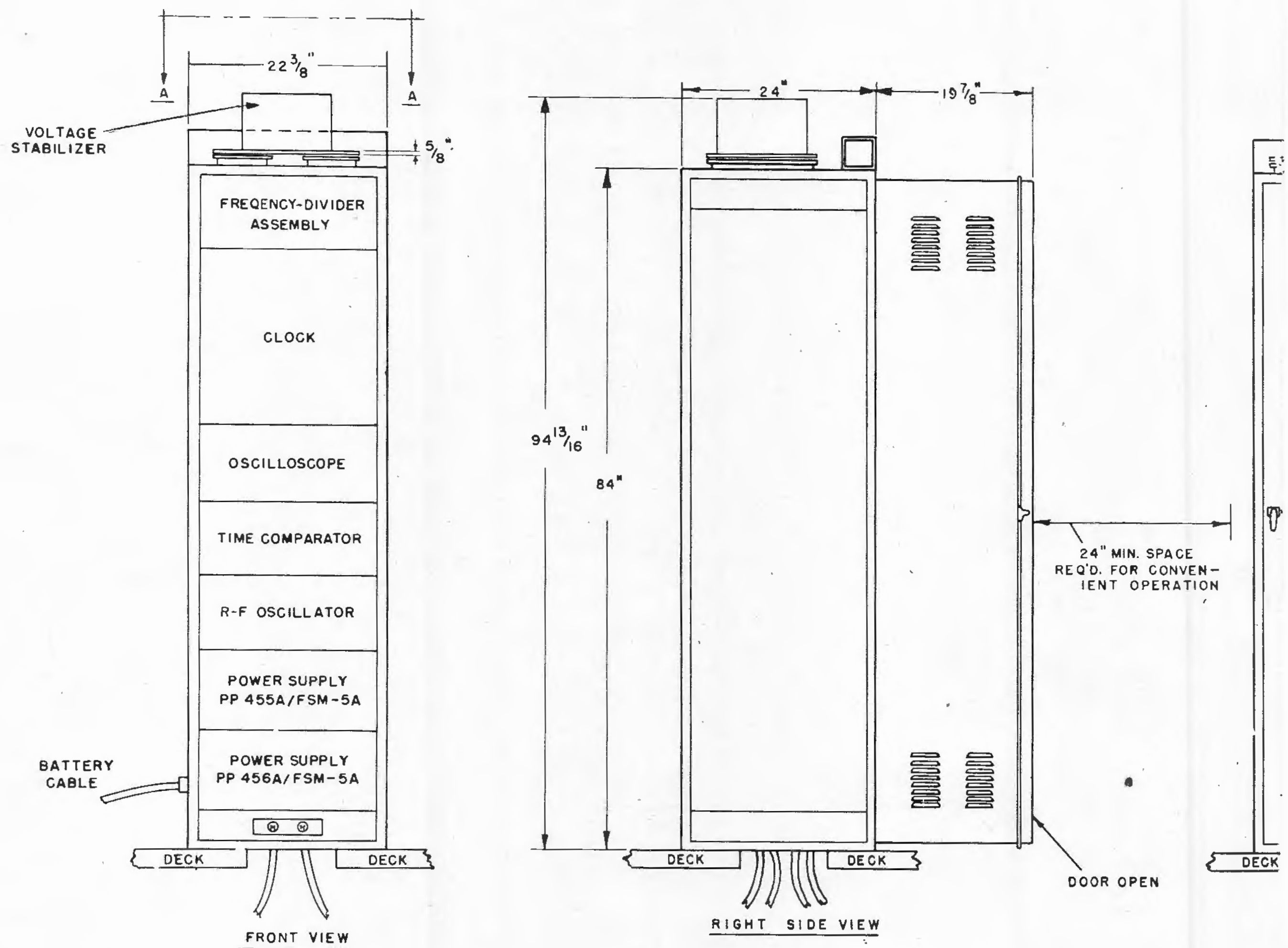


Figure 3-1. Instal

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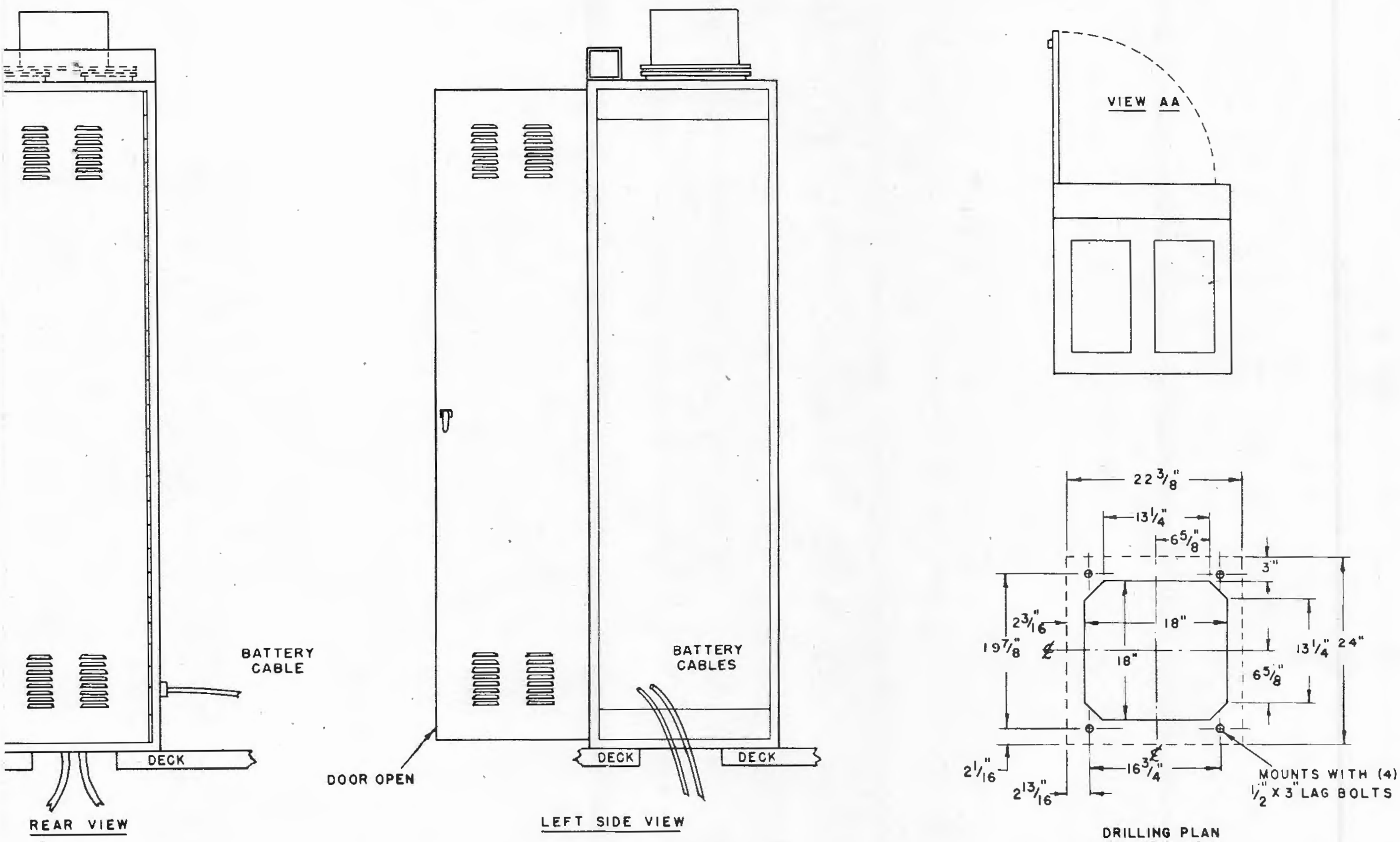
INSTALLATION

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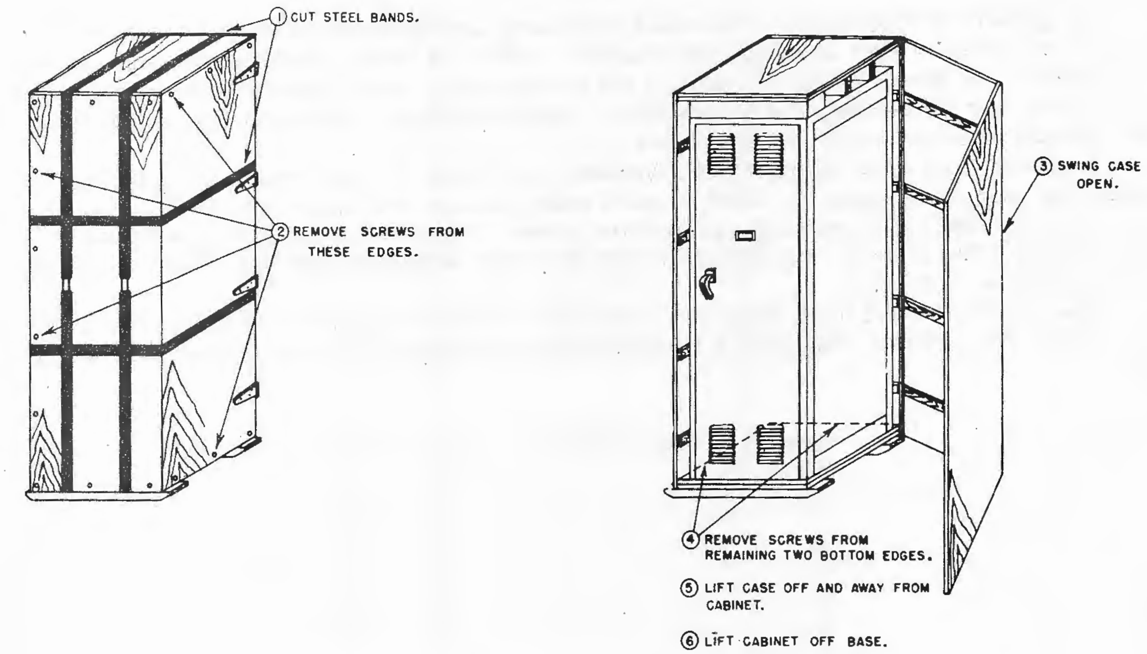


Figure 3-2. Illustration of Cabinet Unpacking

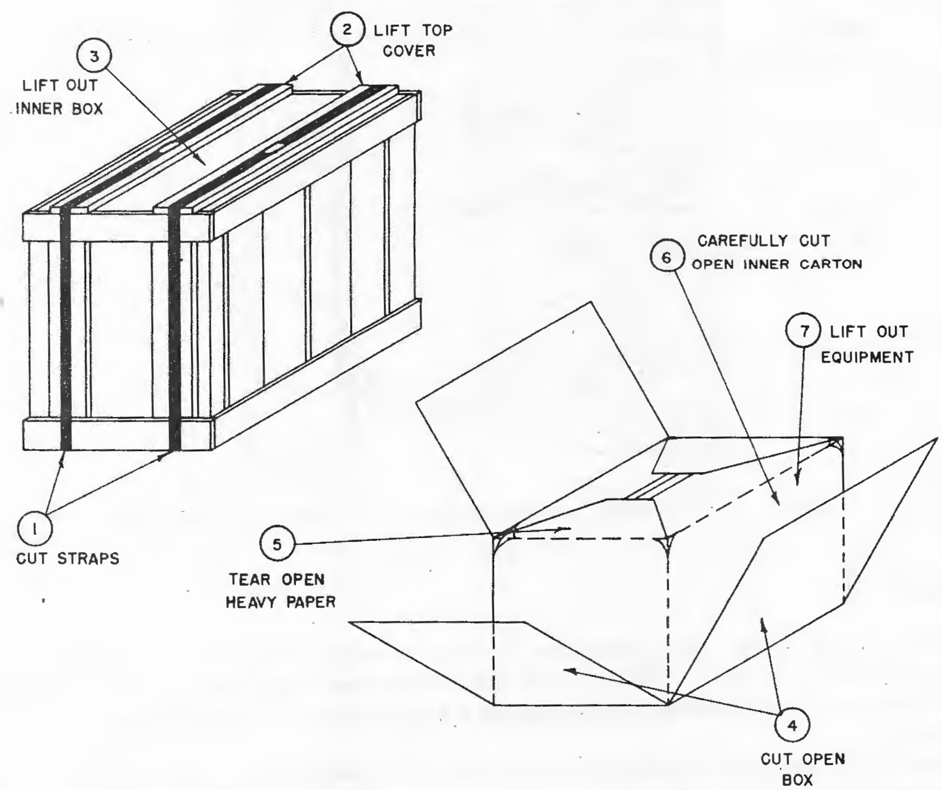


Figure 3-3. Illustration of Equipment Unpacking

To prevent damage to the equipment, the cases should be unpacked with care and each box should be kept in an upright position. After the case is opened, the units should be lifted out by means of the handles on the front panel. Exceptions to this are the cabinet, clock, and time-comparator assembly. Instructions for removing the cabinet from its packing case are given in Figure 3-2.

Extreme care must be used when handling the clock. In removing it from the transit case, one man is required to stand on each side. Each should place one hand on top of the panel and the other under the protective cover. The clock should then be drawn straight up. The transit case should be saved so that it will be available in the event the clock must be reshipped.

The oil bottles and tools supplied in the case should be transferred to the accessory box inside the cabinet. Figure 3-4 illustrates the placement of these accessories in the box.

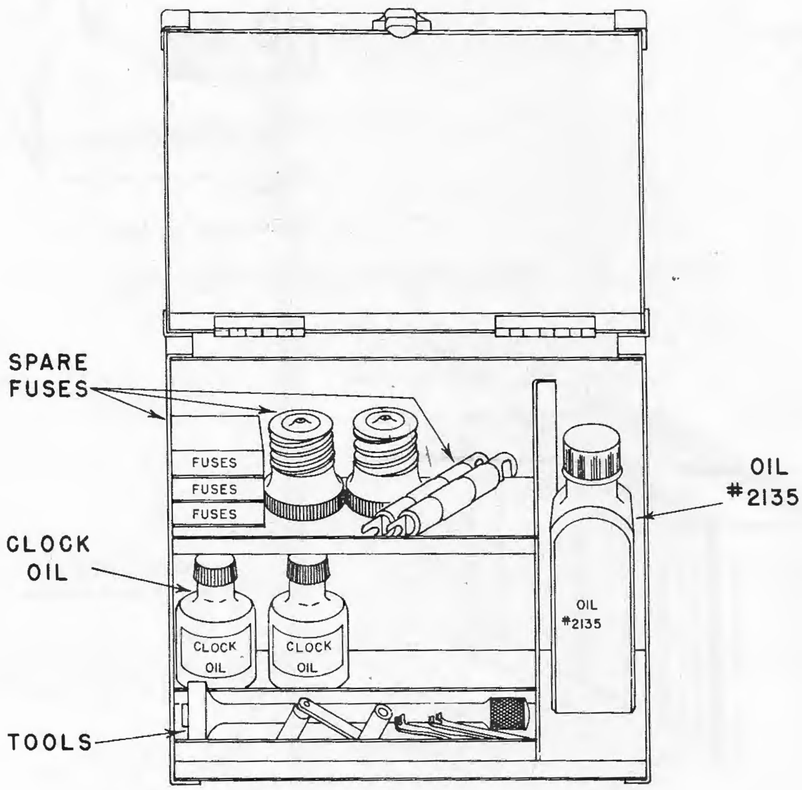


Figure 3-4. Storage Compartment for Clock Accessories

## 4. CABINET

After the foundation is completed, the cabinet is slipped over the prepared mounting surface and secured by bolts. The conduit should then be connected to the switch panel. The equipment must be grounded by means of the lug on the corner gusset at the bottom of the cabinet.

A 10-amp fuse must be installed between the ungrounded side of the B battery and the respective lead to the time standard; a disconnect switch may be installed in series with this fuse. As a pull-type disconnect switch, a 50-amp contact-type pull fuse should be connected in series with the lead connected to the negative side of the A battery. The total resistance of the A battery leads and the pull fuse should not exceed 0.025 ohm.

Install the voltage stabilizer on the shock mounts located on top of the cabinet. Connect the leads from the convenience outlet channel labeled "115 v unregulated ac" to the input terminals of the voltage stabilizer and connect the leads from the convenience outlet channel labeled "115 v regulated ac" to the output terminals of the voltage stabilizer.

## 5. MOUNTING OF UNITS

The units are mounted in the cabinet by starting at the bottom in the order shown in Figure 1-1. Clips for holding the plated strips that cover the mounting screws (6-32 x 1/2 binding head) should be placed under the highest and lowest screw and at intervals in between.

## 6. CONNECTION OF UNITS

Cables used for the internal wiring of the time standard are fastened into the cabinet in such a manner that the plugs are located adjacent to the proper jacks. In this way, mistakes in connection are minimized. The plugs should be inserted in the proper jacks and the connections made to the terminal boards on the clock, cabinet, and oscillator. The wires going to these terminal boards are fastened to fanning strips, so that no mistakes are possible in making the necessary connections. Figure 3-5 shows the rear of the time standard with cables installed, and Figure 3-6 shows the electrical connections.

The cables connecting external devices should be brought in through the bottom of the cabinet and fastened to the left wall by cable clamps. Suitable connectors should then be installed on the ends of the cables. BNC connectors and adapters are furnished with the equipment to make connections to the oscilloscope and auxiliary outputs from the frequency divider.

The battery cables are pushed into the cabinet through the two grommet holes in the side. Lugs are soldered on the battery leads and proper connections made to the terminals in the junction boxes located in the cabinet. Number 4 wire or larger is necessary for the A battery leads that carry the equipment load, and number 10 wire should be used for the B battery leads.

CAUTION—do not connect the batteries until the time standard is operating on the ac power line. Voltages and polarities should be checked before connecting the batteries.

Insert the ac plugs on the various chassis in the nearest convenience outlet along the side of the cabinet. AC power to operate the oscilloscope, Power Supply PP-456A/FSM-5A, and the ATR Battery Eliminator is taken from the convenience outlet channel labeled "115 v regulated ac." All other ac plugs are inserted in the channel labeled "115 v unregulated ac." Care should be taken, therefore, that the power plugs are inserted in the proper outlet channels.

## 7. STARTING THE CLOCK

Lubrication of the clock according to the instructions given in paragraph 2, section 7 is required prior to starting. A drain plug for the oil reservoir (emptied for shipment) is shown in Figure 3-7. The plug is screwed in for normal operation. It is opened only to drain the oil from the reservoir incident to its being replaced or removed for shipment or storage.

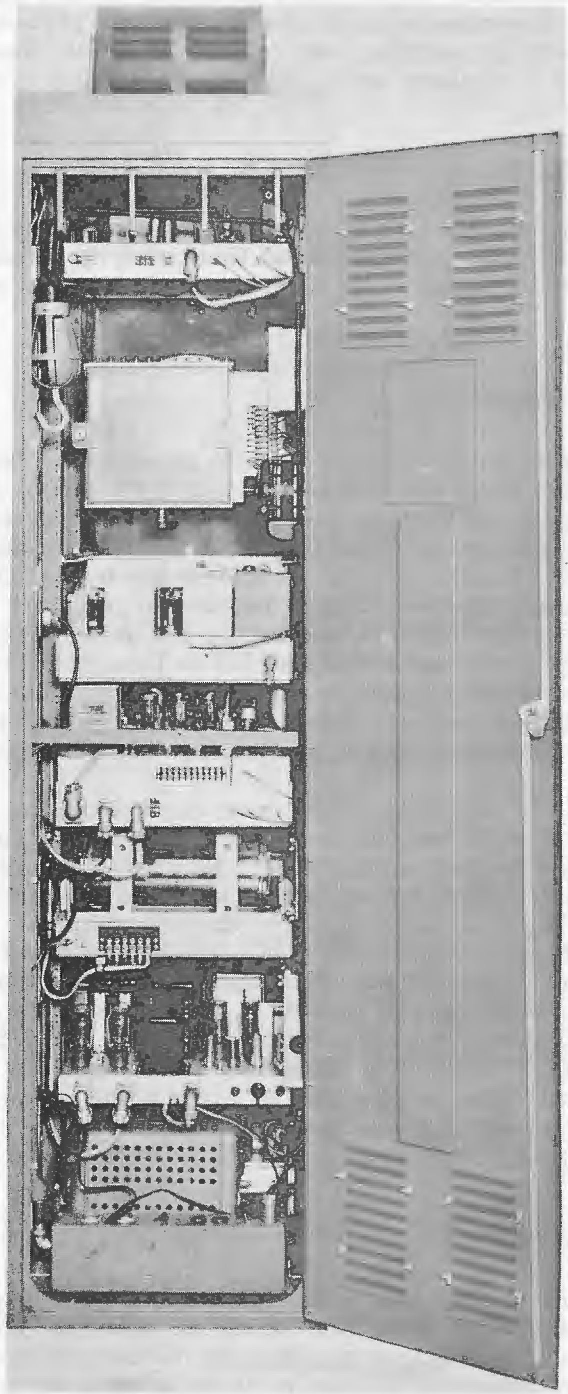

Figure 3-5. Rear View of Time Standard Showing Cables



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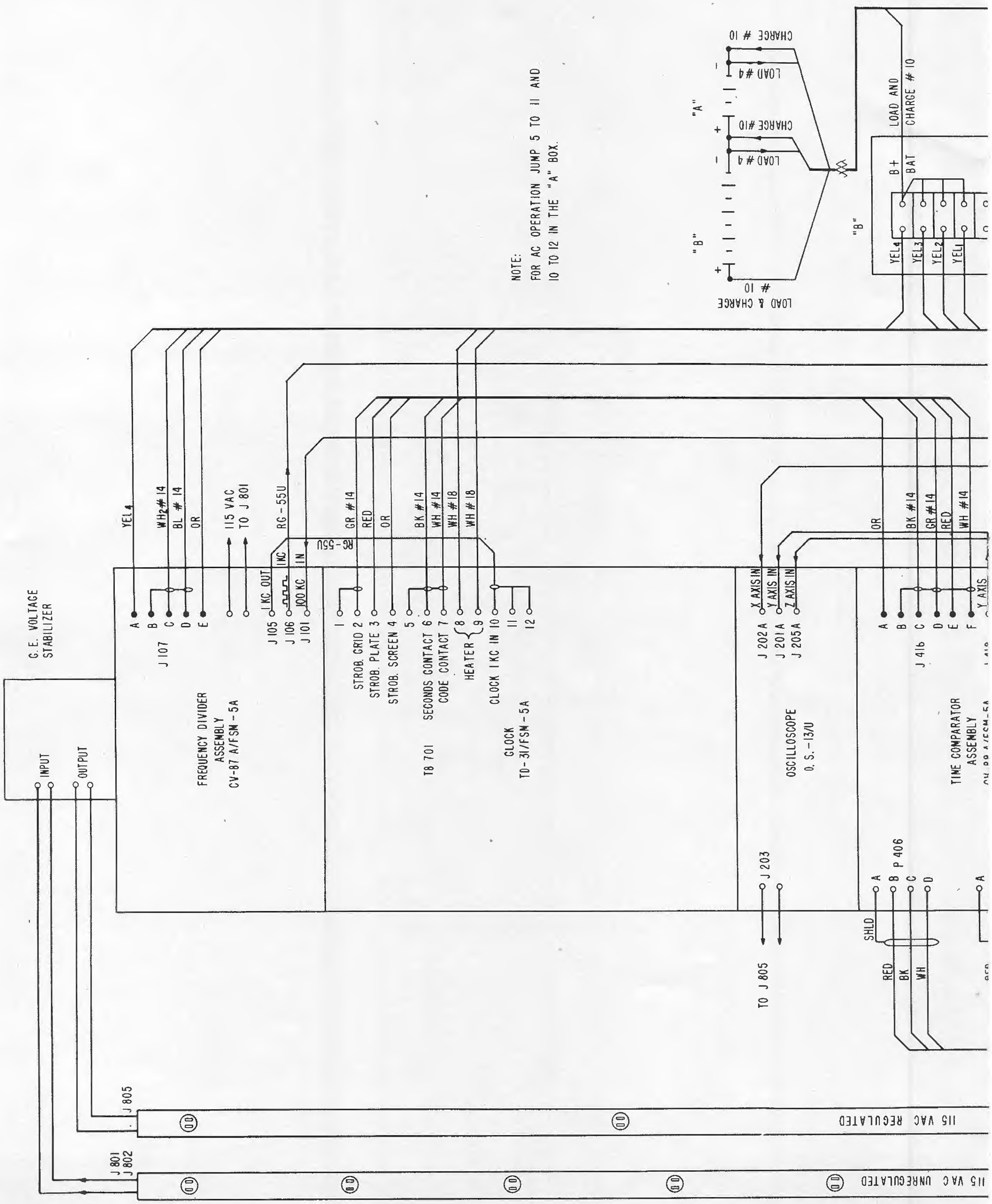


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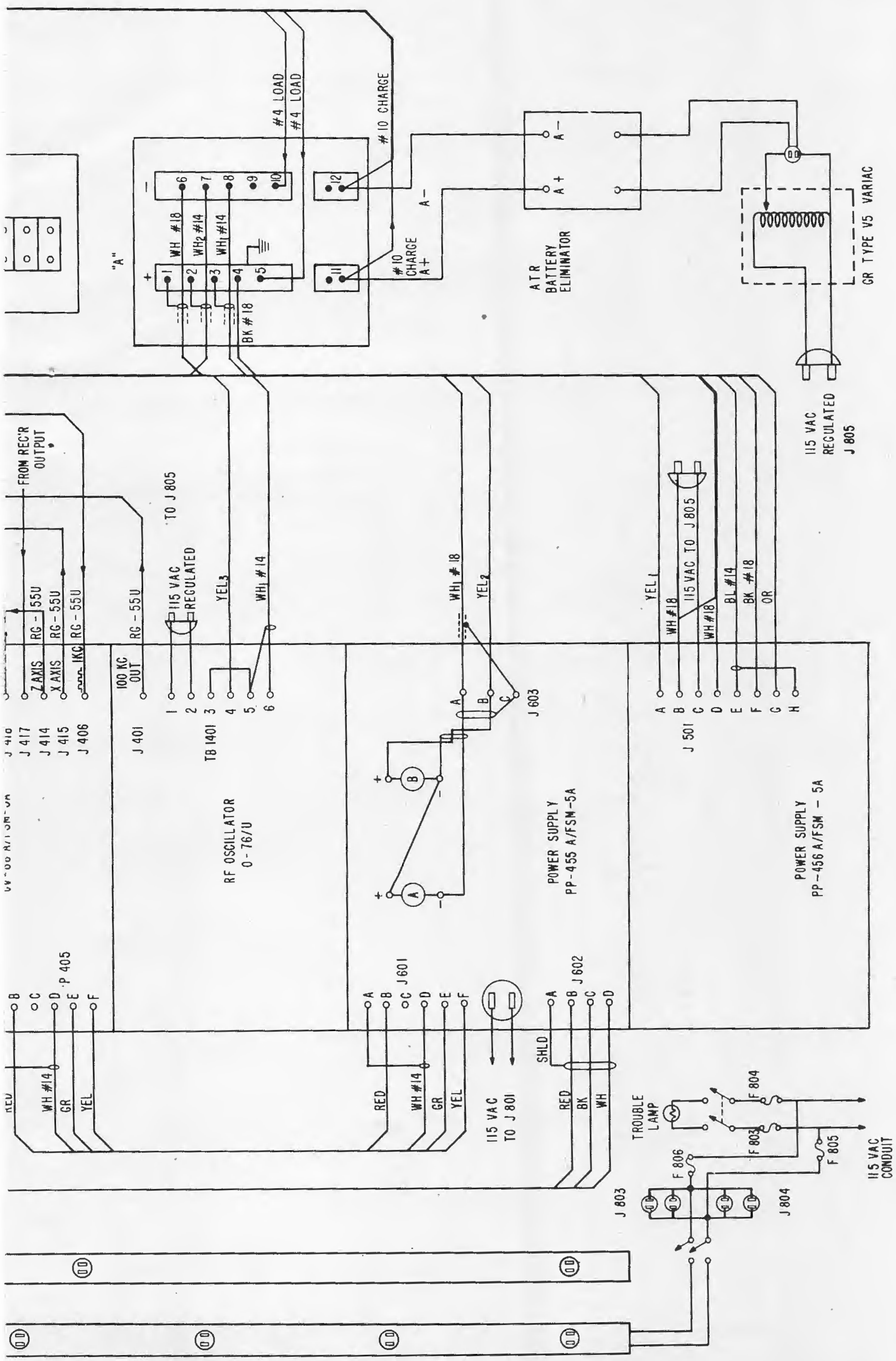


Figure 3-6. Schematic Diagram Showing Interconnection Between Assemblies of Time Standard

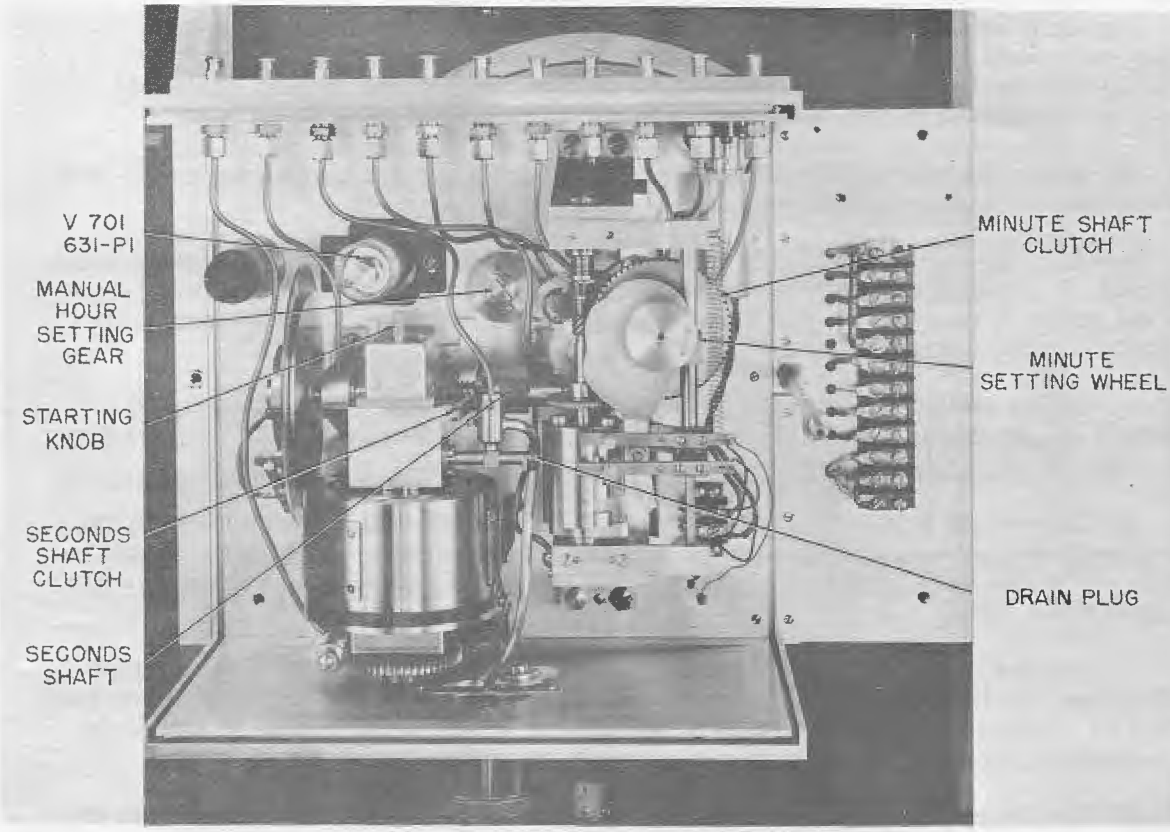


Figure 3-7. Rear View of Clock

<u>CAUTION</u>—When the unit is received, the plug will be screwed in but the reservoir will be empty.

After a two-minute warmup, the frequency divider is started by momentarily closing first the 10 KC START and then the 1 KC START micro switches. A one-kc tone should be audible from the clock assembly. When the tone has been audible for about five minutes, the clock motor should be started. To do this, remove the rear cover by loosening the two hold-down nuts and slide the cover back and off. The starting knob (Figure 3-7) is grasped between the thumb and forefinger and twirled in a clockwise direction.

<u>CAUTION</u>—the knobs on the clock must be rotated only in the direction indicated.

This procedure may have to be repeated several times before the clock starts. The glass disc to the left of the starting knob will rotate continuously when the motor is running. The hour and minute hands of the clock should be set to the approximate correct time according to the procedure for setting the clock (Section 4, paragraph 10). This procedure is used to determine any gross errors in the clock.

## 8. OPERATION CHECK

No accurate adjustments should be attempted until the time standard has been operating at least 24 hours or preferably somewhat longer, since the quartz crystal in the r-f oscillator[1] requires that length of time to stabilize. During this 24-hour period the units may be checked for proper operation. A quick check may be made as follows:

a. Rotate the METER SWITCH on the r-f oscillator through all nine positions. The meter should read about half-scale.

b. Turn the oscilloscope on by means of the power switch located on the front panel. Manipulate INTENSITY, FOCUS, AND POSITION controls until a small spot is obtained in the center of the screen. The X and Y gain controls should be set in the maximum counterclockwise position.

c. Set the SWEEP SELECTOR switch to INT, SYNC SELECTOR to INT, FREQ RANGE to 10K-25K, and FINE FREQ to the midposition. Advance X GAIN until a sweep is obtained.

d. Connect the Y INPUT, J201A, to the 100-kc auxiliary-output jack, J103, on the frequency-divider assembly by means of a patch cord. Advance the Y GAIN. Several cycles of a sine wave should be visible. (Auxiliary output jack locations are shown in Figure 6-1.)

e. Connect the X INPUT, J202A, of the oscilloscope to the 10-kc auxiliary output, J104, from the frequency divider by means of a patch cord and set the sweep selector to the EXT position. A Lissajous pattern, as shown in Figure 3-8A, should be visible on the scope.

f. Disconnect the patch cord from the 100-kc auxiliary output and connect it to the 1-kc auxiliary output, J102. A 10:1 Lissajous pattern, as shown in Figure 3-8B, should then be visible on the scope.

g. Turn off the oscilloscope. Remove line power from the rack by turning off the switch on the panel inside the cabinet. The clock should continue to operate when connected to the A and B batteries. Restore power by turning on the switch. The clock should continue to run. For reliable operation, the A and B batteries which are connected to the time standard should be kept fully charged.

## 9. TIME CHECK

After the 24-hour warmup period has been allowed, the clock may be set accurately and checked. The procedure for accomplishing this is outlined in Section 4.

The U. S. Naval Observatory provides precise time signals and information helpful in operating the time standard. Publications and weekly correction sheets of the Naval Observatory may be obtained from:

The Superintendent of the Naval Observatory, Washington 25, D. C.

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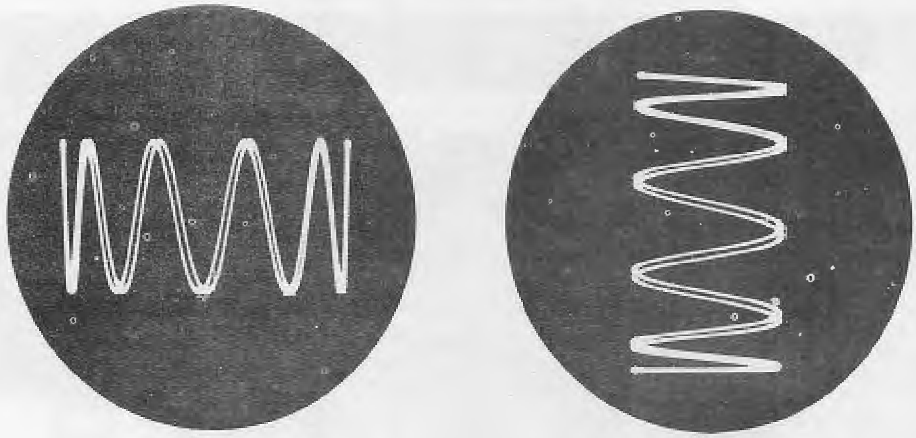
[1] Bell Telephone Laboratories, "D-175730 Frequency Standard," Instruction Bulletin No. 1198, Issue No. 1



(A) X FREQUENCY: 10 KC
Y FREQUENCY: 100 KC

(B) X FREQUENCY: 10 KC
Y FREQUENCY: 1 KC

Figure 3-8. Lissajous Patterns

## 10. SETTING THE CLOCK

The proper procedure for setting the clock (Figures 3-7, 3-8, and 3-9) follows:

### Hour Hand

Using the long wrench from the accessory box in the cabinet, place the smooth end with the two holes in it over the gear shown in Figure 3-9 so that the pins on the gear engage the holes in the wrench. Rotate the wrench counterclockwise (facing the clock from the rear). In this way advance the hour hand to the correct hour. The mechanism is equipped with a detent which can be felt; this must be engaged. Each time the wrench is rotated from one detent position to the next, the hour hand is advanced one hour. Remove the wrench and return it to the accessory box. The hour hand may also be advanced by advancing the minute hand.

### Minute Hand

Depress the lever with a finger of the right hand, (Figure 3-10), and rotate the knurled knob in the direction of the arrow engraved on it. The thumb should hold down the contact carrier block. When the knob has been rotated a fraction of a turn, release the lever and continue turning the knob until a distinct click is heard; the lever is then engaged. The knob should not be allowed to swing around of its own accord. The minute hand is advanced one minute between detents. Continue the process until the hand is at the desired position. The minute and hour hands should be set about one minute ahead of the correct time.

CAUTION—DO NOT SET MINUTE HAND EXCEPT WHEN THE CODE DRUM IS NEAR THE 29-SECOND POSITION. At other times the quartz points may be caught in the code-drum recesses, thus damaging the clock contacts. The safe period is from about 20 to 40 seconds of each minute.

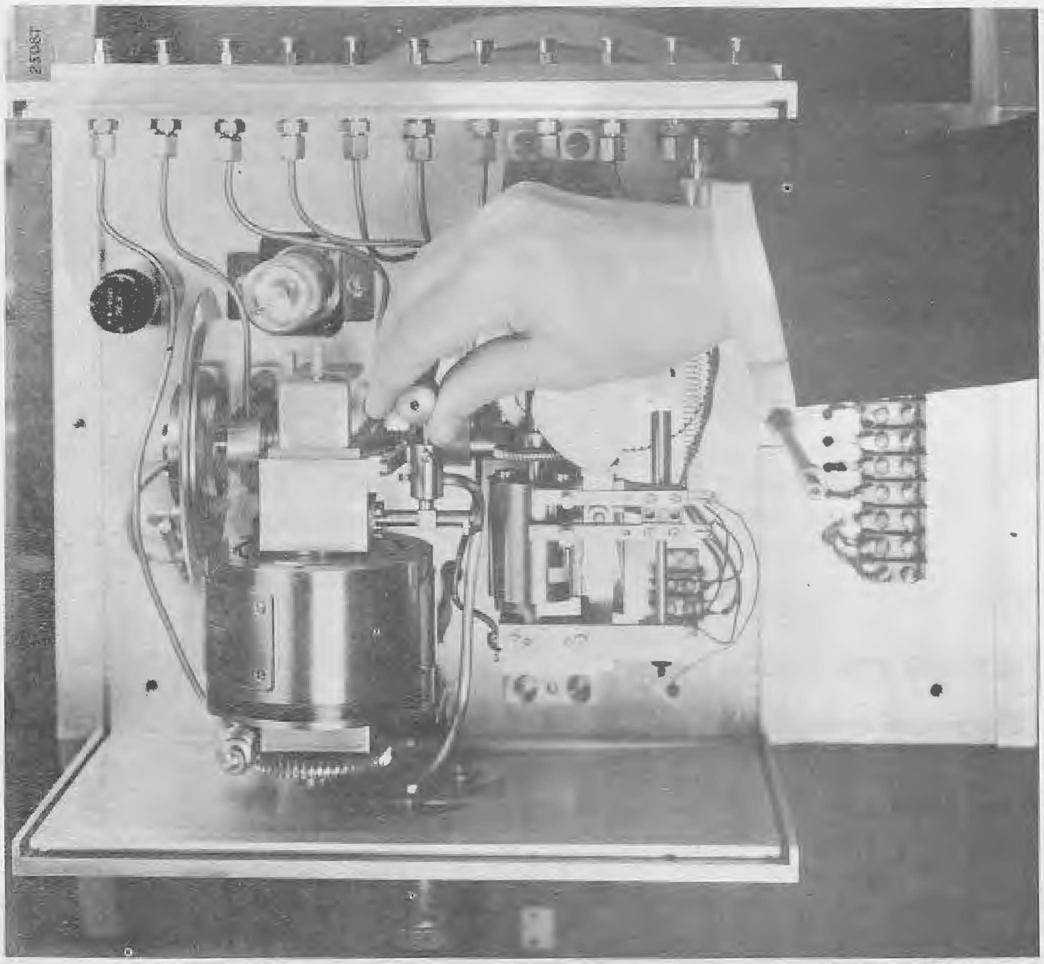


Figure 3-9. View of Clock Showing Hour-Hand Setting Procedure

Second Hand

The actual amount that the clock is ahead of true time should be determined in seconds. The clutch lever (Figure 3-11) should be moved to the right; at the same time (not before) the knurled portion of the drive shaft should be contacted with the finger so that a light drag is obtained on the shaft sufficient to stop it from rotating. It is possible to hear the clock tick, and these ticks should be counted until the number is the three less than the number of seconds the clock is fast. For example, if the clock is 26 seconds fast, 23 ticks should be counted. At this time, the clutch lever should be released and the drag on the shaft should be removed immediately. If the drag is maintained after the clutch has engaged, the clock will be stalled.

The clock should now be within a few seconds of correct time. If it is more than one-half second fast, the foregoing procedure for setting the second hand should be repeated. Apply light pressure to the shaft and momentarily disengage the clutch by moving the lever to the right and then releasing. Retain pressure on the shaft until a click is felt; then release pressure from the shaft immediately. Repeat this process as necessary. The clock should now be correct to within one-half second or less.

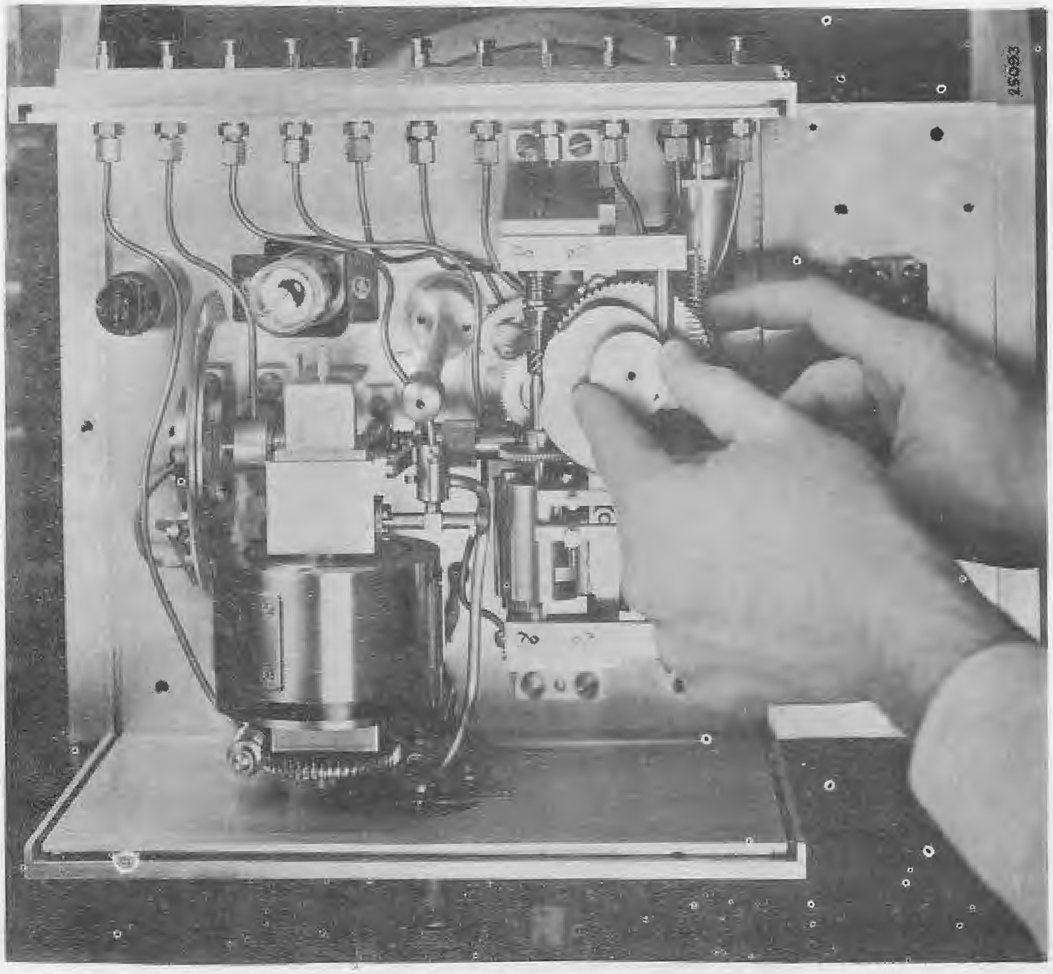


Figure 3-10. View of Clock Showing Minute-Hand Setting Procedure

Time Comparator

To set the clock to the exact time, first refer to the procedure for setting up the time comparator (Section 4). The received radio time signal appears on the face of the oscilloscope. The setting of the millisecond delay dials will depend on how much the clock is ahead of the standard time signal. Retard the clock by means of the FAST-SLOW switch on the frequency divider by holding it in the slow direction until the leading edge of the standard time signal appears at the beginning of the 100-cycle intensified sweep. The dials should be set at 9-9-10 or Z-Z-Z, the zero delay position for the final adjustment.

## 11. CALCULATION OF DELAY

The clock should be set for zero delay if there is no appreciable distance between the transmitter of the standard time signal and the receiver. Under other circumstances, a time delay which is dependent upon the distance between the transmitter and the receiver must be considered. For low frequencies, it may be calculated by means of

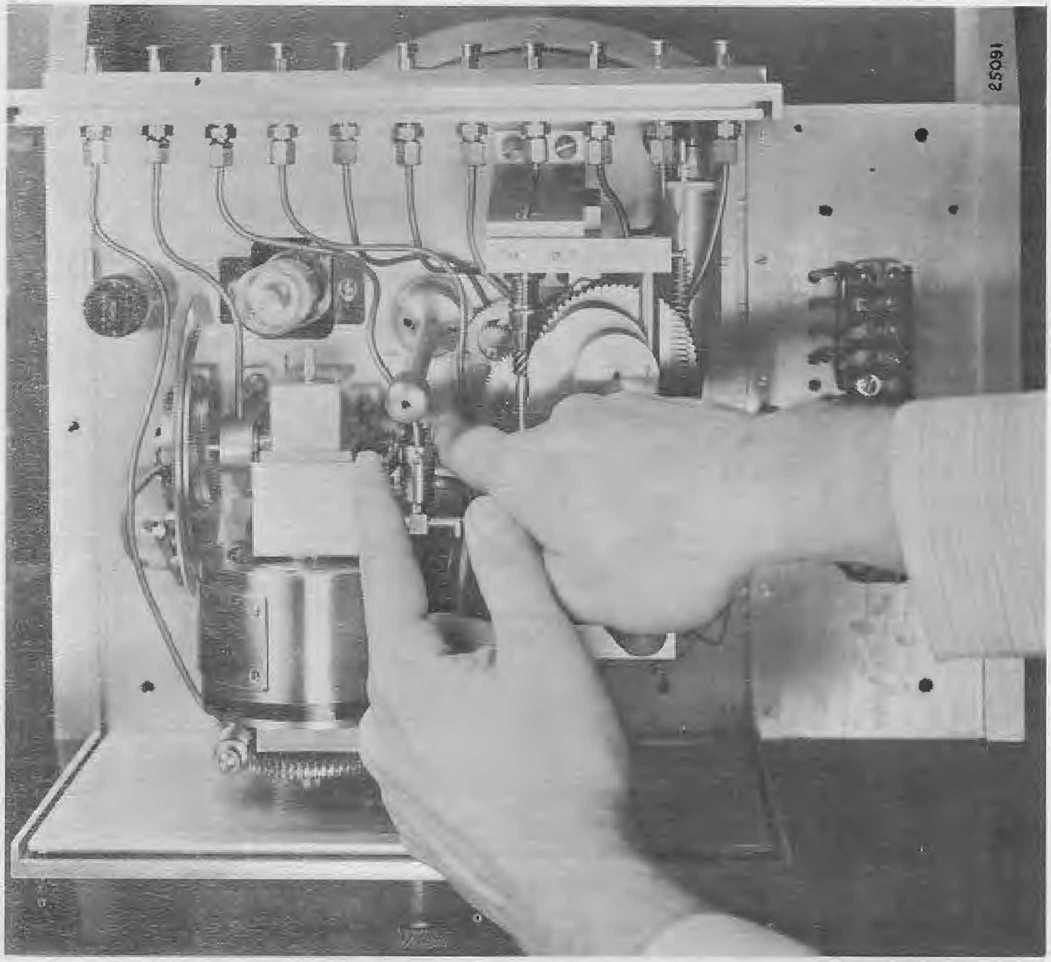



Figure 3-11. View of Clock Showing Second-Hand Setting Procedure

the following formula:

$$t = \frac{d}{161.88} = 0.006177d$$

where d is the distance between the two stations in nautical* (airline) miles and t is the delay in milliseconds. (The $\log_{10}$ of 161.88 is 2.209204.) The time delay for the various transmitters should be calculated and entered in Table 3-1 for convenient reference. This delay may vary temporarily as a result of propagation disturbances, but will average out over a period of time.

Thus, if the delay is calculated to be six milliseconds, the dials should be set at the zero delay position and the CLOCK MS switch held closed in the "fast" or "slow" position until the leading edge of the oscilloscope presentation of the standard time signal coincides

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*Geographical distances may be calculated by use of the U. S. Hydrographic Office publication, H.O. No. 211.



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with the sixth millisecond time marker on the intensified 100-cycle sweep. (Refer to Section 4 for more complete information.)

TABLE 3-1
Propagation Delay

| Station | Freq (kc) | Distance (naut. mi.) | Delay (ms) |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

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# SECTION 4
# OPERATION

## 1. GENERAL CONSIDERATIONS

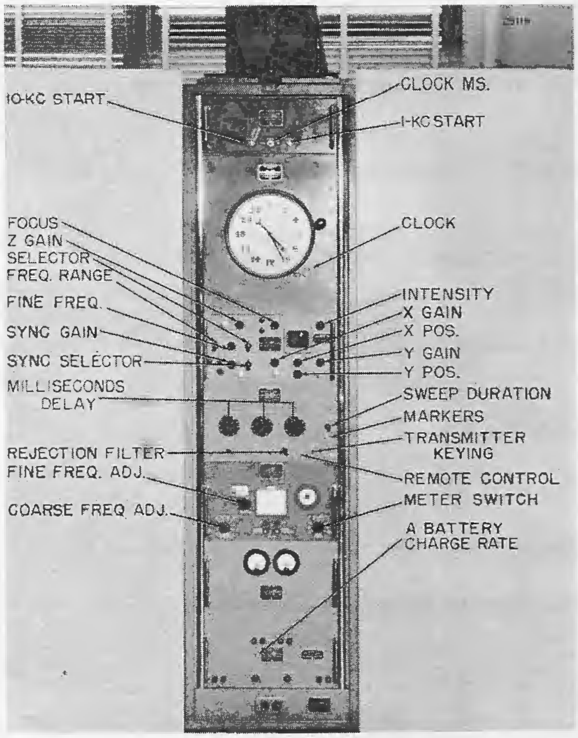
### Operating Conditions

Since the time standard is designed for continuous operation, power should not be removed from the oscillator and clock circuits unless absolutely necessary. Because of the long time required for stabilization of the oscillator, it is important that it be maintained in continuous operation.

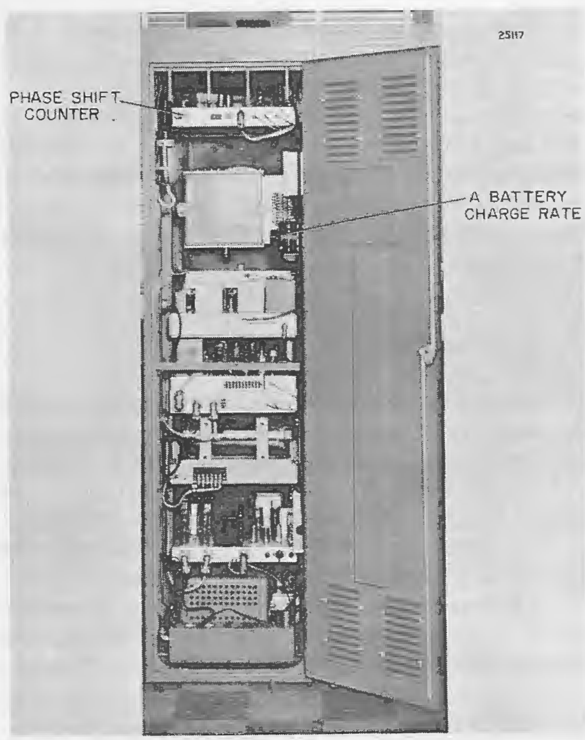
### Function of Controls

The location of operating controls is shown in Figure 4-1; their functions are listed as follows:

| CONTROL | FUNCTION |
|---|---|
| REMOTE CONTROL | Sets remote clock |
| Z GAIN | Controls intensity modulation of oscilloscope |
| FOCUS | Controls focus of oscilloscope spot |
| INTENSITY | Controls brightness of oscilloscope spot |
| FREQ. RANGE | Sets range of oscilloscope internal-sweep frequency |
| FINE FREQ. | Sets fine adjustment of internal-sweep frequency |
| SELECTOR | Selects the internal sweep, the 60-cycle line voltage, or an external-sweep voltage |
| SYNC GAIN | Controls internal-sweep synchronizing voltage |
| SYNC SELECTOR | Selects the internal sync, the 60-cycle line voltage, or an external sync |
| X GAIN | Controls horizontal size of oscilloscope image |
| X POS | Causes oscilloscope image to move to left or right |
| Y GAIN | Controls vertical size of oscilloscope image |
| Y POS | Causes oscilloscope image to move up or down |
| FILTER SELECTOR | Selects 440- or 600-cycle rejection filter or straight-through operation |




(a) Front View




(b) Rear View

Figure 4-1. Location of Controls in Time Standard



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| CONTROL | FUNCTION (Cont.) |
|---|---|
| FINE FREQ. ADJ. | Adjusts frequency of r-f oscillator in steps of one part in $10^9$ |
| COARSE FREQ. ADJ. | Adjusts frequency of r-f oscillator in steps of four parts in $10^6$ |
| METER SWITCH | Connects meter to various parts of r-f oscillator for observation of operation |
| MILLISECONDS DELAY | Delays intensified sweep relative to time-standard keyer output |
| SWEEP DURATION | Selects 100- or 10-ms sweep voltages |
| MARKERS | Turns markers on and off |
| CLOCK MS | Retards or advances clock and keyed time signal |
| TRANSMITTER KEYING | Turns transmitter keying signal on and off |

## 2. TIME-SERVICE OPERATION

### Clock

The clock is set accurately by means of the CLOCK MS switch while observing a radio standard time signal on the oscilloscope. From the calculations determined in Section 3, the proper setting of the delay dials can be ascertained. This number, which remains constant, provides a correction for the difference in time between the transmission and reception of the signal; the number should be entered in Table 3-1 for a given installation. The clock is set by closing the CLOCK MS switch in one direction or the other until the leading edge of the radio standard time signal on the oscilloscope appears coincident with the proper marker on the intensified sweep cycle selected by the millisecond delay dials.

### R-F Oscillator

During the first few months the time standard is in operation, the clock should be checked every day. If a constant trend is apparent over a period of a week, the r-f oscillator should be corrected. The following example will illustrate this procedure.

Assume that the clock has been found to be five milliseconds fast each day and that it has been corrected each time it was checked. The error is five milliseconds in 24 hours or 57.9 parts per $10^9$ (Table 4-1). The fine frequency adjustment on the oscillator[1] therefore is set 57.9 divisions lower.

After the time standard has been in operation for several weeks, the error may not follow a constant trend; instead, the clock may vary between fast and slow time. This situation is normal, and the oscillator should not be adjusted to correct for this condition.

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[1] Bell Telephone Laboratories, "D-175730 Frequency Standard," Instruction Bulletin No. 1198, Issue No. 1

TABLE 4-1
Oscillator Corrections

| Change in Observed Time (ms per day) | Frequency Correction | |
|---|---|---|
| | (parts per $10^6$) | (parts per $10^9$) |
| 0.1 | 0.001157 | 1.157 |
| 0.2 | 0.002314 | 2.314 |
| 0.5 | 0.005785 | 5.785 |
| 1.0 | 0.01157 | 11.57 |
| 2.0 | 0.02314 | 23.14 |
| 3.0 | 0.03471 | 34.71 |
| 4.0 | 0.04628 | 46.28 |
| 5.0 | 0.05785 | 57.85 |
| 6.0 | 0.06942 | 69.42 |
| 7.0 | 0.08099 | 80.99 |
| 8.0 | 0.09256 | 92.56 |
| 9.0 | 0.1041 | 104.1 |
| 10.0 | 0.1157 | 115.7 |
| 11.0 | 0.1273 | 127.3 |
| 12.0 | 0.1388 | 138.8 |
| 13.0 | 0.1504 | 150.4 |
| 14.0 | 0.1620 | 162.0 |
| 15.0 | 0.1736 | 173.6 |
| 20.0 | 0.2314 | 231.4 |
| 25.0 | 0.2893 | 289.3 |
| 30.0 | 0.3471 | 347.1 |
| 40.0 | 0.4628 | 462.8 |
| 50.0 | 0.5785 | 578.5 |
| 60 | 0.6942 | 694.2 |
| 70 | 0.8099 | 809.9 |
| 80 | 0.9256 | 925.6 |
| 90 | 1.041 | 1041.0 |
| 100 | 1.157 | 1157.0 |
| 150 | 1.736 | 1736.0 |
| 200 | 2.314 | 2314.0 |
| 250 | 2.893 | 2893.0 |
| 300 | 3.471 | 3471.0 |
| 350 | 4.050 | 4050.0 |
| 400 | 4.628 | 4628.0 |
| 450 | 5.207 | 5207.0 |
| 500 | 5.785 | 5785.0 |
| 600 | 6.942 | 6942.0 |
| 700 | 8.099 | 8099.0 |
| 800 | 9.256 | 9256.0 |
| 900 | 10.410 | 10410.0 |
| 1 sec | 11.570 | 11570.0 |

Time Comparator

To measure the delay in the reception of a standard time signal, the output from a radio receiver tuned to NSS or WWV is connected to the filter input, J416. The oscilloscope SELECTOR switch is set in the EXT position, and the Z- and X-outputs from the time comparator are connected to the jacks, J205A and J202A.

Turn the oscilloscope Y GAIN and Z GAIN controls fully counterclockwise, and adjust the INTENSITY control so that the sweep is barely visible. Then, decrease the intensity until the trace just disappears. Now, rotate the Z GAIN control so that the intensified sweep is bright and sharp (adjustment of the FOCUS control may be required). Increase the Y GAIN and set the SWEEP DURATION switch in the 100-ms position. Turn the MARKER switch on and rotate the 0-100 milliseconds delay dial until the leading edge of the time signal is visible on the sweep. Then, rotate the 0-10 milliseconds delay dial until the leading edge of the standard time signal is bracketed in the first 10-ms marker interval. Turn the time-comparator SWEEP DURATION switch to the 10-ms position. The delay of the received standard time signal, expressed in milliseconds, is then equal to the MILLISECONDS DELAY dial readings added to the number of marker intervals from the beginning of the sweep to the leading edge of the signal. Since there is small error introduced by the filter, all readings should be made with the REJECTION FILTER switch in the OFF position.

As an example (Figures 4-2 and 4-3), consider that this delay is 165 ms and that the computed propagation time is 20.2 ms. In this case, the CLOCK MS switch is thrown to the "slow" position and held closed until the delay of the radio time signal is 20.2 ms, as indicated by the MILLISECONDS DELAY dials and scope markers. The dials should be set so that the leading edge of the radio time signal does not coincide with the left-hand end of the trace. The reason for this is that the fly-back time delays the beginning of the sweep by a small but indeterminate amount which results in splitting the first marker in two; one half occurs at each end of the sweep. This procedure synchronizes the one-second keying signal from the time standard with the one-second standard radio time signal. The REMOTE CONTROL switch on the time comparator is used in synchronizing a remotely located clock. As the oscillator frequency drifts, it will be necessary to synchronize the time-standard signal with the radio time signal by use of the CLOCK MS

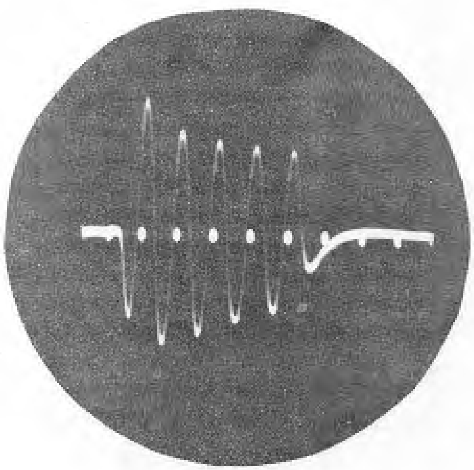

Figure 4-2. Scope Presentation of Radio Time Signal



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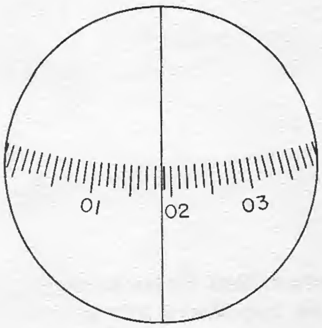


Figure 4-3. Image of Time Scale as Seen Through Microscope Eyepiece

switch. Hence, a record of the phase-shift counter reading on the frequency divider and a record of the time-comparator measurement must be kept. The methods by which synchronism may be maintained are discussed in Section 5.

The counter-decade operation should be checked periodically by means of the strobotron. To make this check, the **MILLISECONDS DELAY** dials should be set in various positions and the number appearing at the hairline in the clock microscope eyepiece should be compared with the delay-dial readings. If the decades are operating properly, the microscope and dial readings should agree to ±1 ms.

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# SECTION 5
# METHODS OF UTILIZATION

## 1. INSTALLATION LOCATION

At most naval shore communication centers such as Pearl Harbor, San Francisco, Balboa, and Washington, the transmitters are in one location and the receivers are at some remote point 20 to 30 miles away.

To operate the time standard in this manner, it must be installed in one of three different ways which include

1. Two complete equipments at the receiving site,
2. Two complete equipments at the transmitting site, or
3. One complete equipment at the receiving site and one at the transmitting site.

Method 1 permits easy comparison with all time transmissions and permits the establishment of a rate comparison for both equipments against Naval Observatory Time. However, the landline and/or radio link associated with the keying system for the transmitters does not maintain a constant fixed delay. Random variations, therefore, may cause undesirable transmission errors.

Method 2 would permit accurate keying of the transmitter and would eliminate the random variations caused by landline and/or radio link. All transmitters, however, would have to be shut down during the period when comparison is being made with the remote time transmission from the Naval Observatory.

An alternate procedure would be to transmit the receiver audio output over a circuit from the receiver site to the transmitter site. In this case, the circuit delay must be known each time a comparison is being made.

Method 3 embodies the desirable features of both Methods 1 and 2. The equipment at the transmitter can be used for keying, and no errors from line and/or radio link will be present. The equipment at the receiver site can be used to monitor the transmitter and to rate both equipments from Naval Observatory Time. The standby feature, however, is not as good as that of Methods 1 or 2.

Since only two equipments are available for one communication center, Method 3 appears to be the best method to maintain the oscillator rates properly and to minimize or eliminate keying errors in the system. These conditions of operation are the only ones possible when operating two equipments. For this reason, it is necessary to contend with at least one of the bad features found in each condition of operation. It would be most desirable, therefore, to install two equipments at the receiving site and two at the transmitting site.

## 2. OPERATION PROCEDURE

Any one of these methods requires a communication line and/or radio link between the transmitting station and the receiving site. Under any circumstances, a direct pair of wires is most desirable. For Method 3, these wires can be connected to the 40-volt dc output from TB102 at the receiving site to advance or retard the contacts at the rate of one-millisecond change per second of time. One polarity of the 40 volts advances time; the reverse polarity retards time. In addition, this line can be used simultaneously to carry 1000 cycles from the divider at the receiving site to the transmitting site. By installing an electronic chronograph* at the transmitting site, the oscillator frequency at the transmitting site can be compared with that at the receiving site. This comparison provides a means to rate and thus correct the frequency of the transmitting clock with respect to the clock at the receiving site.

To maintain continuous reliable operation, the equipment at each site should be located in a double-shielded copper room, which is air conditioned at 25°C ±2° with a relative humidity of 40 percent or less. The shield prevents interference from other transmitters at one site or with various receivers at the other site. Air conditioning is essential to maintain the required accuracy.

At the receiving site, both equipments can be rated against Observatory Time only as long as the position of the various phase shifters connected with both systems is known. Therefore, operating personnel must see that all changes are recorded and reported in the proper manner.

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*Leavitt, W. E., "An Electronic Chronograph," NRL Report 4108 (Restricted), February 19, 1953

# SECTION 6
# OPERATOR'S MAINTENANCE

The time standard (Figure 6-1) is a specialized device specifically used to maintain precise time and frequency. Consequently, the maintenance procedures necessarily differ from those applicable to units of similar structure, such as communications equipment.

In maintaining such systems, the usual practice is to remove and test the electron tubes at regular intervals and to replace any tube that shows poor emission or mutual conductance. This procedure is not feasible for certain units of the time standard, because removal of electron tubes or the elimination of primary power will stop the clock and necessitate resetting the hands.

## 1. ROUTINE CHECKS

### Accuracy

The accuracy of the time standard should be checked daily as outlined in Section 4.

### Battery

The specific gravity of the battery electrolyte should be measured periodically with a hydrometer. A table in the instruction book furnished by the battery manufacturer gives the specific-gravity readings for various conditions of charge. Hydrometer readings can also be used to measure the charge rate of the battery; the proper charge rate is the minimum required to maintain a constant specific gravity of the cell electrolyte. Distilled water should be added to the batteries periodically; the amount added per month is also an indication of the charge rate.

The constancy of the A and B voltmeter readings also indicates the charge rate of the batteries. The minimum voltage required to maintain a constant battery voltage (2.15 volts per cell) automatically regulates the proper trickle charge.

To minimize corrosion, the battery posts and cell and cable connectors should be washed with a dilute solution of bicarbonate of soda once a week. They should then be wiped perfectly clean and coated with petrolatum. Even weak battery acid is extremely corrosive, and if any should be spilled or spattered on the battery rack, it should be neutralized immediately with a weak solution of bicarbonate of soda, washed with clean fresh water, and allowed to dry. The instruction book from the battery manufacturer will give necessary information for the proper maintenance of the batteries.

### Time Comparator

Switch each MILLISECONDS DELAY dial on the time comparator to several positions, and observe for each position the number illuminated at the microscope hairline by the strobotron flash. The dials and strobotron reading should agree to within ±1 ms.





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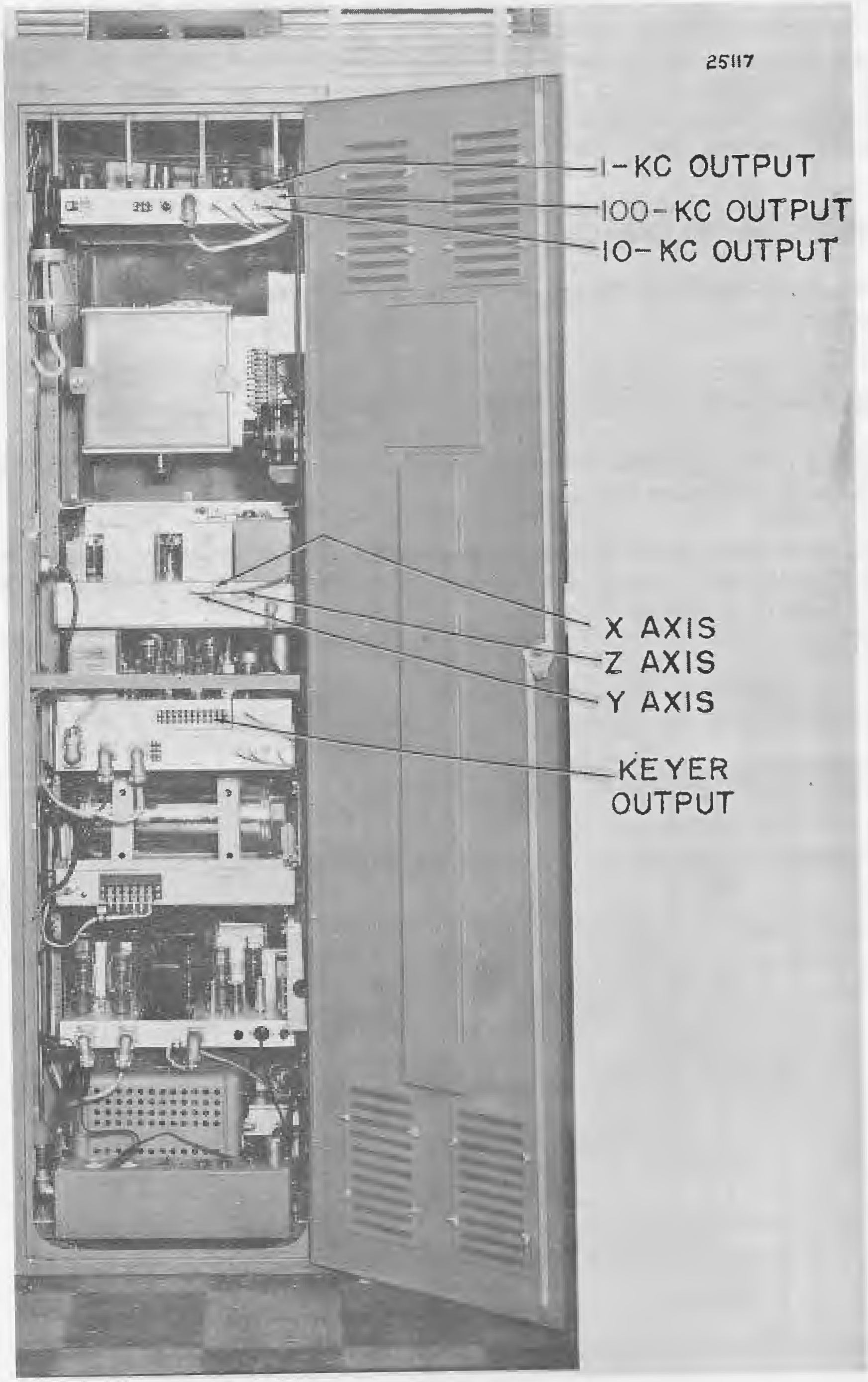


Figure 6-1. Rear View of Time Standard Showing Monitor Jacks

## 2. VENTILATION

Air circulation in the cabinet is regulated by a rear door and adjustable louvers in the top. In cold climates, the openings should be decreased to prevent slow warmup of the electronic components. In warm climates, the louvers should be opened to prevent overheating. If the equipment is installed in an air-conditioned room, repeated adjustment of the louvers is unnecessary. To facilitate the circulation of air, the screens over the louvers must be kept free from dust.

## 3. EMERGENCY MAINTENANCE

Operators shall not perform any of the emergency maintenance procedures without proper authorization.

### Tube Replacement

Tubes that can be replaced without stopping the clock motor or interrupting the standard time and frequency services are

V201 - V213 inclusive (Figure 6-2)
V401 - V419 inclusive (Figure 6-3)
V601 - V611 inclusive (Figure 6-4)
V501 - V503 inclusive (Figure 6-5)
V701 (Figure 6-6)

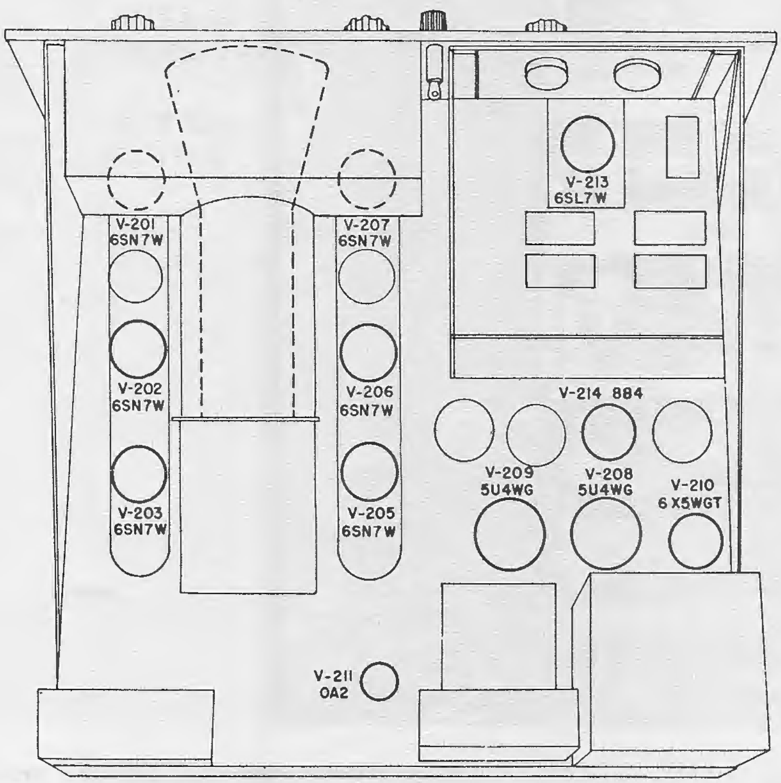


Figure 6-2. Location of Oscilloscope Tubes

To prevent interruption of the standard time and frequency service, Tubes V105, V106, V111, V113, and V116 (Figure 6-7) must be replaced without removing power from the chassis. Replacement of Tubes V101, V102, V103, V104, V107, V108, V109, V110, V112, and V114 (Figure 6-7) and all tubes in the r-f oscillator will interrupt the time and frequency service and require the entire equipment to be shut down.

### Fuse Replacement

<u>WARNING</u>—never replace a fuse with one of higher rating unless continued operation of the equipment is more important than probable damage. If a fuse burns out immediately after replacement (Tables 6-1 and 6-2), do not replace it a second time until the cause has been corrected.

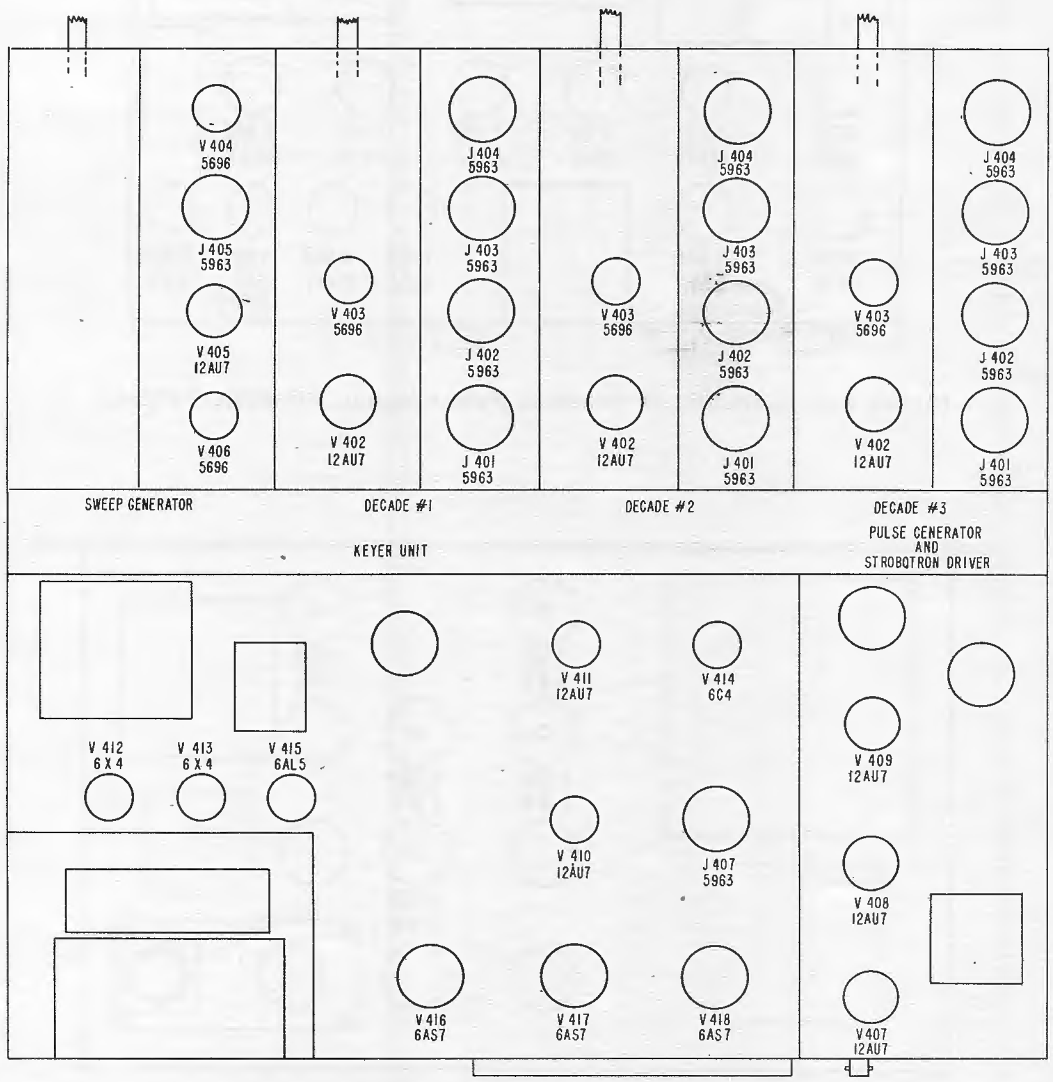


Figure 6-3. Location of Tubes in Time Comparator

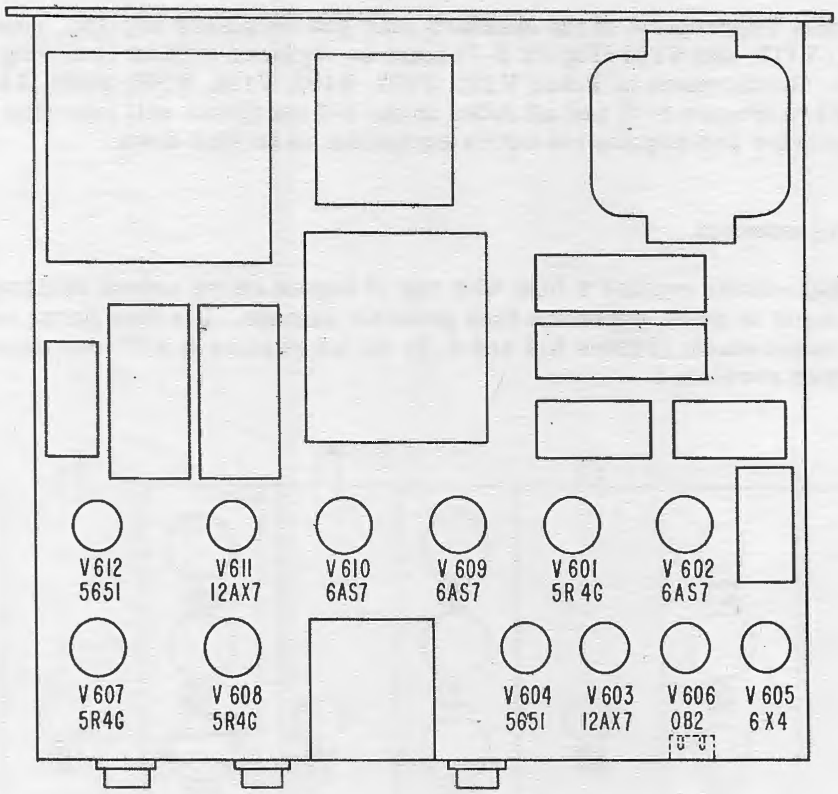


Figure 6-4. Location of Tubes in Power Supply PP-455A/FSM-5A

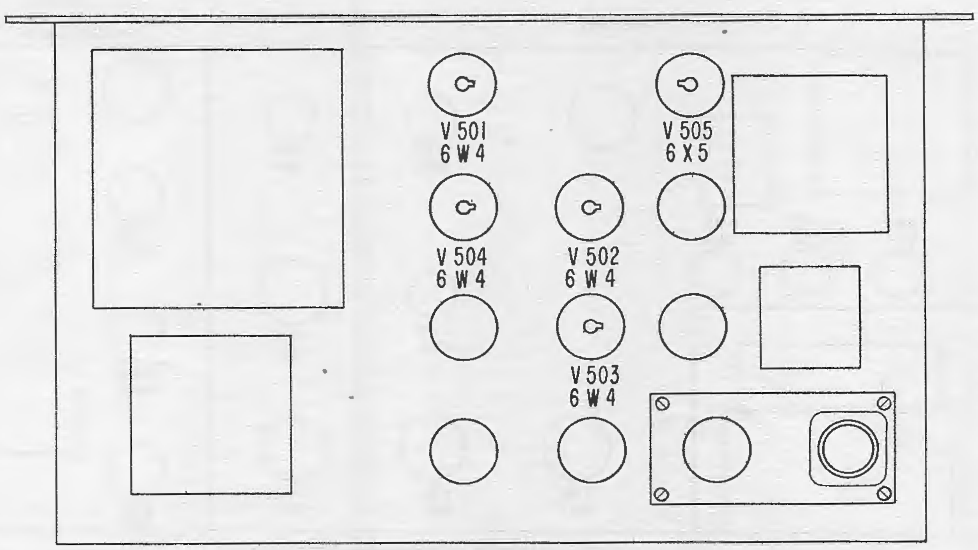


Figure 6-5. Location of Tubes in Power Supply PP-456A/FSM-5A

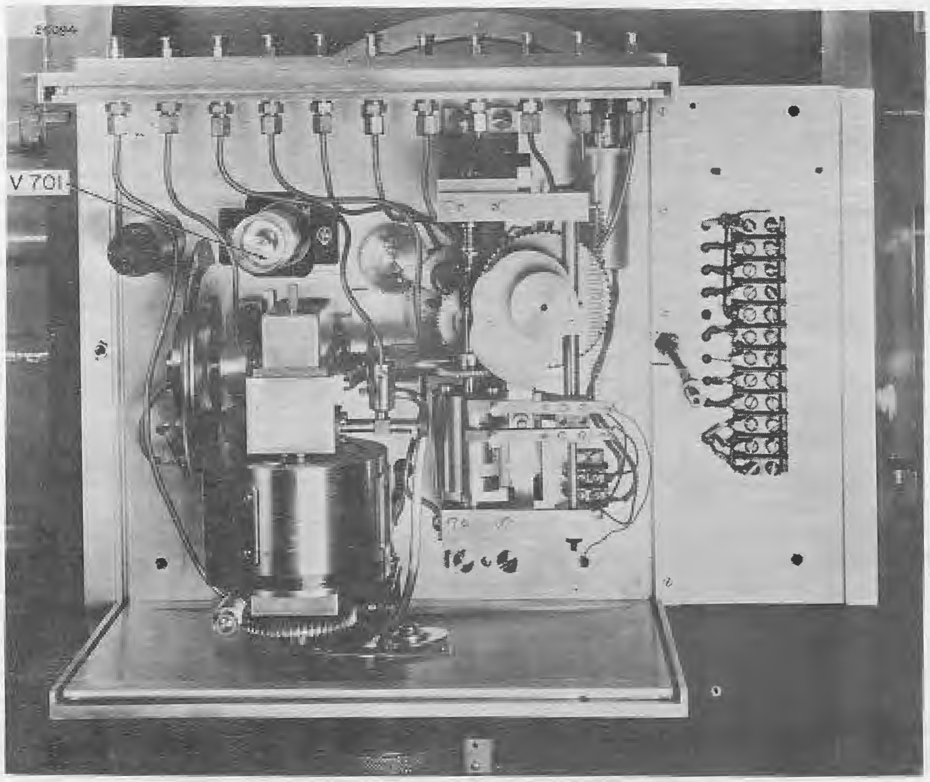


Figure 6-6. Rear View of Clock

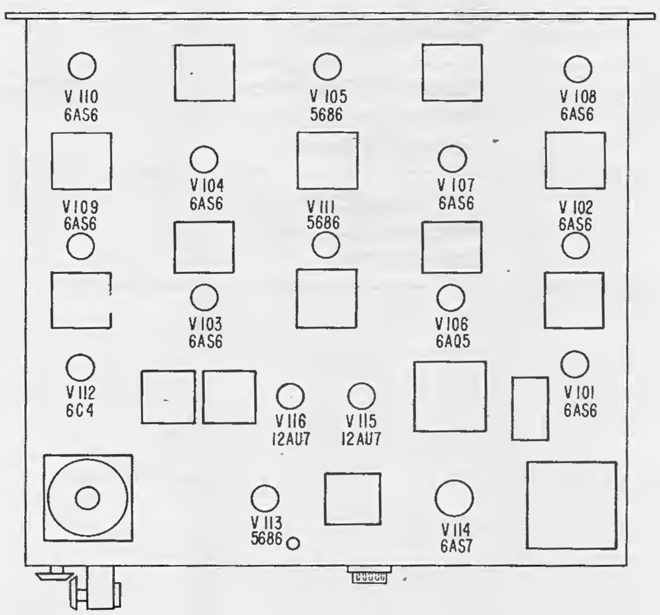


Figure 6-7. Location of Tubes in Frequency Divider



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TABLE 6-1
Fuse Failures

| Defective Unit | Symptoms | Probable Failure in Fuse | Rating (amps) |
|---|---|---|---|
| Oscilloscope | Not Operating | F201<br>F202 | 2<br>2 |
| Time Comparator | Not Operating | F601<br>F602 | 5<br>5 |
| Power Supply PP-455A/FSM-5A | Pilot Lamp Off Frequency Divider and R-F Oscillator Inoperative | F501<br>F502 | 5<br>5 |
| Power Supply PP-456A/FSM-5A | Auxiliary Circuit in the Frequency Divider Inoperative | F503<br>F504<br>F505 | 5<br>5<br>5 |
| Trouble Light | Not Operating | F803<br>F804 | 1<br>1 |
| Time Standard | Not Operating | F806<br>F805 | 15<br>15 |
| R-F Oscillator | Heater-Power Fuse Alarm Lights (may not light immediately) | F1401 | 1 |
| R-F Oscillator | Clock Not Operating. Plate-Supply Fuse Alarm Lights | F1402 | 1/8 |
| ATR Battery Eliminator | R-F Oscillator and Frequency Divider Inoperative | F801 | 5 |

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TABLE 6-2
Location, Use, and Rating of Fuses

| Fuse | Unit | Location | Protects | Rating | | Serial Number |
|---|---|---|---|---|---|---|
| | | | | (amps) | (volts) | |
| F201<br>F202 | Oscilloscope | Front panel lower left | T201 | 2 | 250 | Buss AGC-2 (3AG) |
| F601<br>F602 | Power Supply PP-455A/FSM-5A | Rear chassis lower right | T601<br>T602 | 2 | 250 | Buss AGC-2 (3AG) |
| F501<br>F502 | Power Supply PP-456A/FSM-5A | Front panel lower right | T501 | 5 | 250 | Buss AGC-5 (2AG) |
| F505 | Power Supply PP-456A/FSM-5A | Front panel lower center | B-batteries | 5 | 250 | Buss AGC-5 (3AG) |
| F503<br>F504 | Power Supply PP-456A/FSM-5A | Front panel lower left | T502 | 2 | 250 | Buss AGC-2 (3AG) |
| F803<br>F804 | Cabinet | Lower right inside wall of cabinet | Trouble light | 1 | 250 | Buss AGC-1 (3AG) |
| F805<br>F806 | Cabinet | Left side of switch panel | Main line | 15 | 125 | Navy 28102-15 |
| F-1401 | RF-Oscillator | Front panel (left) | Heater | 1 | 125 | Fusetron MDL-1 Bussman |
| F-1402 | RF-Oscillator | Front panel (right) | Plate supply | 1/8 | 250 | Slo-blo-fuse #1263 Little fuse |

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SECURITY INFORMATION

# SECTION 7
# PREVENTIVE MAINTENANCE

Since the most effective maintenance work is preventive maintenance,* a periodic examination of the equipment will often prevent troublesome breakdowns. It is not possible, however, to shut down the time standard without interrupting the standard time and frequency services. Therefore, if the equipment should be rendered inoperative through failure of a vacuum tube† or other component, preventive maintenance that cannot ordinarily be performed should then be undertaken, e.g., checking tubes in those units which drive the clock.

WARNING—both line power and battery power must be removed before working on any part of the equipment. Otherwise, dangerous voltages may be encountered.

## 1. CLEANING

The equipment must be kept clean and the emergency storage batteries must be kept free of acid and corrosion.

Dust from the inside of the cabinet may be removed by means of a vacuum cleaner equipped with a flexible rubber nozzle. Do not use compressed air to blow out dirt. No attempt should be made to clean the inside of the clock as the delicate machinery may be damaged. Keep the dust cover in place except when actually adjusting the clock.

## 2. LUBRICATION

Using one drop of the specified lubricant (Table 7-1) in each oil cup except cup no. 3, lubricate the clock periodically according to Figure 7-1. The amount of oil used in cup no. 3 should be just sufficient to cause an overflow into the plastic cup.

TABLE 7-1
Clock Lubricants

| Type of Oil | Federal Stock Catalog Number | Unit Quantity Available | Nearest Commercial Equivalent |
|---|---|---|---|
| Navy Symbol 2135<br>Clock Oil | 14-0-2608 | Quart<br>1/2 oz | SAE 20 Motor Oil<br>None* |

*May be obtained from U.S. Navy Navigational Repair Facility

Once a month remove the clock cover, and using oil no. 2135 on a clean stiff-bristle brush, swab all exposed spiral gears and apply a thin film to the guide of the block that

*The attention of maintenance personnel is invited to the requirements of chapter 67 of the Bureau of Ships manual of the latest issue.

†When testing tubes, the 6X5 rectifiers should be checked carefully for heater-to-cathode leakage or breakdown.

carries the code contacts. Also check freedom of movement of the carrier-block cam roller and lubricate if necessary.

Empty the plastic oil drip cup from time to time as it fills. The oil in it must be discarded. The cup may be removed by turning it one third of a turn counterclockwise.

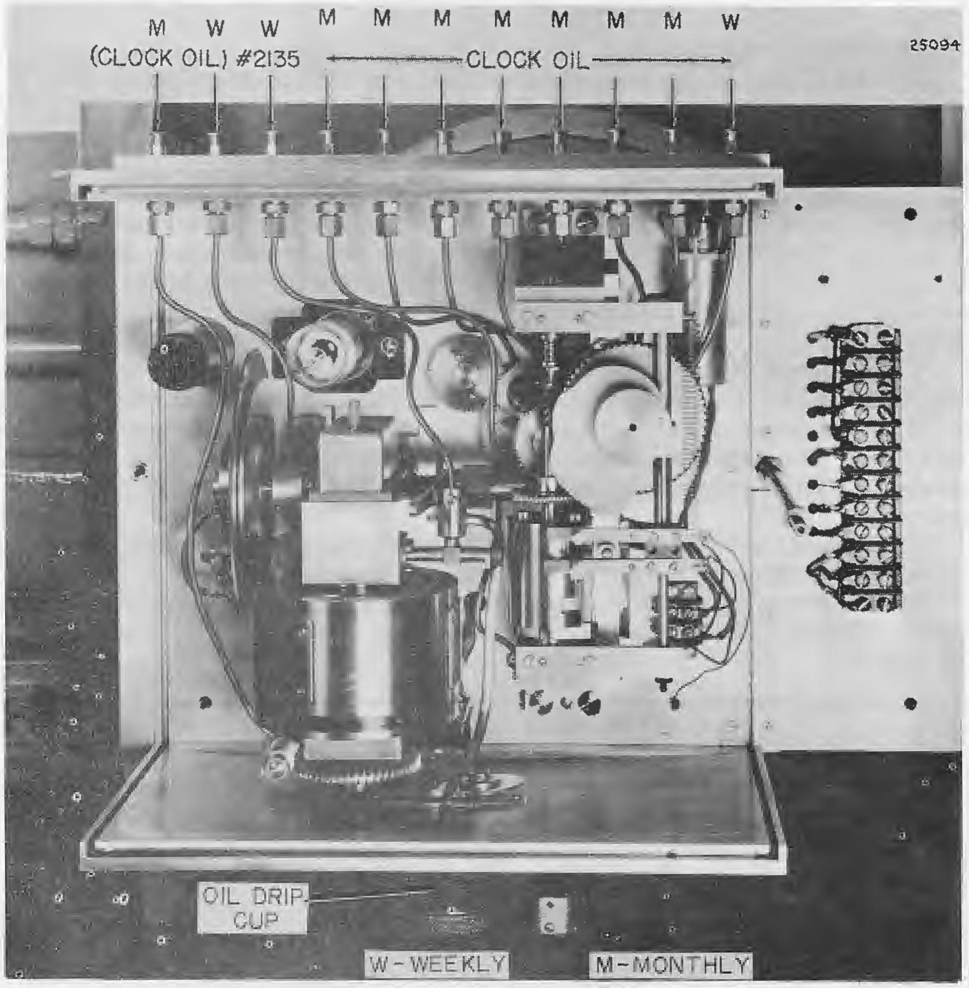


Figure 7-1. Rear View of Clock Showing Lubrication Points and Schedule

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## BUSHIPS

# FAILURE REPORTS

When any part of the equipment fails as a result of defective or worn parts, improper operation, or external influences, a Failure Report card (form NBS-383) must be filled out and forwarded to BUSHIPS in the franked envelope which is provided. Full instructions are found on each report.

In filling out the card, be sure that it carries adequate information. For example, under "Circuit Symbol" use the proper identification taken from the schematic drawings, such as T-803 in the case of a transformer, or R207 for a resistor. Do not sacrifice clarity for brevity. Use the back of the card to give a complete description of the cause of failure, and attach an extra piece of paper if necessary.

The purpose of this report is to inform BUSHIPS concerning the cause and rate of failures. The information is used in the design of future equipment and in the maintenance of adequate supplies necessary to keep the present equipment operating. The cards you send in, together with hundreds of other reports, furnish information which keeps the Bureau advised on the performance of the equipment.

This report is not a requisition. You must request the replacement of parts through your Officer-in-Charge in the usual manner.

Make certain you have a supply of Failure Report cards and envelopes on board. They may be obtained from the nearest district publications and printing office.

# SECTION 8
# CORRECTIVE MAINTENANCE

Corrective maintenance* is interpreted to mean the location and rectification of trouble which has already occurred, i.e., repairs which are not expected of the operator. It is assumed that technical personnel with radio training are available for this work.

## 1. LOCATION OF FAULTS

In tracing faults, an orderly systematic procedure should be followed. Generally, failure of the equipment can be traced without difficulty to one of the major units, and the trouble shooter's first problem is to locate the unit which has failed.

After the difficulty has been traced to one of the major units (time-comparator assembly, clock, etc.), the technician should proceed in a series of logical steps to further isolate the cause of the trouble.

In electronic equipment, the most frequent cause of trouble is tube failure. If a fault occurs in the equipment, each tube should be checked immediately and any found low in emission should be replaced with a similar tube. Isolation of the circuit at fault is often helpful in determining the position of a faulty tube.

A check of all fuses should be made immediately if the equipment is inoperative. In case an open fuse is found, it may be an indication that there is an overload in one of the circuits. Replace the fuse with one of the same rating and observe whether or not the replacement fails. An overload may be caused by faulty parts, a short circuit due to a foreign particle, or a bad electrical connection. Short-circuited components may be readily found with an ohmmeter or continuity checker. The dc resistance of various circuits may be checked in order to locate the fault.

When making checks for faults in the equipment, reference to test data is often helpful in isolating the source of difficulty. If the section of the equipment in which the fault occurs can be determined, the trouble may be located with a minimum of effort.

CAUTION—disconnect power before measuring resistance.

Continuity checks and voltage measurement in circuits still operative will be helpful in isolating the trouble. For this purpose, it is necessary to have an ac-dc voltmeter having an internal resistance of not less than 1000 ohms per volt; the meter should be equipped with a battery for continuity and resistance measurement. The oscilloscope is used to locate faults in the signal sections of the equipment.

## 2. TROUBLE SHOOTING

Any irregularities which occur in properly installed equipment will be attributable to misadjustment of one or more of the controls or to the failure of some component. If a fuse fails, the equipment should be examined carefully to locate the cause.

CAUTION—before attempting any repair or adjustment of the time standard, carefully check all input voltages and signals. It is most likely that one of these is at fault.

A trouble-shooting chart (Figure 8-1), mechanical and electrical adjustment locations (Figures 8-2, 8-4, 8-5, and 8-6), chassis-wiring photographs (Figures 8-12 through 8-17),

*Bureau of Ships Manual, Chapter 67

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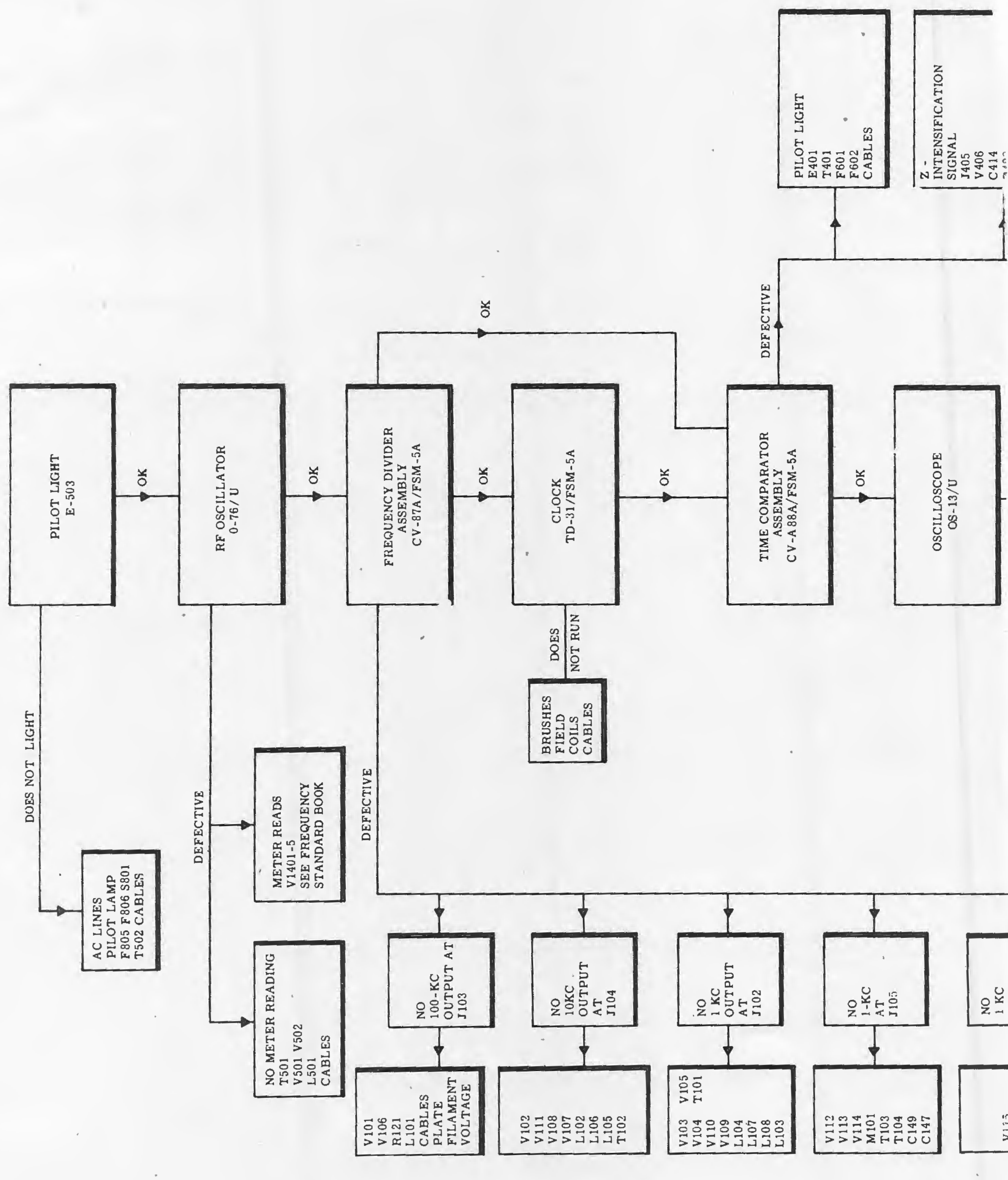




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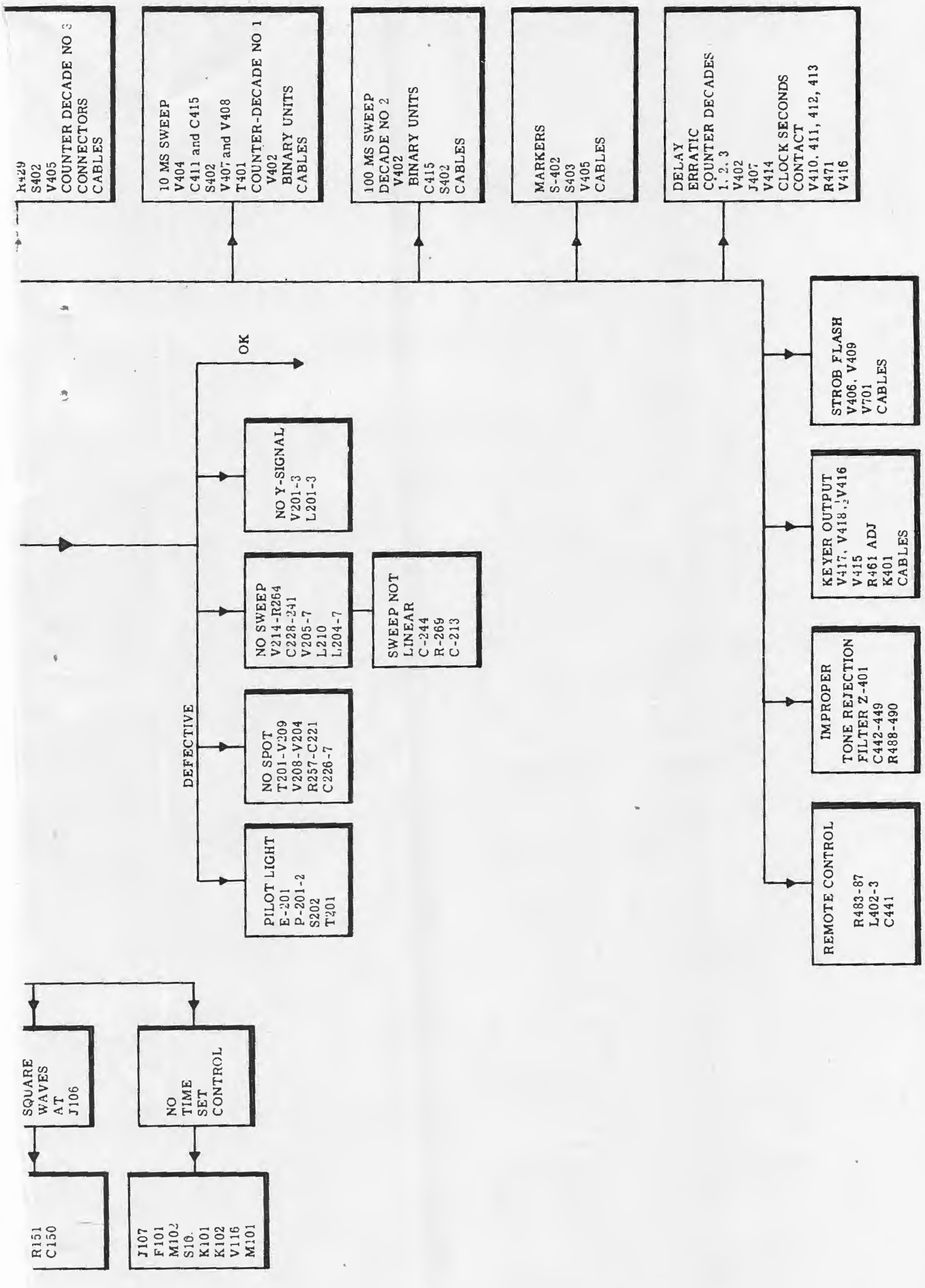


Figure 8-1. Trouble Shooting Chart



ION

and circuit diagrams (Figures 8-18 through 8-27) have been prepared to assist maintenance personnel. Waveforms at various points in the circuit are shown by the oscillograms in Figure 8-29.

## 3. ELECTRICAL ADJUSTMENTS

### Frequency Divider

The frequency-divider tuning condensers are of the fixed-mica or paper type. Generally, no further adjustments are required since the circuit has been tuned. In the event tuning is necessary, a variable-frequency oscillator and the oscilloscope, OS-13/U, are recommended for use. Tuning should be as close as possible, and the calibration of the audio oscillator should be checked at the various frequencies encountered before starting.

The tuning procedure is as follows:

a. With the oscilloscope probe on the grid resistor of V102, apply 100 kc to grid 1 of V101. The plate impedance, Z101, should peak at 100 kc.

b. Remove V107, and with the probe on grid 1 of V108, apply 10 kc to grid 1 of V102. The plate impedance, Z102, should peak at 10 kc.

c. Leave V107 out, remove V102, and with the probe on the grid 1 connection of V107, apply 30 kc to grid 1 of V108. The plate impedance, Z106, should peak at 30 kc.

d. Replace V107, and with V102 out and with the probe on the grid 3 connection of V102, apply 90 kc to grid 1 of V107. The plate impedance, Z105, should peak at 90 kc.

e. Replace V102, and with the probe on J104, apply 10 kc to grid 1 of V111. The plate impedance, Z102, should peak at 10 kc.

f. Apply 10 kc to grid 1 of V103, and with the probe on grid 1 of V104, Z103 should peak at 10 kc.

g. Remove V109, and with the probe on grid 1 of V110, apply 1 kc to grid 1 of V104. The plate impedance, Z104, should peak at 1 kc.

h. Leave V109 out, and with the probe on grid 1 of V109, apply 3 kc to grid 1 of V110. The plate impedance, Z108, should peak at 3 kc.

i. Replace V109; remove V104, and with the probe on the grid 3 connection of V104, apply 9 kc to grid 1 of V109. The plate impedance, Z107, should peak at 9 kc.

j. Replace V104, and with the probe on J102, apply 1 kc to grid 1 of V105. The plate impedance, Z101, should peak at 1 kc.

### Time Comparator

In this assembly (Figure 8-2), which consists of six plug-in units, patch cords are furnished to test the various units.

<u>Pulse Generator and Strobotron Driver</u>—The negative grid bias on the blocking oscillator is adjusted by means of the resistor, R449. If the time comparator is inoperative

or operates erratically, the trouble may be caused by improper bias on the blocking-oscillator tube. The bias is set by means of the screw-driver adjustment of R449. With the oscilloscope probe on the plate of V408B, adjust the bias until stable operation at 1 kc is obtained.

Keyer Unit—Low, transmitter keying voltage and/or incorrect reset of the counter decades (indicated by disagreement between the readings on the switches labeled S401 and the strobotron) may be a result of improper bias on V411. To adjust this bias:

1. Disconnect the clock-seconds-contact connection to the terminal board, TB701.

2. Connect the time comparator lead to the seconds contact on TB701 to ground.

3. Adjust R461 until the maximum keyer output voltage at TB401 as measured by a high-impedance voltmeter, is about 1.0 volt.

4. Reconnect the clock seconds contact to TB701.

If this adjustment does not correct the situation, check the input circuit and binary.

Counter-Decade and Binary Plug-in Units—Spare counter decades and binaries are furnished so that defective ones may be located by substitution. When it has been determined that a particular counter decade is defective, the binary plug-in units associated with the decade should be checked in the binary tester (Figure 8-3).

The neon lamp V421, which is mounted in the lower left-hand side of the panel (looking from the front), is flashed by the multivibrator, V420, at a rate equal to its natural frequency. The output from the multivibrator is a square wave of about 100 volts peak to peak. Adjustment of the potentiometer, R499, varies the square-wave rise time from 1 to 10 $\mu$sec per 90 volts. If the binary, which is inserted in J422, is switching properly, the neon lamp, V422, mounted to the right of V421 and fired by the binary output, should flash at one half the rate of the multivibrator over about 70 percent of the range of R499. If the binary does not switch properly, check the tube and other components.

Even though the binary switches correctly there may be a bad connection between the plug and one or more of the feedback or reset resistors. These connections are checked by inserting the binary in J419 and the test pins of an ohmmeter in the pin jacks, J420 and J421. The resistance for each position of S408 is measured. The correct resistance value for each switch position is shown by the data card on the front panel of the binary tester.

Oscilloscope

Linearity Adjustment—In using the internal sweep, the image is sometimes crowded to one side of the screen as a result of misadjustment of the linearity control, C244 (Figure 8-4). To correct the linearity, apply a rather high frequency sine wave (about 100 kc) to the Y-axis and adjust C244 until the spacing between successive sine waves is uniform. To obtain the best average setting, switch the FREQ RANGE control successively to all positions. It will then be necessary to change the input frequency in order to view the image. The 1-, 10-, and 100-kc auxiliary output jacks on the frequency divider may be used in this test.





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Power Supply PP-455A/FSM-5A

Output Voltage Adjustment—The screw-driver adjustments of the potentiometers, R621 and R606, vary the 450 and 300 supply voltages over a limited range. Normally, no adjustment of these potentiometers will be required since they are set at the correct value by the manufacturer.

## 4. CLOCK ADJUSTMENTS

Maintenance of the clock mechanism by field activities should be confined to lubrication and adjustment or repair of contacts as required. OTHER REPAIRS OR ADJUSTMENTS OF THE CLOCK MOVEMENT WILL NOT BE UNDERTAKEN BY FIELD ACTIVITIES WITHOUT SPECIFIC AUTHORITY OF THE BUREAU OF SHIPS IN EACH INSTANCE (see paragraph 6, Section 8).

Three sets of electrical timing contacts are used in the clock (Figure 8-6). To adjust the code and final-signal contact spacing, fit the end of the small steel spanner wrench into the slots on the contact-screw locking nut and loosen. Make necessary adjustments by means of the knurled contact screw and retighten the locking nut with the spanner wrench.

The contacts are maintained as follows:

a. Seconds contact—operated by the cam mounted on the seconds shaft. When the contact is open, the air gap is approximately 0.01 inch. If the contact surfaces are burned, polish with crocus cloth; if pitted, rotate the lower contact plate slightly.

b. Code contact—operated by the code contact cams and the master cam. When the contact is open, the air gap is approximately 0.01 inch. Polish the contact surfaces periodically with crocus cloth.

c. Final-signal contact—operated by the final-signal cam and the master cam. When the contact is open, the air gap is approximately 0.01 inch. Polish the contact surfaces periodically with crocus cloth.

d. If the code contact does not open and close during the period that the seconds contact is closed, loosen the mounting screws and slide the contact assembly to the right or left as required. Movement to the right causes earlier operation.

e. The final-signal contact should open while the seconds contact is open and should remain open approximately one second to produce the final signal on the hour. To adjust the duration of open contact, move the contact screw in or out; slide the contact assembly to the right or left to adjust the time of contact opening as in (4).

## 5. VOLTAGE AND RESISTANCE MEASUREMENTS

Values of voltage and resistance from each tube-socket terminal to ground are given in Figures 8-7 through 8-11. Similar values measured from terminal board and connector terminals to ground and/or other terminals are given in Table 8-1.

TABLE 8-1
Terminal Voltage and Resistance Measurements

| Jack No. | Pin Number | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 or A | 2 or B | 3 or C | 4 or D | 5 or E | 6 or F | 7 or G | 8 or H | 9 or I | 10 or J | 11 or K | 12 or L |
| J-107 (Battery Discon-nected) | R=800K V=222 | R=0 V=0 | R=0.6 V=6.9 | R=0.2 V=6.0 AC | R = ∞* V=400 | --- | --- | --- | --- | --- | --- | --- |
| J-105 | 180v (1 KC) | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| J-106 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| J-102 | V=2.7 (1 KC) | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| J-104 | V=8.8 (10 KC) | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| J-103 | V=16.0 (100 KC) | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| P-405 | R=0 V=0 | R=60M (B to E 115v ac) | NC | R=0.2 V=7.0 vac | R=70M (Jump E-F to Measure) | R=70M | --- | --- | --- | --- | --- | --- |
| P-406 | R=0.1 V=0 | R=10K V=430 | R=∞ V=-105 | R=9K V=280 | --- | --- | --- | --- | --- | --- | --- | --- |
| TB-1401 | R = ∞ (115v ac Between 1-2) | R = ∞ | R=0 V=0 | R=200K V=150 | R=0 V=0 | R=0.2 V=6.1 | --- | --- | --- | --- | --- | --- |
| TB-701 | R=0 V=0 | R=450K | R=15K V=245 | R=13K V=57 | R=0 V=0 | R=0 or 140K V=0 to -23 | R = ∞ V=0 | R=∞ 115 AC Between 8-9 | R=200M | R=90 V=185 | R=0 V=0 | R=0 V=0 |

*Several MΩ or open

## 6. CLOCK FAILURES

When a clock unit fails and cannot be restored, a deferred message stating the nature of the casualty must be sent to BuShips (Code 910), with an information copy to Superintendent, U. S. Naval Observatory. This will enable BuShips to initiate repair or replacement action if the clock mechanism is affected and will keep the Superintendent informed of the operational readiness of the Time Service System. When the unit is restored, a similar deferred message should be sent.

FIELD ACTIVITIES WILL MAKE NO REPAIRS TO THE MECHANICAL PARTS OF THE CLOCK MOVEMENT, EXCEPT AS HEREAFTER NOTED, WITHOUT SPECIFIC AUTHORITY OF THE BUREAU OF SHIPS IN EACH INSTANCE. When a clock movement fails and cannot be restored by simple adjustment or by local repair of the clock contacts (as set forth in paragraph 4), the following procedure will be undertaken:

a. Upon receipt of a clock-movement failure report, the Bureau of Ships will either cause a qualified instrument maker to be ordered to the station to effect repairs, or will cause a spare clock movement to be shipped at once from the U. S. Naval Observatory.

b. In the event that a complete spare clock movement is shipped to the station, the station force is deemed qualified to remove the defective unit and install the spare. The defective unit will then be shipped to:

Superintendent
U. S. Naval Observatory
Washington 25, D. C.

A copy of all shipping data will be sent to the Bureau of Ships and the U. S. Naval Observatory.

c. Any defective clock movement returned to the U. S. Naval Observatory will be repaired by that activity and placed in store for future issue as a replacement. The spare movement installed at the station will become an integral part of the complete crystal clock unit and will remain so until future repair or overhaul necessitates its removal.

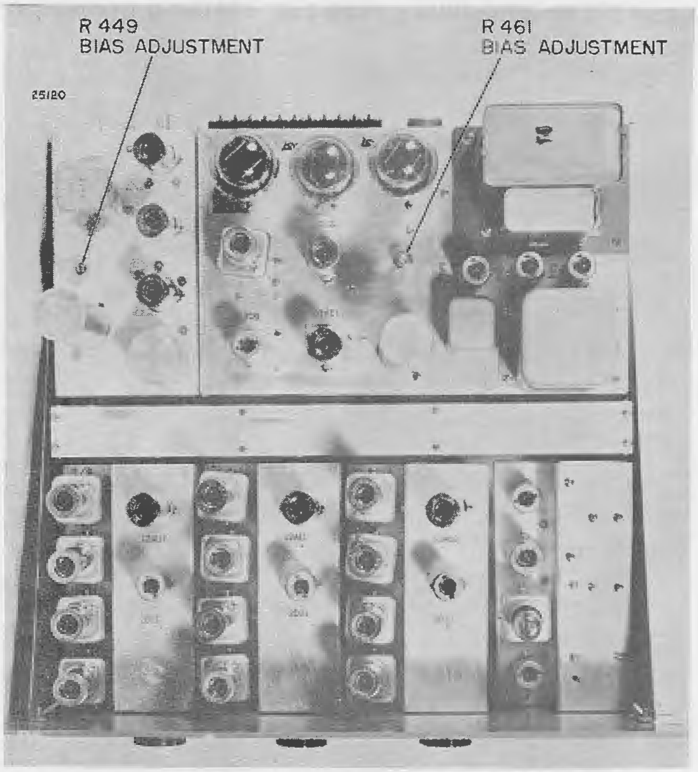


Figure 8-2. Top View of Time Comparator Showing Location of Electrical Adjustments



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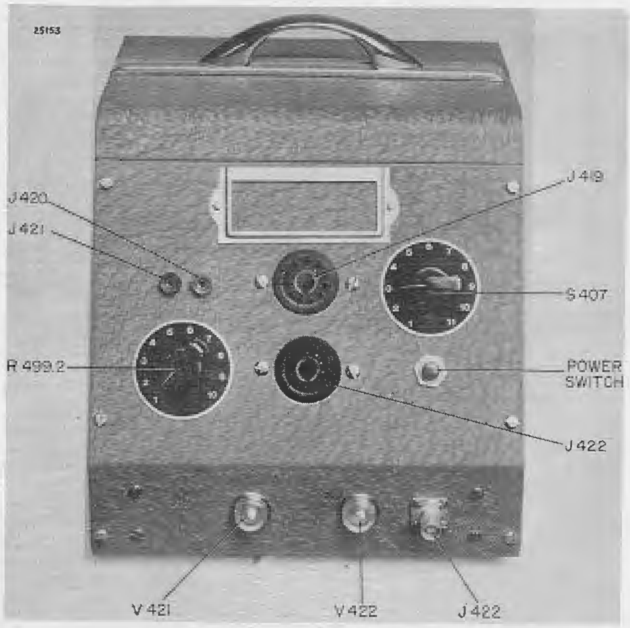


(a) Front View

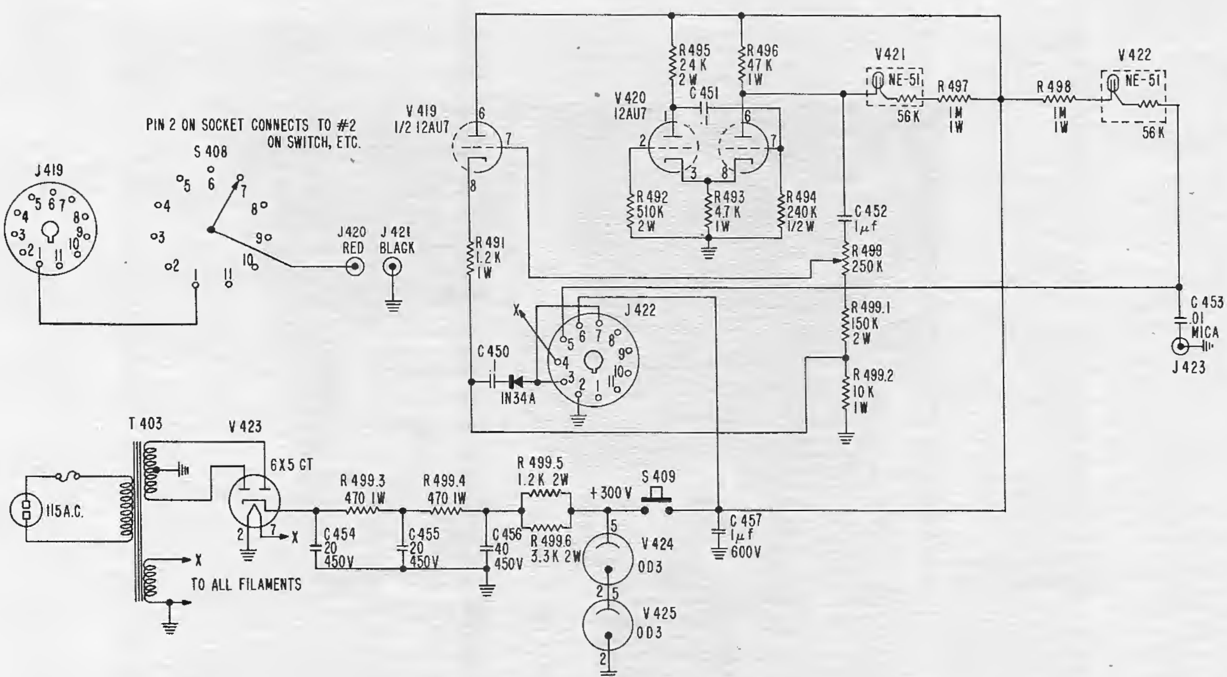


Figure 8-3. Binary Tester

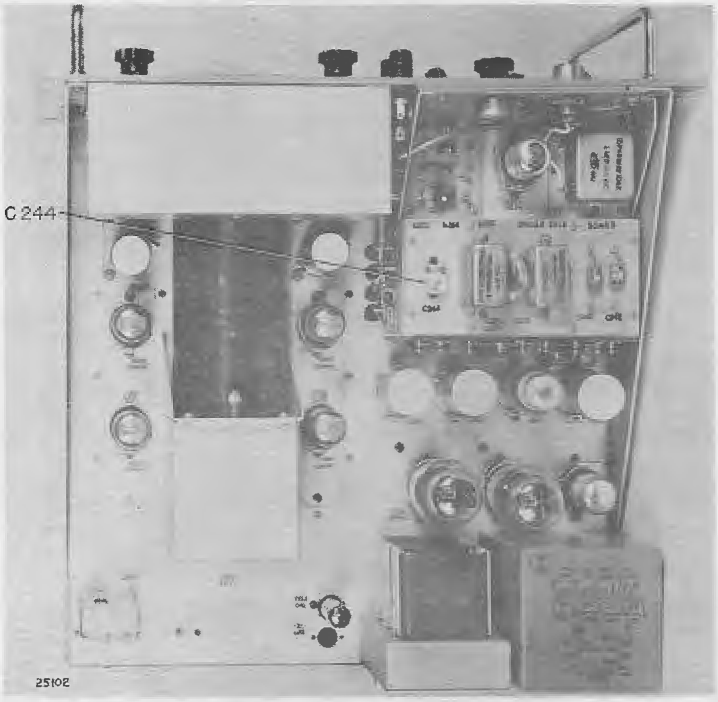


Figure 8-4. Top View of Oscilloscope Showing Location of Electrical Adiustments

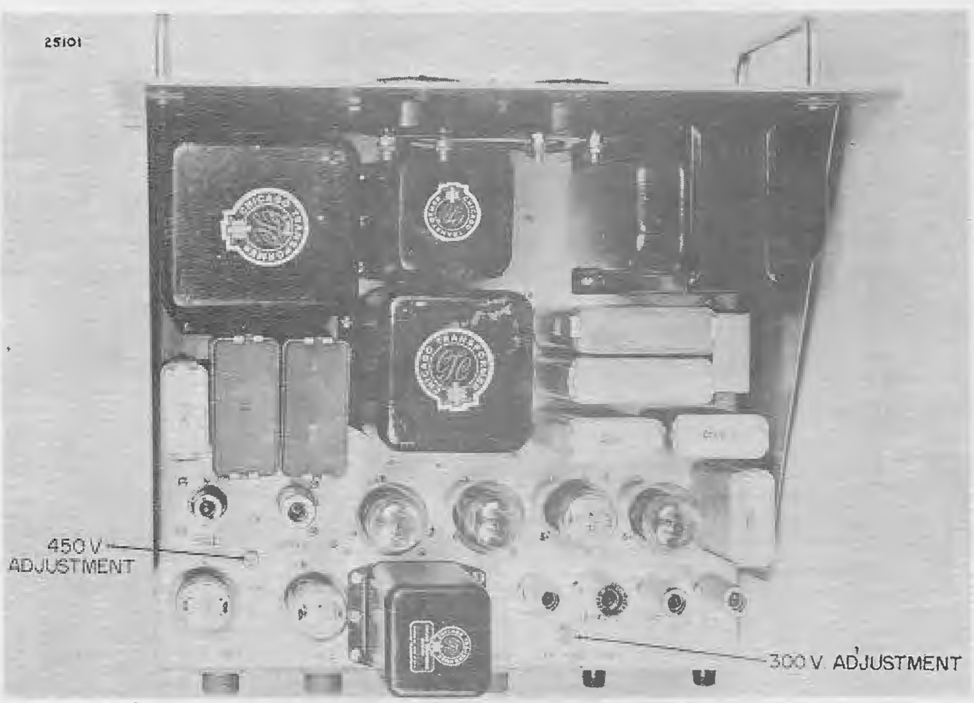


Figure 8-5. Top View of Power Supply PP-455A/FSM-5A Showing Electrical Adjustments



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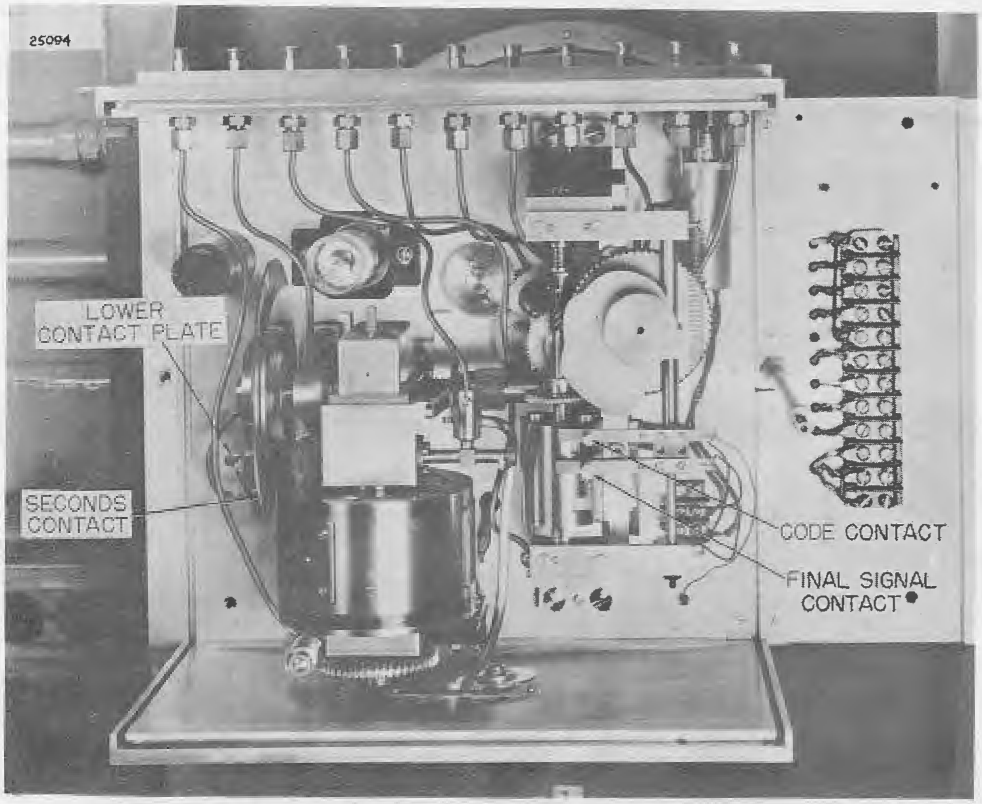


Figure 8-6. Rear View of Clock Showing Contact Adjustments



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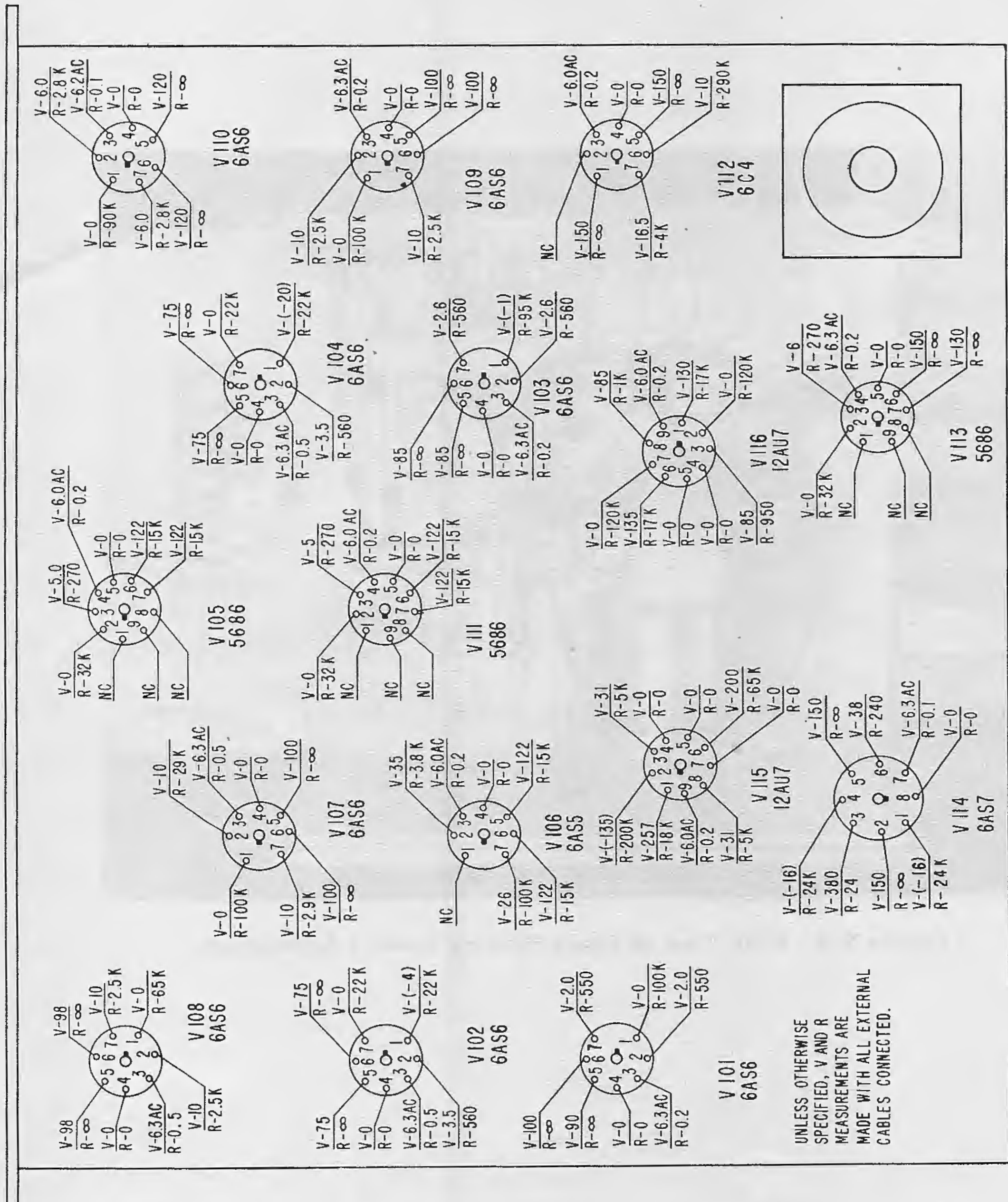


Figure 8-7. Voltage and Resistance Test Points in Frequency Divider





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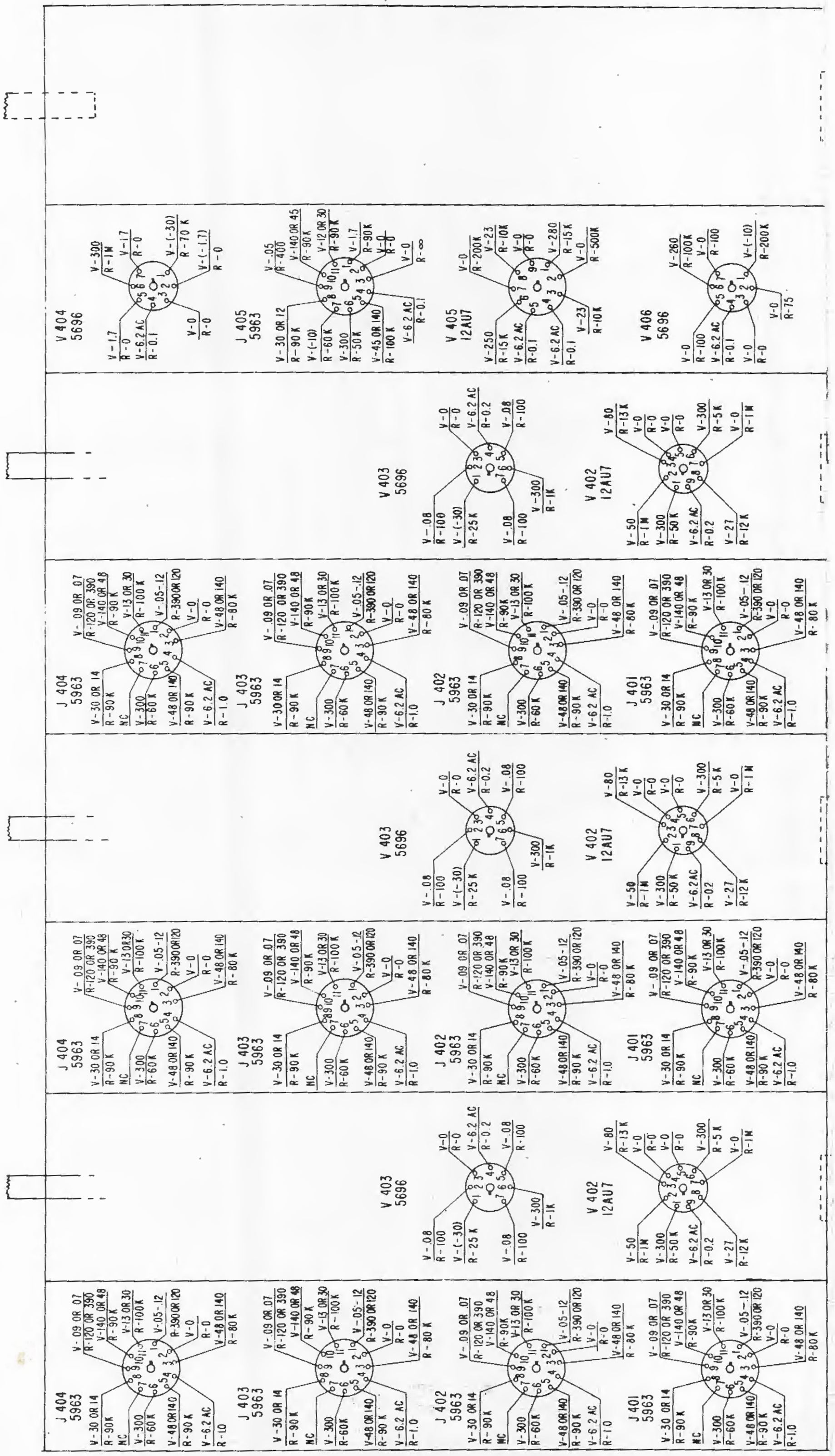


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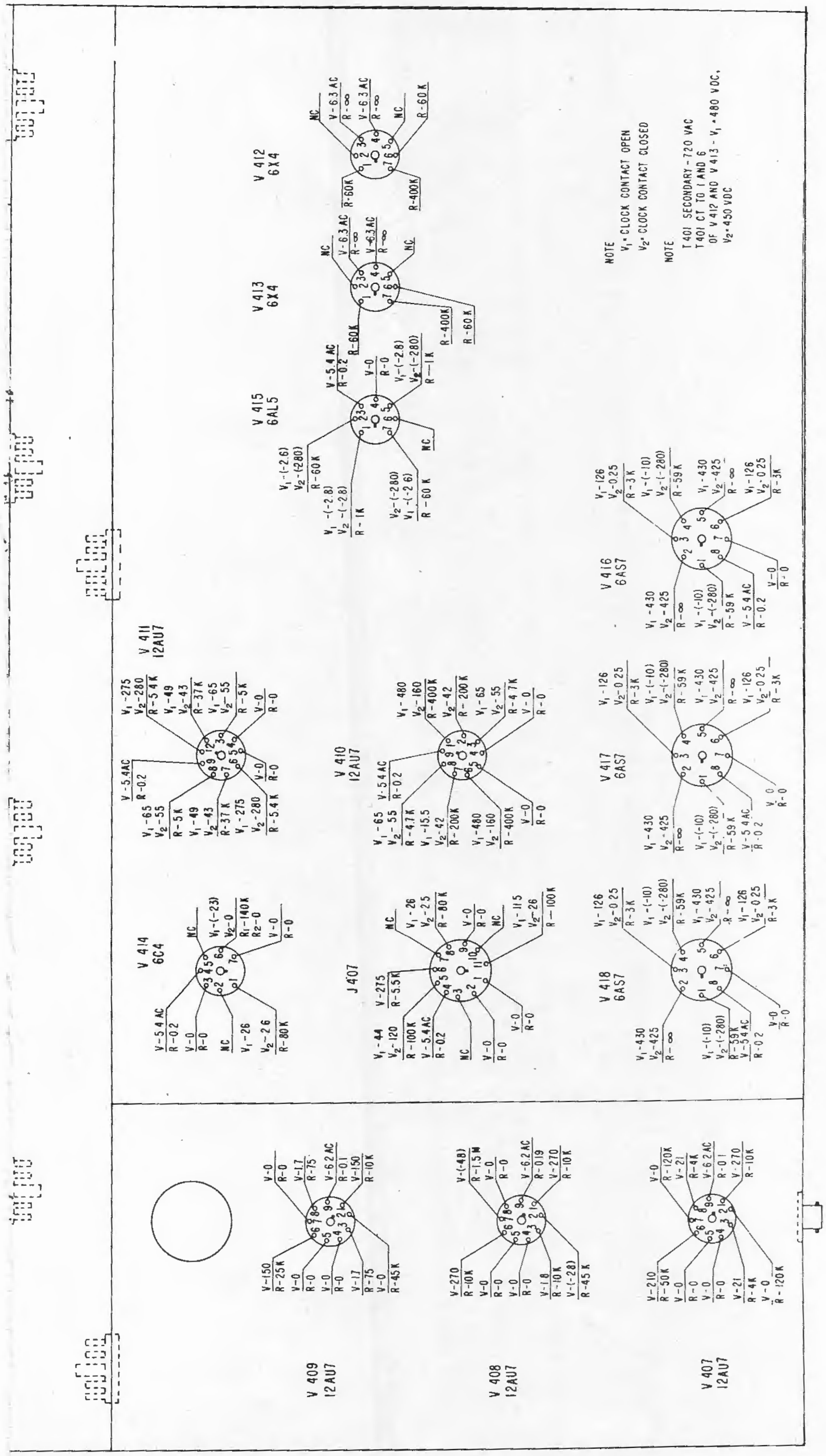


Figure 8-8. Voltage and Resistance Test Points in Time Comparator

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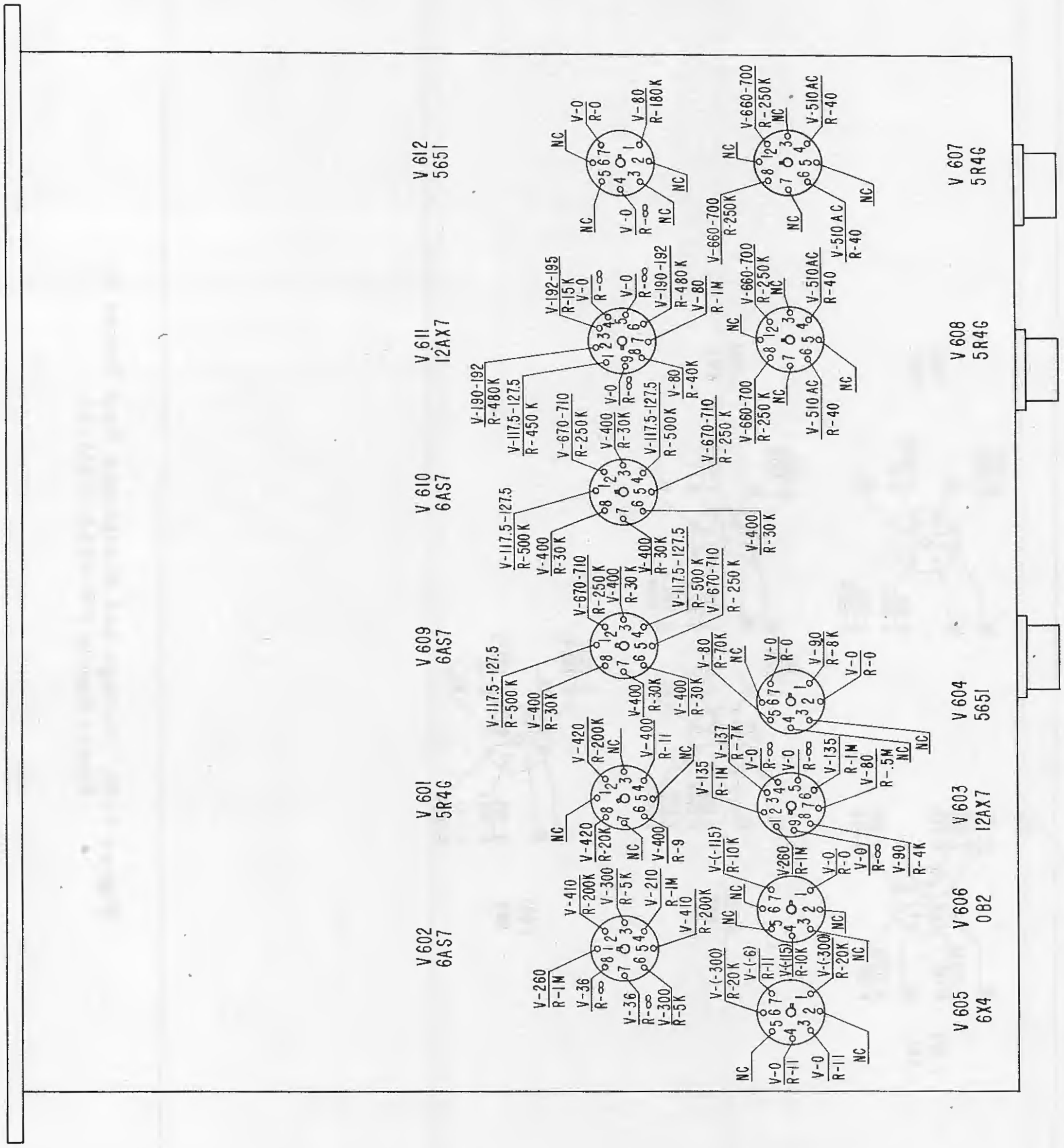


Figure 8-9. Voltage and Resistance Test Points in Power Supply PP-455A/FSM-5A





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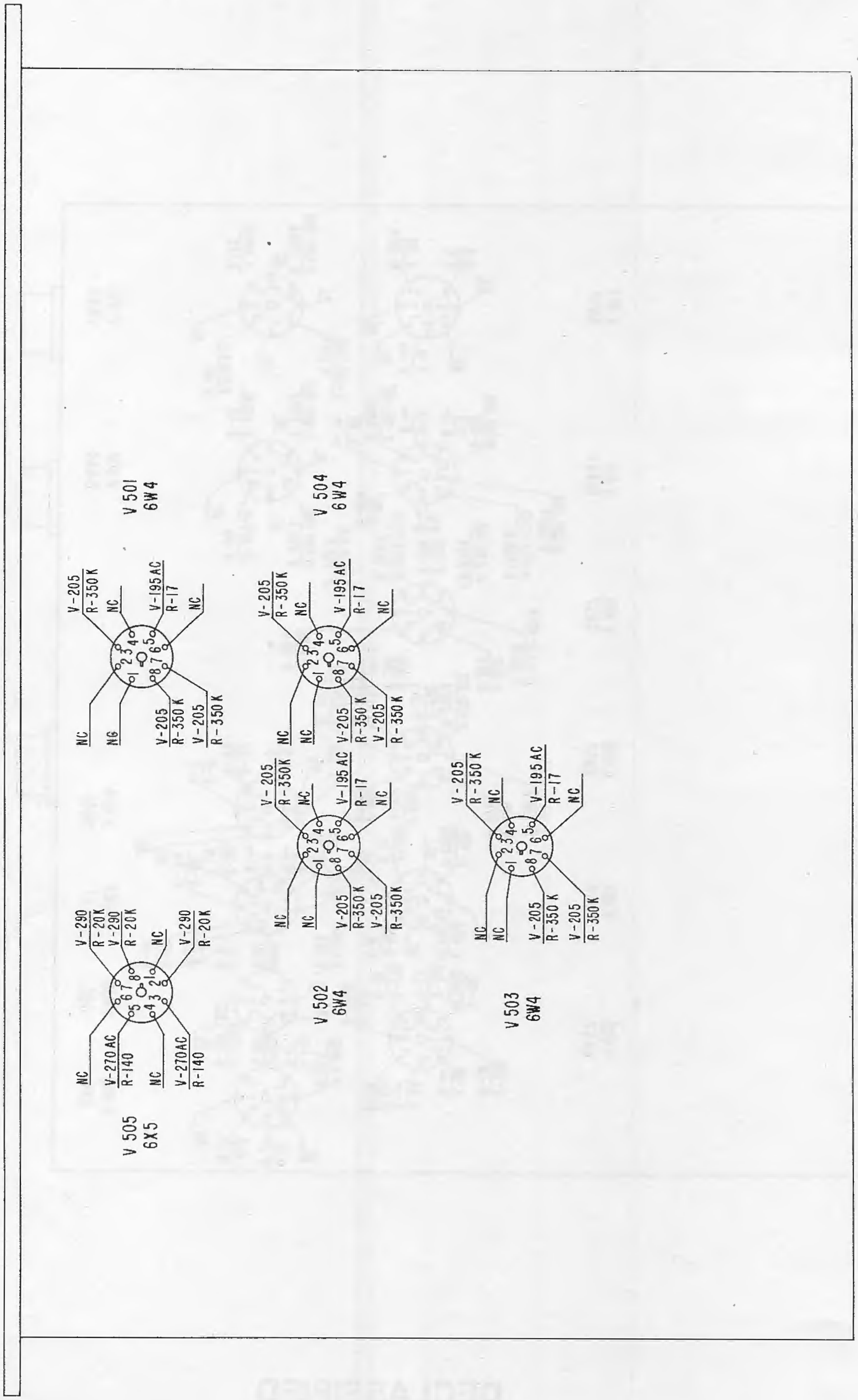


Figure 8-10. Voltage and Resistance Test Points in Power Supply PP-456A/FSM-5A



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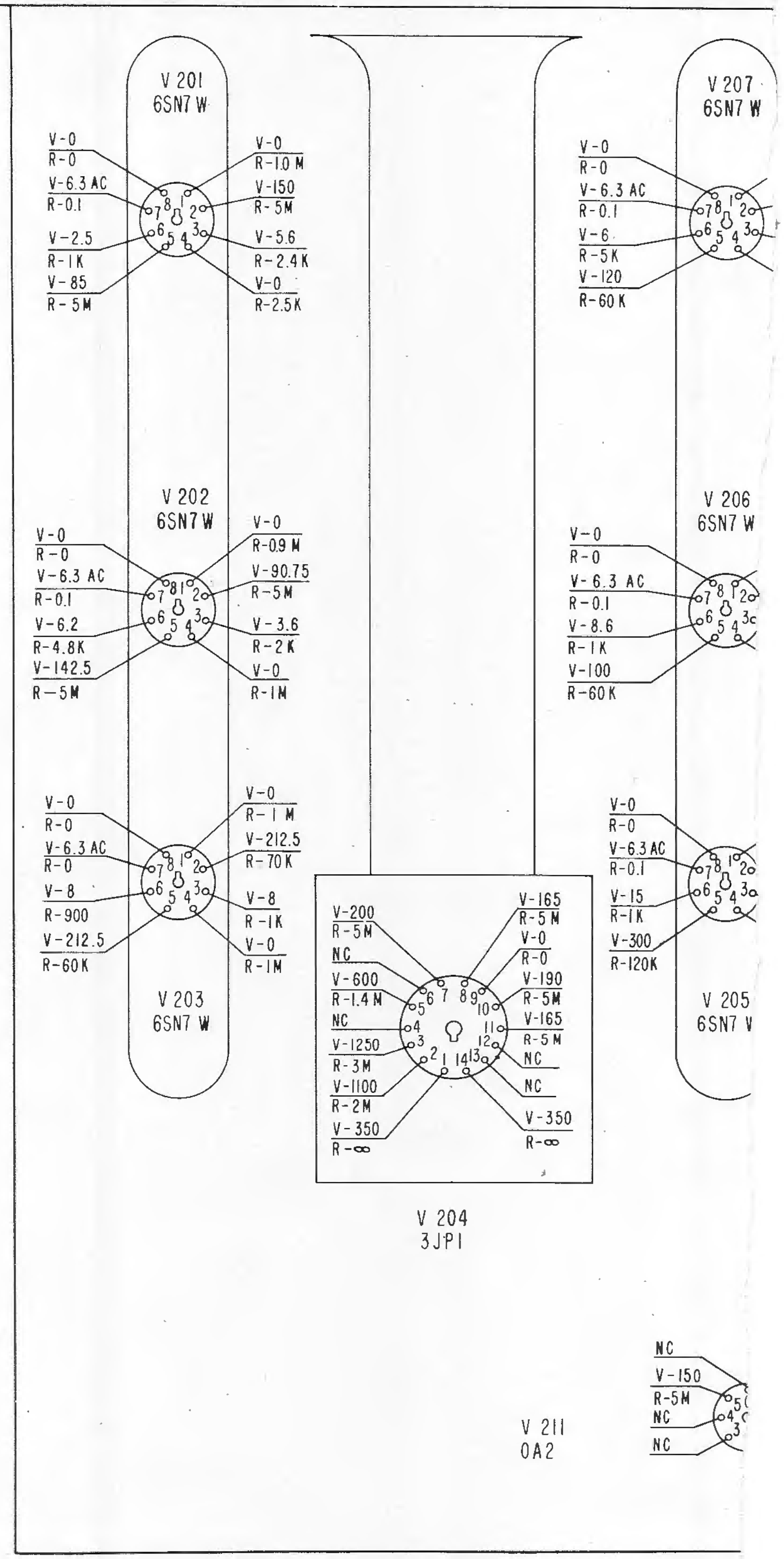
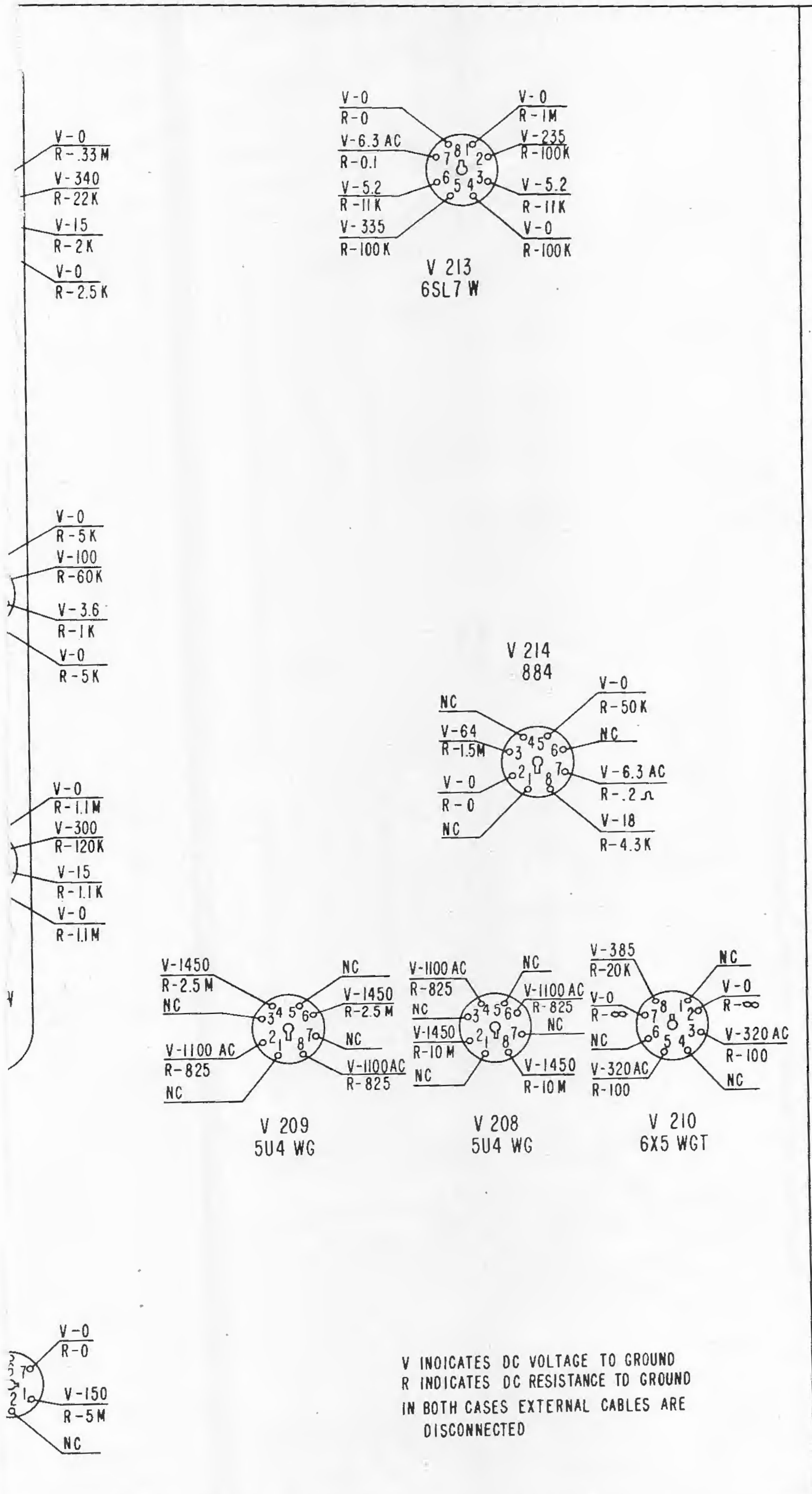



Figure 8-11. Voltage and Re,




sistance Test Points in Oscilloscope



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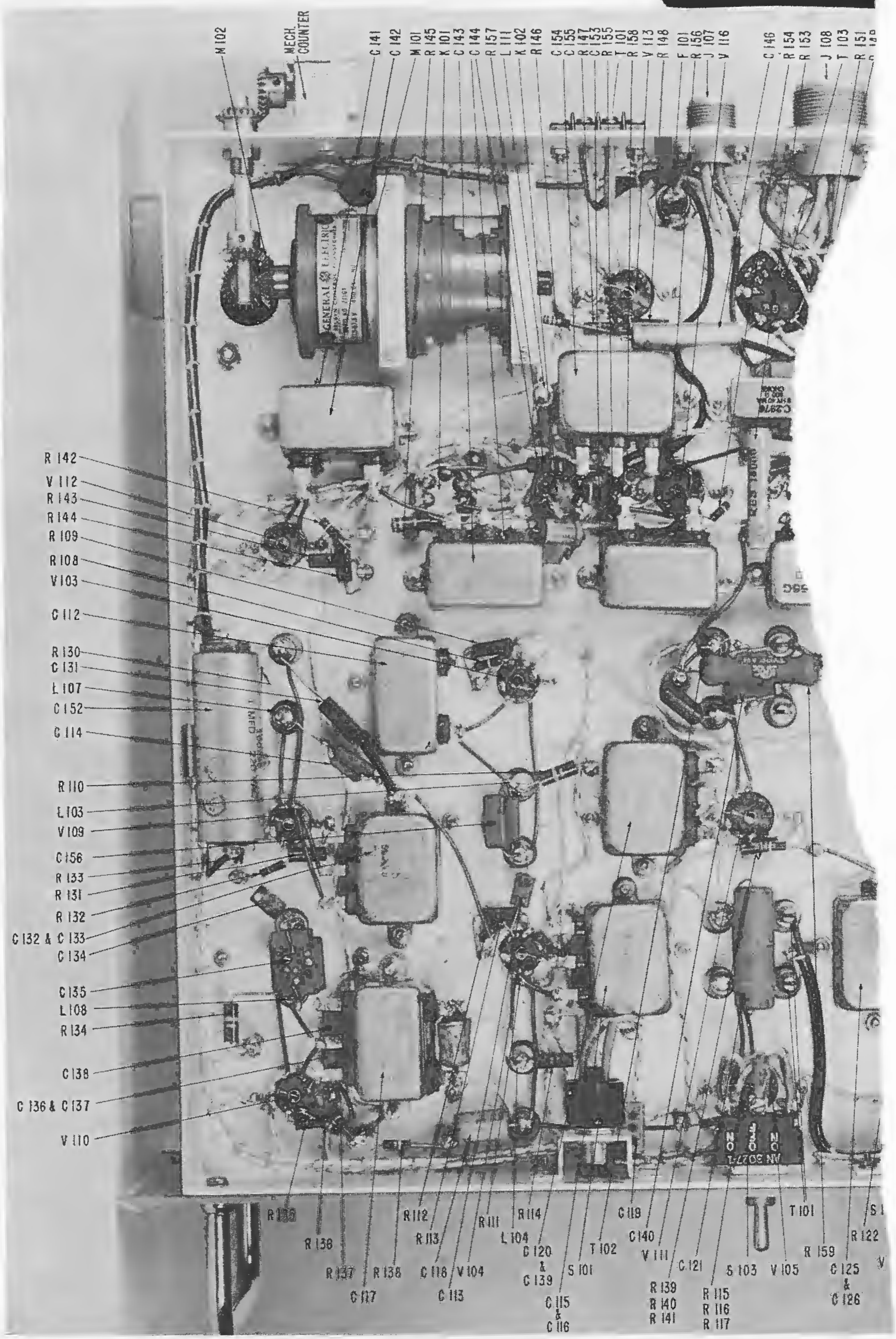
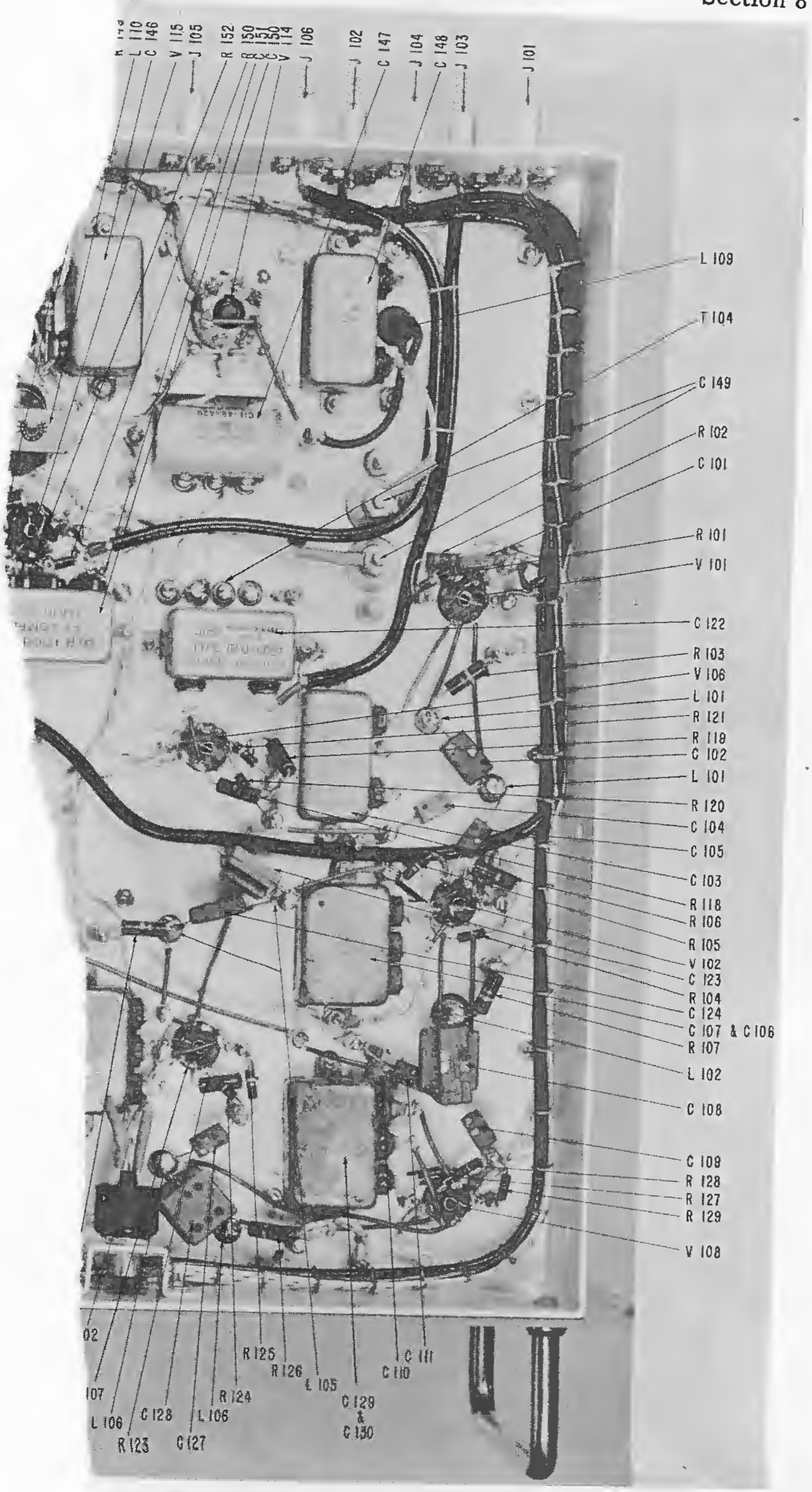



Figure 8-12. Chassis Wiring of Freque



L 110
C 146
V 115
J 105
R 152
V 114
J 106
J 102
C 147
J 104
C 148
J 103
J 101
L 109
T 104
C 149
R 102
C 101
R 101
V 101
C 122
R 103
V 106
L 101
R 121
R 119
C 102
L 101
R 120
C 104
C 105
C 103
R 118
R 106
R 105
V 102
C 123
R 104
C 124
C 107 & C 106
R 107
L 102
C 108
C 109
R 128
R 127
R 129
V 108
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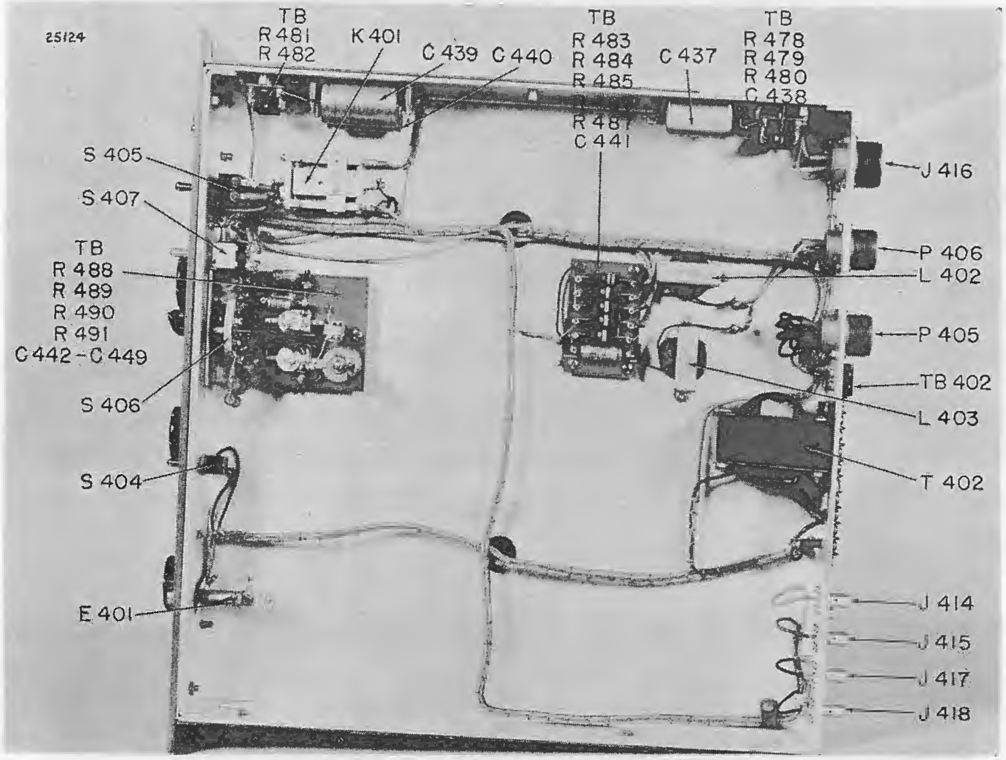


Figure 8-13. Chassis Wiring of Time Comparator





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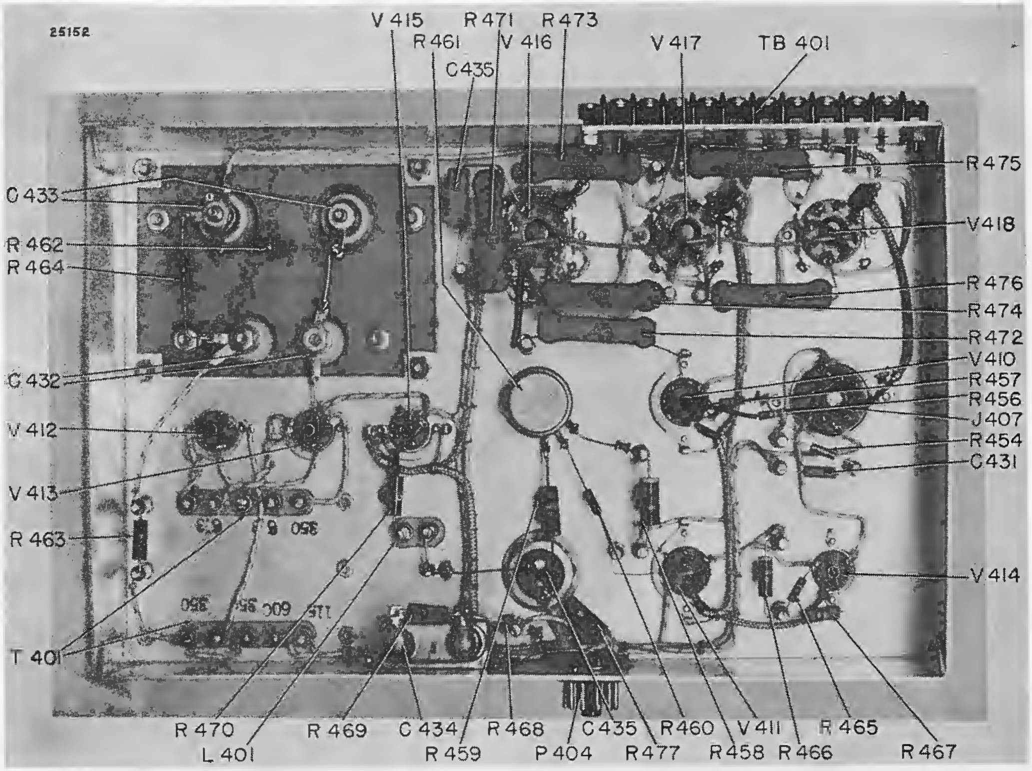
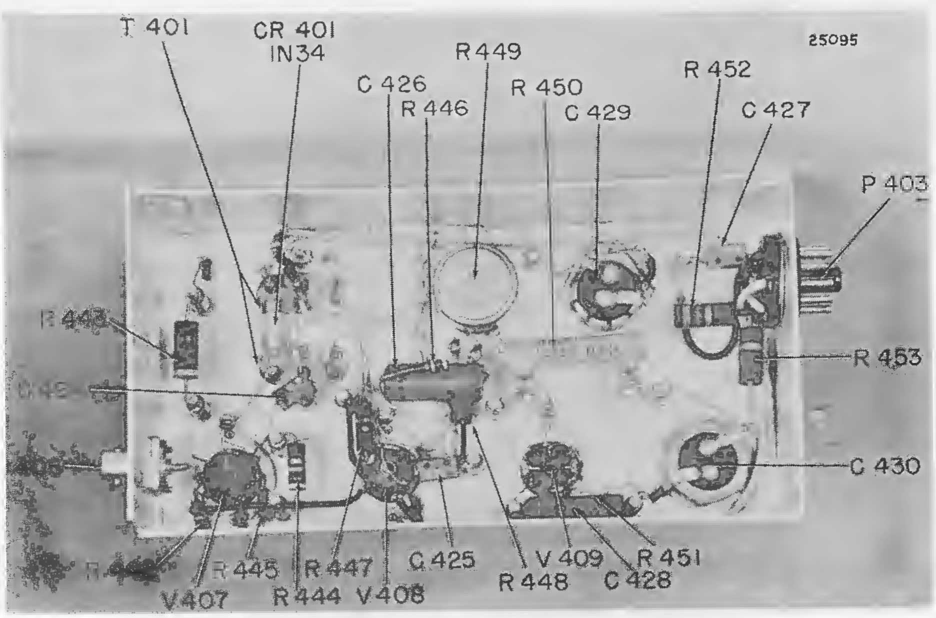



(a) Keyer




(b) Pulse Generator and Strobotron Driver

Figure 8-14. Chassis Wiring of Time-Comparator Units



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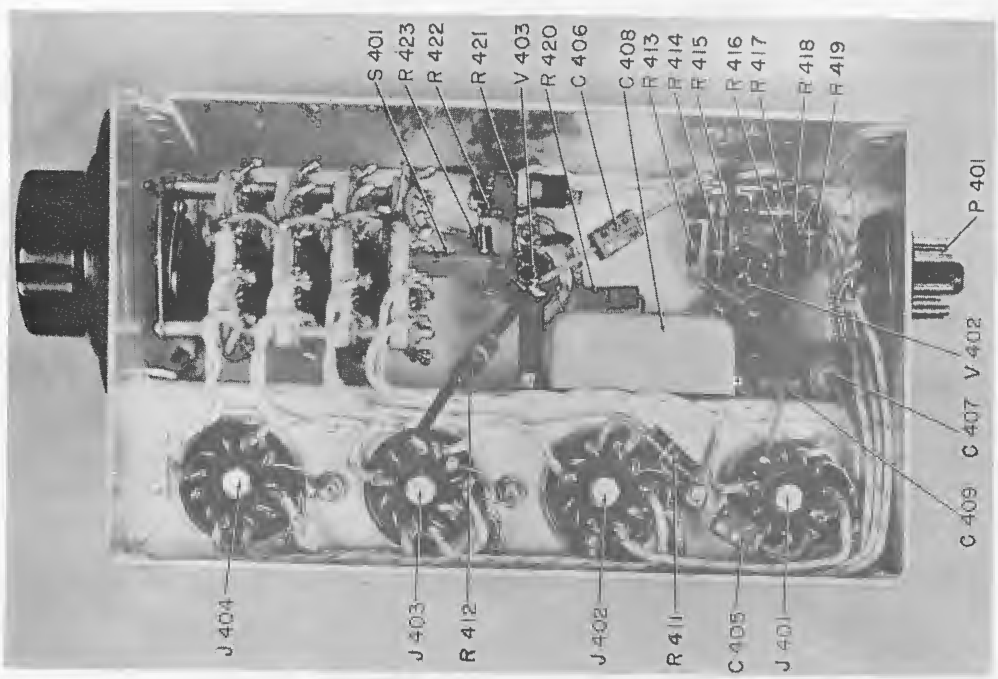
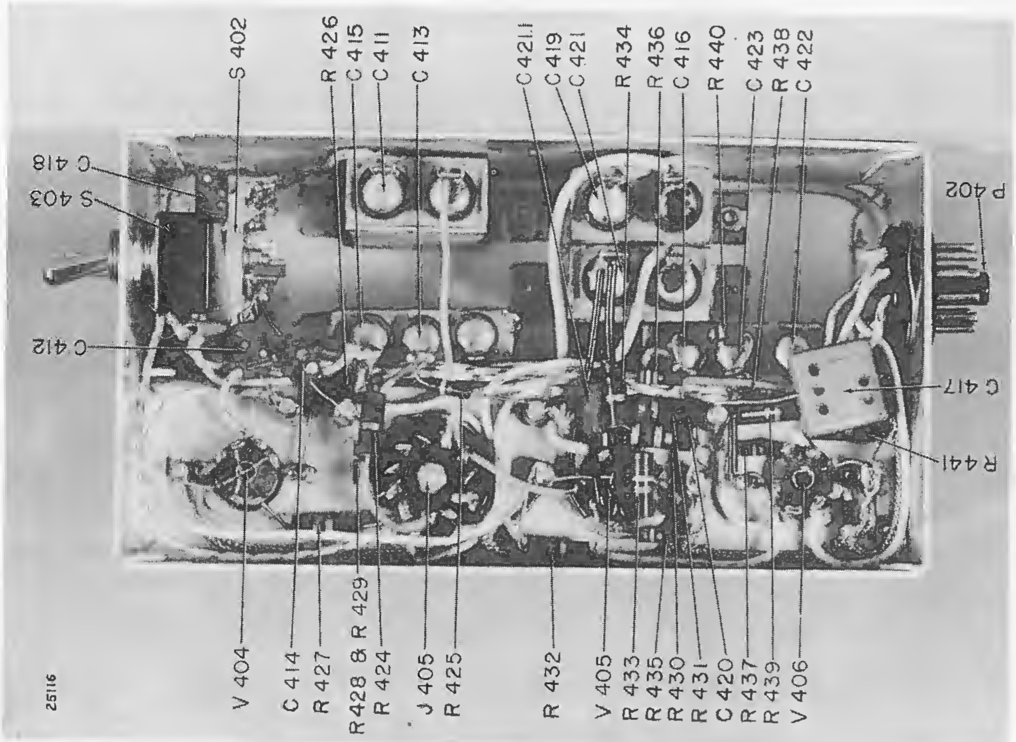



(c) Counter Decade




(d) Sweep Generator

Figure 8-14 (Cont'd) Chassis Wiring of Time-Comparator Units



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| | | | |
|---|---|---|---|
| 1 | Red | 54 | A Slate |
| 2 | Black | 54 | B Slate |
| 3 | White | 55 | Bare |
| 4 | Orange | 56 | Slate |
| 5 | Black | 57 | Slate |
| 6 | Blue | 58 | A Slate |
| 7 | Blue | 58 | B Slate |
| 8 | Blue | 59 | Yellow |
| 9 | Blue | 60 | White |
| 10 | Brown | 61 | White |
| 11 | Brown | 62 | Brown |
| 12 | White | 63 | White |
| 13 | Blue | 64 | Black |
| 14 | Orange | 65 | Black |
| 15 | White | 66 | Yellow |
| 16 | Black | 67 | Blue |
| 17 | Red | 68 | Green |
| 18 | Red | 69 | Yellow |
| 19 | Black | 70 | Red |
| 20 | Brown | 71 | Red |
| 21 | Blue | 72 | Black |
| 22 | Blue | 73 | Black |
| 23 | White | 74 | Black |
| 24 | Brown | 75 | Yellow |
| 25 | Black | 76 | Blue |
| 26 | Red | 77 | Blue |
| 27 | Blue | 78 | Blue |
| 28 | Black | 79 | Blue |
| 29 | Red | 80 | White |
| 30 | Red | 81 | White |
| 31 | Brown | 82 | Green |
| 32 | Red | 83 | White |
| 33 | Red | 84 | Blue |
| 34 | Black | 85 | Blue |
| 35 | Red | 86 | Blue |
| 36 | Red | 87 | Black |
| 37 | Black | 88 | Black |
| 38 | Red | 89 | Red |
| 39 | Black | 90 | Black |
| 40 | Brown | 91 | Green |
| 41 | Black | 92 | Green |
| 42 | Brown | 93 | White |
| 43 | Black | 94 | Yellow |
| 44 | Red | 95 | Green |
| 45 | Red | 96 | Yellow |
| 46 | Brown | 97 | Blue |
| 47 | Brown | 98 | Black |
| 48 | Blue | 99 | Brown |
| 49 | Blue | 100 | Blue |
| 50 | Brown | 101 | Blue |
| 51 | Brown | 102 | Red |
| 52 | Brown | 103 | Black |
| 53 | Brown | 104 | Red |

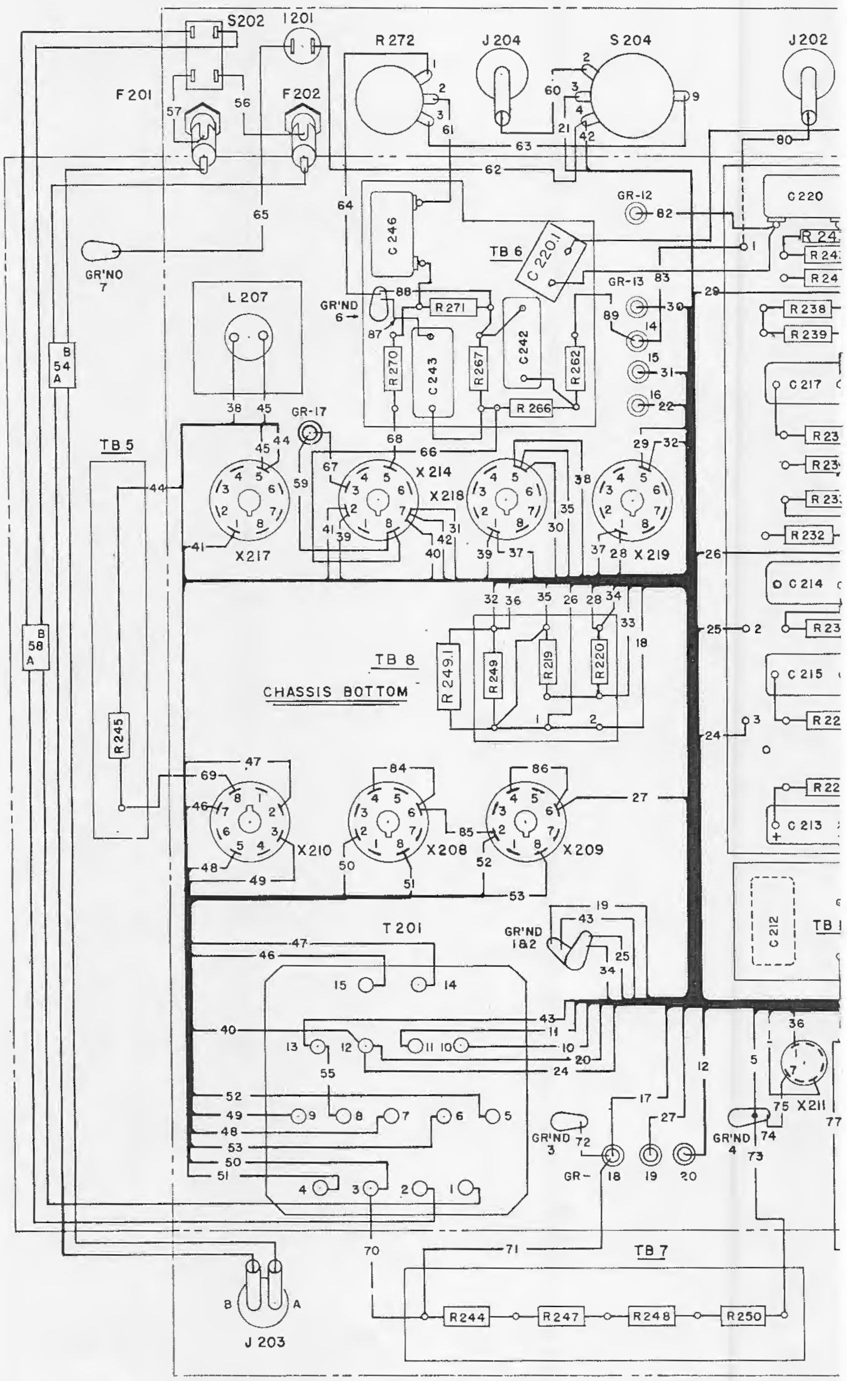
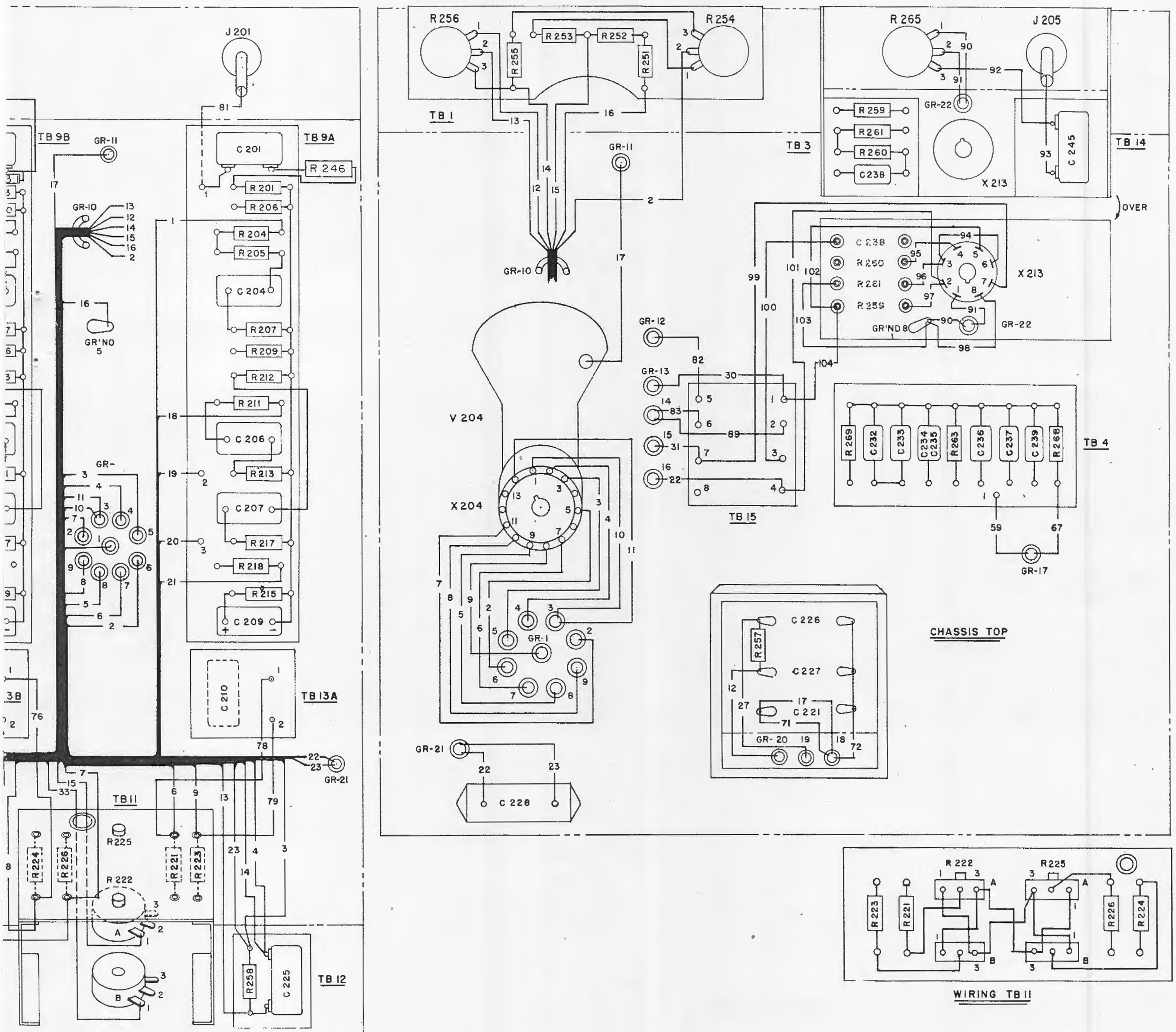



Figure 8-15.




Chassis Wiring of Oscilloscope

[redacted]

1 Red
2 Green
3 Blue
4 Red
5 Red
6 Brown
7 White
8 Blue
9 Blue
10 Blue
11 Blue
12 Red
13 Yellow
14 Yellow
15 Yellow
16 Yellow
17 Yellow
18 Yellow
19 Blue
20 Yellow
21 Yellow
22 Yellow
23 Yellow
24 Blue
25 Bare

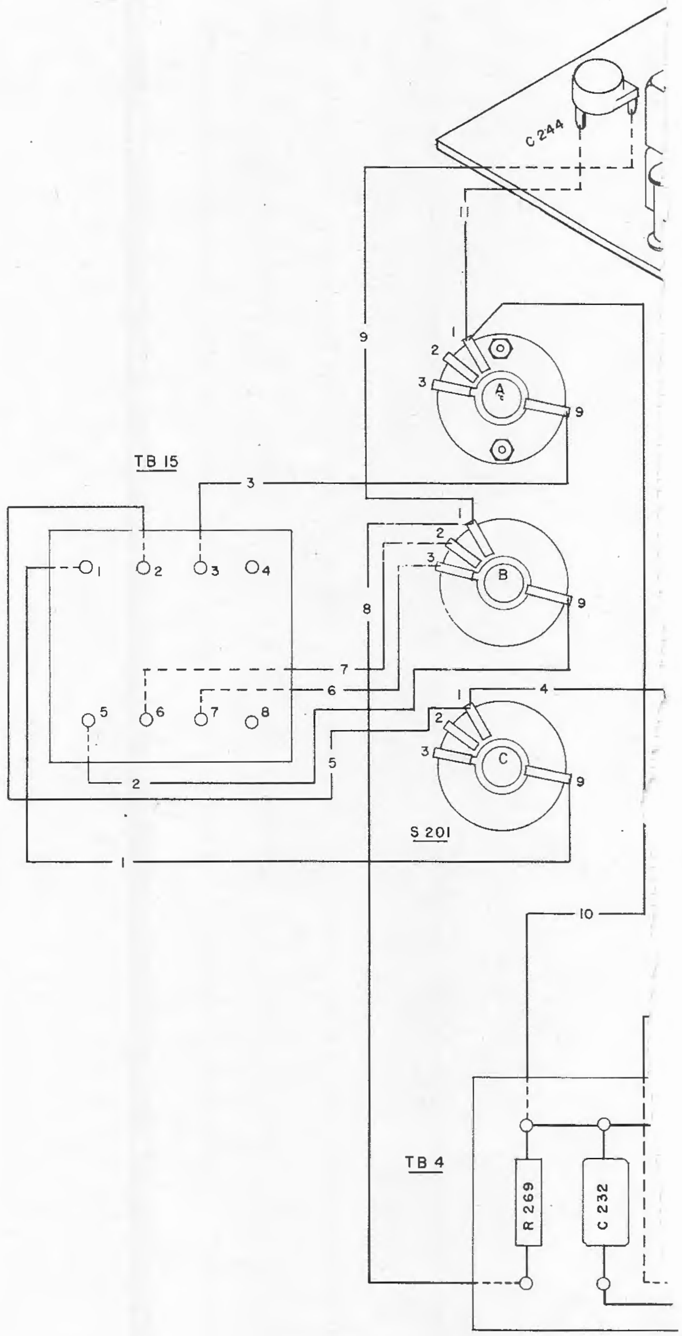
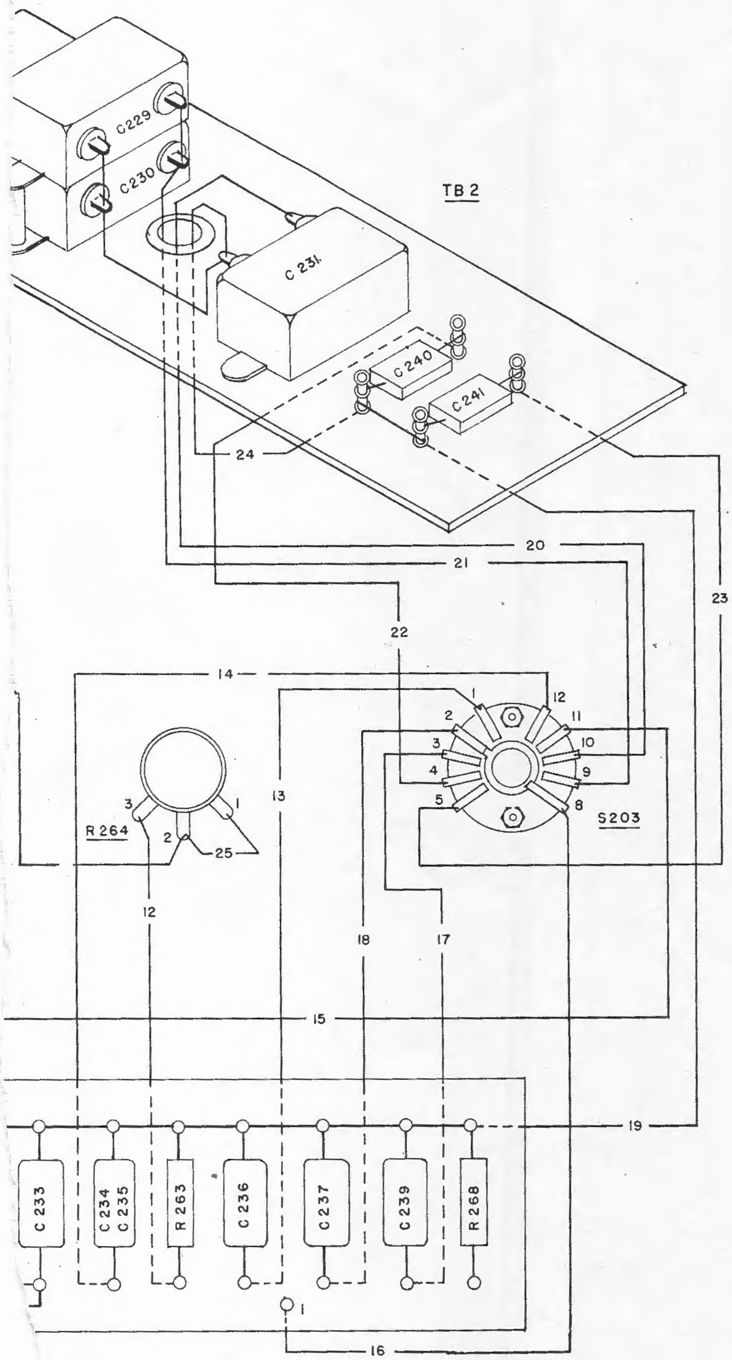


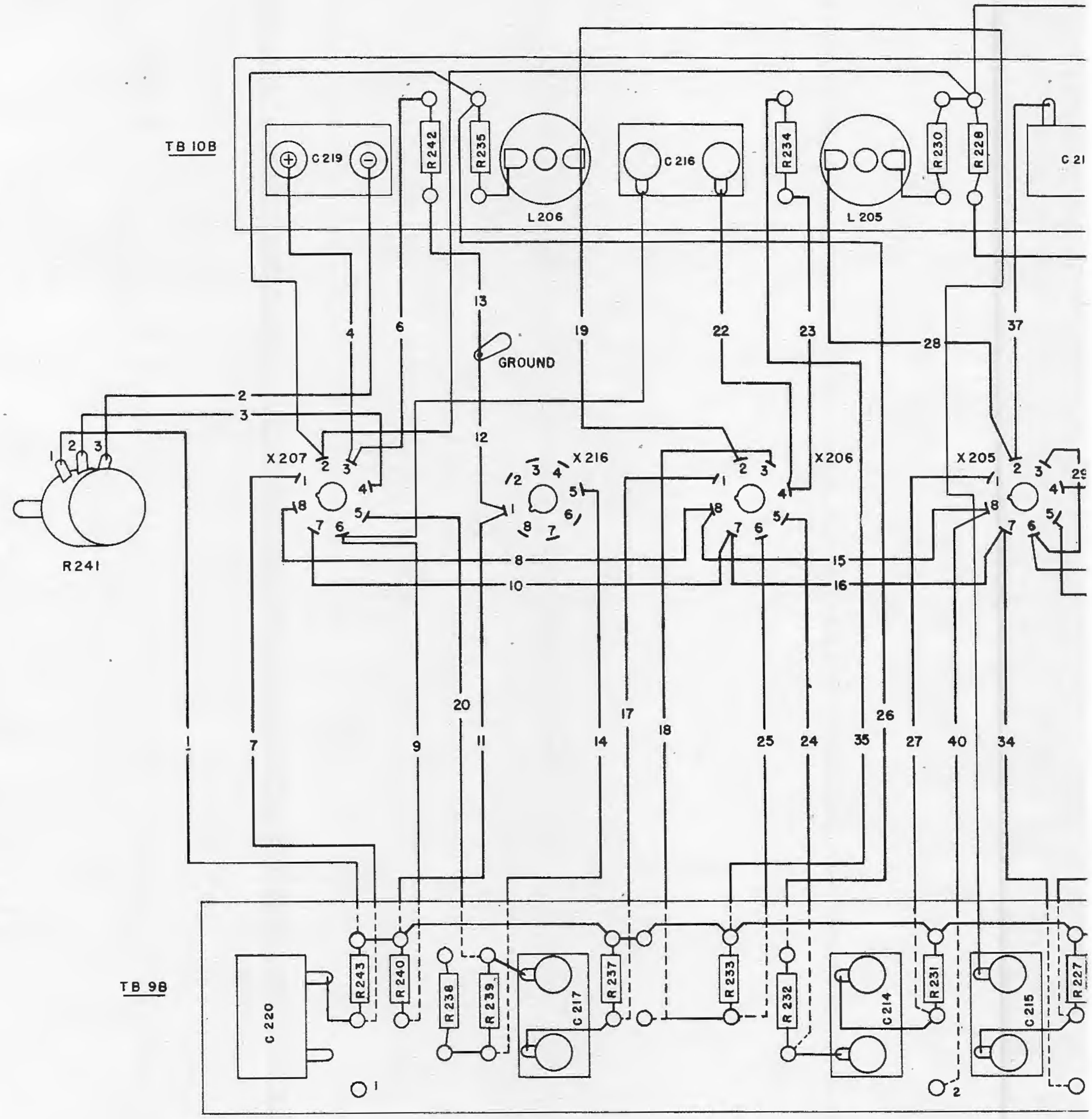

Figure 8-15 (Cont'd.). Chassis Wirin

S[redacted]

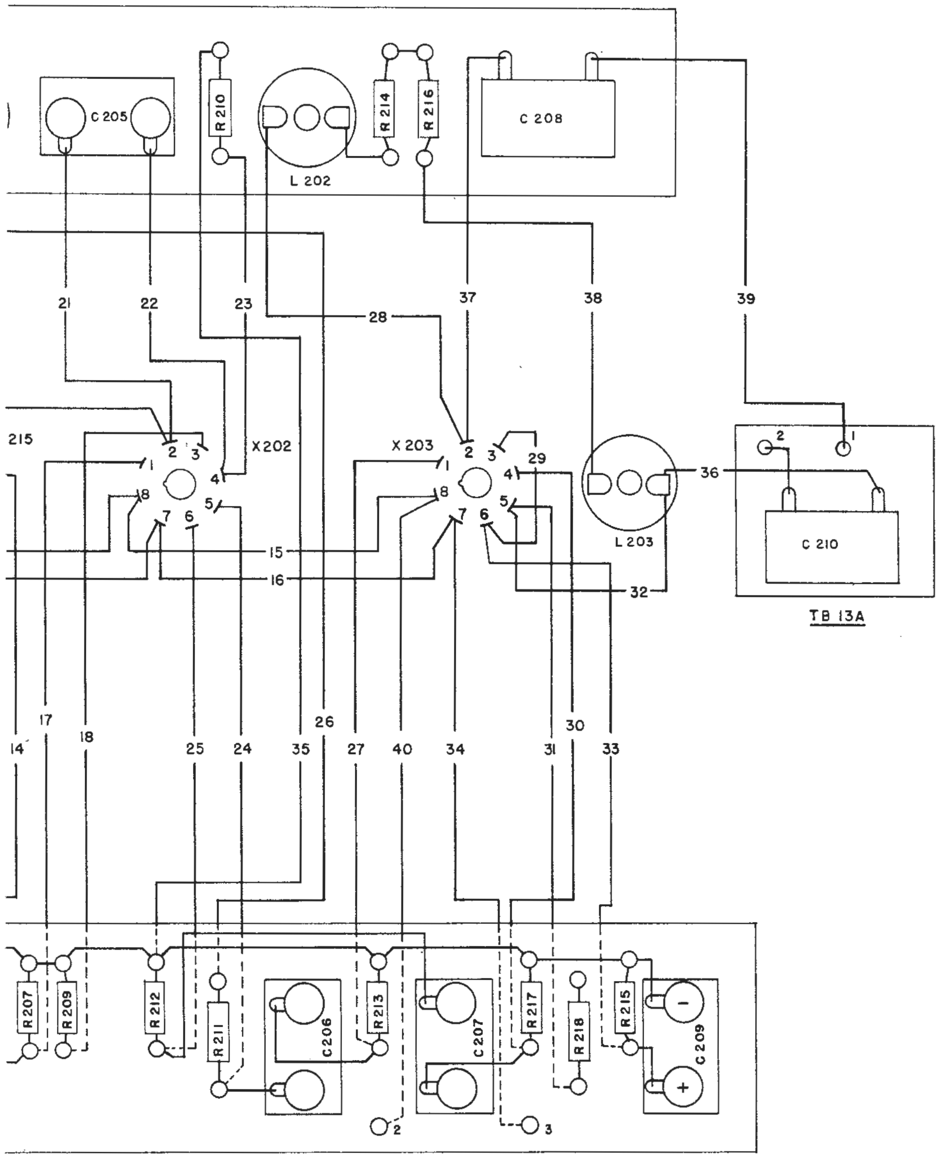



g of Oscilloscope

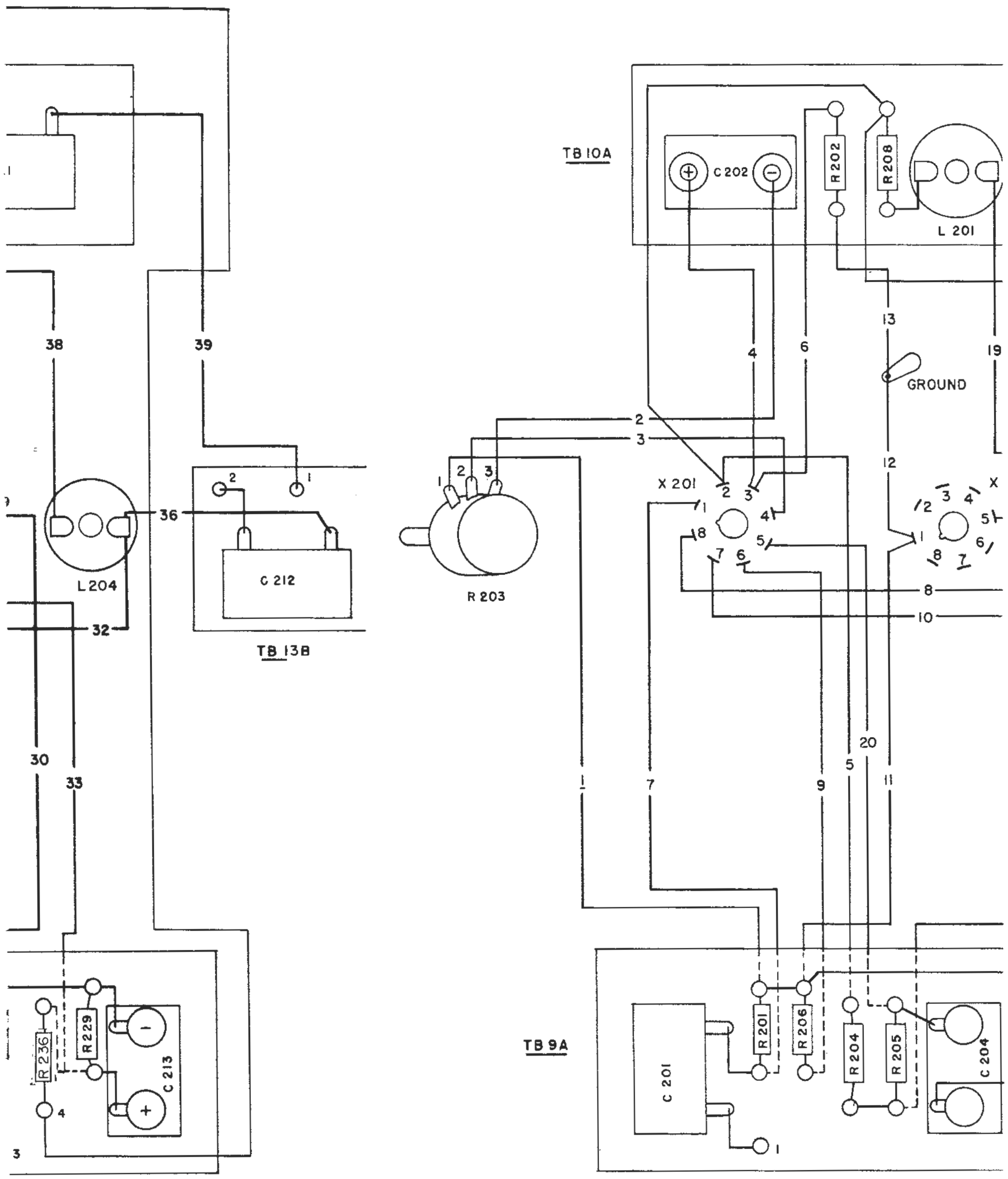
| | |
|---|---|
| 1 | Black |
| 2 | Green |
| 3 | Green |
| 4 | Yellow |
| 5 | Red |
| 6 | Yellow |
| 7 | Green |
| 8 | Black |
| 9 | Yellow |
| 10 | Brown |
| 11 | Black |
| 12 | Black |
| 13 | Black |
| 14 | Red |
| 15 | Black |
| 16 | Brown |
| 17 | Green |
| 18 | Yellow |
| 19 | Blue |
| 20 | Blue |
| 21 | Blue |
| 22 | Green |
| 23 | Green |
| 24 | Blue |
| 25 | Yellow |
| 26 | Red |
| 27 | Green |
| 28 | Blue |
| 29 | Yellow |
| 30 | Green |
| 31 | Blue |
| 32 | Blue |
| 33 | Yellow |
| 34 | Brown |
| 35 | Black |
| 36 | Blue |
| 37 | Blue |
| 38 | Blue |
| 39 | Blue |
| 40 | Black |




Fi


C 205
R 210
L 202
R 214
R 216
C 208
21
22
23
28
37
38
39
215
X202
X 203
29
L 203
36
C 210
TB 13A
15
16
32
17
18
14
25
24
35
26
27
40
34
30
31
33
R 207
R 209
R 212
R 211
C206
R 213
C 207
R 217
R 218
R 215
C 209
2
3

[redacted]




gure 8-15 (Cont'd.). Chassis Wiring of Oscilloscope

[redacted]

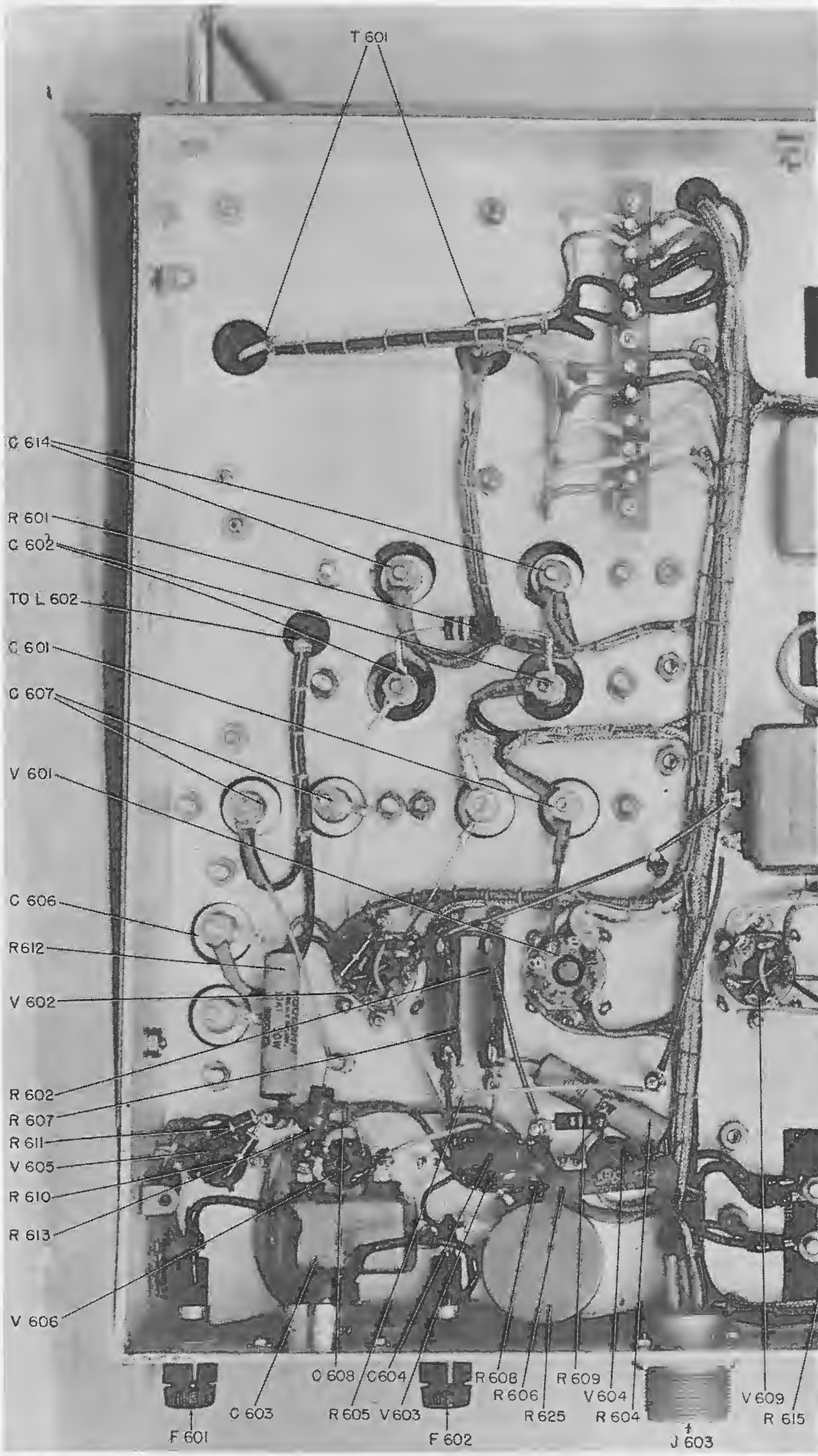
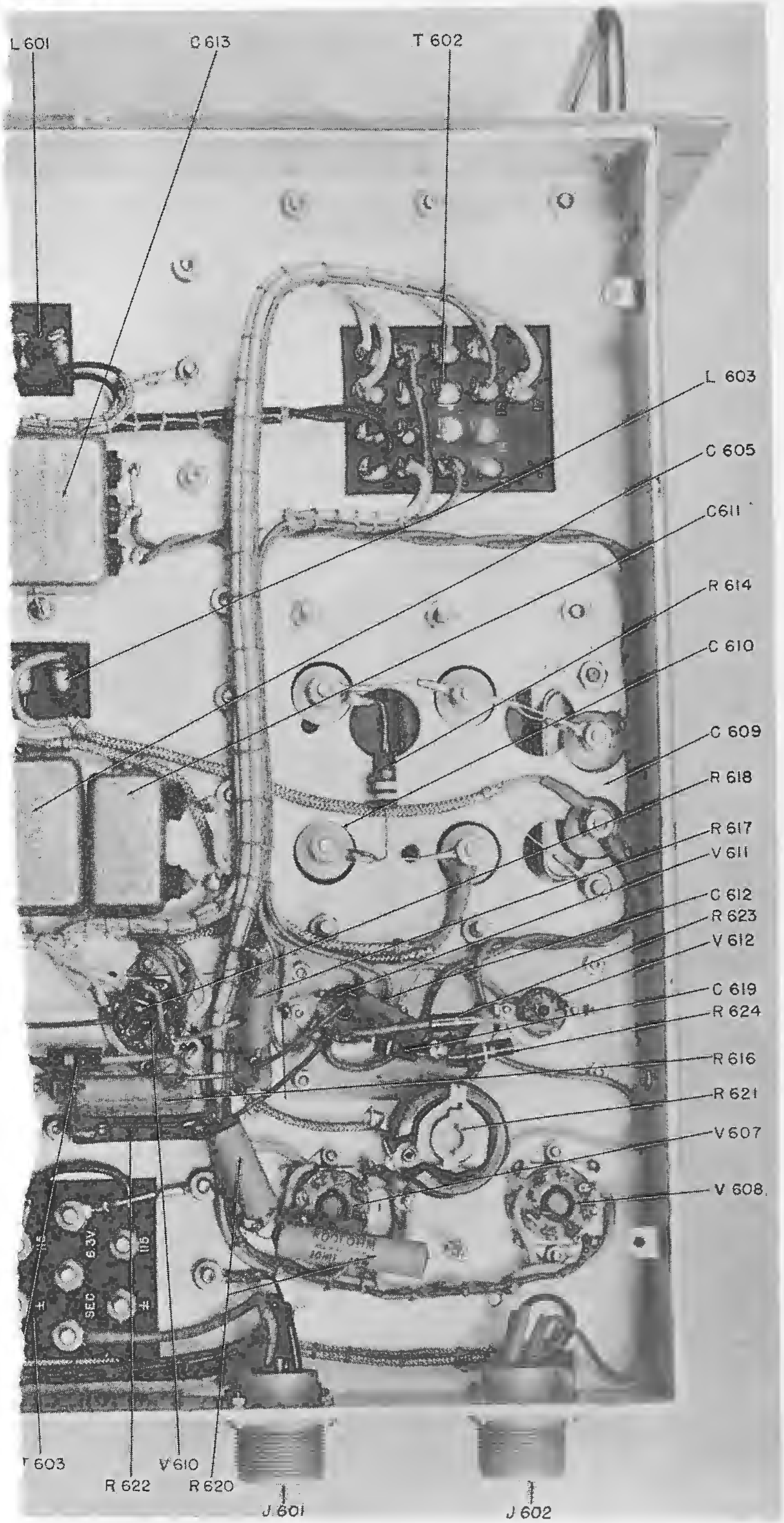



Figure 8-16. Chassis Wiring of Pow




*er Supply PP-455A/FSM-5A*

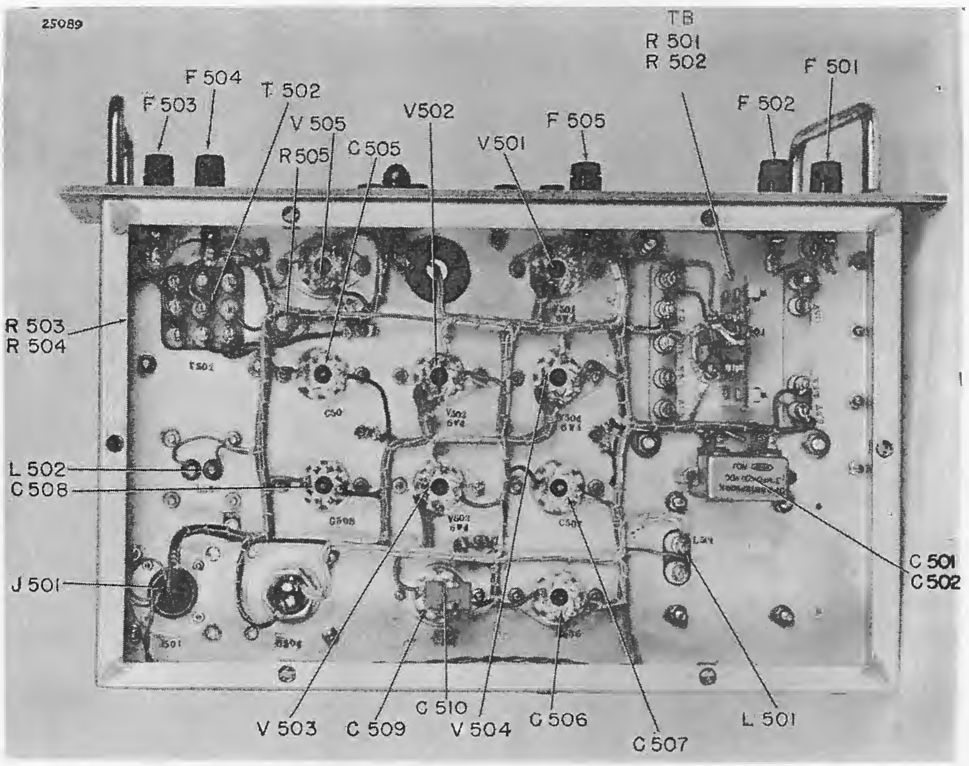



**Figure 8-17. Chassis Wiring of Power Supply PP-456A/FSM-5A**

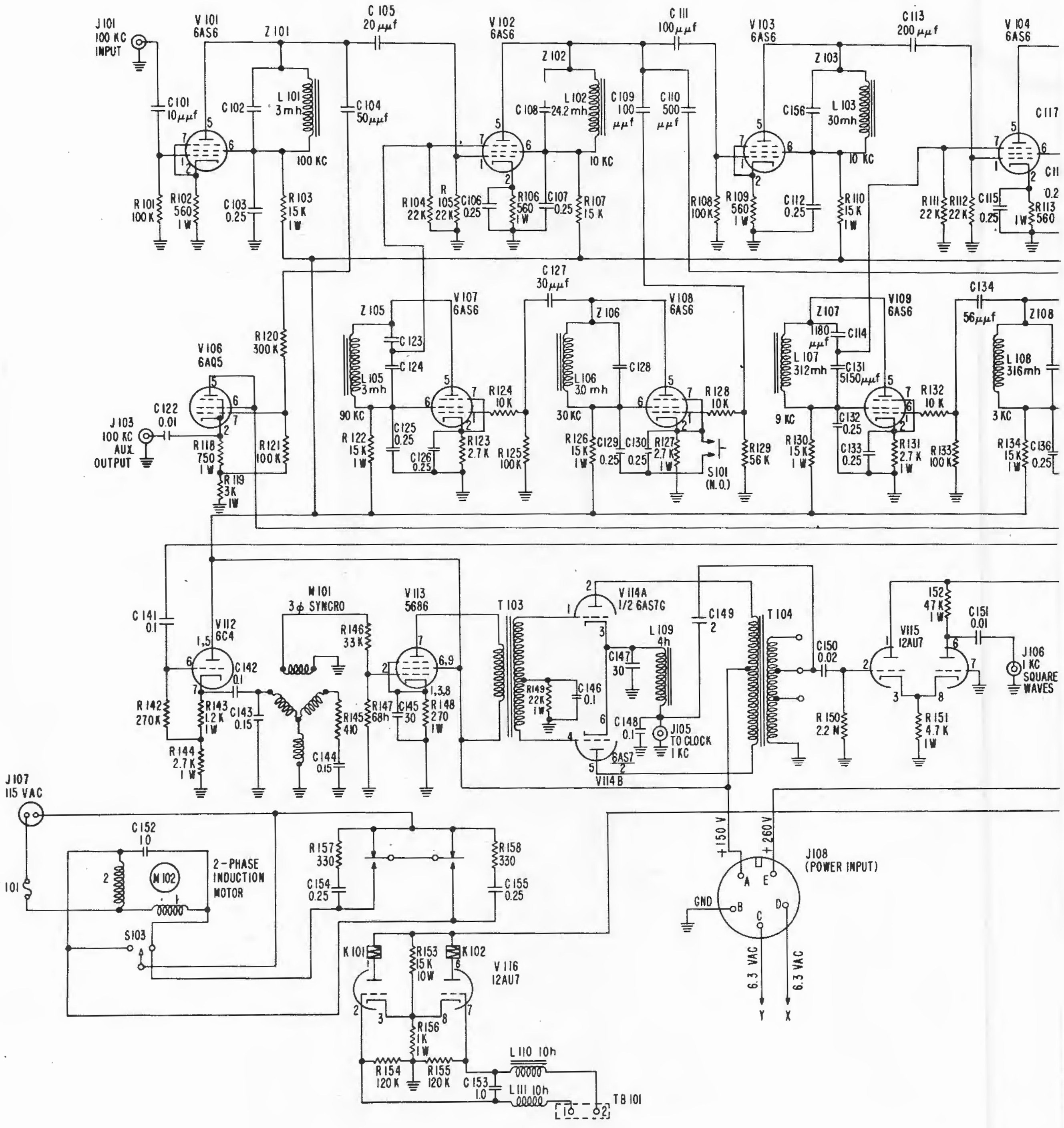
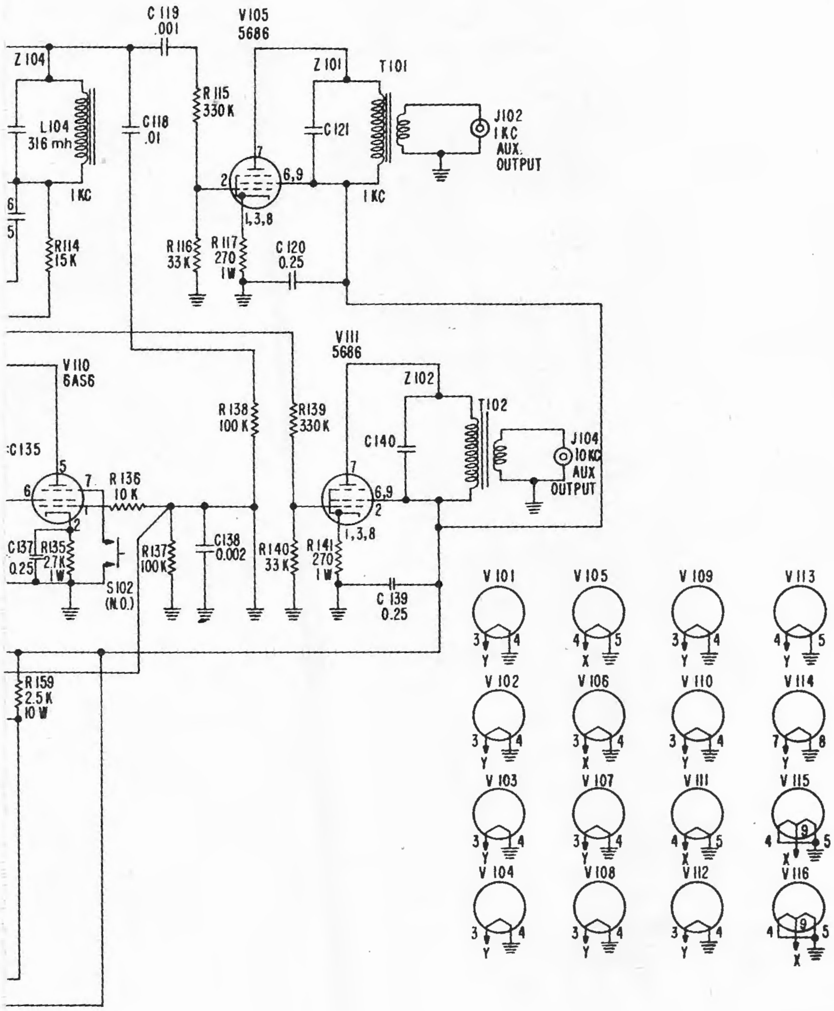



Figure 8-18. Schematic Diagram of Frequency

 [redacted]


C 119
.001
V105
5686
Z 104
Z 101
T 101
R 115
330 K
C 118
.01
L104
316 mh
C 121
J102
1 KC
AUX.
OUTPUT
1 KC
6,9
1,3,8
R114
15 K
R 116
33 K
R 117
270
1 W
C 120
0.25
V111
5686
V110
6AS6
Z 102
T102
R 138
100 K
R139
330 K
C140
J104
10KC
AUX
OUTPUT
C135
R 136
10 K
C137
0.25
R135
2.7K
1W
S102
(N.O.)
R137
100K
C138
0.002
R140
33 K
R141
270
1W
C 139
0.25
R 159
2.5 K
10 W
V 101
V 105
V 109
V 113
V 102
V 106
V 110
V 114
V 103
V 107
V 111
V 115
V 104
V 108
V 112
V 116

Divider

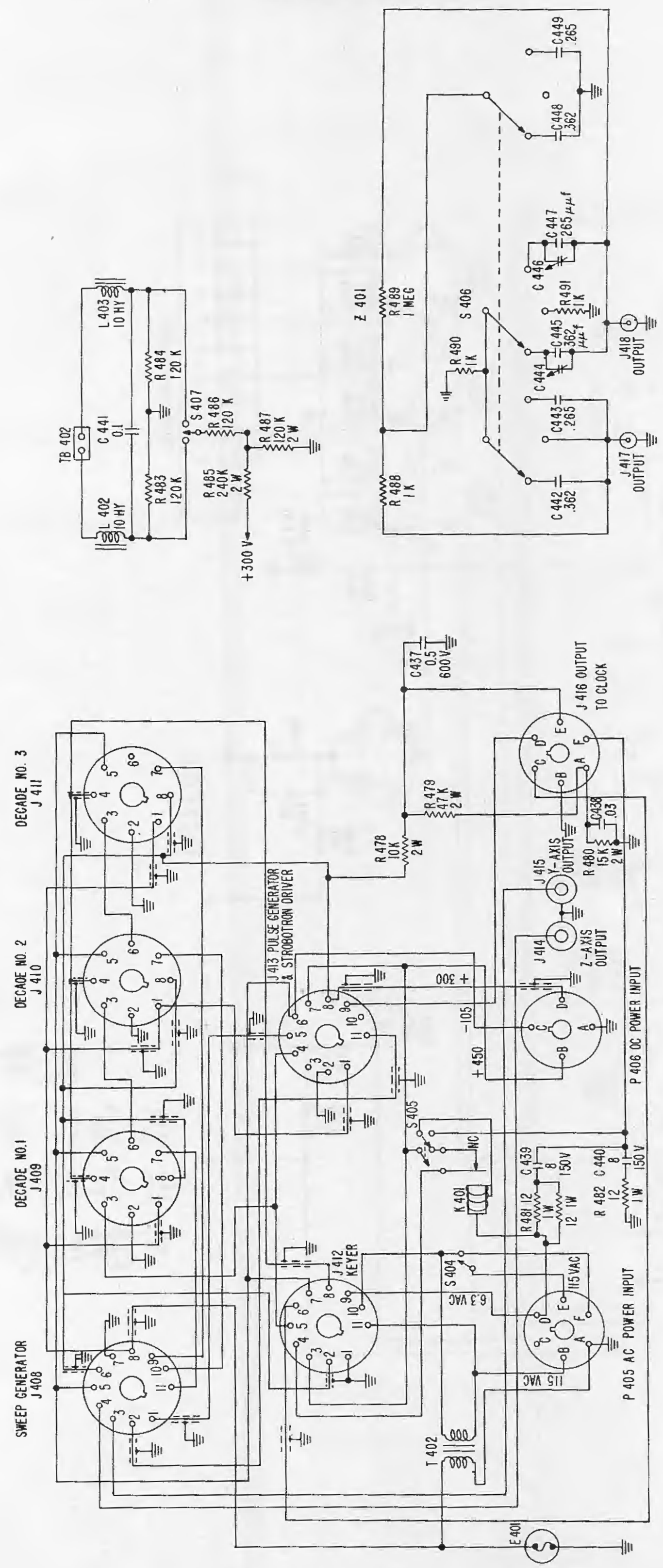



Figure 8-19. Schematic Diagram Showing Interconnection Between Units of Time Comparator

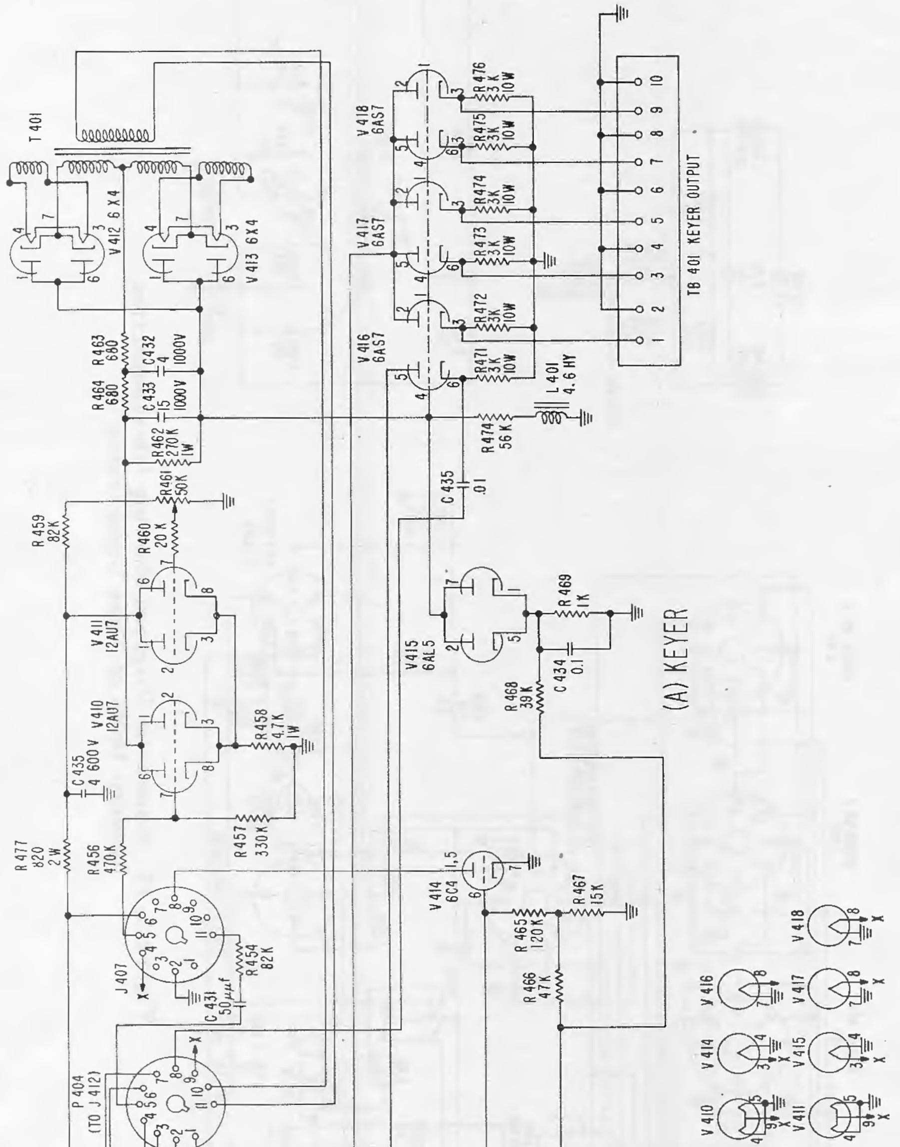



Figure 8-20. Schematic Diagram of Keyer



[redacted]

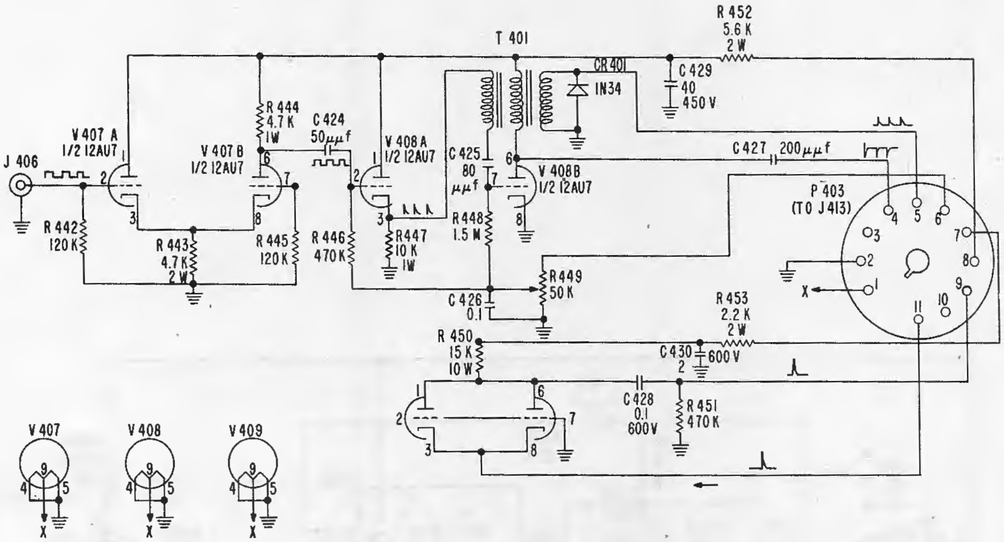



Figure 8-21. Schematic Diagram of Pulse Generator and Strobotron Driver

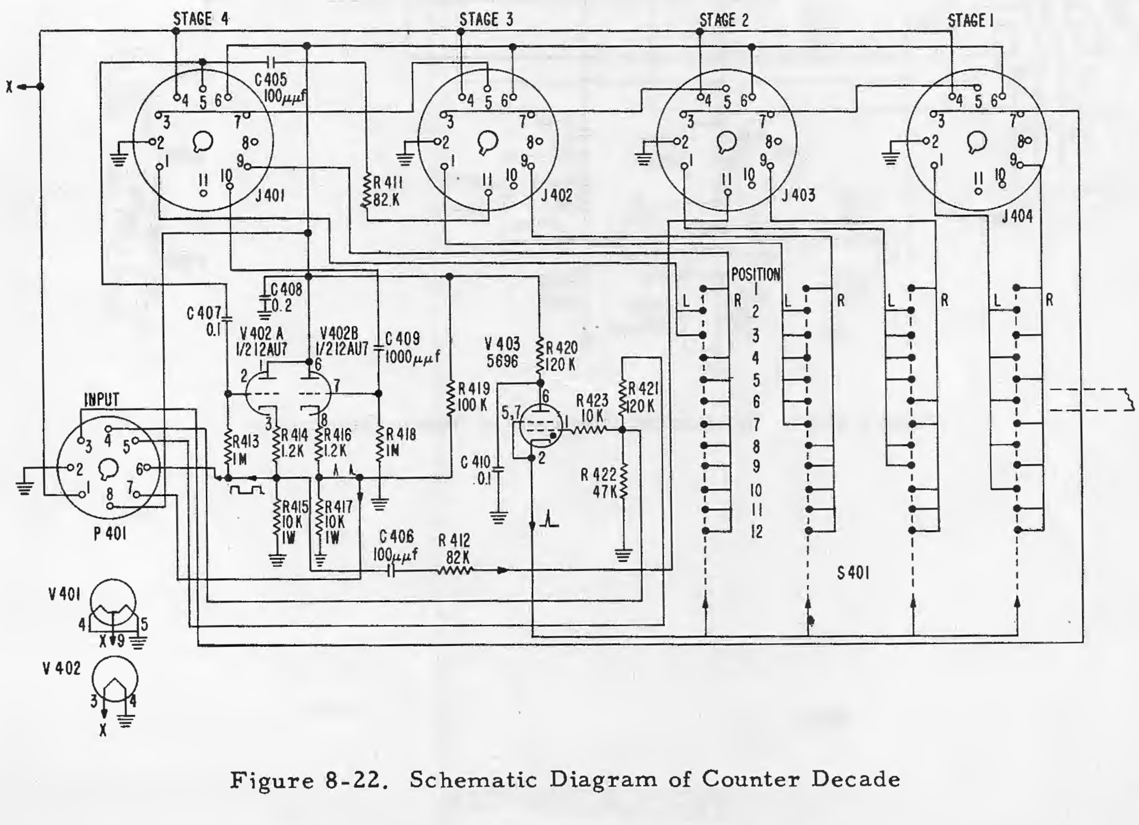



Figure 8-22. Schematic Diagram of Counter Decade

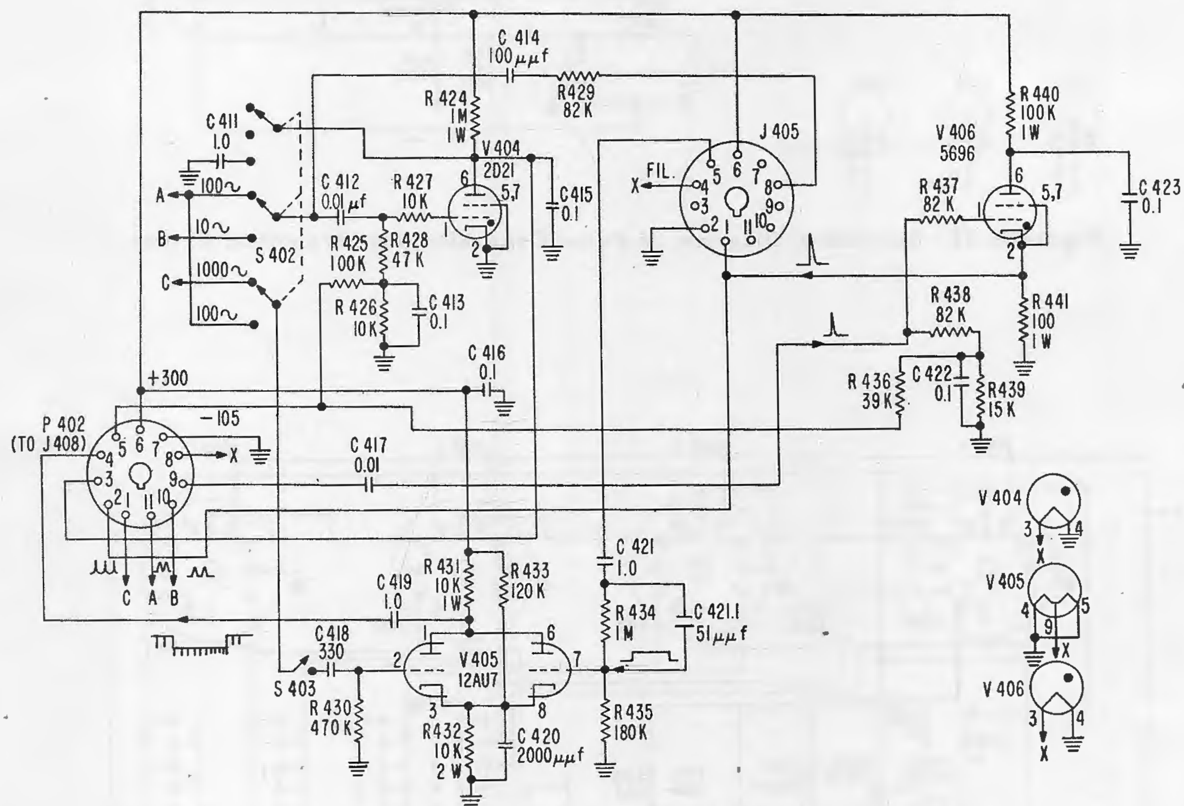
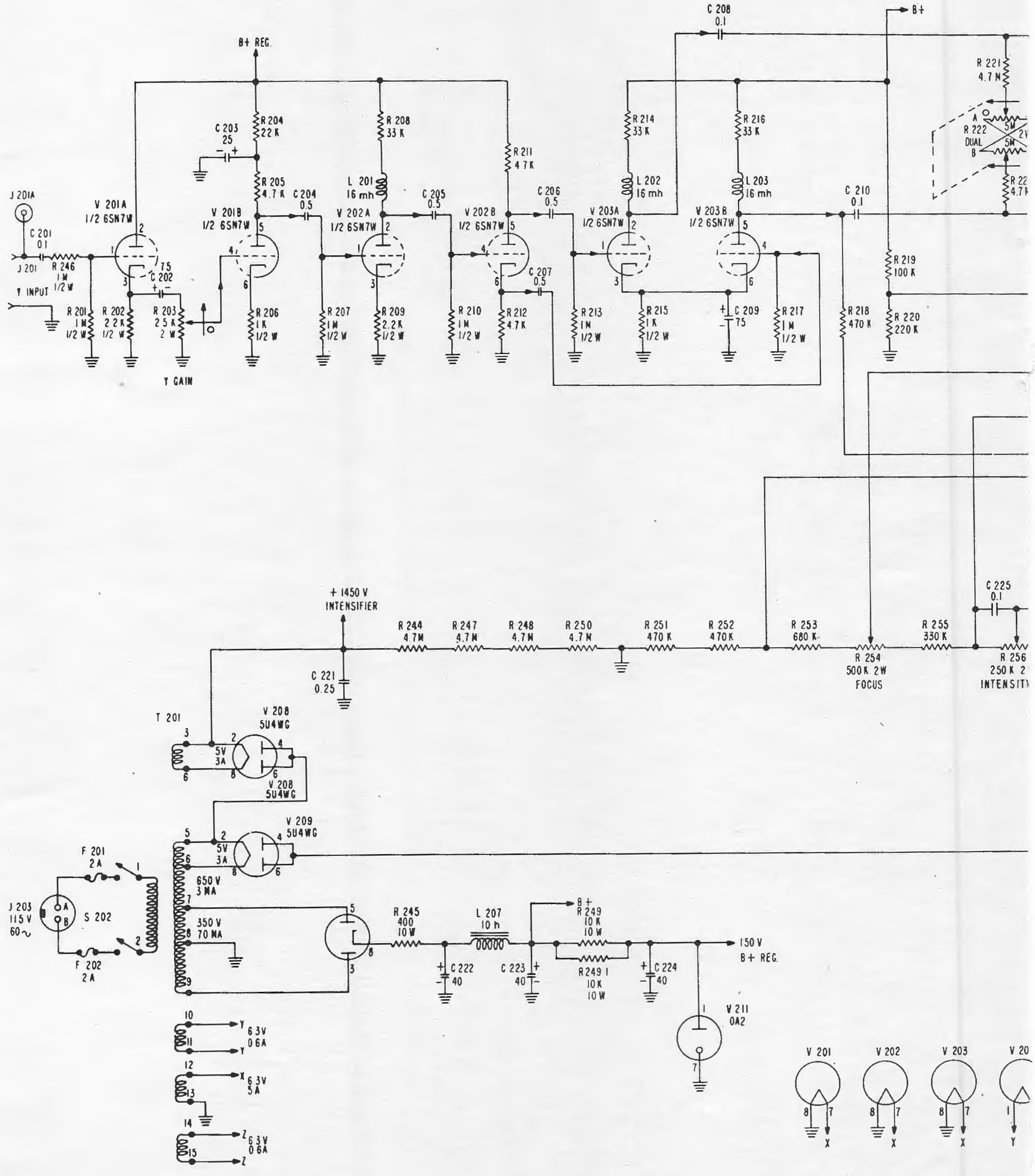



Figure 8-23. Schematic Diagram of Sweep Generator





[redacted]


B+ REG.
C 208
0.1
B+
R 221
4.7 M
R 222
DUAL
J 201A
C 201
0.1
J 201
Y INPUT
R 246
1 M
1/2 W
V 201A
1/2 6SN7W
C 203
25
R 204
22 K
R 205
4.7 K
C 204
0.5
V 201B
1/2 6SN7W
C 202
75
R 201
1 M
1/2 W
R 202
2.2 K
1/2 W
R 203
2.5 K
2 W
Y GAIN
R 206
1 K
1/2 W
R 208
33 K
L 201
16 mh
V 202A
1/2 6SN7W
C 205
0.5
R 207
1 M
1/2 W
R 209
2.2 K
1/2 W
R 211
4.7 K
V 202B
1/2 6SN7W
C 206
0.5
C 207
0.5
R 210
1 M
1/2 W
R 212
4.7 K
R 214
33 K
L 202
16 mh
V 203A
1/2 6SN7W
R 213
1 M
1/2 W
R 215
1 K
1/2 W
R 216
33 K
L 203
16 mh
V 203B
1/2 6SN7W
C 209
75
R 217
1 M
1/2 W
C 210
0.1
R 219
100 K
R 218
470 K
R 220
220 K
+ 1450 V
INTENSIFIER
R 244
4.7 M
R 247
4.7 M
R 248
4.7 M
R 250
4.7 M
R 251
470 K
R 252
470 K
R 253
680 K
R 254
500 K 2W
FOCUS
R 255
330 K
C 225
0.1
R 256
INTENSITY
C 221
0.25
T 201
V 208
5U4WG
5V
3A
V 209
5U4WG
F 201
2 A
J 203
115 V
60 ~
S 202
F 202
2 A
650 V
3 MA
350 V
70 MA
R 245
400
10 W
L 207
10 h
B +
R 249
10 K
10 W
R 249 1
10 K
10 W
150 V
B + REG.
C 222
40
C 223
40
C 224
40
V 211
0A2
6.3 V
0.6 A
6.3 V
5 A
6.3 V
0.6 A
V 201
V 202
V 203

[redacted]

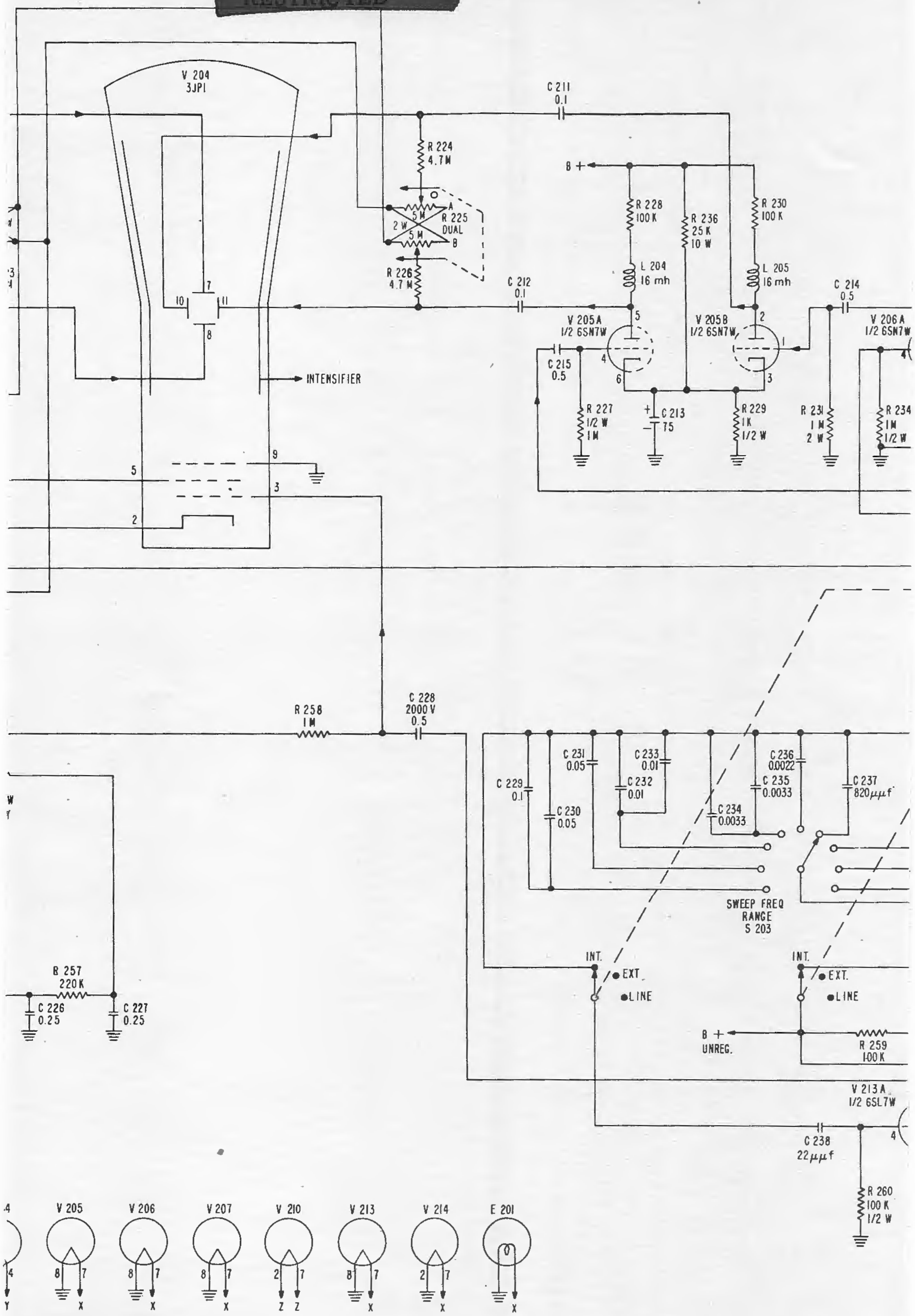
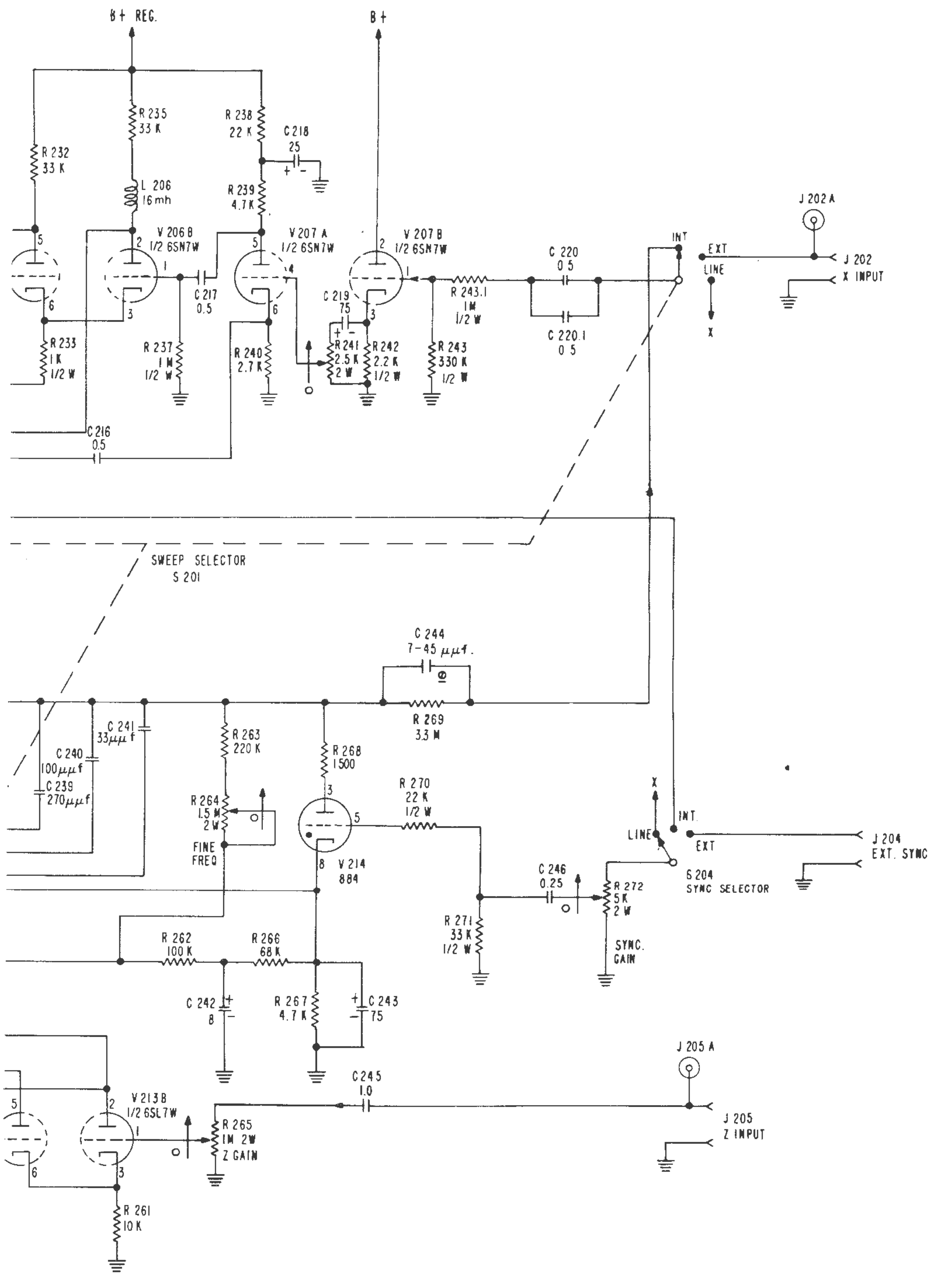



Figure 8-24. Schematic Diagram of Oscilloscope

S[redacted]


B+ REG.
B+
R 235 33 K
R 238 22 K
C 218 25
R 232 33 K
L 206 16 mh
R 239 4.7 K
V 206 B 1/2 6SN7W
V 207 A 1/2 6SN7W
V 207 B 1/2 6SN7W
C 217 0.5
C 219 75
R 241 2.5 K 2 W
R 242 2.2 K 1/2 W
R 243.1 1 M 1/2 W
R 243 330 K 1/2 W
C 220 0.5
C 220.1 0.5
R 233 1 K 1/2 W
R 237 1 M 1/2 W
R 240 2.7 K
C 216 0.5
INT
EXT
LINE
X
J 202 A
J 202 X INPUT
SWEEP SELECTOR S 201
C 244 7-45 μμf.
R 269 3.3 M
C 241 33μμf
C 240 100μμf
C 239 270μμf
R 263 220 K
R 268 1500
R 264 1.5 M 2 W
FINE FREQ
V 214 884
R 270 22 K 1/2 W
C 246 0.25
R 272 5 K 2 W
SYNC. GAIN
R 271 33 K 1/2 W
S 204 SYNC SELECTOR
J 204 EXT. SYNC
R 262 100 K
R 266 68 K
C 242 8
R 267 4.7 K
C 243 75
J 205 A
C 245 1.0
V 213 B 1/2 6SL7W
R 265 1M 2W Z GAIN
J 205 Z INPUT
R 261 10 K

[redacted]

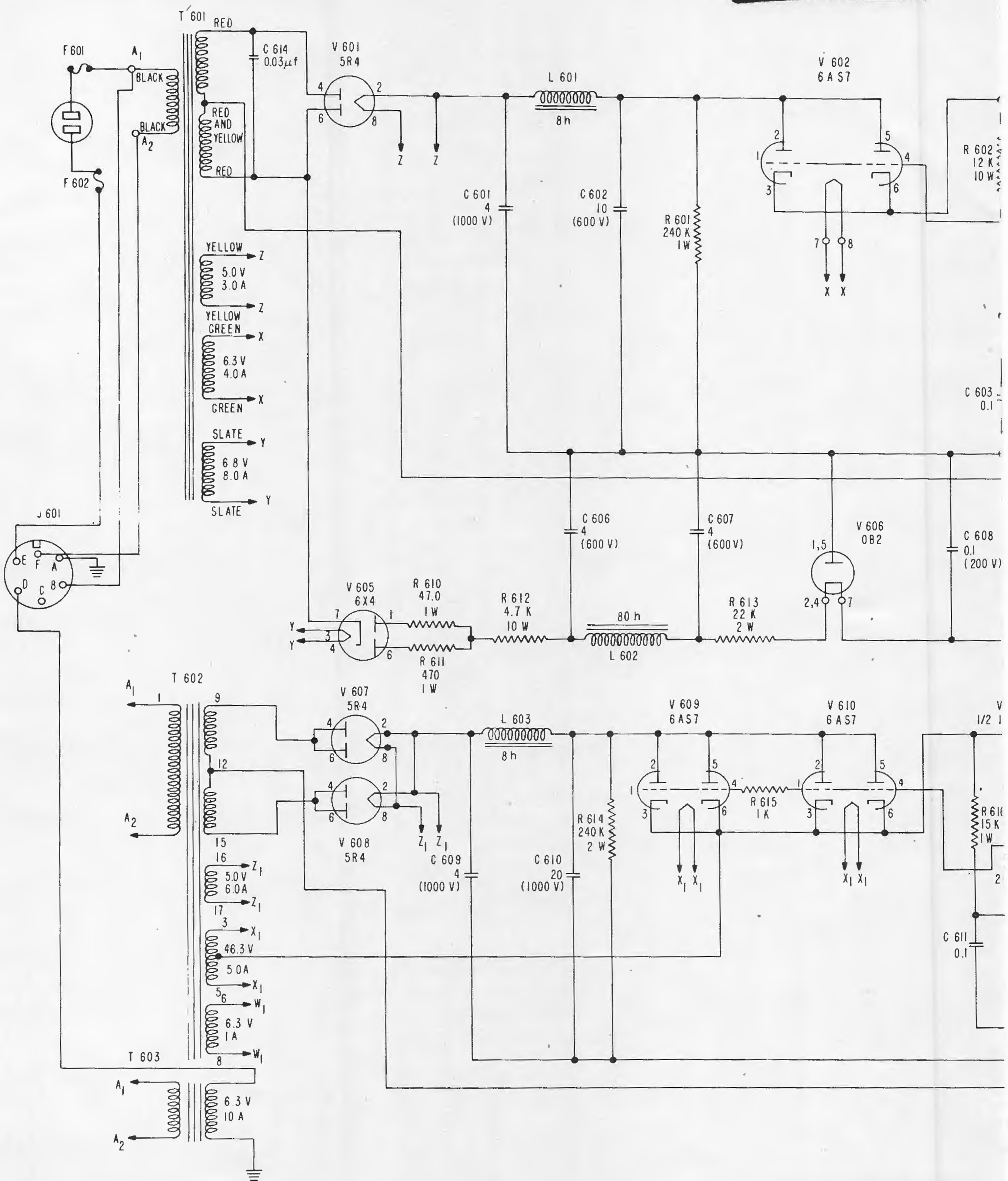
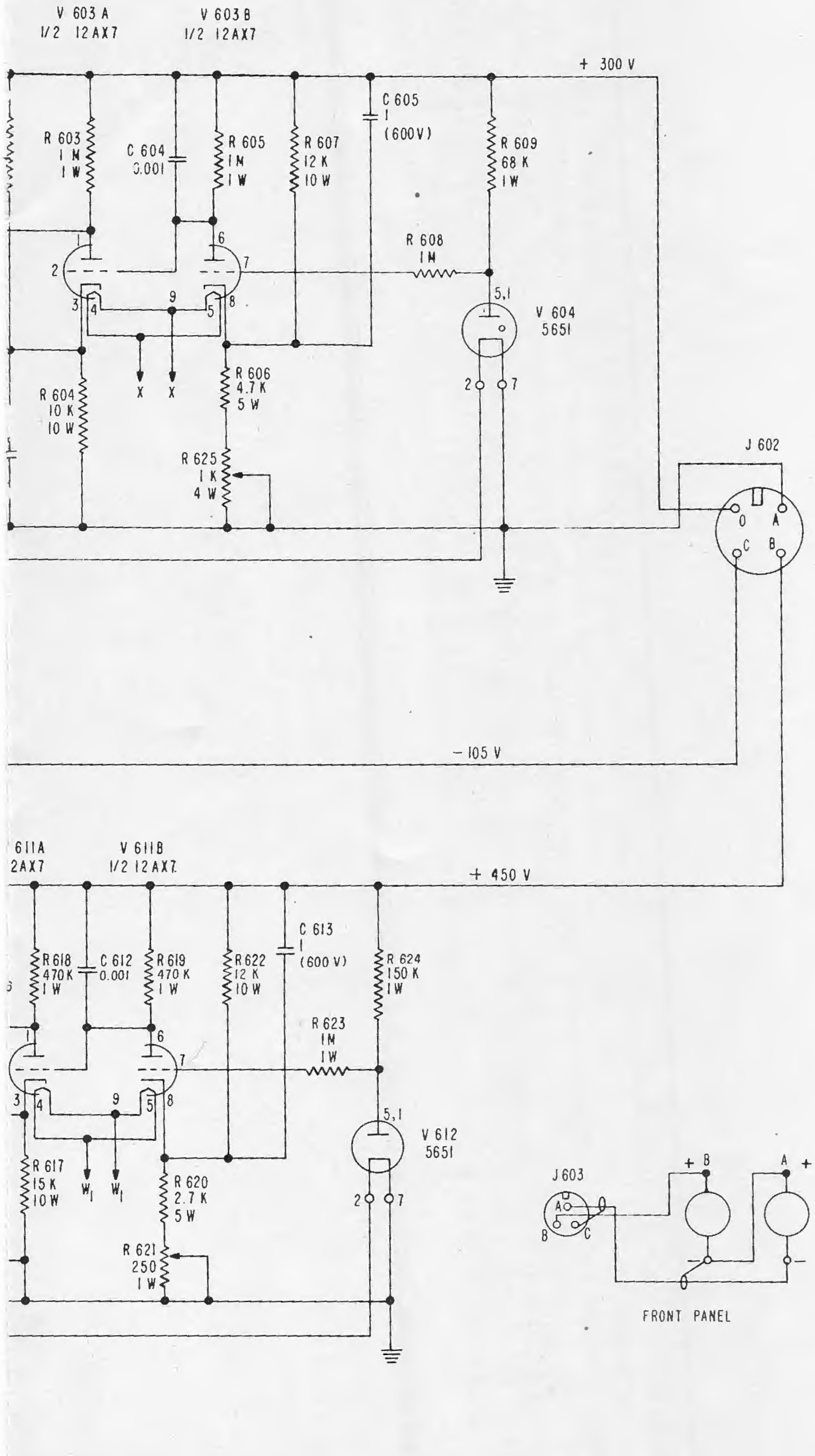



Figure 8-25. Schematic Diagram of Power Supply PP.

[redacted]


V 603 A
1/2 12AX7
V 603 B
1/2 12AX7
+ 300 V
R 603
1 M
1 W
C 604
0.001
R 605
1 M
1 W
R 607
12 K
10 W
C 605
1
(600 V)
R 609
68 K
1 W
R 608
1 M
V 604
5651
R 604
10 K
10 W
R 606
4.7 K
5 W
R 625
1 K
4 W
J 602
- 105 V
611A
2AX7
V 611B
1/2 12AX7
+ 450 V
R 618
470 K
1 W
C 612
0.001
R 619
470 K
1 W
R 622
12 K
10 W
C 613
1
(600 V)
R 624
150 K
1 W
R 623
1 M
1 W
V 612
5651
R 617
15 K
10 W
R 620
2.7 K
5 W
R 621
250
1 W
J 603
FRONT PANEL

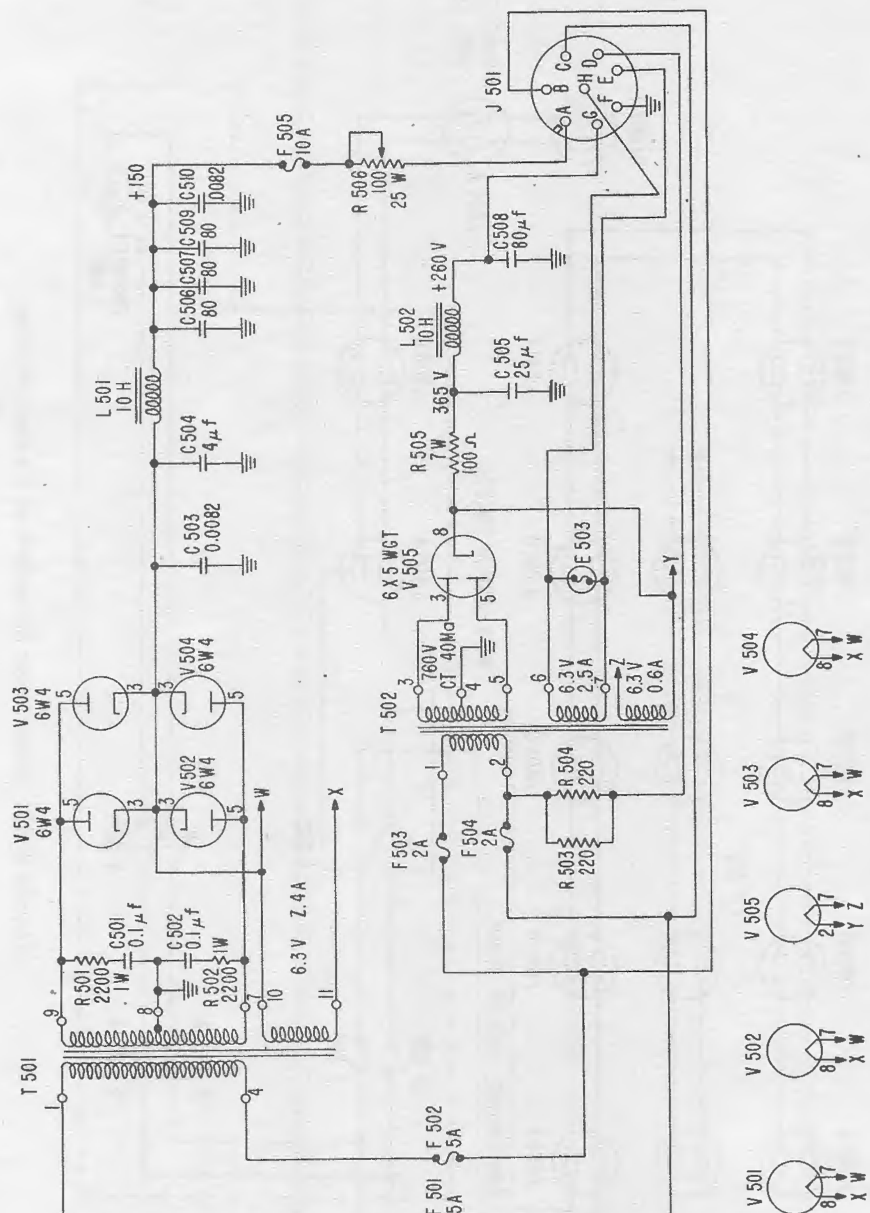



Figure 8-26. Schematic Diagram of Power Supply PP-456A/FSM-5A

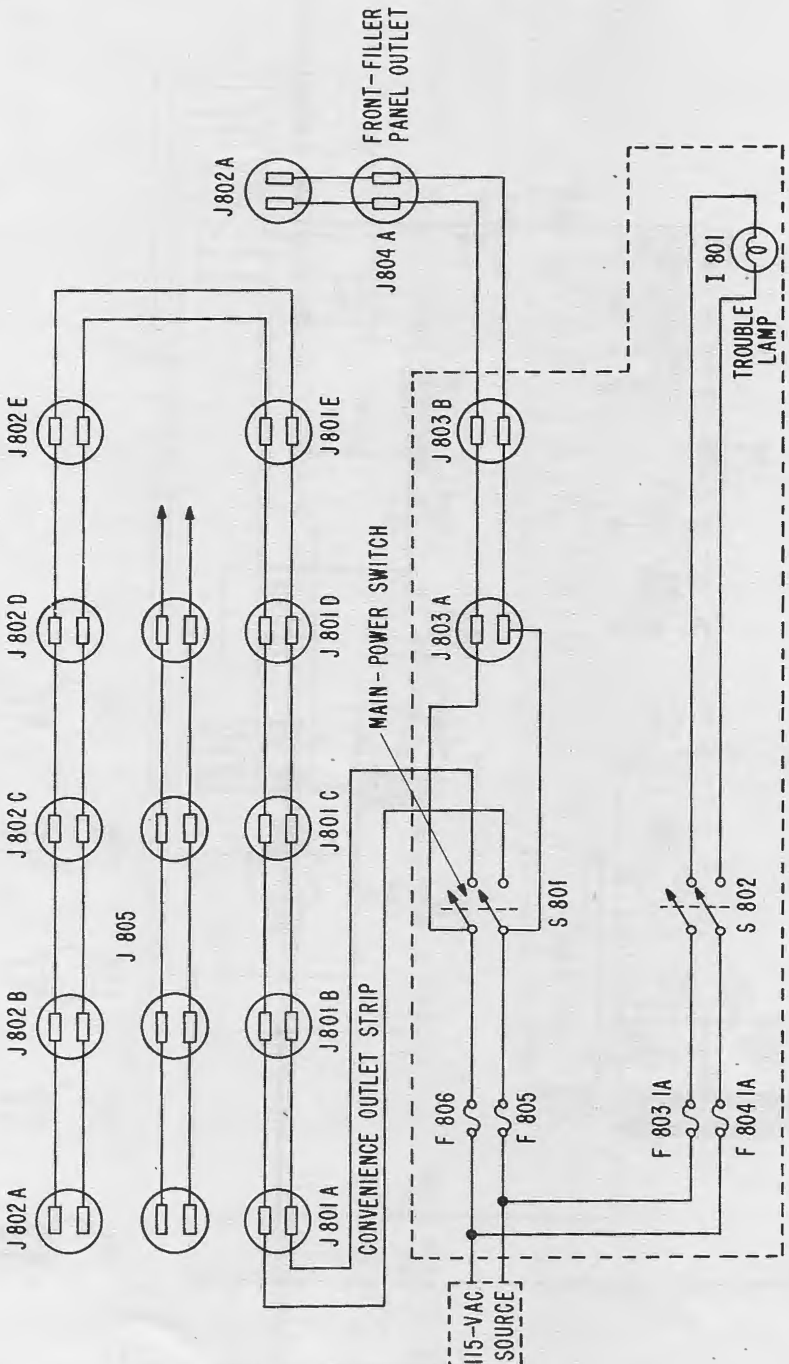



Figure 8-27. Schematic Diagram of Cabinet Wiring





[redacted]

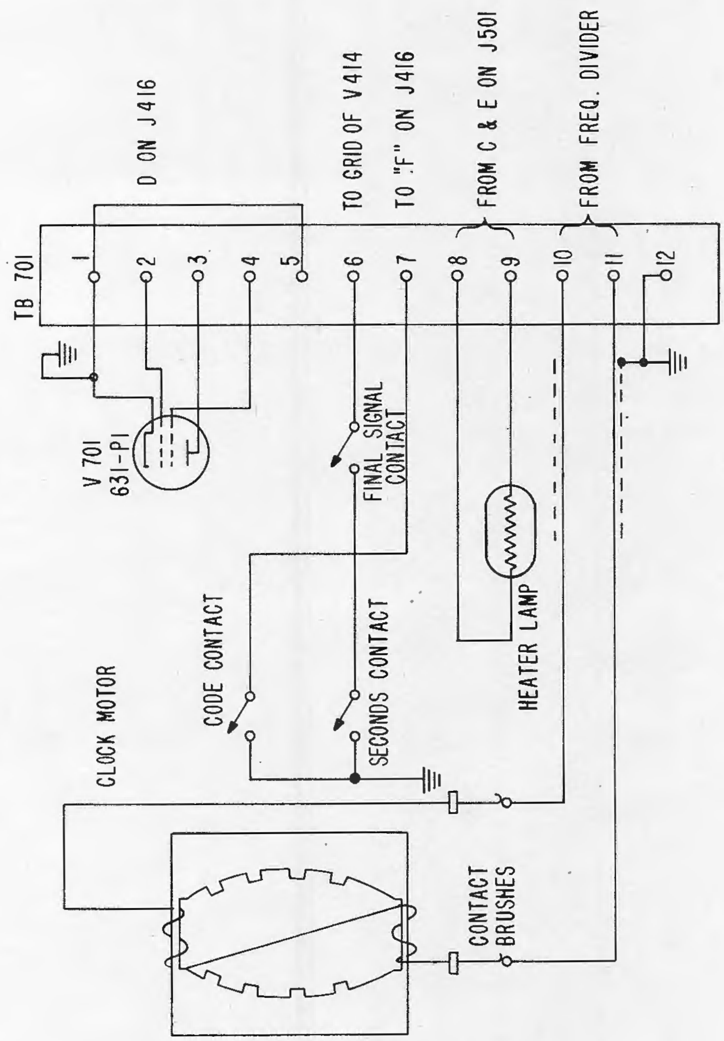
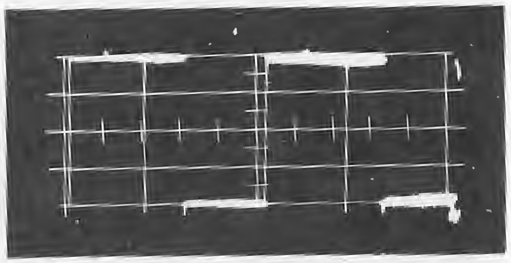
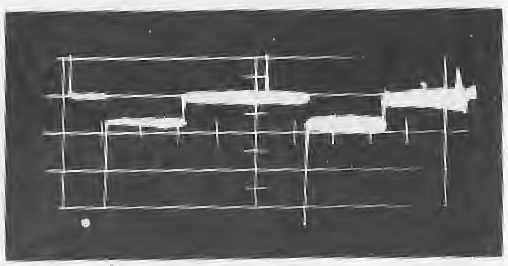



Figure 8-28. Schematic Diagram of Clock Wiring

R412 of Counter Decade No. 1
95 Volts Peak to Peak
2000 $\mu$s/cm

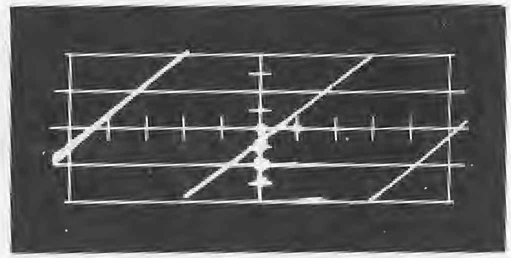


J402, Pin 5 of Counter Decade No. 1
90 Volts Peak to Peak
2000 $\mu$s cm

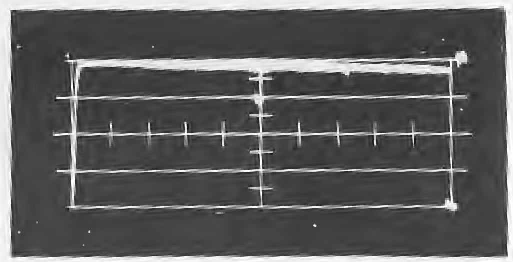


R411 of Counter Decade No. 1
90 Volts Peak to Peak
2000 $\mu$s/cm

V404, Pin 1,
22 Volts Peak to Peak
2000 $\mu$s/cm

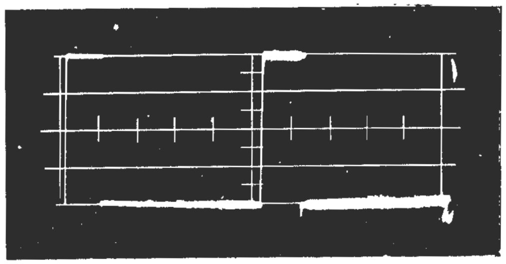


V404, Pin 6
24 Volts Peak to Peak
2000 $\mu$s/cm

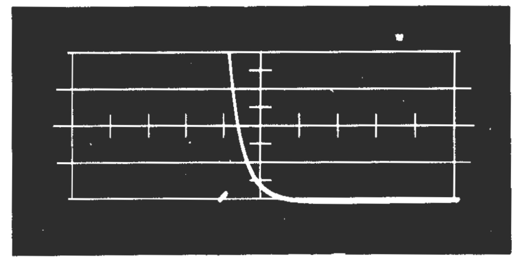


J405, Pin 5
95 Volts Peak to Peak
1000 $\mu$s/cm

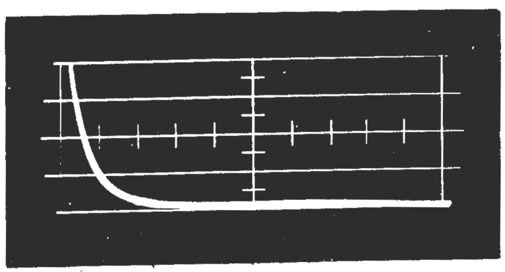
DECLASSIFIED



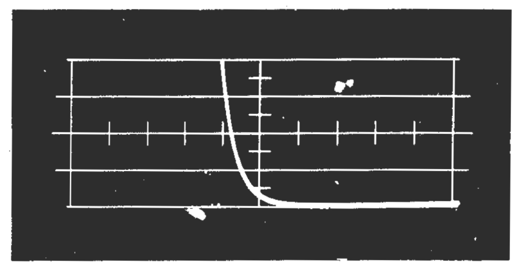
J403, Pin 5 of Counter Decade No. 1
90 Volts Peak to Peak
2000 μs/cm



V406, Pin 1
260 Volts Peak to Peak
20 μs/cm

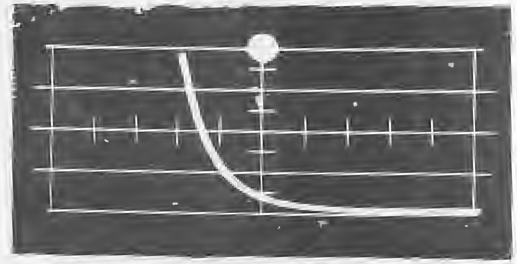


V403, Pin 1 of Counter Decade No. 1
300 Volts Peak to Peak
22 μs/cm

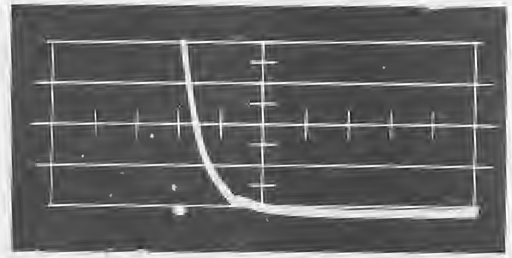


V406, Pin 2
285 Volts Peak to Peak
20 μs/cm

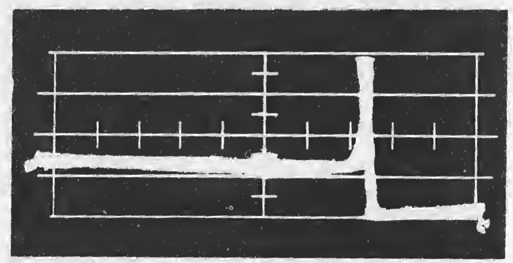
Figure 8-29. Voltage-Waveform Test Points in Time Comparator



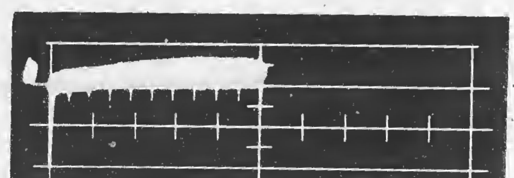
V409, Pins 1 & 6
240 Volts Peak to Peak
200 μs/cm

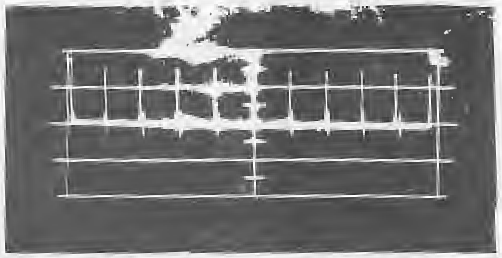


V403, Pin 2
250 Volts Peak to Peak
20 μs/cm

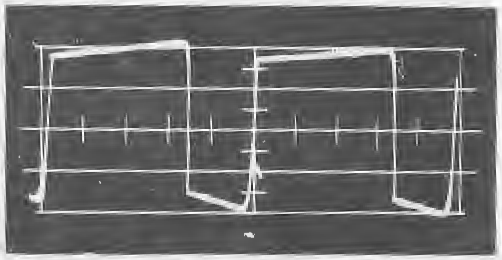


V405, Pin 2
100 Volts Peak to Peak
1 μs/cm

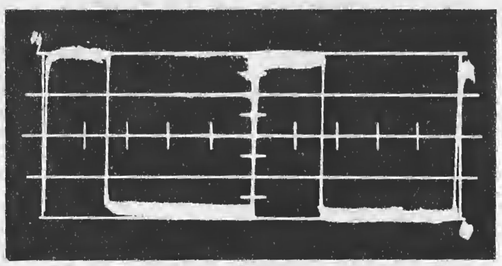




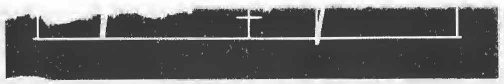
V405, Pins 1 & 6
7 Volts Peak to Peak
1000 μs/cm



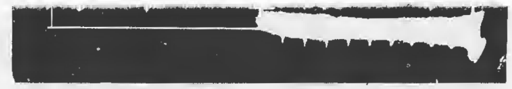
J406
65 Volts Peak to Peak
200 μs/cm



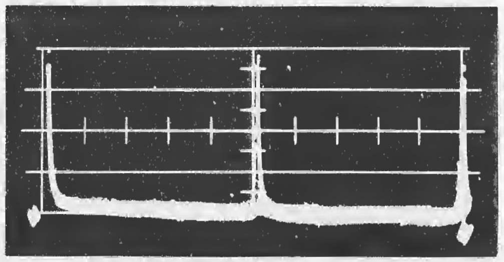
J407, Pin 6
90 Volts Peak to Peak
200 μs/cm



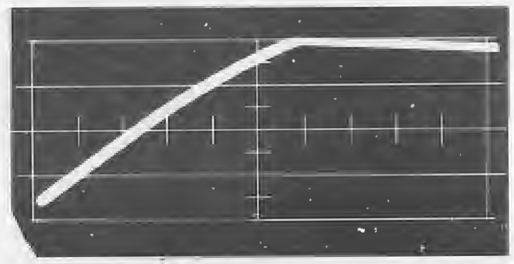
V408A, Pin 2
90 Volts Peak to Peak
200 $\mu$s/cm



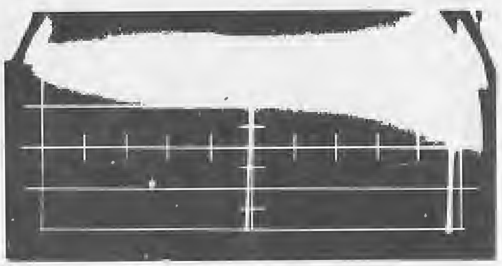
V405, Pin 7
12 Volts Peak to Peak
2000 $\mu$s/cm



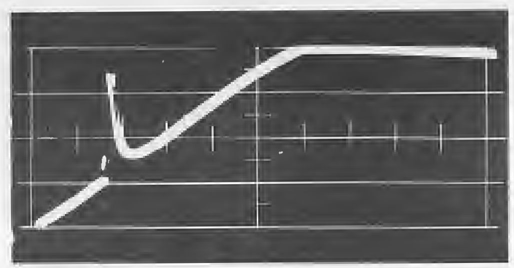
V408A, Pin 3
55 Volts Peak to Peak
200 $\mu$s/cm



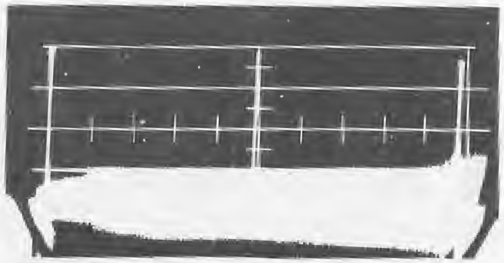
V416, Pin 4
220 Volts Peak to Peak
20 $\mu$s/cm



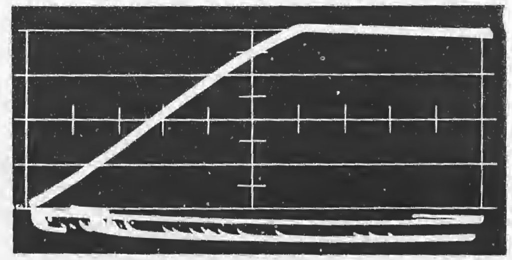
V408B, Pin 6
145 Volts Peak to Peak
200 $\mu$s/cm



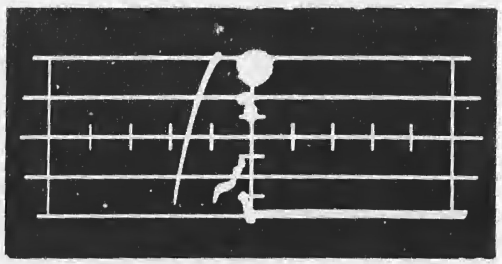
V416, Pin 3
120 Volts Peak to Peak
20 $\mu$s/cm



1N34
120 Volts Peak to Peak
200 μs/cm



V416, Pin 6
120 Volts Peak to Peak
20 μs/cm



V409, Pins 3 & 8
80 Volts Peak to Peak
200 μs/cm

Figure 8-29 (Cont'd). Voltage-Waveform Test Points in Time Comparator

# SECTION 9
# PARTS LIST

## 1. Binary Plug-In Unit CV-88A1/FSM-5A

| Part No. | Description |
|---|---|
| **CAPACITOR** | |
| C401 | Mica, 51 $\mu\mu$f, 500 v |
| C402 | Mica, 51 $\mu\mu$f, 500 v |
| C403 | Mica, 51 $\mu\mu$f, 500 v |
| C404 | Disc, ceramic, 0.01 $\mu$f |
| **TUBE** | |
| V401 | 5963 |
| **RESISTOR** | |
| R401 | 47 K, 1 w |
| R402 | 47 K, 1 w |
| R403 | 47 K, 1 w |
| R404 | 270 K, 1/2 w |
| R405 | 270 K, 1/2 w |
| R406 | 100 K, 1/2 w |
| R407 | 100 K, 1/2 w |
| R408 | 390 $\Omega$, 1/2 w |
| R409 | 12 K, 1 w |
| R410 | 390 $\Omega$, 1/2 w |
| **JACK** | |
| P400 | 11-prong octal |

## 2. Counter Decade CV-88A2/FSM-5A

| Part No. | Description |
|---|---|
| **CAPACITOR** | |
| C405 | Mica, 100 $\mu\mu$f, 600 v |
| C406 | Mica, 100 $\mu\mu$f, 600 v |
| C407 | Metallized paper, 0.1 $\mu$f, 600 v |
| C408 | Bathtub, 2 x 0.1 $\mu$f, 600 v |
| C409 | Mica, 1000 $\mu\mu$f, 500 v |
| C410 | Bathtub, 0.1 $\mu$f, 600 v |
| **TUBE** | |
| V402 | 12AU7 |
| V403 | 5696 |
| **RESISTOR** | |
| R411 | 82 K, 1 w |
| R412 | 82 K, 1/2 w |
| R413 | 1 M$\Omega$, 1/2 w |
| R414 | 1.2 K, 1 w |
| R415 | 10 K, 1 w |
| R416 | 1.2 K,1 w |
| R417 | 10 K, 1 w |
| R418 | 1 M$\Omega$, 1 w |
| R419 | 100 K, 1 w |
| R420 | 120 K, 1 w |
| R421 | 120 K, 2 w |
| R422 | 47 K, 1/2 w |
| R423 | 10 K, 1 w |
| **JACK** | |
| J401 | 11-prong socket, Amphenol 78511 |
| J402 | 11-prong socket, Amphenol 78511 |
| J403 | 11-prong socket, Amphenol 78511 |
| J404 | 11-prong socket, Amphenol 78511 |
| P401 | Octal plug, 86CP8 |
| **SWITCH** | |
| S401 | 4-pole 12-position ceramic-wafer (4-ganged sections) |

## 3. Sweep Generator CV-88A3/FSM-5A

| Part No. | Description |
|---|---|
| **CAPACITOR** | |
| C411 | Metal-cased, 1.0 $\mu$f, 600 v |
| C412 | Mica, 230 $\mu\mu$f, 600 v |
| C413 | Metal-cased, 0.1 $\mu$f, 600 v |
| C414 | Mica, 100 $\mu\mu$f, 600 v |
| C415 | Metal-cased, 0.1 $\mu$f, 600 v |
| C416 | Metal-cased, 0.1 $\mu$f, 600 v |
| C417 | Mica, 10,000 $\mu\mu$f, 600 v |
| C418 | Mica, 330 $\mu\mu$f, 600 v |



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| Part No. | Description |
|---|---|
| **CAPACITOR** | |
| C419 | Metal-cased, 1.0 $\mu$f, 600 v |
| C420 | Mica, 2000 $\mu\mu$f, 600 v |
| C421 | Metal-cased, 1.0 $\mu$f, 600 v |
| C421.1 | Mica, 51 $\mu\mu$f, 600 v |
| C422 | Metal-cased, 0.1 $\mu$f, 600 v |
| C423 | Metal-cased, 0.1 $\mu$f, 600 v |
| **TUBE** | |
| V404 | 5696 |
| V405 | 12AU7 |
| V406 | 5696 |
| **RESISTOR** | |
| R424 | 1 M $\Omega$, 1 w |
| R425 | 100 K, 1 w |
| R426 | 10 K, 1 w |
| R427 | 10 K, 1 w |
| R428 | 47 K, 1/2 w |
| R429 | 82 K, 1/2 w |
| R430 | 470 K, 1 w |
| R431 | 10 K, 1 w |
| R432 | 10 K, 1 w |
| R433 | 120 K, 1 w |
| R434 | 1 M $\Omega$, 1 w |
| R435 | 180 K, 1/2 w |
| R436 | 39 K, 1/2 w |
| R437 | 82 K, 1/2 w |
| R438 | 82 K, 1/2 w |
| R439 | 15 K, 1 w |
| R440 | 100 K, 1 w |
| R441 | 100 $\Omega$, 1 w |
| **JACK** | |
| J402 | 11-prong plug, Amphenol 86CP11 |
| P405 | 11-prong socket, Amphenol 78S11 |
| **SWITCH** | |
| S402 | 3PDT, ceramic-wafer |
| S403 | SPST, bat-handle toggle |

4. Pulse Generator CV-88A4/FSM-5A

| Part No. | Description |
|---|---|
| **CAPACITOR** | |
| C424 | Mica, 50 $\mu\mu$f, 500 v |
| C425 | Mica, 200 $\mu\mu$f, 500 v |
| C426 | Metallized paper, 0.1 $\mu$f, 600 v |
| C427 | Mica, 200 $\mu\mu$f, 500 v |
| C428 | Metallized paper, 0.1 $\mu$f, 600 v |
| C429 | Paper, 40 $\mu$f, 600 v |
| C430 | Paper, 2.0 $\mu$f, 600 v |
| **TUBE** | |
| V407 | 12AU7 |
| V408 | 12AU7 |
| V409 | 12AU7 |
| **RESISTOR** | |
| R442 | 120 K, 1/2 w |
| R443 | 4.7 K, 2 w |
| R444 | 47 K, 1 w |
| R445 | 120 K, 1/2 w |
| R446 | 470 K, 1/2 w |
| R447 | 10 K, 1 w |
| R448 | 1.5 M $\Omega$, 1 w |
| R449 | 50-K rheostat, ABJLU 5031 |
| R450 | 15 K, 10 w, wire-wound |
| R451 | 470 K, 1 w |
| R452 | 5.6 K, 2 w |
| R453 | 2.2 K, 2 w |
| **TRANSFORMER** | |
| T401 | NRL 6413 |
| **JACK** | |
| P403 | 11-prong plug, Amphenol 86CP11 |
| J406 | UG 290/U connector |
| **CRYSTAL** | |
| CR401 | 1N34 |

5. Keyer Unit CV-88A5/FSM-5A

| Part No. | Description |
|---|---|
| **CAPACITOR** | |
| C431 | Mica, 50 $\mu\mu$f, 500 v |
| C432 | Metal-cased, 4.0 $\mu$f, 1000 v |
| C433 | Metal-cased, 15.0 $\mu$f, 1000 v |
| C434 | Bathtub, 0.1 $\mu$f, 600 v |

| Part No. | Description |
|---|---|
| CAPACITOR | |
| C435 | Oil-filled, 4.0 $\mu$f, 600 v |
| C436 | Mica, 10,000 $\mu\mu$f, 500 v |
| TUBE | |
| V410 | 12AU7 |
| V411 | 12AU7 |
| V412 | 6X4 |
| V413 | 6X4 |
| V414 | 6C4 |
| V415 | 6AL5 |
| V416 | 6AS7G |
| V417 | 6AS7G |
| V418 | 6AS7G |
| RESISTOR | |
| R454 | 82 K, 1/2 w |
| R455 | 270 K, 1 w |
| R456 | 470 K, 1 w |
| R457 | 330 K, 1 w |
| R458 | 4.7 K, 2 w |
| R459 | 82 K, 2 w |
| R460 | 20 K, 1/2 w |
| R461 | 50-K rheostat, AB type V-5000 |
| R462 | 270 K, 1 w |
| R463 | 680 $\Omega$, 1 w |
| R464 | 680 $\Omega$, 1 w |
| R465 | 120 K, 1/2 w |
| R466 | 47 K, 1 w |
| R467 | 15 K, 1 w |
| R468 | 39 K, 1 w |
| R469 | 1 K, 1 w |
| R470 | 56 K, 1 w |
| R471 | 3 K, 10 w, wire-wound |
| R472 | 3 K, 10 w, wire-wound |
| R473 | 3 K, 10 w, wire-wound |
| R474 | 3 K, 10 w, wire-wound |
| R475 | 3 K, 10 w, wire-wound |
| R476 | 3 K, 10 w, wire-wound |
| R477 | 820 $\Omega$, 2 w |
| INDUCTOR | |
| L401 | 4.6 h, 3410 turns #38, NRL 6721 |
| TRANSFORMER | |
| T401 | 2 x 350 v 15 ma; 2 x 6.3 v ac, 1A, NRL 6015 |

| Part No. | Description |
|---|---|
| JACK | |
| J407 | 11-prong socket, Amphenol 78S11 |
| P404 | 11-prong plug, Amphenol 86CP11 |
| BARRIER STRIP | |
| TB401 | Jones 10-terminal barrier strip |

6. Time-Comparator Chassis CV-88A/FSM-5A

| Part No. | Description |
|---|---|
| CAPACITOR | |
| C437 | Bathtub, 0.5 $\mu$f, 600 v |
| C438 | Metallized paper, 0.03 $\mu$f, 600 v |
| C439 | Metallized paper, 8.0 $\mu$f, 150 v |
| C440 | Metallized paper, 8.0 $\mu$f, 150 v |
| C441 | Metallized paper, 0.1 $\mu$f, 200 v |
| C442 | Metallized paper, 0.362 $\mu$f, 200 v |
| C443 | Metallized paper, 0.265 $\mu$f, 200 v |
| C444 | 7-45 $\mu\mu$f trimmer |
| C445 | Mica, 362 $\mu\mu$f, 500 v |
| C446 | 7-45 $\mu\mu$f trimmer |
| C447 | Mica, 265 $\mu\mu$f, 500 v |
| C448 | Metallized paper, 0.362 $\mu$f (approx.), 200 v |
| C449 | Metallized paper, 0.265 $\mu$f (approx.), 200 v |
| RESISTOR | |
| R478 | 10 K, 2 w |
| R479 | 47 K, 2 w |
| R480 | 15 K, 2 w |
| R481 | Two 12 $\Omega$, 1 w in parallel |
| R482 | Two 12 $\Omega$, 1 w in parallel |
| R483 | 120 K, 2 w |
| R484 | 120 K, 2 w |
| R485 | 120 K, 2 w |
| R486 | 120 K, 2 w |
| R487 | 240 K, 2 w |
| R488 | 1 K, RC type WW4J, 1/2% |

| Part No. | Description |
|---|---|
| RESISTOR | |
| R489 | 1 M $\Omega$, RC type WW5J, 1/2% |
| R490 | 1 K, RC type WW4J, 1/2% |
| R491 | 1 K, 1/2 w |
| INDUCTOR | |
| L402 | 8 h, 40 ma, 500 $\Omega$, Merit C2976 |
| L403 | 8 h, 40 ma, 500 $\Omega$, Merit C2976 |
| TRANSFORMER | |
| T402 | 6.3 v, 10 amp, Thordarson T21F12 |
| JACK | |
| J408 | 11-prong socket, Amphenol 77-MIP-11 |
| J409 | 8-prong socket, mica-filled bakelite |
| J410 | 8-prong socket, mica-filled bakelite |
| J411 | 8-prong socket, mica-filled bakelite |
| J412 | 11-prong socket, Amphenol 77-MIP-11 |
| J413 | 11-prong socket, Amphenol 77-MIP-11 |
| J414 | UG 290/U connector |
| J415 | UG 290/U connector |
| J416 | AN/3102A-20-15S |
| J417 | UG 290/U connector |
| J418 | UG 290/U connector |
| P405 | AN/3102A-18-12P |
| P406 | AN/3102A-18-10P |
| BARRIER STRIP | |
| TB402 | Jones 2-terminal barrier strip |
| SWITCH | |
| S404 | SPST, bat-handle toggle |
| S405 | DPDT, bat-handle toggle |
| S406 | 3-pole, 3-position, ceramic-wafer |
| S407 | Bat-handle, spring-control, center-off |

| Part No. | Description |
|---|---|
| RELAY | |
| K401 | DPDT, 6 v ac, 10-amp, Advance type 1000 |
| PILOT LIGHT | |
| E401 | No. 47 pilot lamp and jewel assembly |

7. Power Supply PP-455A/FSM-5A

| Part No. | Description |
|---|---|
| CAPACITOR | |
| C601 | Metal-cased, 4 $\mu$f, 1000 v |
| C602 | Metal-cased, 10 $\mu$f, 600 v |
| C603 | Bathtub, 0.1 $\mu$f, 1000 v |
| C604 | Mica, 1000 $\mu\mu$f, 600 v |
| C605 | Bathtub, 1 $\mu$f, 600 v |
| C606 | Metal-cased, 4 $\mu$f, 600 v |
| C607 | Metal-cased, 4 $\mu$f, 600 v |
| C608 | Metallized, 0.1 $\mu$f, 200 v |
| C609 | Metal-cased, 4 $\mu$f, 1000 v |
| C610 | Metal-cased, 2 x 10 $\mu$f, 1000 v |
| C611 | Bathtub, 0.1 $\mu$f, 1000 v |
| C612 | Mica, 1000 $\mu\mu$f, 600 v |
| C613 | Bathtub, 1 $\mu$f, 600 v |
| C614 | Metal-cased, .03 $\mu$f, 900 v |
| TUBE | |
| V601 | 5R4GY |
| V602 | 6AS7G |
| V603 | 12AX7 |
| V604 | 5651 |
| V605 | 6X4 |
| V606 | OB2 |
| V607 | 5R4GY |
| V608 | 5R4GY |
| V609 | 6AS7G |
| V610 | 6AS7G |
| V611 | 12AX7 |
| V612 | 5651 |
| RESISTOR | |
| R601 | 240 K, 1 w |
| R602 | 12 K, 10 w, wire-wound |



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| Part No. | Description |
|---|---|
| RESISTOR | |
| R603 | 1 M Ω, 1 w |
| R604 | 10 K, 10 w, wire-wound |
| R605 | 1 M Ω, 1 w |
| R606 | 4.5 K, 10 w, wire-wound |
| R607 | 12 K, 10 w, wire-wound |
| R608 | 1 M Ω, 1 w |
| R609 | 68 K, 1 w |
| R610 | 470 Ω, 1 w |
| R611 | 470 Ω, 1 w |
| R612 | 4.7 K, 10 w, wire-wound |
| R613 | 2.2 K, 2 w |
| R614 | 240 K, 2 w |
| R615 | 1 K, 1 w |
| R616 | 15 K, 10 w, wire-wound |
| R617 | 15 K, 10 w, wire-wound |
| R618 | 470 K, 1 w |
| R619 | 470 K, 1 w |
| R620 | 2 K, 10 w in series with a 700 Ω, 10 w wire-wound |
| R621 | 250, 25 w rheostat |
| R622 | 12 K, 10 w, wire-wound |
| R623 | 1 M Ω, 1 w |
| R624 | 150 K, 1 w |
| R625 | 1 K, 4 w |
| INDUCTOR | |
| L601 | 8 h, 200 ma, 85 Ω, Chicago R58200 |
| L602 | 12 h, 80 ma, 375 Ω, Thorardson T-20C53 |
| L603 | 8 h, 300 ma, 70 Ω, Chicago R58300 |
| TRANSFORMER | |
| T601 | Sola, CVE 7107 |
| T602 | Chicago, PSR 300 |
| T603 | Chicago, F610, 6.3-v 10-amp |
| JACK | |
| J601 | AN/3102A-18-12S |
| J602 | AN/3102A-18-4S |
| J603 | AN/3102A-18-5P |

| Part No. | Description |
|---|---|
| METER | |
| "A" Voltmeter | 0-10 v dc, Weston, model 301 |
| "B" Voltmeter | 0-300 v dc, Weston, model 301 |

8. Frequency-Divider Assembly CV-87A/FSM-5A

| Part No. | Description |
|---|---|
| CAPACITOR | |
| C101 | Mica, 10 μμf |
| C102 | Mica, 730 μμf (approx.), (tune to 100 kc) |
| C103 | Bathtub, 0.25 μf, 1000 v |
| C104 | Mica, 51 μμf |
| C105 | Mica, 20 μμf |
| C106 | 1/2 Bathtub, 2 x 0.25 μf, 600 v |
| C107 | 1/2 Bathtub, 2 x 0.25 μf, 600 v |
| C108 | Mica, 8590 μμf (approx.) (tune to 10 kc) |
| C109 | Mica, 100 μμf |
| C110 | Mica, 500 μμf |
| C111 | Mica, 100 μμf |
| C112 | Bathtub, 0.25 μf, 600 v |
| C113 | Mica, 200 μμf, 500 v |
| C114* | Mica, 1000 μμf (approx.) (C114 and C131 tuned to 9 kc) |
| C115 | 1/2 Bathtub, 2 x 0.25 μf, 600 v |
| C116 | 1/2 Bathtub, 2 x 0.25 μf, 600 v |
| C117 | 0.08 μf (approx.) mica and bathtub (tune to 1 kc) |
| C118 | Mica, 0.01 μf |
| C119 | Mica, 1000 μμf |
| C120 | 1/2 Bathtub, 2 x 0.25 μf, 600 v |
| C121 | 0.09 μf (approx.) mica and bathtub (tune to 1 kc) |

*It is necessary to select this value, and hence the loop gain, so that frequency division is initiated by closing the start switches. The magnitude of this gain, however, should not be so large that the divider can be self-started by the driving signal.



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| Part No. | Description |
|---|---|
| CAPACITOR | |
| C122 | Bathtub, 0.01 μf 600 v |
| C123 | Mica, 1000 μμf (approx.) (C123 and C124 tuned to 90 kc) |
| C124 | Mica, 5100 μμf (approx.) (C123 and C124 tuned to 90 kc) |
| C125 | 1/2 Bathtub, 2 x 0.25 μf, 600 v |
| C126 | 1/2 Bathtub, 2 x 0.25 μf, 600 v |
| C127* | Mica, 30 μμf (approx.) |
| C128 | Mica, 9100 μμf (approx.) (tune to 30 kc) |
| C129 | 1/2 Bathtub, 2 x 0.25 μf, 600 v |
| C130 | 1/2 Bathtub, 2 x 0.25 μf, 600 v |
| C131* | 5150 μμf (approx.) (C114 and C131 tuned to 9 kc) |
| C132 | 1/2 Bathtub, 2 x 0.25 μf, 600 v |
| C133 | 1/2 Bathtub, 2 x 0.25 μf, 600 v |
| C134* | Mica, 56 μμf |
| C135 | Mica, 8000 μμf (approx.) (tune to 3 kc) |
| C136 | 1/2 Bathtub, 2 x 0.25 μf, 600 v |
| C137 | 1/2 Bathtub, 2 x 0.25 μf, 600 v |
| C138 | Mica, 2000 μμf |
| C139 | 1/2 Bathtub, 2 x 0.25 μf |
| C140 | 15,600 μμf (approx.) (tune to 10 kc) |
| C141 | Bathtub, 0.1 μf, 400 v |
| C142 | Bathtub, 0.1 μf, 400 v |
| C143 | Bathtub, 3 x 0.05 μf, 600 v |
| C144 | Bathtub, 3 x 0.05 μf, 600 v in parallel with metallized condenser, 0.03 μf (approx.), 200 v |
| C145 | Electrolytic, 50 μf, 25 v |

| Part No. | Description |
|---|---|
| CAPACITOR | |
| C146 | Bathtub, 0.1 μf, 1000 v |
| C147 | Electrolytic, 40 μf, 150 v |
| C148 | Bathtub, 0.1 μf, 400 v |
| C149 | Metal-cased, 2 μf, 600 v |
| C150 | Bathtub, 0.05 μf, 1000 v |
| C151 | Bathtub, 0.02 μf, 600 v |
| C152 | Tubular, 1.0 μf, 220 v |
| C153 | Bathtub, 1.0 μf, 600 v |
| C154 | 1/2 Bathtub, 2 x 0.25 μf, 600 v |
| C155 | 1/2 Bathtub, 2 x 0.25 μf, 600 v |
| C156 | Mica, 7480 μμf (approx.) (tune to 10 kc) |
| TUBE | |
| V101 | 6AS6 |
| V102 | 6AS6 |
| V103 | 6AS6 |
| V104 | 6AS6 |
| V105 | 5686 |
| V106 | 6AQ5 |
| V107 | 6AS6 |
| V108 | 6AS6 |
| V109 | 6AS6 |
| V110 | 6AS6 |
| V111 | 5686 |
| V112 | 6C4 |
| V113 | 5686 |
| V114 | 6AS7G |
| V115 | 12AU7 |
| V116 | 12AU7 |
| RESISTOR | |
| R101 | 100 K, 1/2 w |
| R102 | 560 Ω, 1 w |
| R103 | 15 K, 1 w |
| R104 | 22 K, 1/2 w |
| R105 | 22 K, 1/2 w |
| R106 | 560 Ω, 1 w |
| R107 | 15 K, 1 w |
| R108 | 100 K, 1/2 w |
| R109 | 560 Ω, 1 w |
| R110 | 15 K Ω, 1 w |
| R111* | 22 - 100 K, 1/2 w |

* It is necessary to select this value, and hence the loop gain, so that frequency division is initiated by closing the start switches. The magnitude of this gain, however, should not be so large that the divider can be self-started by the driving signal.

| Part No. | Description |
|---|---|
| RESISTOR | |
| R112 | 22K, 1/2 w |
| R113 | 560 Ω, 1 w |
| R114 | 15 K, 1 w |
| R115 | 330 K, 1/2 w |
| R116 | 33 K, 1/2 w |
| R117 | 270 Ω, 1 w |
| R118 | 750 Ω, 1 w |
| R119 | 3 K, 1 w |
| R120 | 300 K, 1/2 w |
| R121 | 100 K, 1/2 w |
| R122 | 15 K, 1 w |
| R123 | 2.7 K, 1 w |
| R124 | 10 K, 1/2 w |
| R125 | 100 K, 1/2 w |
| R126 | 15 K, 1/2 w |
| R127 | 2.7 K, 1 w |
| R128 | 10 K, 1/2 w |
| R129 | 56 K, 1/2 w |
| R130 | 15 K, 1 w |
| R131 | 2.7 K, 1 w |
| R132 | 10 K, 1/2 w |
| R133 | 100 K, 1/2 w |
| R134 | 15 K, 1 w |
| R135 | 2.7 K, 1 w |
| R136 | 10 K, 1/2 w |
| R137 | 100 K, 1/2 w |
| R138 | 100 K, 1/2 w |
| R139 | 330 K, 1/2 w |
| R140 | 33 K, 1/2 w |
| R141 | 270 Ω, 1 w |
| R142 | 270 K, 1/2 w |
| R143 | 1.2 K, 1 w |
| R144 | 2.7 K, 1 w |
| R145 | 430 Ω, 1 w |
| R146 | 33 K, 1/2 w |
| R147 | 68 K, 1/2 w |
| R148 | 270 Ω, 1 w |
| R149 | 22 K, 1 w |
| R150 | 2.2 M Ω, 1/2 w |
| R151 | 4.7 K, 1 w |
| R152 | 47 K, 1 w |
| R153 | 15 K, 10 w, wire-wound |
| R154 | 120 K, 1/2 w |
| R155 | 120 K, 1/2 w |
| R156 | 1 K, 1 w |
| R157 | 330 Ω, 1 w |
| R158 | 330 Ω, 1 w |
| R159 | 2.5 K, 10 w, wire-wound |

| Part No. | Description |
|---|---|
| INDUCTOR | |
| L101 | 3 mh, 2 Ω, 450T #25, NRL 5893 |
| L102 | 30 mh, 2 Ω, 615T #25, NRL 5411D |
| L103 | 30 mh, 2 Ω, 615T #25, NRL 5411D |
| L104 | 316 mh, 22 Ω, 2010T #30, NRL 5411D |
| L105 | 3 mh, 2 Ω, 450T #25, NRL 5893 |
| L106 | 3 mh, 2 Ω, 450T #25, NRL 5893 |
| L107 | 316 mh, 22 Ω, 2010T #30, NRL 5411D |
| L108 | 316 mh, 22 Ω, 2010T #30, NRL 5411D |
| L109 | 4 h, 200 ma, 145 Ω, Thorardson 20C54 |
| L110 | 8 h, 40 ma, 500 Ω, Merit 2976 |
| L111 | 8 h, 40 ma, 500 Ω, Merit 2976 |
| TRANSFORMER | |
| T101 | Primary 230 mh, 4.5 Ω, 1042T #34, secondary 0.5 Ω, 194T #34, NRL 5411C |
| T102 | Primary 10.2 mh, 143Ω, 218T #31, secondary 12 Ω, 61T #25, NRL 5411B |
| T103 | UTC A18 |
| T104 | Primary 2.6 h, 14.4 Ω, 225 v CT, 450T#30, secondary 64.2 Ω, 615 and 730 volt taps, 800T #33, NRL 5822 |
| JACK | |
| J101 | UG-290/U connector |
| J102 | UG-290/U connector |
| J103 | UG-290/U connector |
| J104 | UG-290/U connector |
| J105 | UG-290/U connector |
| J106 | UG-290/U connector |
| J107 | AN/3102A-125-3P |
| J108 | AN/3102A-18-11P |
| BARRIER STRIP | |
| TB101 | Jones 2-terminal barrier strip |

| Part No. | Description |
|---|---|
| SWITCH | |
| S101 | Grayhill, pushbutton, normally open |
| S102 | Grayhill, pushbutton, normally open |
| S103 | SPDT, bat-handle toggle, momentary contact |
| RELAY | |
| K101 | DPDT, plate, 1000 Ω, 5 ma, Sigma |
| K102 | DPDT, plate, 1000 Ω, 5 ma, Sigma |
| SELSYN | |
| M101 | Selsyn control transformer, GE 2-J1G1 |
| MOTOR | |
| M102 | Holtzer-Cabot, reversible, 2-phase, 60 rpm, 115 v, 60 cycles ac |

## 9. Power Supply PP-456A/FSM-5A

| Part No. | Description |
|---|---|
| CONDENSER | |
| C501 | Paper, 0.1 μf, 600 v |
| C502 | Paper, 0.1 μf, 600 v |
| C503 | Mica, 8200 μμf, 500 v |
| C504 | Paper, 4 μf, 600 v |
| C505 | Electrolytic, 25 μf, 450 v |
| C506 | Electrolytic, 80 μf, 450 v |
| C507 | Electrolytic, 80 μf, 450 v |
| C508 | Electrolytic, 80 μf, 450 v |
| C509 | Electrolytic, 80 μf, 450 v |
| C510 | Mica, 8200 μμf, 500 v |
| TUBE | |
| V501 | 6W4 |
| V502 | 6W4 |
| V503 | 6W4 |
| V504 | 6W4 |
| V505 | 6X5 WGT |
| RESISTOR | |
| R501 | 2.2 K, 1 w |
| R502 | 2.2 K, 1 w |
| R503 | 220 Ω, 2 w |
| R504 | 220 Ω, 2 w |
| R505 | 100 Ω, 7 w |
| R506 | 100 Ω, 25 w rheostat |
| INDUCTOR | |
| L501 | Stancor C1414, 7.5 h, 400 ma, 60 Ω |
| L502 | 10 h, 75.0 ma, 280 Ω |
| TRANSFORMER | |
| T501 | Lavoie no. C-1363523 |
| T502 | Power, 560 v, 40 ma, Lavoie |
| JACK | |
| J501 | AN/W-C-591 |
| LAMP | |
| E503 | Incandescent, 6.8 v, 0.25 amp |
| FUSE | |
| F501 | Cartridge, 3AG, 5-amp, 1/4" x 1-1/4" |
| F502 | Cartridge, 3AG, 5-amp, 1/4" x 1-1/4" |
| F503 | Cartridge, type 3AG |
| F504 | 2-amp, 1/4" x 1-1/4" |
| F505 | Cartridge, type 3AG, 10A 1/4" x 1-1/4" |

## 10. Oscilloscope OS-13/UA

| Part No. | Description |
|---|---|
| CAPACITOR | |
| C201 | Hermetically sealed metal case, 0.1 μf, 600 v |
| C202 | Dry electrolytic, 75 μf, 25 v |
| C203 | Dry electrolytic, 25 μf, 400 v |
| C204 | Paper, 0.5 μf, 600 v |
| C205 | Paper, 0.5 μf, 600 v |
| C206 | Paper, 0.5 μf, 600 v |
| C207 | Paper, 0.5 μf, 600 v |
| C208 | Hermetically sealed metal case, 0.1 μf, 600 v |

| Part No. | Description |
|---|---|
| CAPACITOR | |
| C209 | Dry electrolytic, 75 μf, 25 v |
| C210 | Hermetically sealed metal case, 0.1 μf, 600 v |
| C211 | Hermetically sealed metal case, 0.1 μf, 600 v |
| C212 | Hermetically sealed metal case, 0.1 μf, 600 v |
| C213 | Dry electrolytic, 75 μf, 25 v |
| C214 | Paper, 0.5 μf, 600 v |
| C215 | Paper, 0.5 μf, 600 v |
| C216 | Paper, 0.5 μf, 600 v |
| C217 | Paper, 0.5 μf, 600 v |
| C218 | Dry electrolytic, 25 μf, 400 v |
| C219 | Dry electrolytic, 75 μf, 25 v |
| C220 | Bathtub, 0.5 μf, 600 v |
| C220.1 | Bathtub, 0.5 μf, 600 v |
| C221 | Hermetically sealed metal case, 0.25 μf, 2000 v |
| C222 | Dry electrolytic, 40 μf, 400 v |
| C223 | Dry electrolytic, 40 μf, 400 v |
| C224 | Dry electrolytic, 40 μf, 400 v |
| C225 | Hermetically sealed metal case, 0.1 μf, 600 v |
| C226 | Hermetically sealed metal case, 0.25 μf, 2000 v |
| C227 | Hermetically sealed metal case, 0.25 μf, 2000 v |
| C228 | Hermetically sealed metal case, 0.5 μf, 2000 v |
| C229 | Hermetically sealed metal case, 0.1 μf, 600 v |
| C230 | Paper, 0.05 μf, 600 v |
| C231 | Paper, 0.05 μf, 600 v |
| C232 | Mica, 10,000 μμf, 300 v |

| Part No. | Description |
|---|---|
| CAPACITOR | |
| C233 | Mica, 10,000 μμf, 300 v |
| C234 | Mica, 3,300 μμf, 500 v |
| C235 | Mica, 3,300 μμf, 500 v |
| C236 | Mica, 2,200 μμf, 500 v |
| C237 | Mica, 820 μμf, 500 v |
| C238 | Mica, 22 μμf, 500 v |
| C239 | Mica, 270 μμf, 500 v |
| C240 | Mica, 100 μμf, 500 v |
| C241 | Mica, 33 μμf, 500 v |
| C242 | Dry electrolytic, 8 μf, 350 v |
| C243 | Dry electrolytic, 75 μf, 25 v |
| C244 | Rotary-type trimmer, 7-45 μμf, ceramic |
| C245 | Bathtub, 1.0 μf, 600 v |
| C246 | Paper, 0.25 μf, 600 v |
| TUBE | |
| V201 | 6SN7GT |
| V202 | 6SN7GT |
| V203 | 6SN7GT |
| V204 | 3JP1 |
| V205 | 6SN7GT |
| V206 | 6SN7GT |
| V207 | 6SN7GT |
| V208 | 5U4G |
| V209 | 5U4G |
| V210 | 6X5WGT |
| V211 | OA2 |
| V212 | Deleted |
| V213 | 6SL7GT |
| V214 | 884 |
| RESISTOR | |
| R201 | 1 M Ω, 1/2 w |
| R202 | 2.2 K, 1/2 w |
| R203 | 2.5 K, 2 w, variable |
| R204 | 22 K, 1 w |
| R205 | 4.7 K, 1 w |
| R206 | 1 K, 1/2 w |
| R207 | 1 M Ω, 1/2 w |
| R208 | 33 K, 1 w |
| R209 | 2.2 K, 1/2 w |
| R210 | 1 M Ω, 1/2 w |
| R211 | 4.7 K, 1 w |



 [redacted]

| Part No. | Description |
|---|---|
| RESISTOR | |
| R212 | 4.7 K, 1 w |
| R213 | 1 M Ω, 1/2 w |
| R214 | 33 K, 1 w |
| R215 | 1 K, 1/2 w |
| R216 | 33 K, 1 w |
| R217 | 1 M Ω, 1/2 w |
| R218 | 470 K, 1 w |
| R219 | 100 K, 1 w |
| R220 | 220 K, 1 w |
| R221 | 4.7 M Ω, 1 w |
| R222 | 5.0 M Ω, 2 w, dual, variable |
| R223 | 4.7 M Ω, 1 w |
| R224 | 4.7 M Ω, 1 w |
| R225 | 5.0 M Ω, 2 w, dual, variable |
| R226 | 4.7 M Ω, 1 w |
| R227 | 1 M Ω, 1/2 w |
| R228 | 100 K, 1 w |
| R229 | 1 K, 1/2 w |
| R230 | 100 K, 1 w |
| R231 | 1 M Ω, 1/2 w |
| R232 | 33 K, 1 w |
| R233 | 4.7 K, 1 w |
| R234 | 1 M Ω, 1/2 w |
| R235 | 33 K, 1 w |
| R236 | 25 K, 10 w, wire-wound |
| R237 | 1 M Ω, 1/2 w |
| R238 | 22 K, 1 w |
| R239 | 4.7 K, 1 w |
| R240 | 4.7 K, 1/2 w |
| R241 | 2.5 K, 2 w, variable |
| R242 | 2.2 K, 1/2 w |
| R243 | 330 K, 1/2 w |
| R243.1 | 1 M Ω, 1/2 w |
| R244 | 4.7 M Ω, 1 w |
| R245 | 400 Ω, 10 w, wire-wound |
| R246 | 200 Ω, 2 w |
| R247 | 4.7 M Ω, 1 w |
| R248 | 4.7 M Ω, 1 w |
| R249 | 10 K, 10 w, wire-wound |
| R249.1 | 10 K, 10 w, wire-wound |
| R250 | 4.7 M Ω, 1 w |
| R251 | 470 K, 1 w |
| R252 | 470 K, 1 w |
| R253 | 680 K, 1 w |
| R254 | 500 K, 2 w, variable |
| R255 | 330 K, 1 w |
| R256 | 250 K, 2 w |
| R257 | 220 K, 1 w |
| RESISTOR | |
| R258 | 4.7 M Ω, 1 w |
| R259 | 4.7 M Ω, 1 w |
| R260 | 5.0 M Ω, 2 w, dual, variable |
| R261 | 4.7 M Ω, 1 w |
| R262 | 1 M Ω, 1/2 w |
| R263 | 220 K, 1 w |
| R264 | 1.5 M Ω, 2 w, variable |
| R265 | 1.0 M Ω, 2 w, variable |
| R266 | 68.0 K, 1 w |
| R267 | 4.7 K, 1 w |
| R268 | 1.5 K, 1 w |
| R269 | 3.3 M Ω, 1 w |
| R270 | 22.0 K, 1/2 w |
| R271 | 33 K, 1/2 w |
| R272 | 5 K, 2 w, variable |
| INDUCTOR | |
| L201 | 16.5 mh |
| L202 | 16.5 mh |
| L203 | 16.5 mh |
| L204 | 16.5 mh |
| L205 | 16.5 mh |
| L206 | 16.5 mh |
| TRANSFORMER | |
| T201 | Lavoie part no. C-136334 |
| JACK | |
| J201 | Deleted |
| J202 | Deleted |
| J203 | AN/3102-12S-3P |
| J204 | Navy and Signal Corps N17-C73108-5890 |
| J205 | Deleted |
| J201A | UG 290/U connector |
| J202A | UG 290/U connector |
| J205A | UG 290/U connector |
| SWITCH | |
| S201 | Rotary, 3-pole, 3-position, 3-decks, Oak type 38401DH3C |
| S202 | DPST, toggle, 6-amp, 125 v ac, N17S-73172-4277 |
| S203 | Rotary, single-pole, 9-position, Oak type 38400 PHIC |
| S204 | Rotary, single-pole, 3-position, 3-throws |
| TUBE | |
| V701 | 631-P1 |

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