INSTRUCTION AND OPERATING MANUAL

FOR

MODEL 335B

F.M. MONITOR and
MODULATION METER

Type No. 92848

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

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Those entries above that are marked <---- are considered to be essential to the proper care of operation of this instrument and it is strongly recommended that those entries be read thoroughly before attempting to put this instrument into operation.

-hp-
MODEL 335B
FM FREQUENCY MONITOR
AND MODULATION METER

SPECIFICATIONS

FREQUENCY MONITOR

Frequency Range: Any frequency from 88 mc to 108 mc. Supplied with crystal of frequency matching customer's transmitter.

Deviation Range: +3 kc to -3 kc mean frequency deviation.

Accuracy: Deviation indicator accuracy better than ±1000 cps (± .001%)

Power Required: Approximately 2 watts. Operates satisfactorily at levels above and below 2 watts.

MODULATION METER:

Modulation Range: Meter reads full scale on modulation swing of 100 kc. Scale calibrated to 100% at 75 kc; 133% at 100 kc.

Accuracy: Within 5% modulation percentage over entire scale.

Meter Characteristics: Meter damped in accordance with FCC requirements. Reads peak value of modulation peak of duration between 40 and 90 milliseconds. Meter returns from full reading to 10% of full value within 500 to 800 milliseconds.

Frequency Response: Flat within $\pm\frac{1}{2}$db from 50 to 15000 cps.

External Meters: Provisions are made for installation of remote meter having full scale sensitivity of 400 microamperes. Scale should indicate 100% modulation at 300 microamperes. Extra meters can be supplied with unit.

PEAK LIMIT INDICATOR

Peak Limit Range: From 50% to 120% modulation (75kc = 100%). Provision for external peak indicators.

AUDIO OUTPUT

Frequency Range: 20 cps to 20 kc. Response flat within $\pm\frac{1}{2}$db. Equipped with standard 75 microsecond de-emphasis circuit.

Distortion: Less than 0.25% at 100% modulation.

Output Voltage: 10 volts into 20,000 ohms at low frequencies at 100% modulation at low frequencies.

Noise: At least 75 db below audio output level resulting from 100% modulation at low frequencies.

Monitoring Output: 4.0 mw into 600 ohms balanced, at 100% modulation at low frequencies.

Size: Front Panel $10\frac{1}{2}$" x 19" x 13" deep.

Power: 115 volts 50/60 cps primary power. Requires approximately 150 volts.

-hp-
MODEL 335B
FM FREQUENCY MONITOR
AND MODULATION METER

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INTRODUCTORY

The -hp- Model 335B FM Frequency Monitor and Modulation Meter has been designed for monitoring the carrier frequency and modulation of FM broadcast transmitters.

The instrument also demodulates the carrier to provide essentially distortion-free audio output for aural monitoring and for measuring transmitter performance characteristics. The instrument has been carefully designed to provide the utmost in stability and in trouble-free performance. The carrier deviation meter reads the center frequency without being affected by modulation and does not require frequent calibration adjustments. The performance of the equipment is to a high degree independent of monitoring power supplied by the transmitter, line voltage variations, tube characteristics, and temperature changes within the range of variation normally encountered in broadcast service.

In addition to monitoring the carrier frequency and modulation of the transmitter, the Model 335B allows measurements of (a) incidental AM modulation, (B) FM noise, and (c) percentage modulation of the transmitter by the carrier null method.

This manual pertains both to the Model 335B and the Model 335BR. The suffix "R" distinguishes the rack-mounting style from the cabinet style.

UNPACKING

The crystal oven, its crystal, and the 200 kc/s check crystal used in this instrument are packed separately to minimize the possibility of damage in transit. The crystal oven should be unwrapped carefully being careful not to damage the thermometer protruding from the side of the oven. The RF fittings for the rf input cable (not supplied) are also packaged with the crystal oven.

When the equipment is first unpacked, it should be carefully inspected for possible damage in transit and to make certain that all tubes and lamps are secure in their sockets. If any shipping damage is discovered, follow the directions set out in the Warranty at the back of the manual. If the instrument is returned to the factory for any reason, the crystal oven must be packed separately to prevent its falling out of the socket and damaging the interior of the cabinet. The 200 kc check crystal also should be packed separately.

The crystal oven and check crystal should be placed in their sockets before the dust cover is replaced in this inspection.

I N S T A L L A T I O N

LOCATION

Special precautions should be taken to install the Model 335B so that a generous circulation of air is maintained. In order to obtain good circulation, it is desirable to mount the instrument above patch cord panels or other low power systems. The instrument can be operated in quite high ambient temperatures if this precaution is followed.

In no case should the instrument be operated in surroundings such that the crystal oven thermostat loses control; the crystal oven thermostat pilot lamp should flash intermittently, showing that the thermostat is controlling the oven temperature. If the lamp does not light, the air flow around the instrument should be increased.

ELECTRICAL CONNECTIONS

There are three sets of electrical connections to be made to the Model 335B and all of these connections are made on the back side of the instrument:

(1) The motor base type plug on the instrument should be connected to a nominal 115-volt, 50/60 cycle single phase supply. It should be noted that the power source for the oven is connected permanently across the input circuit ahead of the power switch so that the crystal will be maintained at the proper temperature when the equipment is turned off and not in use.

(2) A coaxial type connector (Navy type-49194) is provided and should be connected to the monitoring pick-up provided by the transmitter manufacturer. Fifty-ohm coaxial cable such as RG-8/U should be used to connect the Model 335B to the pick-up loop. Relatively long lengths of cable can be tolerated for this connection. Directions for adjusting the monitoring pick-up on the transmitter are given on page 5 of this manual.

(3) An eight-point terminal strip provides connections for audio output, an external modulation

meter, and external peak modulation indicator lights.

(a) Monitoring Output: When terminals 3 and 4 are connected together, terminals 1 and 2 provide an audio signal for feeding a 600-ohm balanced circuit. The nominal output is 1.5 volts (4 mw) at 100% modulation at low modulating frequencies.

(b) High Level Output: A high level output is provided between terminal 3 and ground (terminal 5) for use with a noise and distortion analyzer or a high impedance monitoring amplifier. The nominal output is 10 volts at 100% modulation at low modulating frequencies and the applied load should not be less than 20,000 ohms. When making noise and distortion measurements, terminal 4 should be disconnected from terminal 3 to prevent any undesirable loading by the monitoring circuits.

(c) External Modulation Meter: Terminals 5 and 6 are normally joined by a 1000-ohm resistor. If an external modulation meter is to be used, this resistor should be removed and the meter connected between these terminals, 6 being the positive connection and 5 (ground) the negative. The external meter should be identical to the one in the instrument in order to indicate accurately and have the proper dynamic characteristics. It is recommended that extra modulation meters be obtained from the Hewlett-Packard Company, giving the serial number of the unit for which they are intended.

(d) External Peak Modulation Indicator: An external indicating lamp may be placed in parallel with the one in the instrument by connecting it between terminals 7 and 8. Either a 3- or a 6- watt, 120 volt lamp may be used. Not more than a few hundred micromicro-farads of capacity should be introduced by this connection so that it is desirable to use short lengths of low capacity cable.

All leads connecting to the terminal strip and AC power connections should be isolated from strong RF fields, preferably using shielded wire.

I N I T I A L   A D J U S T M E N T S

The initial adjustments for this unit are the same as the usual operating adjustments, except for the adjustment of the transmitter pick-up loop. The following adjustments should be made when the Model 335B is first installed and as often as desired thereafter:

(1) Turn on the instrument and allow a heating period of at least a few hours, because the main crystal

will take some time to be heated to its proper temperature. Disconnect the pick-up loop. During the warm-up, keep a close check reading on the crystal thermometer which is visible through the front panel. If the reading of this thermometer overshoots 65°C by any appreciable amount, the cause usually will be found to be that the mercury column in either the thermometer or thermostat is not united. These columns can be re-united by removing the unit in question and alternately heating and cooling the unit.

Steps 2 and 5 below can be performed after only a few minutes warm-up, although as long a warm-up as possible should be allowed before performing step 6.

(2) Open the panel door and set the CALIBRATE - USE - CARRIER LEVEL switch to the CALIBRATE position. The CARRIER DEVIATION meter will read close to center scale and the PERCENT MODULATION meter will read approximately 100%.

Adjust the SET TO ZERO DEV. control so that the CARRIER DEVIATION meter reads exactly zero. Adjust the SET TO 100% control so that the PERCENT MODULATION meter reads exactly 100%. These controls adjust the counter circuits to normal operation.

(3) Set the CALIBRATE - USE - CARRIER LEVEL switch to a position halfway between USE and CARRIER LEVEL. There is a detent mechanism at this point, although not labelled on the panel.

A reading on the PERCENT MODULATION meter between 40 and 75 will be obtained with no signal coming from the transmitter. This reading should be peaked by adjusting the condenser marked MULT on the chassis (not on front panel). With this condenser peaked, a reading of at least 40 on the PERCENT MODULATION meter should be obtained.

(4) The condenser marked OSC on the chassis should not need adjustment. However, if a reading of less than 40 is obtained with the previous adjustment in (3) above, it may be desirable to retune the oscillator tank circuit will be found to vary slowly on one side of the maximum and rapidly on the other side. The proper setting for this condenser is that which will give a reading about 15% below the maximum on the side which varies slowly. This adjustment is not critical, since it affects only slightly the frequency and stability of the crystal oscillator.

(5) Next, set the CALIBRATE - USE - CARRIER

LEVEL switch to the CARRIER LEVEL position and adjust the pick-up loop in the transmitter to give a reading between 50 and 100 on the PERCENT MODULATION meter. The carrier input level is not critical. The power from the transmitter can be adjusted from about one-tenth of a watt to 4 watts without affecting the accuracy of the Model 335B.

The reading on the PERCENT MODULATION meter with the switch in the CARRIER LEVEL position is approximately proportional to the input voltage. With 10 volts of RF voltage from the transmitter, a reading of approximately 100% will be obtained on the PERCENT MODULATION meter with the switch in the CARRIER LEVEL position.

(6) The frequency of the comparison oscillator in the equipment has been adjusted to the specified channel at the factory and can be expected to be within a few hundred cycles of the correct frequency when the instrument is received. After the equipment has been turned on for several hours, the temperature of the crystal oven will come up to 65° C. If it is desired to check the frequency of the monitor against a standard transmission, this may be done and the frequency of the monitor can be adjusted by means of the screwdriver adjustment marked CRYSTAL TUNING under the cover on the front panel. This adjustment should be made with the switch in the USE position.

(7) The instrument is now ready for operation and only those adjustments described under "Maintanance" in this manual should be required.

(8) When making noise measurements on transmitters operating on channels 201,221,241,261,281,300, or on channels near those, a spurious beat note may appear in the audio output of the monitor. Its maximum amplitude is approximately 65 db below the output for 100% modulation at low frequencies. The signal is caused by a harmonic of the 200 kc I.F. signal beating with the high frequency crystal signal: hence, by detuning either the transmitter or the monitor crystal oscillator a few hundred cycles, the frequency of the beat can easily be shifted to a high frequency where the de-emphasis in the monitor will place it below the residual noise.

O P E R A T I O N

CONTROLS

The panel controls with their functions are given below:

CONTROL	FUNCTION
USE - CALIBRATE - CARRIER LEVEL	Connect front panel meters so as to enable the instrument to be calibrated, to check the performance of the comparison frequency multiplier circuits, and to measure the carrier input level from the transmitter.
SET TO 100%	Adjusts current in final switching tubes to proper magnitude to insure that sensitivity of both the CARRIER DEVIATION indication and PERCENT MODULATION indication are correct.
SET TO ZERO DEVIATION	Adjusts balancing current in CARRIER DEVIATION meter so that zero deviation is indicated when exactly 200 kc is applied to the counter circuits. This adjustment is made in the CALIBRATE position of the USE - CALIBRATE switch. In this position a 200 kc voltage from an internal 200 kc crystal-controlled oscillator is applied to the counter circuits.
CRYSTAL TUNING	Adjusts frequency of local crystal-controlled comparison oscillator so the monitor can be adjusted to read zero deviation for the correct frequency.
MODULATION POLARITY	Connects the modulation and peak indicators so they respond in accordance with either positive or negative swings of modulation.
PEAK MODULATION INDICATOR	Adjusts the firing point of the peak modulation indicator lamp so the modulation level at which the flash will be obtained can be set.
CRYSTAL TEMPERATURE	Thermometer which indicates temperature within crystal oven; normal temperature is approximately 65°C.

In addition to these controls on the front panel, three controls are located on the chassis of the equipment. A potentiometer R49, located on a terminal board at the left side underneath the chassis, is provided to adjust the voltage regulator circuit if necessary when the voltage regulator tubes are changed. A screw driver control of the tuning condenser (Osc) in the crystal tank circuit is located just behind the crystal oven on top of the chassis. Further back of the panel in the same area is located the crystal multiplier tank circuit control (MULT) which is also a screwdriver adjustment.

When the equipment has been installed and adjusted in accordance with the foregoing instructions, nothing further is necessary during the operation except occasionally to check the readings of the CARRIER DEVIATION meter and the MODULATION meter in the CALIBRATE position. The CARRIER DEVIATION meter should read exactly zero and the MODULATION meter should read exactly 100% with the switch in CALIBRATE position. Any variations from these readings may be corrected from time to time by means of the SET TO ZERO DEVIATION control and the SET TO 100 control.

It may also be desirable occasionally to check the carrier level by returning the switch to the CARRIER LEVEL position and reading the modulation meter. Any reading in this position between 50 and 100 will provide satisfactory operation.

OVER MODULATION INDICATOR

The modulation meter in the Model 335B FM Frequency Monitor and Modulation Meter has been designed so that it will indicate 90% of the value of a modulation peak of 85 milliseconds duration. Further, the modulation meter will fall to 10% from a 100% reading in not less than 500 milliseconds and not more than 800 milliseconds after the complete removal of 100% modulation. These design requirements are in accordance with FCC standards.

In practice, however, many bursts of modulation in a typical program are of much shorter duration than 85 milliseconds--perhaps one or two milliseconds--and the Model 335B does not indicate the full peak value of modulation bursts of extremely short duration. Nevertheless, these short intervals of high modulation are important, because, if substantial overmodulation occurs on such peaks, the result may be detected in receivers and also may cause adjacent channel interference.

In order to prevent these conditions, it is recommended that the Model 335B be operated with its overmodulation indicator (lamp) adjusting knob set not higher than 70% and that the modulation of the transmitter be adjusted so that occasional flashing of the overmodulation indicating lamp is obtained with common program material. This will mean that the general program level will result in the order of 50% modulation as indicated by the meter. Modulation peaks of short duration will be higher than this value but probably will not exceed 100%. This condition of operation is desirable as it permits the true capabilities of high quality, unique only to FM more nearly to be realized. Overmodulation is to be avoided as it results in considerable deterioration of the program quality.

Any limiting amplifier used in the audio system should be essentially instantaneous in its action. Limiting amplifiers having a control action slower than a few milliseconds will permit modulation peaks going considerably above the 100% level. This emphasis of short modulation peaks by limiting amplifiers is particularly bad in FM Systems due to the pre-emphasis of the high frequencies in the system. Therefore it is recommended that limiting amplifiers be avoided unless their characteristics and effects on the entire system are well known.

M E A S U R E M E N T S

MEASUREMENT OF INCIDENTAL AMPLITUDE MODULATION ON FM BROADCAST CARRIERS

A special jack is provided in the -hp- Model 335B FM monitor and Modulation Meter to facilitate the measurement of spurious AM modulation on the carrier of FM broadcast transmitters. This jack is located on the back of the instrument and is marked J3. Measurements of spurious AM modulation can be made with the use of this jack and a sensitive vacuum-tube voltmeter in the following manner:

1. Couple the unmodulated RF voltage from the transmitter to the Model 335B so that the RF voltage causes a reading of 100% on the PERCENT MODULATION meter when the CALIBRATE - USE - CARRIER LEVEL switch is in the CARRIER LEVEL position. This is equivalent to a carrier voltage of 10 volts or to an audio level (assuming 100% AM modulation

of +22.2 db referred to a zero reference on one milliwatt in 600 ohms). If it is not possible to couple closely enough to obtain a reading of 100%, record the reading obtained.

2. Connect a tip-and-sleeve 1/4" diameter telephone type plug to a sensitive vacuum tube voltmeter and connect the voltmeter to J3 on the back of the Model 335B. An -hp- Model 400A, 400C, or the VTVM section of an -hp- Model 330B or 330C can be used for this measurement. The lead connecting the voltmeter to the jack should be shielded and the capacity should not exceed 100 mmf. Also connect a 2-megohm resistor across the terminals of the voltmeter so that the resistor is shunting the line to the Model 335B.

3. Read and record the audio voltage reading obtained on the voltmeter.

4. The percentage of AM modulation can then be obtained from the following formula:

$$\% \text{ AM} = \frac{\text{Audio Voltage} \times 1000}{\text{carrier reading in } \%}$$

For example, assume the RF input was set to 100% and that a reading of 0.1 volt was obtained on the voltmeter. Then, the percentage of amplitude modulation is:

$$\frac{0.1 \times 1000}{100} = \frac{100}{100} = 1\%$$

5. On a db basis, 100% carrier reading corresponds to an audio level of +22.2 db. The meter reading of 0.1 volt corresponds to -17.8 db. Therefore the AM modulation expressed in db is 22.2 db +17.8 db or 40 db. Thus, the spurious AM is 40 db below the condition of 100% AM modulation.

NOISE GENERATED IN MONITOR

The noise generated in the Model 335B is at least 75 db below the audio output level resulting from 100% modulation at low frequencies. Assuming that 100% modulation at a low frequency provides exactly 10 volts output at the high-impedance audio output of the Model 335B, the noise as measured across a 20,000 ohm minimum load on terminals 3 and 5 should be not more than 1.8 millivolts.

Noise should be measured with the switch in the CALIBRATE position. In no case should noise be measured by removing the RF input from the monitor with the switch in the USE position, nor should the noise be measured by shorting the RF input. When the RF is removed with the switch in the USE position, the monitor operates with the equivalent of a floating grid circuit causing an increase in the noise level.

MODULATION CHECK

The percent modulation of an FM transmitter may be measured conveniently by the carrier null method using the IF signal from this monitor. Jack J2, which is a phone jack on the rear of the chassis, supplies a small IF signal which is normally 200 kc in frequency and contains the full FM swing of the transmitter. This output should be connected to the antenna terminal of a communications type receiver, preferably one which will tune to 200 kc. However, the signal is approximately a square wave, so that the second or third harmonic could be used. The transmitter should be unmodulated and the receiver BFO adjusted to give a beat note of several hundred cycles. As sine wave modulation is gradually applied to the transmitter, the amplitude of the transmitter carrier, and hence the receiver beat note output, will go through successive amplitude nulls. Table 1 on page 11 gives various combinations of percentage modulation and modulating frequency for the convenient number of nulls.

Other combinations may be computed using the following relation:

$$\text{Modulation index} = \frac{\text{frequency swing}}{\text{modulating frequency}}$$

The values of the modulation index for which the carrier disappears are those which are equal to the argument of the zero order Bessel function when the function has zero value. These values of modulation indices are given in the following table. Additional values are spaced at intervals of pi.

Null No.	Mod. Index
1	2.405
2	5.520
3	8.654
4	11.792
5	14.931
6	18.071
7	21.212
8	24.353
9	27.494
10	30.635

If the receiver is tuned to 200 kc, a modulation swing of 75 kc is used at 100% modulation. However, if it is tuned to a harmonic, the modulation swing is also multiplied, giving a correspondingly higher modulation swing for 100% modulation.

It should be noted that the accuracy of measurement of modulation percentage is equal to the accuracy of calibration of the modulation frequency. Also, it is necessary that the modulation signal have low distortion if the nulls are to be very sharply indicated.

The method described is useful in setting the modulation monitor sensitivity if it becomes necessary to replace some critical part. Components whose value directly affects the accuracy of the modulation meter are R38, R39, R40, R53, R58, and the meter M1 itself. If any of these parts are replaced, it will be necessary to use exact duplicate values or reset R39 as follows: With the transmitter modulated 100% with some convenient frequency between 1 and 5 kc. Set R26 for 100% reading in the USE position. Then switch to CALIBRATE and set R39 for 100% reading. The monitor should read correctly as long as this 100% reading is maintained in the CALIBRATE position.

TABLE I

	Receiver tuned to 200 KC (75KC = 100% mod.)		Receiver tuned to 400 KC (150 KC = 100% mod.)		Receiver tuned to 600 KC (225KC=100%mod.)	
No. of Nulls	% Mod.	Audio Freq.	% Mod.	Audio Freq.	% Mod.	Audio Freq.
2	100 73.6 36.8	13,950 10,000 5,000	55.2	15,000	36.8	15,000
3	100 115.4 57.7	8,670 10,000 5,000	100 86.5 57.7	17,330 15,000 10,000	57.7	15,000
4	100 78.6 31.4	6,360 5,000 2,000	100 78.6 39.3	12,720 10,000 5,000	78.6	15,000
5	100 99.5 39.8	5,020 5,000 2,000	100 99.5 49.8	10,050 10,000 5,000	100 66.4 33.2	15,070 10,000 5,000
6	100 120.5 38.2	4,150 5,000 2,000	100 120.5 60.2	8,300 10,000 5,000	100 80.3 40.2	12,450 10,000 5,000
8	100 129.9 64.9	3,080 4,000 2,000	100 81.2 32.5	6,160 5,000 2,000	100 108.2 54.1	9,240 10,000 5,000
10	100 81.7 40.8	2,450 2,000 1,000	100 102.1 40.8	4,900 5,000 2,000	100 68.1 27.2	7,340 5,000 2,000

M A I N T E N A N C E

DAILY MAINTENANCE

A daily maintenance check of the Model 335B is recommended before the transmitter is put on the air. This check can be made quickly by means of the internal calibration controls provided on the equipment. The following procedure is recommended:

(1) Set the switch under the panel door to the CALIBRATE position. Set the CARRIER DEVIATION meter to zero and the PERCENT MODULATION meter to 100% by means of the correspondingly marked controls.

(2) Next, set the switch halfway between the USE and CARRIER LEVEL positions. In this position the MODULATION meter should read at least "40" with no power coming from the transmitter.

(3) When the transmitter power is turned on, set the switch to the CARRIER LEVEL position to make certain that RF power is being received from the transmitter. A reading between 50 and 100 should be obtained on the PERCENT MODULATION meter. Lower readings indicate insufficient power being received from the transmitter.

(4) Make certain that the front panel thermostat indicates that the temperature of the crystal oven is at 65 degrees Centigrade.

(5) Set the switch to the USE position. The instrument is now ready for use.

(6) If any of the above readings fail to come within the limits indicated, follow the procedure described under "Installation" or check for tube failure.

TUBE REPLACEMENT

All of the tubes in this instrument, with the exception of the crystal oscillator tube, can be changed without special precaution. When any tube is changed, it is desirable to go through the routine maintenance check as described above.

If the crystal oscillator tube is changed, a shift in frequency of the comparison oscillator may cause an error of several hundred cycles in the reading of the CARRIER DEVIATION meter. Although this variation is well within the limits of accuracy prescribed for FM service, it is desirable to check this frequency when the oscillator tube V1 is replaced.

Tubes in the voltage regulator circuit can be replaced without appreciably affecting the accuracy of the instrument, although it is desirable to measure the regulated voltage whenever any of tubes V10B, V13, V14, or V15 are replaced. The regulated voltage should be set at 300 volts dc by means of R49.

If abnormally high or low line voltages are present at the station installation, it may be desirable to check the operation of the voltage regulator at line voltages within the range likely to be encountered. This check can be made by connecting a dc meter to the regulated side of the power supply and varying the input line voltage to the instrument with an auto-transformer over the anticipated range of line voltage. The dc voltage will be constant within the region of control of the regulator circuit and will change at the end of the region of control. This region of control can be adjusted somewhat by potentiometer R49. Normally, a variation in line voltage from 105 volts to 125 volts will have no measurable effect on the accuracy of the monitor.

STANDARDIZING OF COMPARISON OSCILLATOR FREQUENCY

The frequency of the local comparison oscillator is of the order of 5 megacycles. The circuits have been designed so this oscillator can operate at 1/20 of a frequency 200 kc less then the transmitter frequency. This design facilitates checking of the crystal oscillator in the monitor because the frequency is always a multiple of 5 kc. Thus, a source of 5 kc signal controlled by a crystal can be first set to zero beat with a W.W.V. transmission at 5 megacycles. Then this same 5 kc frequency will beat with the local comparison oscillator frequency to provide a difference signal well within the audio range. This beat can be brought to zero beat with the pre-standardized 5 kc signal by means of the crystal tuning adjustment of the FM monitor. The only equipment necessary for this adjustment is a receiver which will cover the frequency range around 5 megacycles and a source of 5 kc voltage which can be crystal controlled and adjusted slowly.

Many stations will prefer to use standard monitoring service periodically to check their transmitters. In this case, it is desirable to adjust the transmitter in accordance with the instructions of the frequency monitoring service and adjust the FM monitor to the transmitter immediately thereafter.

Checks of the crystal frequency should not be required except over very long intervals. The accuracy of the Model 335B is such as to insure variations in readings of not more than 200 cycles over long periods of time.

R. F. TUNING

Retuning of the RF circuits is indicated if the MODULATION meter reads less than "40" when the CALIBRATE - USE - CARRIER LEVEL switch is set midway between the USE and CARRIER LEVEL positions with no power coming from the transmitter. (With power coming from the transmitter, the reading will be 10 or so higher on the MODULATION meter than with no transmitter power.)

Tuning the RF section of the Model 335B consists solely of peaking the crystal oscillator V1. This oscillator operates at one-twentieth of a frequency 200 kc below the transmitter antenna frequency $\frac{\text{(xmitter-200KC)}}{20}$.

Since the Model 335B monitors the 88-108 mc band, the oscillator operates in the vicinity of 5 mc, the exact frequency depending upon the particular channel for which it is to be used.

To aid in tuning the oscillator, the MODULATION meter acts as a tuning indicator when the CALIBRATE - USE - CARRIER LEVEL switch is set midway between the USE and CARRIER LEVEL positions (with no transmitter power applied). This tuning should be made as follows:

(1) The dust cover should be removed from the instrument. Switch should be midway between USE and CARRIER LEVEL positions.

(2) Tune C2 (marked MULT on chassis) for a maximum reading on MODULATION meter.

(3) Tune C6 (marked OSC on chassis) on the high frequency side of resonance for a reading about 15% below the maximum obtainable. On the high frequency side of resonance the meter reading varies much slower than on the low frequency side as C6 is tuned. By tuning 15% or more down in level, the frequency of oscillation is made practically independent of tuning.

(4) If the reading on the MODULATION meter is now less than "40", a new 6AC7 tube should be inserted and allowed to heat for twenty minutes or more. The proceedure should then be repeated.

CHANGE OF CHANNEL

If it is necessary to retune the oscillator completely as, for example, when a new crystal for a different channel is inserted, the following procedure is recommended.

With no crystal in the circuit or when the new crystal is inserted, a reading of about "20" is often obtained on the MODULATION meter when the switch is midway between the USE and CARRIER LEVEL positions. This reading is caused by oscillation due to the 200kc tuned circuits in the plate and screen circuits.

Now, perform step (3) above. The MODULATION meter reading will fall off when C6 is tuned to the proper frequency (unless C2 should happen to be tuned properly, in which case the MODULATION meter reading will rise).

Now perform steps (2) and (3) in that order to complete the retuning of the oscillator. There is a possibility that C2 (MULT) can be tuned to the wrong harmonic, because the tuning range of C2 is about 25% and the circuit tunes to the fourth harmonic of the crystal. This can be avoided by removing the bottom plate from the Model 335B and observing that condenser C2 (MULT) is adjusted near minimum capacity for the higher channels and near maximum capacity for the lower channels. Another indication of tuning C2 to the wrong harmonic is that the CARRIER DEVIATION meter will read off scale when the Model 335B is returned to service.

It should also be remembered that the frequency of oscillator V1 can be adjusted over a range of several kc of the transmitter antenna frequency by means of the CRYSTAL TUNING control. Therefore, when using a new crystal, the Model 335B should not be used on a new channel until the crystal frequency (and thus the accuracy of the Model 335B) has been checked accurately or the Model 335B zeroed against a transmitter whose frequency is known at the time of comparison.

CIRCUIT DESCRIPTION

BRIEF DESCRIPTION OF OPERATION

The general operation of the Model 335B can be described by referring to the block diagram on Page 18. The transmitter frequency is combined with an accurately controlled frequency derived from a crystal-controlled oscillator in the instrument so that a difference frequency of 200 kc plus or minus the modulation components is obtained. The frequency of this 200 kc mean difference frequency is measured by frequency counter circuits. The frequency counter circuits also demodulate the signal. From this demodulated signal the percentage of modulation is measured.

Also, audio voltages are obtained for measuring the distortion and frequency response characteristics of the transmitter.

The local crystal-controlled oscillator operates at 1/20 of a frequency 200 kc less than the transmitter frequency $\frac{(f_{xmitter}-200kc)}{20}$. The output of the crystal controlled oscillator is multiplied four times and fed into a triode mixer at 1/5 of the final frequency. The final multiplication is obtained in the mixer circuit.

The frequency counter circuits are of the pulse integrating type and are designed to provide a high degree of linearity over the frequency range of 100 kc to 300 kc. A direct current meter in the output circuit of these counter tubes is used to measure the frequency deviation of the carrier. In order to use a meter of adequate sensitivity, a dc compensating current exactly equal to the current generated in the counter circuits with 200 kc applied is used to balance the meter current to zero when the carrier of the transmitter is on frequency. The sensitivity of this meter is such that, when the counter circuits are driven by a frequency which deviates by 3 kc above or 3 kc below 200 kc, a full scale reading is obtained.

Since the 200 kc signal applied to the counter circuits contains also the full modulation swing, the counter circuits can be arranged to demodulate the frequency modulation. The magnitude of this demodulated voltage is used to measure the percentage modulation of the transmitter. The audio amplifier which follows the frequency counter circuits, drives the modulation meter and the peak modulation indicator.

The frequency counter circuits are extremely stable and will drift generally less than 100 cycles over a 24-hour period. However, an internal 200 kc check frequency is provided to set the frequency deviation meter to zero deviation and thus assure accurate calibration of the frequency counter circuits.

The calibration of the modulation monitor is standardized by standardizing the current fed into the frequency counter circuits.

Audio output voltages are provided for monitoring or measuring the transmitter output.

The deviation meter is fully protected from overloads and no damage to the instrument will occur if the transmitter input is suddenly removed.

An external modulation meter may be connected in series with the internal meter. Terminals are provided at the rear of the chassis for this purpose.

DETAILED DESCRIPTION OF CIRCUITS

The schematic diagram of the Model 335B at the back of this manual should be followed in conjunction with the following description.

Tube V1 is the local crystal oscillator tube which generates the basic frequency with which the transmitter frequency is compared. This tube is operated as an electron coupled oscillator. The crystal is connected from grid to ground when switch S2 is in the USE position. The crystal is mounted in a double chamber oven whose temperature is regulated by means of a mercury column thermostat. The characteristics of this oven are such that the temperature at the crystal varies by considerably less than 1 degree C as a function of time and over an ambient range from +10 degrees to +40 degrees C.

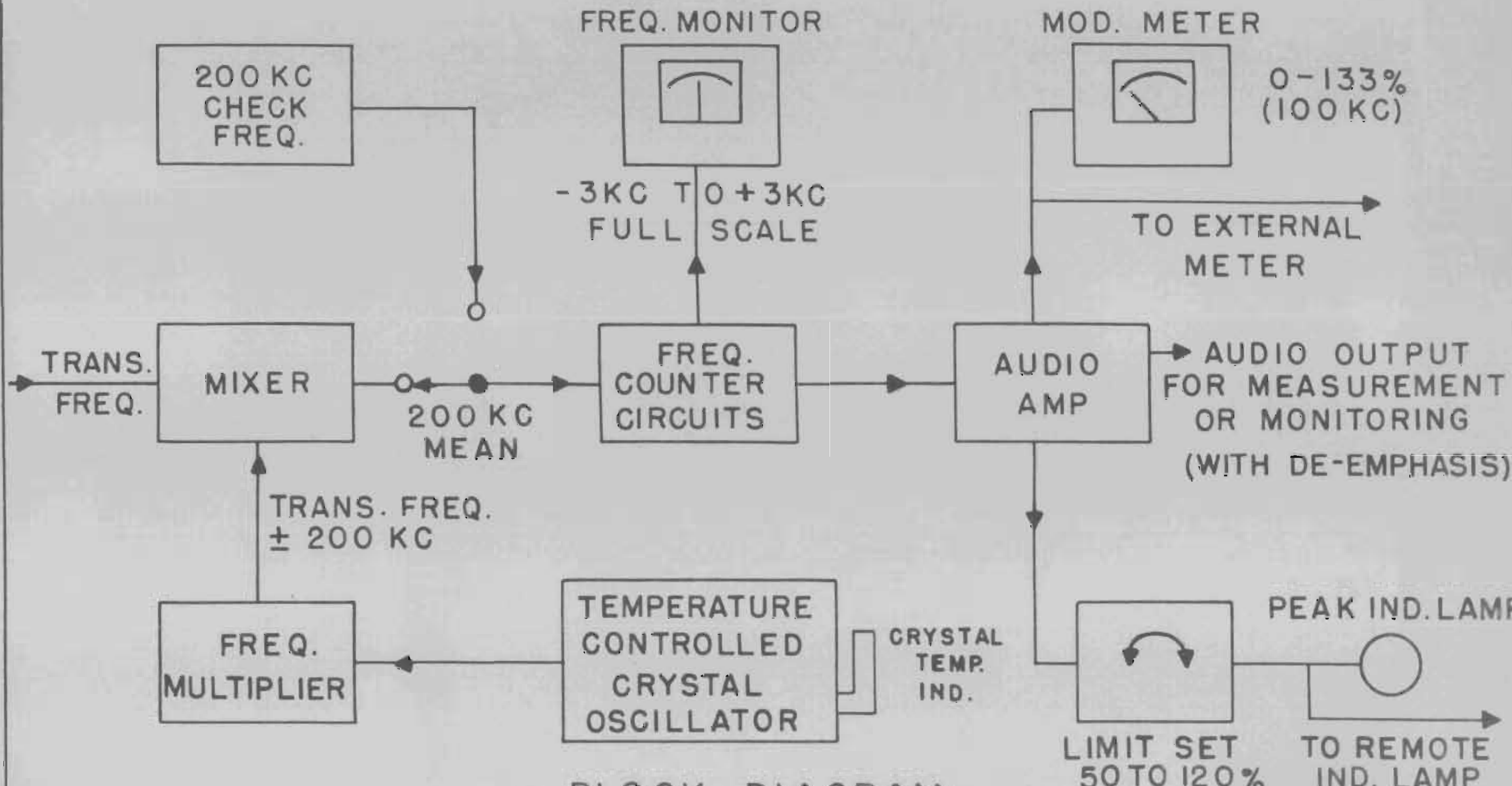
The screen of V1 is tuned to the crystal frequency by means of L3 and C6. The plate is tuned to four times the crystal frequency by means of L1, C2, and C3.

A small capacity C1 is connected directly across the crystal and provides for adjustment of the crystal frequency by about 3 kc around the nominal transmitter frequency.

V2A is the mixer tube. A signal from the transmitter is applied directly to the cathode of V2A across R9 and R10 parallel. The input signal is fed to the mixer through a 50-ohm concentric cable and the characteristics of the termination R9 and R10 are such that a standing wave ratio of not over 1.1/1 is obtained looking into the RF input. The grid of V2A is driven by the output voltage from the crystal oscillator tube at a frequency of four times the crystal frequency. This signal combines with the signal from the transmitter to give a difference frequency in the plate circuit of V2A which is 200 kc plus the full modulation swing contained in the monitored signal.

V1 is also arranged to provide the 200kc signal for calibration of the pulse counter circuits. This signal is obtained by switching a 200kc crystal between grid and ground of V1 and tuning the screen circuit of V1 to 200kc by means of L4 and C8. A 200kc resonant circuit, L2 and C5, is placed in series with the high frequency resonant circuit in the plate of V1. This is possible because the tuning

MODEL 335B
FM FREQUENCY MONITOR AND MODULATION METER



BLOCK DIAGRAM

1940-S-403

capacities C8 and C5 are large enough to provide adequate by-passing for the high frequency voltages generated when V1 is connected in the USE position. Switching is done by means of switch S2B which connects the input of the counter circuits to either the output of mixer tube V2A in the USE position or directly to the 200kc voltage in the output of V1 in the CALIBRATE position.

V2B serves as an amplifier tube to amplify the 200kc signal. A crystal limiter, Y1 and Y2, is connected to the grid circuit of V2B so that the driving voltage is limited and clipped to provide a square wave shape.

V3 is a phase inverter which applies the 200 kc signal to the grids of V4 and V5 which are the initial switching tubes. The space current for V4 and V5 are derived from a constant current generator tube V6. This tube has a large un-bypassed cathode resistor R60, and the grid of V6 is held at a constant potential from the regulated power supply by means of R23 and R24. With this circuit, the current passing through V6, and consequently V4 and V5, is, to a high degree, independent of the amplitude of the driving signal on tubes V4 and V5.

The operation of switching tubes V4 and V5 can be described as follows: The grid of V4 is driven positive while the grid of V5 is driven to cut off. All the current from V6 flows through V4 and R21, thereby generating a flat topped wave across R21. When the grid of V5 is positive, a similar action takes place with all of the current flowing through R22. Thus, the output of switching tubes V4 and V5 provides a driving signal in switching tubes V7 and V8 which is nearly independent of the amplitude of the 200 kc voltage, provided the 200 kc voltage is at least large enough to provide the switching action thus described. Switching tubes V7 and V8 operate in similar manner. When the grid of V7 is driven positive, the constant current provided by V9 flows through V7. In this case, however, C22 takes all of the current initially, but as the charge of C22 is building up, more of the current flows through R33 until finally C22 is fully charged to a voltage which is exactly equal to the constant current provided by V9 flowing through R33. In this manner, a pulse of accurately controlled current flows through C22 for each alternative half cycle. In a similar manner, the switching of V8 generates a pulse of accurately controlled current through C26.

C22 and C26 provide an additional function. Since C22 is fully charged when the voltage changes so as to cause V8 to conduct, the anode of tube V7 is held at a low voltage, thus assisting in the cut-off of V7 at the instant tube V8 begins to draw current. In this manner, the time of rise of current conduction in tubes V7 and V8 is extremely rapid so that either one tube or the other is conducting the entire constant current.

If the circuit constants are so arranged that C22 and C26 are fully charged within 1/2 cycle of the highest frequency involved, the amount of current flowing through C22 is a function of frequency only. The current pulses flowing through C22 and C26 are rectified by means of a bridge rectifier, and the resulting dc current is applied to M2. This operation makes the response of M2 directly proportional to frequency. In order to balance out the reading which would be obtained on M2 with a 200kc signal, some current is applied in reverse through M2. This current is generated by a voltage drop across resistor R37 which carries the same current which flows through current regulator tube V9 and through switching tubes V7 or V8.

The sensitivity of this circuit as a frequency meter is directly proportional to this constant current. The balancing current in the meter varies in exact accordance with the constant current. Thus, should there be variations in either the constant current or in the characteristics of the tubes, the meter will still read zero center with 200 kc applied. The current applied to the deviation meter consists of a series of pulses of direct current, the AC components of which are by-passed through C30. C30 is also effective to low audio frequencies, thus preventing the meter from trying to follow the modulation.

When frequency modulation is applied to this counter circuit, the rectified value of the current varies linearly with modulation. This rectified current generates an audio signal in the primary of transformer T4. V17 serves as an audio amplifier stabilized with feedback by means of a tertiary winding on T4 so the response and gain is stabilized. The audio output from V17 is applied to V16A which serves as an impedance transformer to operate the modulation meter. V16B serves as an impedance transformer to provide a distortion-free audio output for monitoring and for measuring purposes.

The networks and the rectifier which determine the operation of modulation meter M1 are connected to the cathode circuit of V16A. This circuit is a peak reading voltmeter in which a dc voltage is generated across C39 equal in value to the peak value of the audio frequency. C38 is arranged to feed additional power into the modulation meter M1 on rapid upswings, and the network of R53, in combination with C38, together with the dynamic characteristics of the meter movement provide the desired response and time characteristics of the modulation meter. The same dc voltage which operates the modulation meter is fed through R61 to the grid of V11. V11 is a thyratron arranged to flash a lamp when the peak value of audio voltage exceeds a pre-set level which is controlled by R42 in the cathode circuit of V11.

Since the sensitivity of the deviation meter and the calibration of the modulation meter are dependent, among other things, on the magnitude of the constant current switched by tubes V7 and V8, arrangements have been made for accurately measuring that current. Switch S2C and S2B connect meter M1 to measure the constant current fed to the switching tubes. This current is adjusted by means of R26 in the grid of V9.

V10A is a tube which compensates for hum generated in the switching tubes. The hum voltage is picked up in T3, amplified in V10A, and applied as a control signal on V9. This feature is of importance when the equipment is used for measuring purposes.

Meter M1 is also arranged to measure the grid current of the mixer tube. When the switch is in the CARRIER LEVEL position, Meter M1 is connected to the grid circuit of V2A so that the grid current drawn by V2A because of application of input voltage can be determined. When switch S2 is in a position halfway between USE and CARRIER LEVEL, meter M1 is connected so as to measure the grid current of V2A generated by the application of voltage from the local oscillator. Thus, the tuning of the circuits in the screen and plate of V1 can be adjusted to make sure adequate voltage is obtained from the local crystal to provide proper mixing action.

De-emphasis of the audio voltage is obtained by a network R52 and C46 in the grid of V16B.

V14, V10B, V13, and V15 provide a regulated voltage supply for the operation of the critical circuits in the equipment. V12 together with T1, L11, L12, C32, C33, and C34 provide the dc power for the operation of the equipment.

The rectifier crystals in the output of the switching tubes and other critical components are filtered and by-passed to eliminate spurious rf pickup which otherwise might have a deleterious effect on the operation of the equipment.

CHART OF CRYSTAL FREQUENCIES

FOR MODEL 335B

F. M. CHANNEL	TRANSMITTER FREQUENCY	335B CRYSTAL FREQ.	F. M. CHANNEL	TRANSMITTER FREQUENCY	335B CRYSTAL FREQ.
201	88.1	4395	251	98.1	4895
202	88.3	4405	252	98.3	4905
203	88.5	4415	253	98.5	4915
204	88.7	4425	254	98.7	4925
205	88.9	4435	255	98.9	4935
206	89.1	4445	256	99.1	4945
207	89.3	4455	257	99.3	4955
208	89.5	4465	258	99.5	4965
209	89.7	4475	259	99.7	4975
210	89.9	4485	260	99.9	4985
211	90.1	4495	261	100.1	4995
212	90.3	4505	262	100.3	5005
213	90.5	4515	263	100.5	5015
214	90.7	4525	264	100.7	5025
215	90.9	4535	265	100.9	5035
216	91.1	4545	266	101.1	5045
217	91.3	4555	267	101.3	5055
218	91.5	4565	268	101.5	5065
219	91.7	4575	269	101.7	5075
220	91.9	4585	270	101.9	5085
221	92.1	4595	271	102.1	5095
222	92.3	4605	272	102.3	5105
223	92.5	4615	273	102.5	5115
224	92.7	4625	274	102.7	5125
225	92.9	4635	275	102.9	5135
226	93.1	4645	276	103.1	5145
227	93.3	4655	277	103.3	5155
228	93.5	4665	278	103.5	5165
229	93.7	4675	279	103.7	5175
230	93.9	4685	280	103.9	5185
231	94.1	4695	281	104.1	5195
232	94.3	4705	282	104.3	5205
233	94.5	4715	283	104.5	5215
234	94.7	4725	284	104.7	5225
235	94.9	4735	285	104.9	5235
236	95.1	4745	286	105.1	5245
237	95.3	4755	287	105.3	5255
238	95.5	4765	288	105.5	5265
239	95.7	4775	289	105.7	5275
240	95.9	4785	290	105.9	5285
241	96.1	4795	291	106.1	5295
242	96.3	4805	292	106.3	5305
243	96.5	4815	293	106.5	5315
244	96.7	4825	294	106.7	5325
245	96.9	4835	295	106.9	5335
246	97.1	4845	296	107.1	5345
247	97.3	4855	297	107.3	5355
248	97.5	4865	298	107.5	5365
249	97.7	4875	299	107.7	5375
250	97.9	4885	300	107.9	5385

TABLE OF REPLACEABLE PARTS

Cir-cuit Ref.	Description	-hp- Stock.No.	Manufacturer and Type
C1	CAPACITOR: variable (trimmer type); approx 25 mmf max; locking type shaft	12-15	Sarkes-Tarzian: J-24P
C2	CAPACITOR: variable (trimmer type); approx 50 mmf max; locking type shaft	12-16	Sarkes-Tarzian; J-55L
C3	CAPACITOR: ceramic; 47 mmf; 500 vdcw	15-34	Electrical Reactance Corp: SI-7 NPO
C4	CAPACITOR: mica; 5000 mmf; 300 vdcw	14-14	Mica mold: Type W
C5	CAPACITOR: silver mica; 620 mmf ±5%; 500 vdcw	15-12	Sangamo: Type J
C6	CAPACITOR: variable (trimmer type) approx 100 mmf max; locking type shaft	12-17	Sarkes-Tarzian: J-103L
C7	CAPACITOR: silver mica; 1800 mmf; 500 vdcw	15-19	Sangamo: Type CR
C8	CAPACITOR: silver mica; 620 mmf ±5%; 500 vdcw	15-12	Sangamo: Type J
C9	CAPACITOR: mica; 5000 mmf; 300 vdcw	14-14	Mica mold: Type W
C10	CAPACITOR: ceramic; NPO: 22 mmf; 500 vdcw	15-2	Electrical Reactance Corp: CI-2
C11	CAPACITOR: mica; 5000 mmf; 300 vdcw	14-14	Micamold: TypeW
C12	CAPACITOR: mica ; 1000 mmf; 300 vdcw	14-11	Micamold: Type OXM
C13	CAPACITOR: ceramic; NPO: 22 mmf; 500 vdcw	15-21	Electrical Reactance Corp: CI-2
C14 a,b	CAPACITOR: paper; two sections each 0.25 mf; 600 vdcw	17-14	General Electric: 23F628
C15	CAPACITOR: mica; 1000 mmf; 300 vdcw	14- 11	Micamold: Type OXM
C16	CAPACITOR: mica; 1000 mmf; 300 vdcw	14-11	Micamold: Type OXM
C17	CAPACITOR: mica; 1000 mmf; 300 vdcw	14-11	Micamold: Type OXM
C18	CAPACITOR: mica; 1000 mmf; 300 vdcw	14-11	Micamold: Type OXM
C19	CAPACITOR: paper; 1 mf; 600 vdcw	17-12	General Electric: 23F467G103
C20	CAPACITOR: paper; 1 mf; 600 vdcw	17-12	General Electric: 23F467G103

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Manufacturer and Type
C21	CAPACITOR: ceramic; 1000 mmf; feed thru type	15-21	Electrical Reactance Corp: CF-1
C22	CAPACITOR: ceramic; NPO: 110 mmf ±2 %	15-22	Electrical Reactance Corp: SI-7
C23	This reference not assigned.		
C24 a,b	CAPACITOR: paper; two sections each 0.25 mmf; 600 vdcw	17-14	General Electric: 23F628
C25	CAPACITOR: paper; 0.05 mf; 600 vdcw	16-15	Aerovox: Type 684
C26	CAPACITOR: ceramic; NPO; 110 mmf ±2%	15-22	Electrical Reactance Corp: SI-7
C27	CAPACITOR: ceramic; 1000 mmf; feed thru type	15-21	Electrical Reactance Corp: CF-1
C28	This reference not assigned		
C29	CAPACITOR: ceramic; 1000 mmf; feed thru type	15-21	Electrical Reactance Corp: CF-1
C30	CAPACITOR: dry electrolytic; 50 mf; 50 vdcw	18-50	Mallory: TC-39
C31	CAPACITOR: paper; 1 mf; 600 vdcw	17-12	General Electric: 23F467G103
C32	CAPACITOR: paper; 4 mf; 600 vdcw	17-10	Cornell-Dubilier: TLA 6040
C33	CAPACITOR: paper; 4 mf; 600 vdcw	17-10	Cornell-Dubilier: TLA 6040
C34	CAPACITOR: paper; 4 mf; 600 vdcw	17-10	Cornell-Dubilier: TLA 6040
C35	CAPACITOR: paper; 1 mf; 600 vdcw	17-12	General Electric: 23F467G103
C36	CAPACITOR: paper; 1 mf; 600 vdcw	17-12	General Electric: 23F467G103
C37	CAPACITOR: paper; 4 mf; 600 vdcw	17-10	Cornell-Dubilier; TLA 6040
C38A	CAPACITOR: paper; 1 mf; 600 vdcw	17-12	General Electric: 23F467G103

Circuit Ref.	Description	-hp- Stock No.	Manufacturer and Type
C38B	CAPACITOR: paper; 1 mf; 600 vdcw	17-12	General Electric: 23F467G103
C39	CAPACITOR: paper; 4 mf; 600 vdcw	17-10	Cornell-Dubilier: TLA 6040
C40	CAPACITOR: dry electrolytic; 10 mf; 450 vdcw	18-10	Mallory: Type WB-72
C41	CAPACITOR: silver mica: NPO; 62 mmf; 500 vdcw	15-25	Aerovox: Type 1469
C42	CAPACITOR: dry electrolytic; 50 mf; 50 vdcw	18-50	Mallory: Type TC-39
C43	CAPACITOR: paper; 1 mf; 600 vdcw	17-12	General Electric: 23F467G103
C44	CAPACITOR: mica; 1000 mmf; 300 vdcw	14-1000	Micamold: Type OXM
C45	CAPACITOR: paper; 1 mf; 600 vdcw	17-12	General Electric: 23F467G103
C46	CAPACITOR: silver mica; 510 mmf ±5%; 500 vdcw	15-24	Micamold: Type PO
C47	CAPACITOR: ceramic; 110 mmf	15-22	Electrical Reactance Corp: SI-7
C48	This reference not assigned.		
C49	CAPACITOR: mica; 150 mmf; 500 vdcw	14-150	Micamold: Type OXM
C50	CAPACITOR: mica; 150 mmf; 500 vdcw	14-150	Micamold: Type OXM
C51	CAPACITOR: mica; 150 mmf; 500 vdcw	14-150	Micamold: Type OXM
C52	CAPACITOR: mica; 150 mmf; 500 vdcw	14-150	Micamold: Type OXM
C53	CAPACITOR: mica; 150 mmf; 500 vdcw	14-150	Micamold: Type OXM
C54	CAPACITOR: mica; 150 mmf; 500 vdcw	14-150	Micamold: Type OXM
C55	CAPACITOR: mica; 150 mmf; 500 vdcw	14-150	Micamold: Type OXM
C56	CAPACITOR: mica; 150 mmf; 500 vdcw	14-150	Micamold: Type OXM
C57	CAPACITOR: mica; 1000 mmf; 300 vdcw	14-11	Micamold: Type OXM
C58	CAPACITOR: mica; 1000 mmf; 300 vdcw	14-11	Micamold: Type OXM
C59	CAPACITOR: mica; 1000 mmf; 300 vdcw	14-11	Micamold: Type OXM

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Manufacturer and Type
C60	CAPACITOR: mica; 150 mmf; 500 vdcw	14-150	Micamold: Type OXM
C61	CAPACITOR: mica; 150 mmf; 500 vdcw	14-150	Micamold: Type OXM
C62	CAPACITOR; mica; 150 mmf; 500 vdcw	14-150	Micamold: Type OXM
F1	FUSE: cartridge type, size 3AG; rated 0.025 amp, 250 volts	211-6	Littelfuse: 312.25
F2	FUSE: cartridge type, size 3AG; rated 2 amp; slow-blow type	211-16	Bussman: MDL2
I1	LAMP: incandescent; 6 watts; 120 volts; candelabra screw base	211-5	General Electric: S6/6W
I2	LAMP: incandescent; 6-8 volts, 0.15 lamp; min bayonet base	211-47	General Electric: #47
J1	UHF PANEL JACK: Navy Type -49194	38-50	Amphenol: #83-1R
J2	JACK: telephone type	38-10	Switchcraft
J3	JACK: telephone type	38-10	Switchcraft
L1	COIL: 0.9 microhenry; phenolic form	35F-60A	Hewlett-Packard: 35G-60A
L2	COIL: 1.1 millihenry; phenolic form	35F-60B	Hewlett-Packard: 35F-60B
L3	COIL: 2 microhenry; phenolic form	35F-60C	Hewlett-Packard: 35F-60C
L4	COIL: 0.9 millihenry; phenolic form	35F-60D	Hewlett-Packard: 35F-60D
L5	COIL: 1.5 microhenry choke; phenolic form	48-1	Electrical Reactance Corp
L6	COIL: 1.5 microhenry choke; phenolic form	48-1	Electrical Reactance Corp
L7	COIL: 1.5 microhenry choke; phenolic form	48-1	Electrical Reactance Corp
L8	COIL: 1.5 microhenry choke; phenolic form	48-1	Electrical Reactance Corp
L9	COIL: 1.5 microhenry choke; phenolic form	48-1	Electrical Reactance Corp

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Manufacturer and Type
L10	COIL: 1.5 microhenry choke; phenolic form	48-1	Electrical Reactance Corp
L11	FILTER CHOKE: 6 henries at 125 madc; 240 dc ohm	M-61 (911-12A)	Robert M. HadleyCo. #8169A
L12	FILTER CHOKE: 6 henries at 125 madc; 240 dc ohm	M-61 (911-12A)	Robert M. Hadley: #8169A
M1	METER: 400 microamp full scale 4-1/4" x 3-15/16"; illuminated type	112-13	Weston: Model 861
M2	METER: zero center microammeter; 15-0-15 microamps full scale; 4-1/4" x 3-15/16"; illuminated type	112-12	Weston: Model 861
R1	RESISTOR: composition; 270,000 ohms; ½ watt	23-270K	Allen-Bradley: EB-2741
R2	HEATER: wirewound; 5 ohms (part of oven assembly; see entry following "Xtal-2"		
R3	RESISTOR: composition; 56000 ohms; 1 watt	24-56K	Allen-Bradley: GB-5631
R4	RESISTOR: composition; 22000 ohms; 2 watts	25-22K	Allen- Bradley: HB-2231
R5	RESISTOR: composition; 120,000 ohms; 1 watt	24--120K	Allen-Bradley: GB-1241
R6	RESISTOR: composition; 18000 ohms; 2 watts	25-18K	Allen-Bradley: HB-1831
R7	RESISTOR: composition; 30,000 ohms; ½ watt	23-30K	Allen-Bradley: EB-3031
R8	RESISTOR: composition 6800 ohms; 1 watt	24-6800	Allen-Bradley: GB-6821
R9	RESISTOR: composition; 100 ohms; 2 watts	25- 100	Allen-Bradley: HB-1011
R10	RESISTOR: composition; 100 ohms; 2 watts	25-100	Allen-Bradley: HB-1011
R11	RESISTOR: composition; 10,000 ohms; 1 watt	24-10K	Allen-Bradley: GB-1031
R12	RESISTOR: composition; 100 ohms; 1 watt	24-100	Allen-Bradley: GB-1011

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Manufacturer and Type
R13	RESISTOR: composition; 820 ohms; 1 watt	24-820	Allen-Bradly; GB-8211
R14	RESISTOR: composition; 8200 ohms; 1 watt	24-8200	Allen-Bradley: GB-8221
R15	RESISTOR: composition; 560,000 ohms 1 watt	24-560K	Allen-Bradley:
R16	RESISTOR: composition; 82000 ohms; 1 watt	24-82K	Allen-B radley: GB-8221
R17	RESISTOR: composition; 4700 ohms; 2 watts	25-4700	Allen-Bradley; HB-4721
R18	RESISTOR: composition; 4700 ohms; 2 watts	25-4700	Allen-Bradley: HB-4721
R19	RESISTOR: composition; 33000ohms; 1 watt	24-33K	Allen-Bradley: CB-3331
R20	RESISTOR: composition;33000 ohms; 1watt	24-33K	Allen-Bradley: GB-3331
R21	RESISTOR: composition; 4700 ohms; 2 watts	25-4700	Allen-Bradley: HB-4721
R22	RESISTOR: composition; 4700 ohms; 2 watts	25-4700	Allen-Bradley; HB-4721
R23	RESISTOR: composition; 560,000 ohms; 1 watt	24-560K	Allen-Bradley: GB-5641
R24	RESISTOR: composition; 82000 ohms; 1 watt	24-82K	Allen-Bradley: GB-8231
R25	RESISTOR: composition; 830,000 ohms; precision type; 1 watt	31-830K	Wilkor: CP-1
R26	POTENTIOMETER: composition; 50,000 ohms	210-13	Centralab: 33-010-176
R27	RESISTOR: composition; 103,000 ohms; precision type; 1watt	31-103K	Wilkor: CP-1
R28	RESISTOR: composition; 1500 ohms; 2 watts	25-1500	Allen-Bradley: HB-1521
R29	RESISTOR: composition; 1000 ohms; 1 watt	24-1K	Allen-Bradley: GB-1021
R30	RESISTOR: composition; 220,000 ohms; 1 watt	24-220K	Allen-Bradley: GB-2241

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Manufacturer and Type
R31	RESISTOR: composition; 33000 ohms; 1 watt	24-33K	Allen-Bradley: CB-3331
R32	RESISTOR: composition; 33000 ohms; 1 watt	24-33K	Allen-Bradley: GB-3331
R33	RESISTOR: wirewound on phenolic card; 1200 ohms; precision type	35F-55	Hewlett-Packard: 35F-55
R34	RESISTOR: wirewound on phenolic card; 1200 ohms; precision type	35F-55	Hewlett-Packard 35F-55
R35	POTENTIOMETER: wire und; 300 ohms; screwdriver adjusting	210-53	Centralab; 21-010-358
R36A	RESISTOR: precision wirewound type; 9100 ohms; wound on phenolic card	35F-55A	Hewlett-Packard: 35F-55A
R36B or R37B	RESISTOR: precision composition type; 1 watt; exact value selected during manufacturer's tests		Wilkor: CP-1
R37A	RESISTOR: precision wirewound type; 510 ohms; wound on phenolic card	35F-55B	Hewlett-Packard: 35F-55B
R38	RESISTOR: wirewound on phenolic card; 62 ohms; precision type	35F-26	Hewlett Packard 35F-26
R39	POTENTIOMETER: wirewound; 1000 ohms	210-5	Centralab: 21-010-355
R40	RESISTOR: wirewound on phenolic card; 4700 ohms; precision type	35F-27	Hewlett-Packard: 35F-27
R41	RESISTOR: composition; 683,700 ohms; 1 watt; precision type	31-683.7K	Wilkor: CP-1
R42	POTENTIOMETER: wirewound; 25000 ohms	210-10	Clarostat: Type 58
R43	RESISTOR: composition; 14,400 ohms;	31-14.4K	Wilkor: CP-1
R44	RESISTOR: wirewound; 5000 ohms; 20 watts	27-5K	Lectrohm: Type 2R
R45	RESISTOR: wirewound; 4000 ohms; 220watts	26- 4K	Lectrohm: Type 2R
R46	RESISTOR: composition; 560,000 ohms; 1 watt	24-560K	Allen-Bradley: GB-5641
R47A	RESISTOR: composition; 82000 ohms; 2w	25-82K	Allen-Bradley: HB-8231

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Manufacturer and Type
R47B	RESISTOR: composition; 82000 ohms; 2 w	25-82K	Allen-Bradley: HB-8231
R48	RESISTOR: composition; 316000 ohms; 1 w precisionc . type	31-316K	Wilkor: CP-1
R49	POTENTIOMETER; composition; 20,000 ohms	210-16	Contralab: 33-010-725
R50	RESISTOR: composition; 90,000 ohms; 1 watt; precision type	31-90K	Wilkor: CP-1
R51	RESISTOR: composition; 10,000 ohms; 2 watts	25-10K	Allen-Bradley: HB-1031
R52	RESISTOR: composition; 144000 ohms; 1 watt; precision type	31-144K	Wilkor: CP-1
R53	RESISTOR: precision composition type; 33000 ohms; 1 watt	31-33K	Wilkor: CP-1
R54	RESISTOR: composition; 5100 ohms; 1 watt	24-5100	Allen-Bradley: GB-5121
R55	RESISTOR: composition; 22,000 ohms; 2w	25-22K	Allen-Bradley: HB-2231
R56	RESISTOR: precision composition type; 216,300 ohms; 1 watt	31-216.3K	Wilkor: CP-1
R57	RESISTOR: composition; 2200 ohms; 1 watt	24-2200	Allen-Bradley: GB-2221
R58	RESISTOR: precision composition type; 62,000 ohms; 1 watt	31-62K	Wilkor: CP-1
R59	RESISTOR: composition; 560 ohms; 1watt	24-560	Allen-Bradley: GB-5611
R60	RESISTOR: composition; 2,200; 2 watts	25-2,200	Allen-Bradley HB-2221
R61	RESISTOR: composition; 1,000,000 ohms; ½ watt	23-1M	Allen-Bradley: EB-1051
R62	RESISTOR: composition; 18000 ohms; 1 w	24-18K	Allen-Bradley: GB-1831
R63	RESISTOR: composition; 56 ohms; ½ watt	23-56	Allen-Bradley: EB-5601
R64	RESISTOR: composition; 8200 ohms; ½ watt	23-8200	Allen-Bradley: EB-8221

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Manufacturer and Type.
R65	RESISTOR: composition; 12 ohms; $\frac{1}{2}$ w	23-12	Allen-Bradley: EB-2301
R66	RESISTOR: composition; 1 watt; value selected to circuit during calibration; 8200-15000ohms		
R67	RESISTOR: composition; 56 ohms; $\frac{1}{2}$ watt	23-56	Allen-Bradley: EB-5601
R68	RESISTOR: composition; 120,000 ohms; 1 watt	24-120K	Allen-Bradley: GB-1241
R69	RESISTOR: composition; 18000 ohms; 1 w	24-18K	Allen-Bradley: GB-1831
Relay 1	RELAY: SPST: plug-in type	49-6	Sigma Inst: 41RCZ
S1	SWITCH: toggle; SPST; 5/8" bat handle	310-11	Arrow-H &H
S2	SWITCH: rotary; two sections, four pols, five position	310-39	Hewlett-Packard 310-39
S3	SWITCH: toggle; DPDT: 5/8" bat handle	310-41	Arrow H & H
T1	TRANSFORMER: power; 115v, 50/60 cycle pri; sec #1, 520 vdc at 125 ma; sec #2, 5 vac at 3 amp; sec #3, 6.3 vac at 5 amp; sec #4, 6.3 vac at 2 amp; sec #5, 6.3 v at 1 amp	35F-8	Excel Transformer Co 910-26
T2	TRANSFORMER: power; 117v, 50/60 cycle pri; sec #1, 180 v at 0.1 amp; sec #2, 6.3 v at 2 amp	35F-8A (910-32)	Excel Transformer Co 910-32
T3	TRANSFORMER: audio; turns ratio 1:2	(912-10)	Peerless Electrical Products: NO.4603
T4	TRANSFORMER: audio; 20 cps to 20 kc $\pm\frac{1}{2}$db; 300 ohm primary, 1200 ohm and 60,000 ohm sec.	912-7	Transformer Engineer 912-17
T5	TRANSFORMER: audio; 20 cps to 20 kc $\pm\frac{1}{2}$db; 25000 ohm pri, 600 ohm secondary	(35F-9) 912-8	Transformer Engineer 912-8
V1	TUBE: RMA type 6AC7	212-6AC7	
V2	TUBE: RMA type 7F8	212-7F8	
V3	TUBE: RMA type 6AC7	212-6AC7	

TABLE OF REPLACEABLE PARTS

Circuit Ref. ---	Description	-hp- Stock No.	Manufacturer and Type
V4	TUBE: RMA type 6V6	212-6V6	
V5	TUBE: RMA type 6V6	212-6V6	
V6	TUBE: RMA type 6V6	212-6V6	
V7	TUBE: RMA type 6V6	212-6V6	
V8	TUBE: RMA type 6V6	212-6V6	
V9	TUBE: RMA type 6V6	212-6V6	
V10	TUBE: RMA type 6SL7-GT	212-6SL7-GT	
V11	TUBE: RMA type 2050	212-2050	
V12	TUBE: RMA type 5R4GY	212-5R4GY	
V13	TUBE: RMA type VR-75	212-VR-75	
V14	TUBE: RMA type 6Y6G	212-6Y6G	
V15	TUBE: RMA type VR-75	212-VR-75	
V16	TUBE: RMA type 6SN7-GT	212-6SN7-GT	
V17	TUBE: RMA type 6SJ7	212-6SJ7	
Xtal-1	CRYSTAL: quartz; rated 200 kc $\pm$0.02%; 20° C. to 60° C. temp range; includes holder and pins	41-10	Knight: H-13
Xtal-2	CRYSTAL: quartz; freq according to desired channel; temp coeff 1 cycle per mc per degree C.	41-(Spec. freq.)	Billey: Type MC7
...	CRYSTAL OVEN: includes heater, thermometer, and thermostat; does not include crystal	35F-25	Hewlett-Packard : 35F-25
...	THERMOMETER: mercury column element; 55° C. to 75°C. range graduated at 1°C intervals; L-shaped	41-6	Moeller Instrument Co.
...	CONTACT THERMOMETER (Thermostatic switch) mercury column element; operating temperature 65° C.; 0.1° C. differential	41-5	Precision Instrument Co.
Y1 to Y11	RECTIFIER CRYSTAL: Type 1N34	212-34	Sylvania: 1N34

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Manufacturer and Type
	FUSEHOLDER: extractor post type; for size 3AGfuses	312-8	Littelfuse: #342001
	DIAL LIGHT ASSEMBLY (red)	312-93	Dial Light Co: 910 C-161
	KNOB: molded black phenolic: 1-$\frac{1}{2}$" diam; white indicator line	37-5	Kurz-Kasch: S-380-64L
	KNOB: molded black phenolic; 1-1/8" diam; no skirt	M-59	Kur Kasch: S-308-6L
	KNOB: molded black phenolic; 11/16" diam	37-1	Federal Screw Prod: 1110
	SOCKET: tube; standard octal; molded mica-filled phenolic	38-8M	Cinch: 9880
	SOCKET: tube; loctal; polystyrene	38-47	Amphenol: 54-8L
	SOCKET: crystal; molded mica-filled phenolic	38-49	Cinch: 9816
	SOCKET: 6-contact; molded mica-filled phenolic	38-57	Amphenol: 77-MIP-6T
	RECEPTACLE: motor base type; two parallel byaonet contacts	38-52	General Electric: 2711
	LINE CORD: approximately 7$\frac{1}{2}$; parallel type contact plug on one end and motor base type receptacle on other	M-72	Hewlett-Packard M-72
	TERMINAL STRIP: molded black phenolic: 8 terminals	36-38	Jones: 8-141-Y
	FLEXIBLE SHAFT: for $\frac{1}{4}$" shafts 5$\frac{1}{2}$" long.	312-47	National Co. Inc. TX-11 ½

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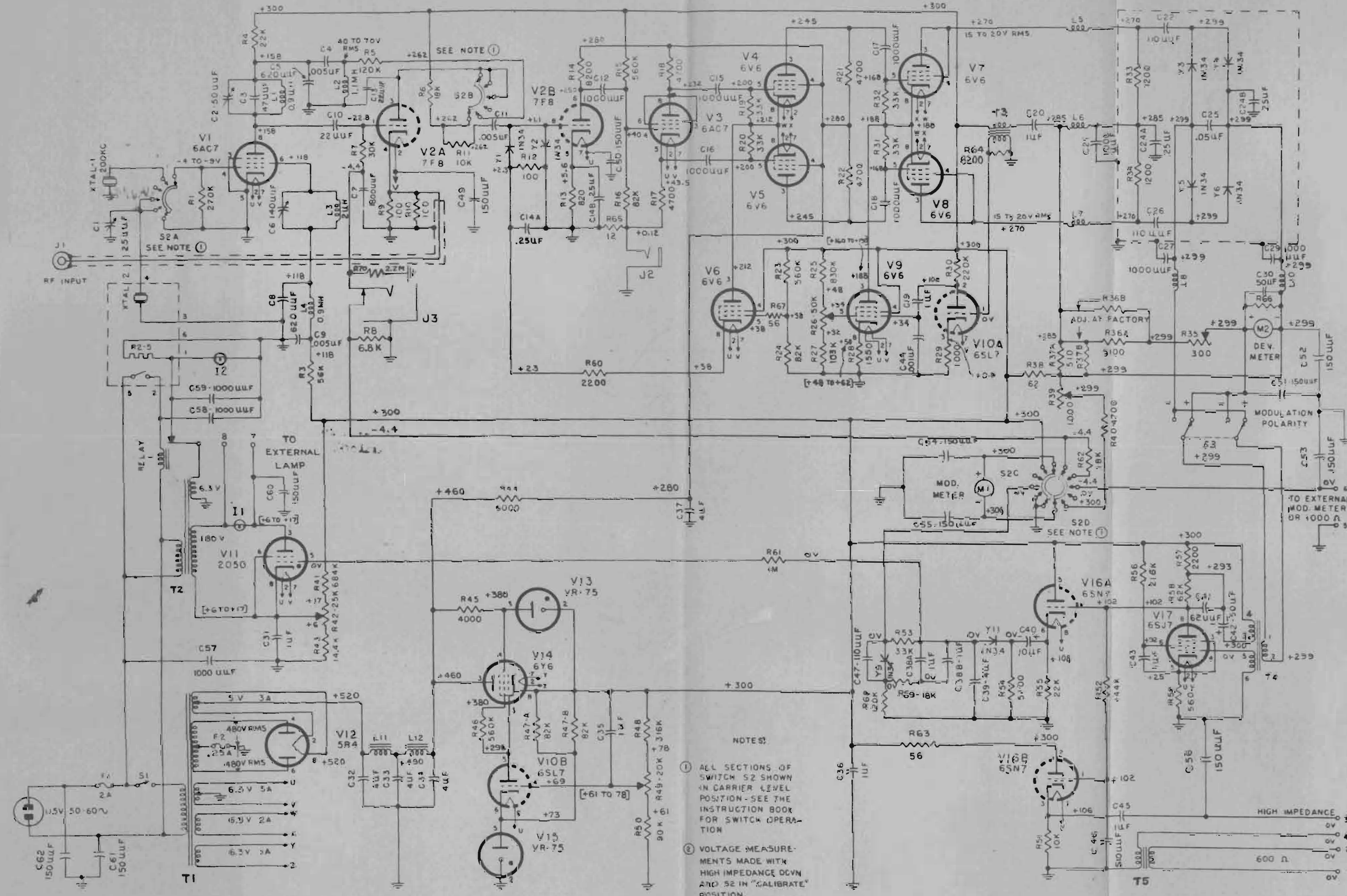

SCHEMATIC DIAGRAM OF -hp- MODEL 335B FM MONITOR AND MODULATION METER

LIST OF MANUFACTURERS CODE LETTERS FOR REPLACEABLE PARTS TABLE

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

CLAIM FOR DAMAGE IN SHIPMENT

The instrument should be tested as soon as it is received. If it fails to operate properly, or is damaged in any way, a claim should be filed with the carrier. A full report of the damage should be obtained by the claim agent, and this report should be forwarded to us. We will then advise you of the disposition to be made of the equipment and arrange for repair or replacement. Include model number, type number and serial number when referring to this instrument for any reason.

WARRANTY

Hewlett-Packard Company warrants each instrument manufactured by them to be free from defects in material and workmanship. Our liability under this warranty is limited to servicing or adjusting any instrument returned to the factory for that purpose and to replace any defective parts thereof (except tubes, fuses and batteries). This warranty is effective for one year after delivery to the original purchaser when the instrument is returned, transportation charges prepaid by the original purchaser, and which upon our examination is disclosed to our satisfaction to be defective. If the fault has been caused by misuse or abnormal conditions of operation, repairs will be billed at cost. In this case, an estimate will be submitted before the work is started.

If any fault develops, the following steps should be taken:

1. Notify us, giving full details of the difficulty, and include the model number, type number and serial number. On receipt of this information, we will give you service instructions or shipping data.

2. On receipt of shipping instructions, forward the instrument prepaid, and repairs will be made at the factory. If requested, an estimate of the charges will be made before the work begins provided the instrument is not covered by the warranty.

SHIPPING

All shipments of Hewlett-Packard instruments should be made via Railway Express. The instruments should be packed in a wooden box and surrounded by two to three inches of excelsior or similar shock-absorbing material.

DO NOT HESITATE TO CALL ON US

HEWLETT-PACKARD COMPANY
Laboratory Instruments for Speed and Accuracy
395 PAGE MILL ROAD PALO ALTO, CALIF.