INSTRUCTION BOOK

479S-3

AUDIO SIGNAL GENERATOR

COLLINS

INSTRUCTION BOOK

FOR

479S-3 AUDIO SIGNAL GENERATOR

COLLINS RADIO COMPANY
Cedar Rapids, Iowa

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SECTION I

GENERAL DESCRIPTION

1-1. OVERALL IDENTIFICATION.

1-2. This handbook has been prepared to aid in the installation, adjustment, operation and maintenance of the 479S-3 Audio Signal Generator.

1-3. PURPOSE OF EQUIPMENT.

1-4. Signal Generator 479S-3 is designed to facilitate the testing and calibrating of Omni-Range Navigation Receivers for aircraft use. In conjunction with the Boonton 211-A RF Signal Generator, it provides a synthesis of signals encountered in reception and interpretation of omni-range, tone localizer, voice, and glide slope facilities. In addition, the various components of these signals are available singly and in combination for test purposes.

1-5. LIMITATIONS. The Localizer information which can be obtained is not continuously variable, but the unit can simulate signals encountered in nine different positions of the aircraft with respect to the center of the runway. Also, voice communication can only be simulated at a fixed audio frequency of 1020 cps. Phase angle and localizer attenuator accuracies at the MOD OUTPUT jack will remain constant provided that resistive loads of 10,000 ohms or greater are used. In addition, the frequency stability of any signal delivered by the 479S-3 is dependent upon the frequency stability of the 60 cps power supplied from the external source.

1-6. GENERAL MAKE-UP. All voltages obtained from the Generator are produced mechanically (see figure 1-2). The 115-volt 60 cps power supplied to the Generator is used to operate two synchronous motors which in turn rotate the generator assemblies. To provide the signals used in radio air navigation, most of the generated voltages are fed to simple resistive and/or reactive networks, and, through the use of switching circuits, signals of the appropriate frequencies are mixed together and made available at the MOD OUTPUT jack. The front panel and base casting fasten to a large bracket, and a cable from the front panel to three plug receptacles on the component chassis connects the circuits on the front panel to those on the base casting. Together the front panel, the base casting, and the bracket can be mounted in a standard 19-inch relay rack.

1-7. ELECTRICAL PERFORMANCE DATA.

a. Maximum voltage across 10,000 ohm load at MOD OUTPUT jack: At least 3.0 volts of any signal with the FUNCTION SELECTOR (S-102) in the SPECIFIC SIG. position, MASTER ATTENUATOR (R-147) full clockwise, and individual signal level controls full clockwise.

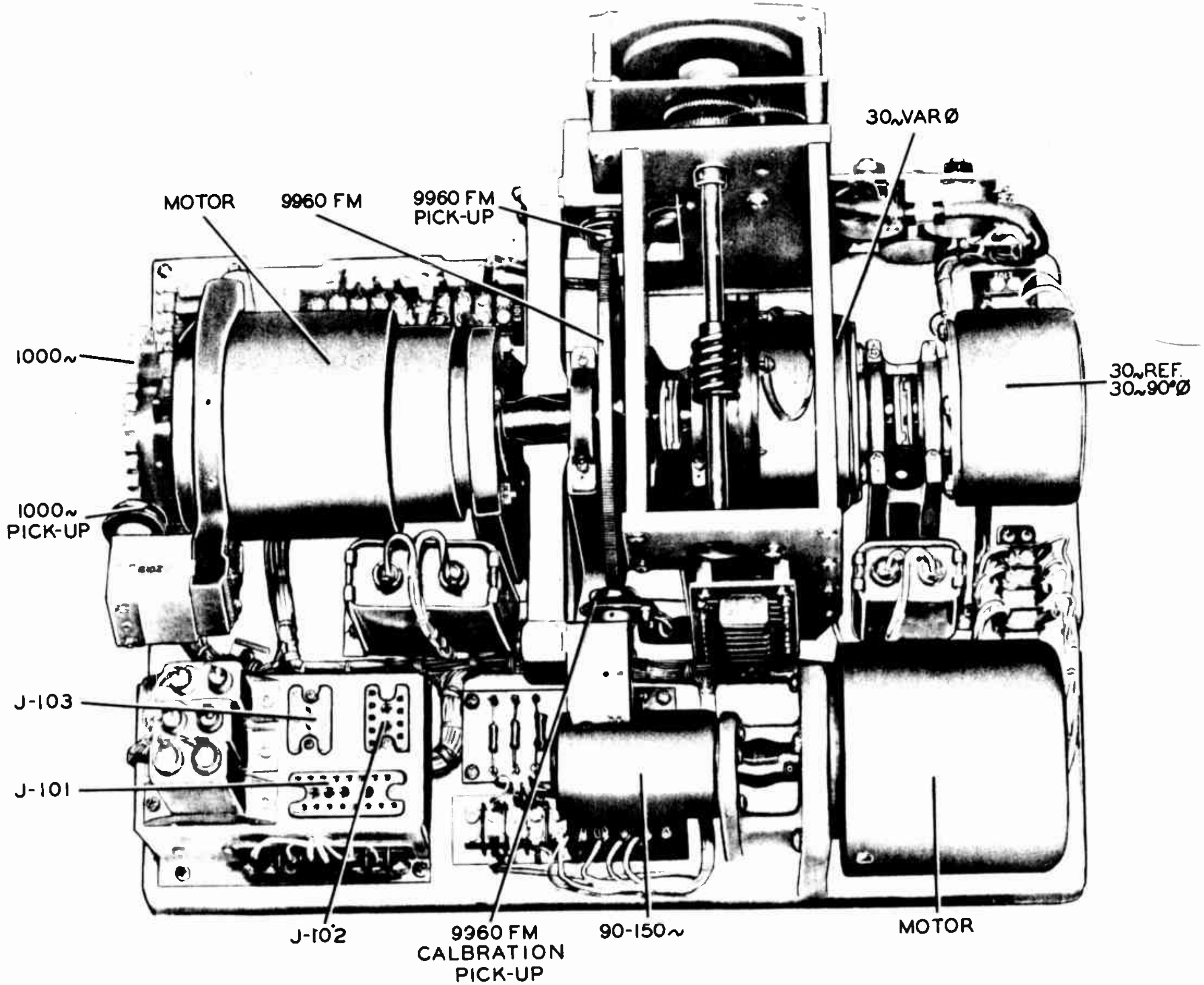


Figure 1-2. Base Casting Assembly

b. Voltage stability: ±5% of pre-set level under all service conditions (humidity from 0 to 100% and temperature from -10°C to +50°C).

c. Frequency Stability: Directly dependent upon the frequency stability of the external 60 cps power source.

d. Phase Angle Stability: ±0.2° of pre-set level under all service conditions.

e. Maximum Distortion (under all service conditions):

30 cps voltages - 2% harmonic
90 cps and 150 cps voltages - 3% harmonic
1000 cps voltage - 5% harmonic
9960 FM and Calibration Signal - 5% AM

f. Current Requirements:

Normal - 1.58 amperes
Maximum Starting - 2.0 amperes

1-8. ROTARY MACHINERY DATA.

UNIT	MFR.	TYPE NO.	VOLTS INPUT	VOLTS OUTPUT	CURRENT RATING
ODR Motor	Eastern Air Devices, Inc.	LH71ZKCJ-1	115	--	1.2 Amp.
Loc Motor	Eastern Air Devices, Inc.	LH71QCJ-2	115	--	0.5 Amp.
Loc Gen	Eastern Air Devices, Inc.	N3E-2	--	8.5	
Var Ø Gen	Eastern Air Devices, Inc.	N2B-1	--	7.0	
2 Ø Gen	Eastern Air Devices,	N2B-2	--	7.0	

1-9. TYPES OF SIGNALS PRODUCED BY THE GENERATOR.

a. 30 cps REF Ø. This is a 30 cps sine wave which is made available at a separate jack on the front panel labeled 30 ~ REF Ø. It is controlable in level by potentiometer adjustment and has a fixed phase angle to which the phase angles of the other signals are referred.

b. 30 cps 90°Ø. This is a 30 cps sine wave which is made available on the front panel at a separate jack labeled 30 ~ 90°Ø. It has a fixed phase angle which leads that of the 30 cps REF Ø by 90° ±1°. No level adjustment is provided on the 479S-3 for this signal.

c. 30 cps VAR Ø. This is a 30 cps sine wave which is made available on the front panel at a separate jack labeled 30 VAR Ø and can also be obtained at the MOD OUTPUT jack. The level of the signal can be varied by potentiometer adjustment when taken from the MOD OUTPUT jack, but the voltage at the 30 ~ VAR Ø jack is not adjustable. By rotating the PHASE ANGLE SELECTOR on the front panel, the phase angle of the 30 cps VAR Ø signal can be varied through 360°. The 30 cps VAR Ø signal is in phase with the 30 cps REF Ø signal when the phase angle dial on the front panel reads "0".

d. 9960 FM. This is a frequency-modulated signal having a center frequency of 9960 cps and frequency modulated at a 30 cps sinusoidal rate with a deviation ratio of 16. In other words, the frequency changes from 9960 cps by ±480 cps at a rate of 30 cps sinusoidal rate. Thus the total spread of frequency is from 9480 cps to 10440 cps. It is made available at the MOD OUTPUT jack and can be varied in level by potentiometer adjustment. The 30 cps signal derived from the 9960 FM signal upon demodulation has a phase angle which is in phase with that of the 30 cps REF Ø signal.

e. ZERO PHASE CALIBRATION SIGNAL. This is the same type of signal as the 9960 FM signal. However, the 30 cps signal derived from the Zero Phase Calibration Signal upon demodulation has a phase angle which is 180° from that of the 30 cps REF Ø signal. The calibration Signal is available at a pair of terminals (E-104.1 and E-104.2) on the component chassis at the rear of the base casting, and the signal level can be varied by potentiometer adjustment.

f. 90 cps. This is a 90 cps sine wave which is made available at the MOD OUTPUT jack. It can be varied in level by potentiometer adjustment.

g. 150 cps. This is a 150 cps sine wave which is made available at the MOD OUTPUT jack. It can be varied in level by potentiometer adjustment.

h. 1000 cps. This is a 1020 cps sine wave which is made available at the MOD OUTPUT jack. Throughout the remainder of the handbook this signal will be referred to as 1000 cps, although the frequency is slightly different. It can be varied in level by potentiometer adjustment.

SECTION II

OPERATION PROCEDURES

2-1. INITIAL TESTS REQUIRED TO INSURE PROPER FUNCTION OF EQUIPMENT. The following procedure outlines step-by-step a method to determine whether the equipment is functioning properly.

a. Connect power cord from 115 volt-60 cps source to 479S-3 input.

b. Throw power switch (S-104) to ON position. Note if pilot light is glowing.

c. Rotate FUNCTION SELECTOR (S-102) to CAL and turn all potentiometers (R103, R116, R128,R133, R136, R138, R151) full clockwise.

d. Rotate SPECIFIC SIGNAL SELECTOR (S-103) to each of its five positions and observe OUTPUT meter (M-101) on front panel to see whether a minimum 1.5 volts on each signal is obtained.

e. Measure output voltage of each of the 30 cps signals at the separate jacks on the front panel. These voltages should be approximately 6 to 8 volts.

f. Measure voltage of Zero Phase Calibration Signal at terminals E-104.1 and E-104.2 on component chassis with a vacuum tube voltmeter (measurement should be at least 3 volts).

g. Rotate SPECIFIC SIGNAL SELECTOR to some position other than 1000 and throw 1000 toggle switch (S-104) to ON. Voltmeter on panel should have a greater reading than when toggle switch is OFF. Also note whether 1000 pilot light works.

2-2. PURPOSE AND USE OF ALL OPERATING CONTROLS. A description of the front panel is made up in Table I. The function of panel controls and parts may be determined by use of the table.

OPERATION PROCEDURES

TABLE I FRONT PANEL DESCRIPTION

Qty	Part	Function or Miscellaneous
1	Front Panel	19" x 10-15/32" - fits standard 19" relay rack.
1	Power Receptacle	115 V 60 cps power input (male).
1	Power Switch & Pilot Light	DPDT toggle switch -- when ON, unit operates. When OFF, unit does not operate.
1	Localizer Attenuator Sw.	Rotary switch to select db attenuation of localizer frequencies.
1	Phase Angle Selector	Knob -- rotate to change phase of 30 cps VAR Ø. Dial -- indicates phase angle of 30 cps VAR Ø with respect to 30 cps REF Ø.
1	Potentiometer Access Door	Open to adjust settings of voltage with potentiometers.
1	A-C Voltmeter	Reads voltage of selected signal at Modulator Output jack.
1	Function Selector	Rotary switch to select functional signals.
1	Specific Signal Selector	Rotary switch to select specific signals.
1	Master Attenuator	Resistance pad to adjust level of specific signals. Does not affect voltages in other positions of Function Selector.
1	1000 cps Switch and Pilot Light	DPDT toggle switch - when ON, 1000 cps is on; when OFF, 1000 cps is off.
4	Output Jacks	BNC connectors - output voltages of modulator.
4	Fuse Holders and Fuses	One fuse on each side of power line plus 2 spares (F101 left, F102 2nd from left). Fuse type - 3AG, 3 amp 250 Volt.
2	Protective Handles	To protect parts mounted on front panel as well as to provide aid in handling of the modulator.

2-3. OPERATION OF EQUIPMENT.

2-4. Signals to be calibrated are tabulated as follows:

TYPE OF SIGNAL	FREQUENCY	% MODULATION
Omni-Range	30 cps VAR Ø 9960 FM	30
Tone Localizer	90 cps 150 cps	20 20
Voice or Station Identification Code	1000 cps	As desired

NOTE

Calibration of 30 cps VAR Ø should be made prior to calibration of 9960 FM and 1000 cps.

2-5. PRELIMINARY STEPS.

a. For the Per Cent Modulation meter of the 211-A, select the scale which gives a full-scale reading for 30% modulation.

b. Reduce the MOD LEVEL control of the 211-A to zero or full counter-clockwise to prevent damage to the Per Cent Modulation meter in case of excessive input voltage.

c. Connect RF cable from MOD OUTPUT jack to EXT MOD INPUT jack of the 211-A

d. Rotate FUNCTION SELECTOR of the 479S-3 to CAL.

e. Open potentiometer door on front panel of 479S-3.

f. Insure that 1000 ~ toggle switch is OFF.

2-6. 30 ~ VAR Ø CALIBRATION.

a. Rotate SPECIFIC SIGNAL SELECTOR to position marked 30 ~ VAR Ø.

b. With a screwdriver, adjust potentiometer marked 30 ~ VAR Ø (R-138) until OUTPUT meter indicates 1.5 volts.

c. Lock potentiometer shaft and check OUTPUT meter to see that reading of 1.5 volts has not changed.

d. Adjust MOD LEVEL control of the 211-A to read full scale or 30% on Per Cent Modulation meter. (The setting of the MOD LEVEL control should remain fixed. Readjustment should not be required.)

2-7. 9960 FM CALIBRATION.

a. Rotate SPECIFIC SIGNAL SELECTOR to position marked 9960 FM.

b. Adjust potentiometer (R-133) marked 9960 FM until the Per Cent Modulation meter again reads full scale.

c. Lock potentiometer shaft and check Per Cent Modulation meter to see that reading has not changed.

d. Normal omni-range signal maý not be obtained by rotating FUNCTION SELECTOR to ODR. However, the 100% scale of the Per Cent Modulation meter of the 211-A should be selected beforehand.

2-8. 90 cps CALIBRATION.

a. With FUNCTION SELECTOR in CAL position, rotate SPECIFIC SIGNAL SELECTOR to position marked 90-150

b. Rotate TONE LOCALIZER to position marked CAL 90 ~.

c. With the scale of the Per Cent Modulation meter on the 211-A selected to read 30% full scale and the MOD LEVEL control set as in 30 cps VAR ∅ calibration, adjust potentiometer (R-116) marked 90 ~ until the Per Cent Modulation meter indicates 20%.

d. Lock potentiometer shaft and check the Per Cent Modulation meter to see that reading has not changed.

e. Read the 90 cps voltage carefully on OUTPUT meter since the 150 cps signal must be set precisely to the same value.

2-9. 150 cps CALIBRATION.

a. Rotate TONE LOCALIZER clockwise to position marked CAL 150 ~.

b. While reading voltage on OUTPUT meter, adjust potentiometer (R-103) marked 150 ~ until reading is exactly equal to the 90 cps reading (refer to e., paragraph 2-8).

NOTE

The adjustment of equal voltages for the 90 cps and the 150 cps signals should be made accurately; small unbalances in these voltages will result in incorrect calibration of the Tone Localizer facility of navigation receivers.

c. Lock potentiometer shaft and check to see that OUTPUT meter reading has not changed.

d. Recheck both voltages for 90 cps and 150 cps.

e. Proper Tone Localizer signals now may be obtained by selecting the 100% scale of the Per Cent Modulation meter of the 211-A and rotating FUNCTION SELECTOR to TONE LOC. TONE LOCALIZER now may be rotated to positions desired for accurate checking or calibration of receivers.

NOTE

The 479S-3 OUTPUT meter-deflection is proportional to the average value of a wave whereas the Per Cent Modulation Meter of the 211-A deflects in proportion to the peak value of a wave. Use of the 479S-3 meter for balance of the Tone Localizer voltages is recommended over the peak-reading meter since it is less susceptible to errors due to small harmonics.

TOR

2-10. 1000 cps CALIBRATION.

a. With FUNCTION SELECTOR on CAL, rotate SPECIFIC SIGNAL SELECTOR to the position marked 1000 ~.

b. With the scale of the Per Cent Modulation meter of the 211-A selected to read 30% full scale and the MOD LEVEL control set as in 30 cps VAR Ø calibration, adjust potentiometer (R-128) marked 1000 ~ until the Per Cent Modulation meter reads percentage of modulation desired.

CAUTION

No. 1. A pilot light is provided to remind the operator that the 1000 cps signal is present at the MOD OUTPUT jack. When the 1000 cps signal is undesired, the operator must heed the warning service provided by the light.

No. 2. Overloading the 3-volt OUTPUT meter is possible when the FUNCTION SELECTOR is on SPECIFIC SIG. Overloading can result ty superimposing the 1000 cps signal on another signal -- or -- by calibrating the Localizer frequencies at a high voltage and then rotating TONE LOCALIZER to one of the DB positions.

2-11. MISCELLANEOUS. Variable level of any signal is obtained by rotating FUNCTION SELECTOR to SPECIFIC SIG and selecting the desired signal by rotating SPECIFIC SIGNAL SELECTOR. The level of each signal except the Tone Localizer frequencies may be varied from 0 to approximately 3 volts by turning the MASTER ATTENUATOR. If the 90 cps and 150 cps calibrations have been executed as previously outlined, each frequency voltage may be varied from 0 to approximately 2 with the MASTER ATTENUATOR.

If more 90 cps or 150 cps voltage is desired, the 90 cps and 150 cps potentiometers behind the access door may be turned after unlocking the shafts. However, the operator should be aware that he is destroying the calibration of the Tone Localizer facility as normally used in receiver testing, and he should re-calibrate this function before using the Generator for such testing.

SECTION III

THEORY OF OPERATION

3-1. GENERAL.

3.2. The 479S-3 is an audio signal generator whose output is an accurate synthesis of the signals encountered in the instrumentation section of Omni-Range receivers. All output voltages are generated mechanically and no amplification is required. In addition to the generators, the circuit includes resistive, inductive and capacitive components sufficient to provide the necessary mixing and level control. Ganged wafer-type switches provide for the selection of the desired output signals which will appear at the output jack either singly or in combination. Since the generators are rotated by 60 cps 115 V synchronous motors, the frequency accuracy of any output signal is directly dependent upon the accuracy of the supply source.

3-3. GENERATION OF SIGNALS.

3-4. 9960 F.M. (See Figure 3-1) One of the two basic signals encountered in omni-range navigation is derived from the frequency modulated sub-carrier whose mid frequency is 9960 cps and whose deviation is ± 480 cycles at a 30 cps rate. Such a signal is developed in Signal Generator 479S-3 by rotating a notched "tone-wheel" in the field of a permanent magnet, thereby disturbing the flux pattern of the magnet and inducing a voltage in the pickup coil surrounding the magnet.

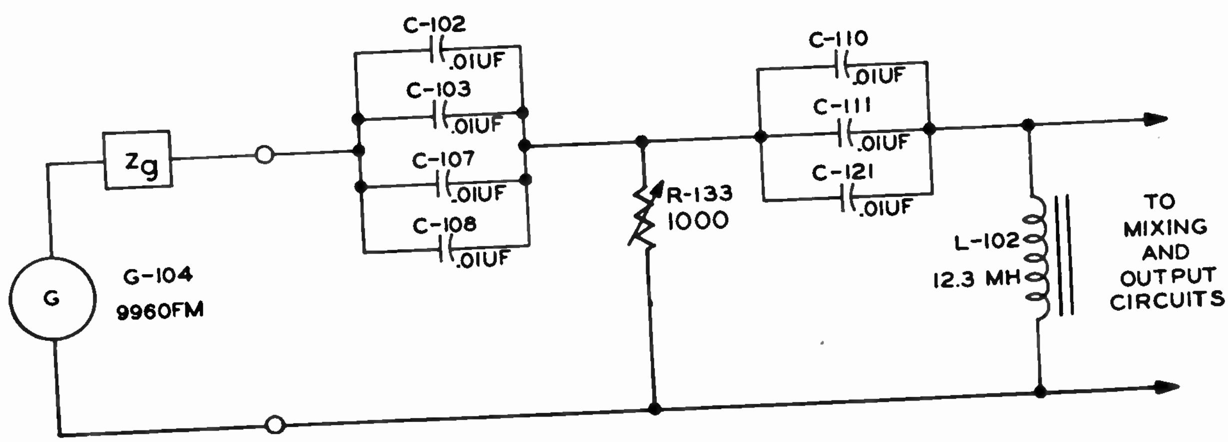


Figure 3-1. Simplified 9960 FM Generating Circuit

3-5. The 9960 FM tone-wheel has a total of 332 notches which are precisely cut with a variable spacing. The tone-wheel is driven at a constant 30 revolutions per second. This causes the flux pattern of the magnet to be disturbed 332 x 30 = 9960 times per second. At the area on the tone-wheel where the notches are closest together, however, they pass the pole-piece of the magnet at the rate of 9960 + 480 = 10440 teeth per second. At the point on the tone-wheel where the notches are farthest apart, they pass the pole-piece at the rate of 9960-480=9480 teeth per second. Between points of maximum and minimum frequency the notch spacing varies at a sinusoidal rate. This provides the proper deviation from the 9960 cps mid-frequency as discussed in the previous paragraph.

3-6. The 500-turn pick-up coil for the 9960 FM signal displays an inductive reactance at 9960 cps. This reactance increases with frequency. Without compensation for this effect severe amplitude modulation would result on the output wave-form. The effect of pick-up coil reactance upon the frequency response of the circuit is held to a minimum by tuning the circuit to series resonance at 9960 cps. This is accomplished by the use of C-102, C-103, C-107 and C-108. The reactance of this series circuit is small over the frequency band of 9480-10440 cps.

3-7. The 5000-ohm potentiometer, R-133, is used to adjust signal level. Since this control merely loads down the resistive generator, the frequency response is unchanged and no amplitude modulation is introduced as the signal level is changed.

3-8. The series resonant circuit consisting of L-102 and the group of parallel capacitors, C-110, C-111 and C-121 is connected across the generator output and the load for the circuit is across L-102. Since the voltage across any one of the reactive elements of a series-tuned circuit is greater than the applied voltage, a voltage gain of approximately two to one is realized. This type of circuitry is used in order to obtain the required three volts output.

3-9. The resonant frequency of the entire circuit is approximately 9000 cps, which is lower than any of the frequencies involved (9480 to 10440 cps.) All signal frequencies fall on the high side of this resonance curve, and the portion of the curve represented by the band from 9480 to 10440 cps is essentially a straight line. This slope response results in undesired 30 cps amplitude modulation of the output signal because the frequency change is at a 30 cps rate. To overcome this amplitude modulation, the tone-wheel is mounted slightly off-center. This causes an additional 30 cps amplitude modulation on the output signal because of the 30 cps rate of the tone-wheel. The eccentricity introduced into the tone-wheel is of the proper amplitude and direction that the two 30 cps amplitude modulating voltages are effectively cancelled. Thus the output signal is essentially free from amplitude modulation.

3-10. Shielded wires are used in this circuit to prevent coupling the 9960 FM into other circuits.

3-11. 30 ~ VAR Ø. (See Figure 3-2). The second audio voltage required in order to synthesize the standard Omni-Range signal is a 30 cps sine wave, the phase of which may be accurately controlled for comparison with the phase of the 30 cps frequency modulation upon the 9960 cps sub-carrier. In Generator 479S-3 this "30 cps variable phase" signal is produced by a generator having a wire-wound stator assembly and a two pole permanent-magnet rotor.

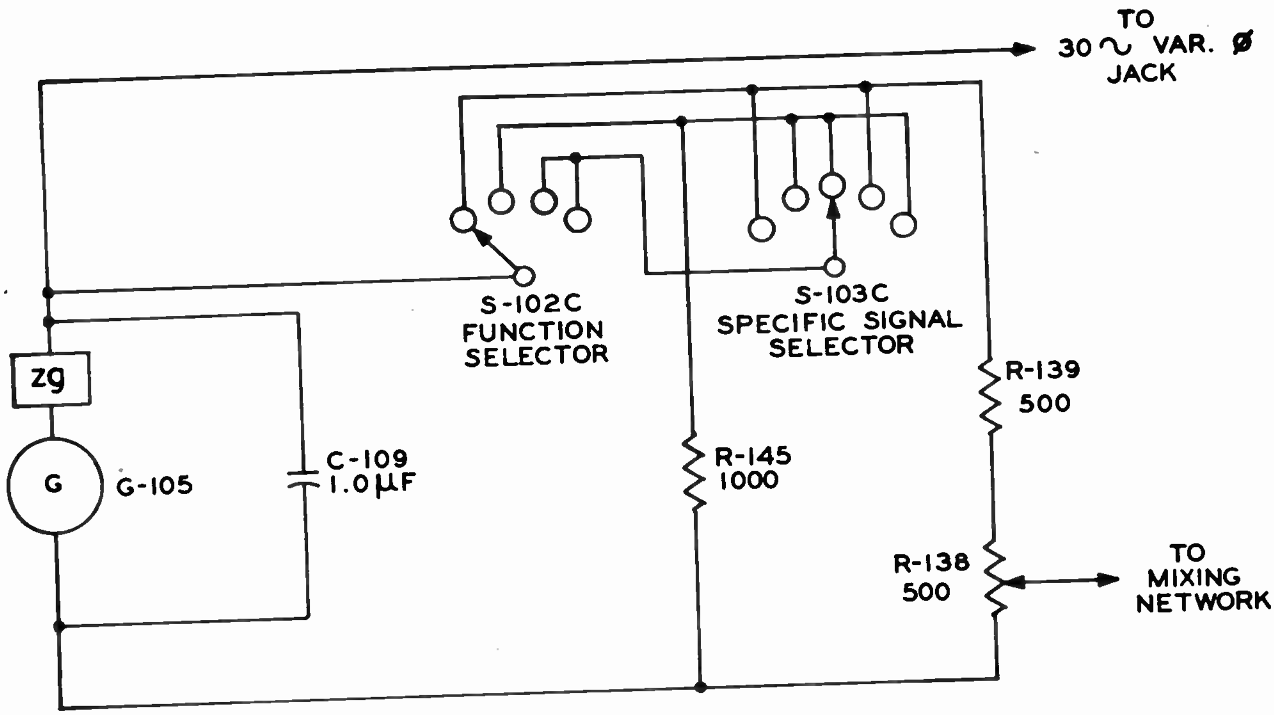


Figure 3-2. Simplified 30-Cycle, Variable Phase Generating Circuit

3-12. The rotor is mechanically coupled to the same motor which is used to rotate the 9960 FM tone-wheel. Output voltage is taken from the stator coils. The stator may be continuously rotated about the rotor axis by an accurately calibrated gearing system. Rotating the stator about the rotor changes the phase of the output voltage with respect to the 30 cps frequency modulation on the tone-wheel.

3-13. The terminal voltage is impressed across a resistive voltage divider consisting of a 500 ohm fixed resistor (R-139) and a 500-ohm potentiometer (R-138). One side of the 30 cps circuit is grounded, and shielding on portions of the other side prevents stray-pickup of other frequencies. A 1.0 uf capacitor (C-109) parallels the generator, which, in conjunction with R-139, forms an R-C filter. The filter removes any of the 9960 FM which might appear at the 30 VAR Ø jack when the 30 cps and the 9960 FM are being mixed.

3-14. To prevent phase shift at the 30~ VAR Ø jack due to changes in loading, a 1000-ohm fixed resistor (R-145) is substituted for the voltage divider when the 30 cps signal is not used in the mixing system. Variation of the potentiometer (R-138) does not introduce changes in the phase angle.

3-15. 1000 CPS. (See Figure 3-3). Generation of the 1000 cps signal is done in the same manner as the 9960 FM. The 1000 cps tone wheel has a total of 34 teeth which are equally spaced around the perimeter. When the wheel is rotated by the drive motor at the rate of 30 cps, the magnetic field of the permanent magnet is disturbed 30 x 34 = 1020 times per second. The resultant 1020 cps voltage is induced in the pick-up coil, and a 1.0 uf capacitor (C-104) resonates the coil reactance.

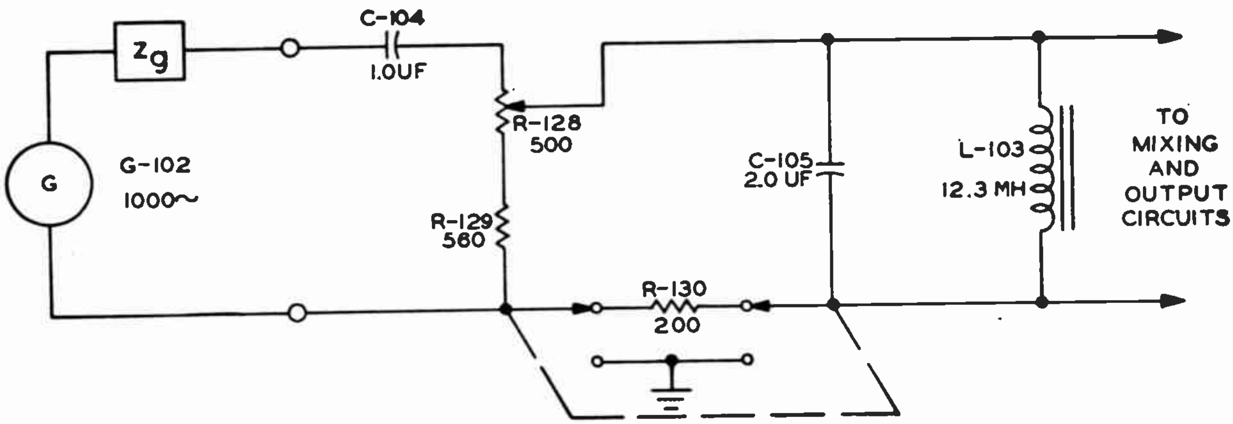


Figure 3-3. Simplified 1020-Cycle Generating Circuit

This combination works into a resistive network of a 500-ohm potentiometer (R-128) and a 560-ohm fixed resistor (R-129). These resistors are paralleled by a tuned circuit of 2.0 uf (C-105) and 12.3 mh (L-103). The signal then works into the mixing and output circuits. A 200 ohm resistor (R-130) equalizes the 1000 cps voltage output between the ODR and Tone Localizer mixing systems.

3-16. CALIBRATION SIGNAL. (See Figure 3-4). This is another 9960 FM voltage which is produced by the 9960 FM tone wheel. The Calibration Signal circuit is identical to that of the 9960 FM with the exception that it does not work into the mixing circuit - however, the inductor (L-101) has an equivalent resistive load (R-137) of 6000 ohms.

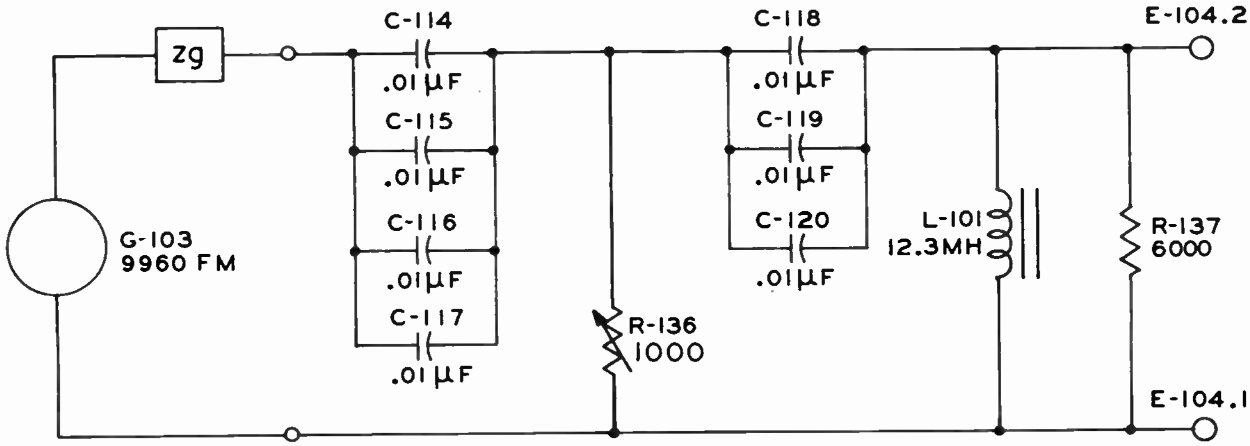


Figure 3-4. Simplified 9960-Cycle FM Generating Circuit (Calibration)

3-17. Although the Calibration Signal voltage is derived in an identical manner as the 9960 FM (paragraphs 3-4 through 3-6) its pickup coil diametrically opposes that of the 9960 FM, the result of which is a phase-angle difference between the two 30 cps signals of 180°.

3-18. One side of the Calibration Signal circuit is grounded, and the output voltage is obtained at terminals E-104.1 and E-104.2 on the component chassis at the rear of the unit. Leads in the circuit are ground-shielded to prevent unwanted coupling of the signal into other circuits.

3-19. 90 CPS AND 150 CPS. (See Figure 3-5). The generator that produces these signals contains two stator windings and a single permanent-magnet rotor.

The variation of resistance in the generator due to temperature change is compensated for by the use of resistors with large negative-temperature coefficients -- that is, when a temperature-increase causes a rise in generator resistance, the NTC resistor in the circuit decreases resistance with the temperature rise, thus acting as a resistance compensator.

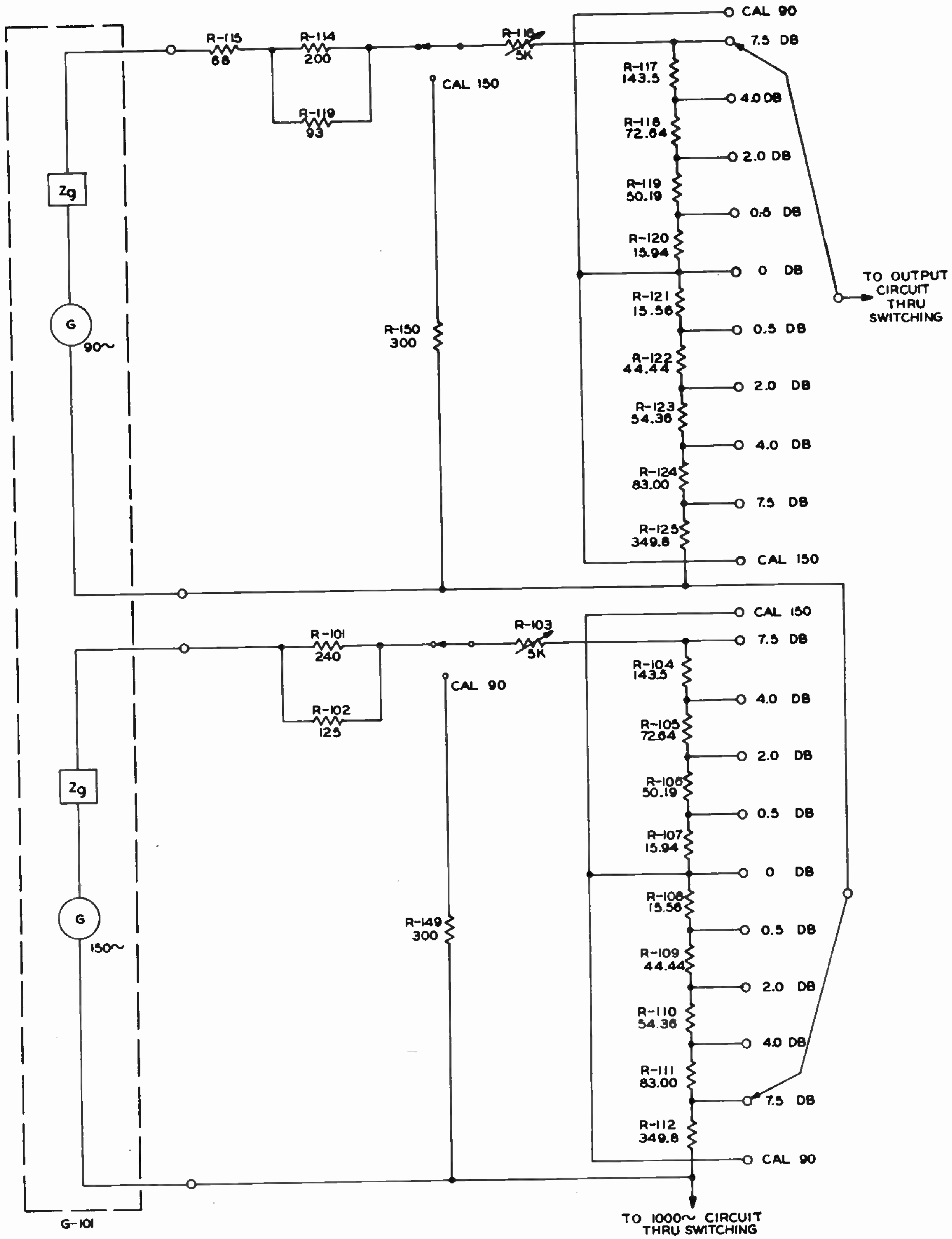


Figure 3-5. Simplified 90-150 Cycle Generator and Mixing Circuits

3-20. In the 150 cps circuit with the generator having a resistance of 223 ohms at 25°C. (+77°F) the 125 ohm (at 25°C) resistor (R-102) is paralleled by a stable 240 ohm resistor (R-101). The sum resistance is approximately 300 ohms.

3-21. In the 90 cps circuit with the generator having a resistance of 172 ohms at 25°C (+77°F) the 93 ohm (at 25°C) resistor (R-113) is paralleled with the stable 200 ohm resistor (R-114). An additional resistance (R-115) of 68 ohms brings the sum resistance here, as in the 150 cps circuit, to approximately 300 ohms.

3-22. The 5000-ohm level controls (R-103 and R-116) of both circuits work into similar precision attenuators. When calibrating either signal level, each arm is at the "0" DB point of its attenuator, and a 300-ohm resistor (either R-149 or R-150) is substituted for the equivalent generator whose signal is not desired.

3-23. 30 CPS REF. Ø AND 30 CPS 90° Ø. (See figure 3-6) These signals are produced by a single generator assembly, and the manner of generation is the same as that of the 30 cps VAR Ø signal. Both generators have internal impedances at +25°C (+77°F) of 62 + j24 ohms at 30 cps.

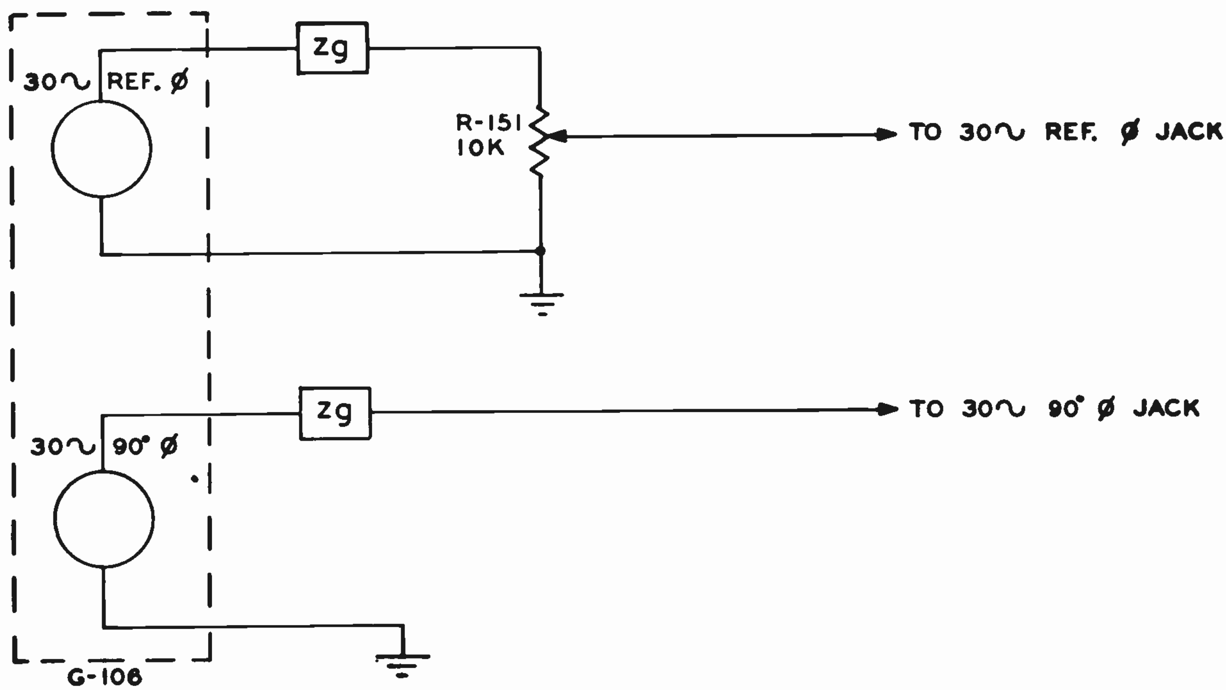


Figure 3-6. Simplified Generating Circuit (30-Cycle Reference Phase and 30-Cycle 90° Phase)

3-24. The REF Ø signal is loaded by a 10,000-ohm level control (R-151), and the output voltage is presented at the 30 ~ REF jack.

3-25. The 90°Ø generator is wired directly to the 30 ~ 90° jack. No level control is provided for this signal.

3-26. Each circuit is grounded on one side and ground-shielded on the other for prevention of signal-stray.

3-27. MIXING CIRCUITS. Two similar circuits are used in the 479S-3 for mixing the various types of signals obtainable at the MOD OUTPUT jack. Both circuits are of the series type whereby only one generator can be operated with one side grounded, and each of the individual circuits is in series with the others in the mixing system with one side of the 30 cps VAR Ø circuit grounded. In the other mixing circuit, the 90 cps, 150 cps, and 1000 cps circuits comprise the network with one side of the 1000 cps circuit grounded. Both mixing circuits work into the output circuit which is composed of either a fixed voltage divider (R-143 and R-144) or a variable T-pad (MASTER ATTENUATOR, R-149) plus the OUTPUT meter (M-101) and the external load on the MOD OUTPUT jack. An additional 2700-ohm voltage-dividing resistor (R-142) is used in the output circuit to reduce the combined 9960 FM - 30 cps VAR Ø signal when the FUNCTION SELECTOR is in the SPECIFIC SIG position. This is to protect the voltmeter from overloads.

SECTION IV

PERIODIC INSPECTION AND MINOR REPLACEMENT

4-1. GENERAL.

4-2. The greatest enemy to uninterrupted service in equipment of this type is corrosion and dirt. Although the equipment has been treated at the factory with ani-corrosive substances, there are the friction surfaces that eventually become exposed to atmospheric elements conducive to corrosion. Corrosion itself is accelerated by the presence of dust and moisture on the component parts of the assembly. It is impossible to keep moisture out of the equipment in certain geographical areas, but foreign particles and dust can be removed by means of a soft brush and a dry, oil-free jet of air. Remove the dust as often as a perceptible quantity accumulates in any part of the equipment. It is very important that rotating equipment, especially the spinning machinery, be kept free of dust to prevent undue wear.

4-3. One of the predominant sources of trouble in equipment located in a salt atmosphere is corrosion. Corrosion resulting from salt spray or salt-laden atmosphere may cause failure of the equipment for no apparent reason. In general it will be found that contacts, such as stop switches, cable plugs and connectors are most affected by cor osion. When it is necessary to operate the 479S-3 in localities subject to such corrosive atmosphere, inspection of wiping contacts, cable plugs, and so on, should be made more frequently in order to maintain efficiency of the equipment.

4-4. PERIODIC INSPECTION. Remove dust from the unit monthly. Any thick concentrations of dust should be wiped up with a clean dry cloth. Follow this operation with a thorough cleaning with an air jet of moderate force.

CAUTION

Do not play a strong jet of air on uncabled wires nor on the pickup coils. These wires can be damaged with a jet of large force.

4-5. MINOR REPLACEMENT. Replacement of fuses can be accomplished at the front panel; however, for pilot-lamp replacement the unit must be removed from the relay rack and lamps removed through cut-outs in sides of bracket.

4-6. LUBRICATION.

TABLE II

Lubrication Chart

UNIT	TYPE	SCHEDULE OR ALTERNATE
DIAL GEARS VAR Ø GENERATOR CASE DRIVE VAR Ø GENERATOR BEARING SURFACES ON CASTING	AN-G-25	Insurance against wear. For smooth operation. Keep well greased but prevent grease from accumulating on sides of gears. Clean excess with solvent. Replace old grease every 1000 hours, or every six months.
30-CYCLE GENERATOR		Bearings are factory-sealed for life.
9960-CYCLE TONE WHEEL BEARINGS		Expected life: 20,000 hours. Possibly much less than 20,000 hours in contaminated areas. Bearings are sealed for life.
90/150-CYCLE GENERATOR		Bearings are factory-sealed for life.
MOTORS		Bearings are factory-sealed for life.

SECTION V

SPECIAL EQUIPMENT

5-1. Equipment necessary to test and align the 479S-3 is listed in table.

TABLE III

TEST EQUIPMENT

TEST EQUIPMENT	CHARACTERISTICS
A.C. VACUUM TUBE VOLTMETER (Example: Ballantine 300)	Freq. Response: 30 - 100 k.c. Full Scale Range: 1, 3, 10 V. Input Impedence: 500 kilohms.
OSCILLOSCOPE (Example: DuMont 304 or 304-H)	Low Distortion. Deflection-plate terminals accessible. High gain.
MULTIMETER (Example: Triplet 630)	Volts, A.C., 3 - 10 Ohms, 0 - 1000, 100,000
DECADE CAPACITANCE BOX (Example: Cornell Dubilier CDA-5)	Range of from 0 to .011 u.f. in .0001 u.f. steps. Minimum voltage rating from 400 V. d.c. to 220 V. a.c.
AUDIO SIGNAL GENERATOR (Example: Hewlett-Packard 205AG)	100 V. across 3500 ohm load. Distortion less than 1% at 30 cycles. Frequency Range: 30 - 10 kc.

SECTION VI

TROUBLE SHOOTING AND CORRECTION

6-1. GENERAL.

6-2. Trouble shooting usually requires removal of the 479S-3 unit from the relay rack, but prior to this an investigation of circuit conditions at the output jacks may be beneficial. If no signals are present at the jacks and preliminary investigation discloses that power input is normal - POWER switch to ON position, fuses normal - then the probable remedy for the failure symptom requires removal of the unit from the rack. In many instances the removal of the base casting from the bracket and front panel may be advantages.

6-3. REMOVAL OF UNIT FROM INSTRUMENT CASE.

a. Remove four large screws holding unit to base of instrument case. Screws are found in four uncovered holes in bottom of case.

b. Remove fourteen large phillips screws on front panel.

c. Grasp handles on front panel and slide unit from case slowly, allowing no interference between dial glass and instrument case. Movement should be on a horizontal plane only. Do not withdraw or replace unit on a vertical plane.

6-4. REMOVAL OF BASE CASTING FROM BRACKET AND FRONT PANEL.

a. Use a No. 8 Bristo wrench to loosen the two set screws on PHASE ANGLE SELECTOR knob and remove knob from shaft.

b. With unit lying on its side and exposing bottom of bracket, loosen each of four large hexagonal screws in bottom approximately one turn. Place unit in normal upright position and remove screws by hand, allowing each respective corner to overhand bench for accessibility.

CAUTION

Do not remove screws until unit is resting in normal upright position -- otherwise, the base casting will fall to bench.

c. Disconnect plugs P-101, P-102, and P-103 from jacks and withdraw casting away from front panel, lifting rear of casting over rear lip of bracket while withdrawing.

d. To set up unit for operation, rotate casting 180 degrees so that plugs P-101, P-102 and P-103 can be inserted into jacks. Replace PHASE ANGLE SELECTOR knob on shaft for variation of dial setting.

6-5. PRELIMINARY INSPECTION.

WARNING

The high-speed moving parts can cause serious injury. Keep hands away from the rotating tone wheels. Be aware of loose clothing that may become ensnarled by teeth of wheels. Roll up loose sleeves; tuck in neck-tie, etc.

Do not allow external leads (such as voltmeter leads) to come into proximity of tone wheels or couplers.

a. Before connecting power cord to A.C. source, make continuity check with an ohmmeter of entire power circuit. (Schematic drawing is located on rear of instrument case.) Continuity check should include toggle switches, rotary switches, fuses and power-input terminals. If continuity to ground appears, correct the condition before applying power to unit. If no continuity to ground exists, rotate generators by hand to determine whether moving parts are free from drag. Check snugness-seating of Plugs P-101, P-102 and P-103.

6-6. SYSTEM TROUBLE SHOOTING. Oscilloscope patterns with a linear 30 cps sweep voltage are shown in figure 6-1. Table IV describes procedures necessary to determine which circuit of the unit is giving trouble, its probable cause and its remedy of possible faults in the circuitry of the unit. Table V shows typical voltages of circuits and where to measure.

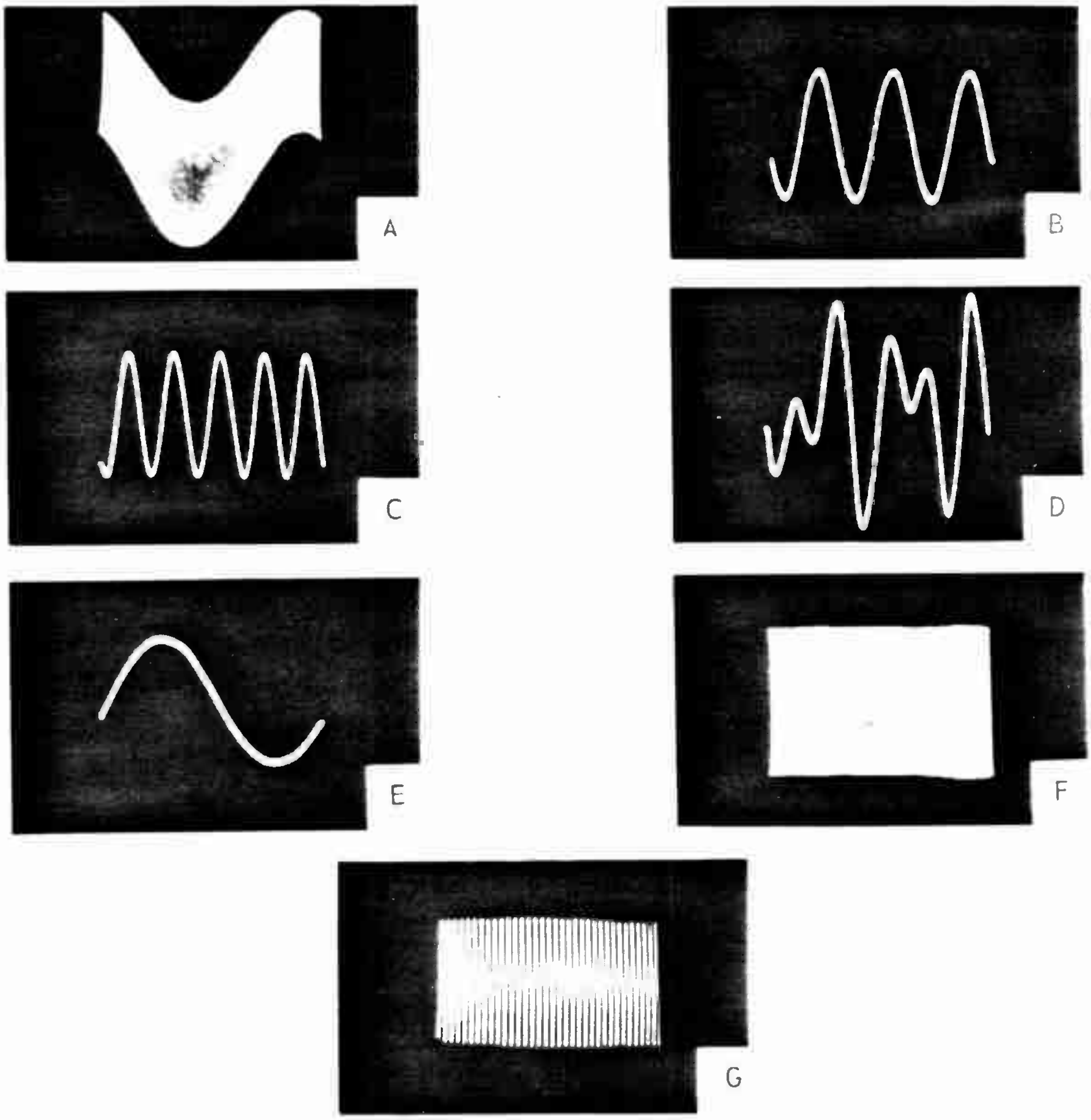
6-7. TONE WHEEL GENERATOR REPLACEMENT. The following procedures apply to replacement of the parts of any of the three tone-wheel generator assemblies; that is, the Calibration Signal, the 1000 cps, and the 9960 FM.

CAUTION

Remove power cord from power source before proceeding. Do not allow motors to run during any part of this procedure except where advised to do so in the procedural text.

NOTE

Remove unit from instrument case as outlined in paragraph 6-3. If work is to be done on 9960 FM pickup, remove base casting from bracket and prepare for operation as outlined in paragraph 6-4.



FUNCTION SELECTOR	SPECIFIC SIGNAL SELECTOR	TONE LOCALIZER	FIG.
ODR SPECIFIC SIG OR CAL	ANY 9960 FM - 30~VAR ϕ	ANY ANY	A
TONE LOC SPECIFIC SIG OR CAL	ANY 90 - 150 ~	CAL 90 ~ CAL 90 ~	B
TONE LOC SPECIFIC SIG OR CAL	ANY 90 - 150 ~	CAL 150 ~ CAL 150 ~	C
TONE LOC SPECIFIC SIG OR CAL	ANY 90 - 150 ~	0 0	D
SPECIFIC SIG OR CAL	30 VAR ϕ	ANY	E
SPECIFIC SIG OR CAL	9960 FM	ANY	F
SPECIFIC SIG OR CAL	1000 ~	ANY	G

Figure 6-1. Oscilloscope Patterns with Linear 30 cps Sweep Voltage

TABLE IV

TROUBLE SHOOTING TABLE

SYMPTOM	PROBABLE CAUSE	REMEDY
1. No signals from any of the four output jacks.	1. Neither of motors running.	1. Check fuses. If open, determine trouble in power circuit by continuity check before replacing fuses.
2. No signals from MOD OUTPUT jack but signals from 30 ~ REF Ø and 30 ~ 90° Ø jacks.	1. Open or accidental ground in output circuit.	1. Make continuity check from MOD OUTPUT jack through switching back to mixing system; also check for accidental grounds at each point.
3. Signals from MOD OUTPUT jack on SPECIFIC SIG. position only (or signals on all positions except SPECIFIC SIG.).	1. Open or accidental ground in output circuit.	1. Check continuity from MOD OUT-PUT jack to S-102 E-11. Also check for accidental grounds at each point.
4. TONE LOC. signals only	1. ODR motor (B-102) not running.	1. Check continuity of power circuitry. 2. If no fault in 1., check C-106, motor condenser. 3. If no fault in 2., replace motor.
	2. Open or accidental ground in ODR mixing system or out-put switching.	1. Check continuity from S-102 D-11 back through switching and ODR mixing system. Also check for accidental grounds at each point.

TABLE IV

TROUBLE SHOOTING TABLE

SYMPTOM	PROBABLE CAUSE	REMEDY
5. All signals except TONE LOCALIZER signals.	1. TONE LOCALIZER attenuator in OFF position.	1. Rotate TONE LOCALIZER.
	2. Loose coupler on Localizer generator (G-101).	1. Tighten coupler set screws.
	3. Localizer motor (B-101) not running.	1. Check continuity of power circuitry. 2. If no fault in 1., check motor condenser (C-101). 3. If no fault in 2., replace motor.
	4. Open or accidental ground in Localizer mixing system or output switching.	1. Insure that both 90 cps and 150 cps are absent. 2. Check continuity from S-102 D-11 back through switching and Localizer mixing system. Also, check for accidental grounds at each point.
6. 1000 cps and Tone Localizer signals only.	1. Loose coupler on ODR motor (B-102).	1. Tighten coupler set screws.
7. No output voltage or low output voltage of one of the following with the mixing circuits operating normally:	1. Trouble in circuit of faulty signal.	1. Insure that individual voltage control is not at a low setting.

TABLE IV

TROUBLE SHOOTING TABLE

SYSTEM	PROBABLE CAUSE	REMEDY
7. (cont.) (a) 30 cps, all Ø (b) 9960 FM (c) 90 cps (d) 150 cps (e) 1000 cps (f) Calibration Signal		2. Investigate Individual circuit at fault. (See table V) 3. If generated voltages are low, see Symptom No. 8.
8. Low generated voltage or no generated voltage.	If 9960 FM, Calibration Signal, or 1000 cps:- 1. Magnetic gap too great. 2. Low strength of magnet. 3. Open or shorted coil.	1. Adjust gap or replace part. (See paragraph 6-11).
	If 30 cps (any phase), 90 cps, or 150 cps:- 1. Low magnetic strength of rotor. 2. Open or shorted stator winding. 3. Open or shorted lead-in wires.	1. If point of trouble is accessible, repair the faulty wire. If not accessible, replace generator. (See paragraphs 7-4, 7-5, 7-6).

TABLE V

TYPICAL VOLTAGES AND RESISTANCES

CIRCUIT UNDER INVESTIGATION	SPECIFIC SIGNAL SELECTOR	TONE LOCALIZER ATTENUATOR	POINT OF MEASUREMENT	VOLTAGE TO GROUND	RESISTANCE TO GROUND	TEST POINT
30 ~ VAR Ø	30 ~ VAR Ø	Any	Center arm of R-138	3.3-4.0	250	11
	30 ~ VAR Ø	Any	E-105.1	6.5-8.0	62	10
	30 ~ VAR Ø	Any	J-104	6.5-8.0	62	25
9960 FM	9960 FM	Any	C-121 (toward L-102)	3.6	500	6
	9960 FM	Any	C-121 (toward R-133)	1.2	1700	5
	9960 FM	Any	E-101.1	0.8	550	4
1000 cps	1000 ~	Any	Center arm of R-128	3.2		21
	1000 ~	Any	E-101.8	3.4	780	1
	1000 ~	Any	E-101.7		700	2
	1000 ~	Any	C-105 (toward L-103)		500	3
90 cps	90-150 ~	CAL 90 ~	Junction of R-120 and R-121	3.2-3.9		24
	90-150 ~	CAL 90 ~	E-105.5	5.7-7.0	440	17
	90-150 ~	CAL 90 ~	E-105.6		280	18
	90-150 ~	CAL 90 ~	R-115 (toward R-113 and R-114)		480	19
	90-150 ~	CAL 90 ~	R-113 (toward 4-101.5)		500	20
150 cps	90-150 ~	CAL 150 ~	E-105.6	3.1-3.8		23
	90-150 ~	CAL 150 ~	R-103	4.9-6.0		22
	90-150 ~	CAL 150 ~	E-105.8	6.4-7.9	185	15
	90-150 ~	CAL 150 ~	J-101.1		240	13
	90-150 ~	CAL 150 ~	E-105.7		3	16
30 cps REF Ø	Any	Any	E-102.4	7.0-8.5	62	14
30 cps 90° Ø	Any	Any	E-102.1	7.0-8.5	62	12
Cal Signal	Any	Any	E-104.2	3.6		9
	Any	Any	R-136	1.1	1200	8
	Any	Any	E-105.4	1.0	45	7

NOTE: FUNCTION SELECTOR IS SWITCHED TO SPECIFIC SIG. MASTER ATTENUATOR AND POTENTIOMETERS TURNED FULL CLOCKWISE.

6-8. REMOVAL OF PICKUP COIL.

a. Back off horizontal-adjustment set screw on rear plate of magnet holder a few turns.

b. Loosen the two set screws on top of magnet holder.

c. Swing magnet and coil out of holder using care to prevent pole face from hitting against teeth of tone wheel.

d. Loosen set screw which holds coil assembly to pole face.

e. Unsolder leads on rear of coil assembly, noting terminals to which shield and wire are connected if replacing coil of 9960 FM or Calibration Signal. This is important since shield braid must be connected to same terminal when coil is replaced. (Interchanging lead connections on 1000 cps coil is of no consequence).

f. Replacement of pickup coil is done in reverse order of the preceding procedure.

6-9. REMOVAL OF MAGNET.

a. Perform steps a. through c. of paragraph 6-8.

b. Loosen set screw which holds pole face to magnet.

c. Remove magnet from pole face.

d. Replacement of magnet is done in the reverse order of removal procedure.

NOTE

Insure that magnet shoulder is flush against rear of pole face so that no visible gap exists.

6-10. REMOVAL OF POLE FACE.

a. Perform steps a. through d. of paragraph 6-9.

b. Loosen set screw which holds pole face to magnet.

c. Remove pole face from magnet and slip it away from coil assembly.

d. Replacement of pole face is done in reverse order of the removal procedure.

NOTE

Insure that magnet shoulder is flush against rear of pole face so that no visible gap exists.

6-11. ADJUSTMENT OF AIR GAP.

CAUTION

Do not allow tone wheel to rotate until advised to do so in the precedural text.

6-12. The adjustment of air gaps requires a preliminary adjustment of the outputs of the tone wheel pickups. The test setup for the operation is as follows:

a. Connect a VTVM in parallel with a 10,000-ohm resistor across the modulator output.

b. Turn all potentiometer shafts on the adjustment panel to their extreme clockwise positions.

c. Rotate MASTER GAIN control to full clockwise position.

6-13. TEST PROCEDURE.

a. With POWER switch to OFF, loosen horizontal-adjustment set screw on back plate of 9960 FM pickup magnet (nearest to front panel).

b. Loosen two locking set screws on top of magnet holder.

c. Set magnet and pole face so that: (1) gap is small between pole face and tooth on tone wheel (approximately 1/16 inch) (2) pole face is centered on wheel with as much of pole face on one side of wheel as on other (3) pole tip is parallel to lands of teeth on tone wheel.

d. Hold assembly in this position and bring two locking set screws down snug against the magnet, but do not tighten with pressure. Tightness must be such that pole face cannot be pushed into wheel with slight pressure on coil assembly and yet can be forced toward wheel by tightening horizontal-adjustment set screw.

e. Repeat steps a. through d. if working with Calibration Signal pickup (located 180° from 9960 FM pickup) and/or with the 1000 cps pickup (mounted on drive motor).

f. Set FUNCTION SELECTOR to SPECIFIC SIG. position and SPECIFIC SIGNAL SELECTOR to 9960 FM.

WARNING

These high-speed moving parts can cause serious injury. Keep hands clear of the spinning tone wheels. Be aware of loose clothing that may become ensnarled by teeth of the wheels. Roll up sleeves. Tuck in necktie, etc. Do not allow external leads (such as voltmeter leads) to be in the proximity of the tone wheels or the couplers.

g. With POWER switch to ON, advance 9960 FM pole face toward tone wheel by adjustment set screw until a modulator output voltage of approximately 2.5 volts is indicated on VTVM.

CAUTION

Use extreme care in preventing pole face from touching tone wheel. This applies to all adjustments of pickup magnets.

h. Set SPECIFIC SIGNAL SELECTOR to 1000 and adjust the 1000 cps pole face to small tone wheel until 2.0 volts is indicated on VTVM.

i. Connect VTVM across Calibration Signal terminals (E104.1 and E104.2) (terminals at rear of Generator).

j. Adjust Calibration Signal pickup magnet (on rear side of large tone wheel) to give a 2.5 volt indication and VTVM. Use procedure of step g.

6-14. REMOVAL OF AM.

6-15. The tone-wheel pickup output-level must be adjusted (see paragraphs 6-11 through 6-13) before removal of AM is performed.

6-16. TEST SETUP.

a. Connect vertical input of oscilloscope to MOD OUTPUT jack of 479S-3 (no other load on jack).

b. Place a short length of No. 26 gauge flexible iron wire through the small hole near the perimeter of the 9960 FM tone wheel and bend over so that wire lies in space between two teeth. Twist the two ends of wire together and cut twist of wires close to wheel. Rotate wheel by hand to insure that no interference exists.

c. Place the same gauge wire on the 1000 cps wheel in a similar manner but with wire bent across top of a tooth. Twist and cut off ends as done in step b. Rotate to determine whether interference exists.

d. Set FUNCTION SELECTOR to CAL and SPECIFIC SIGNAL SELECTOR to 30 ~VAR Ø.

6-17. TEST PROCEDURE.

a. Loosen screws holding 1000 cps tone wheel to its hub, then tighten them as much as possible with the fingers -- not with a screwdriver.

b. Turn POWER switch ON and establish a 30 cps sweep on scope by adjusting sweep so that a single cycle of the 30 cps signal remains on screen.

c. Rotate SPECIFIC SIGNAL SELECTOR to 1000 and observe pattern on scope screen.

d. Adjust horizontal gain on scope so that width of pattern covers approximately 36 spaces on the co-ordinate screen.

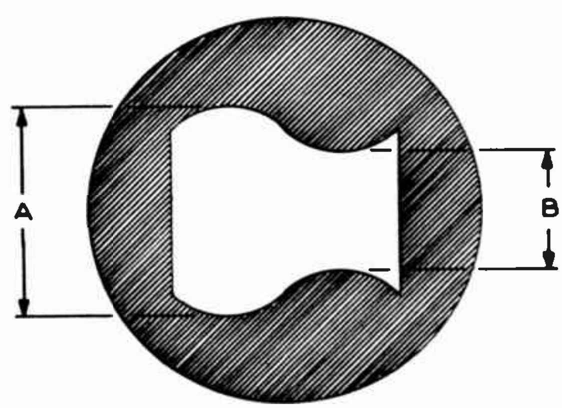
e. Each space on the screen is equal to 10° on the 1000 cps tone wheel. Using the pip (effected by the wire on the wheel) as a reference point, locate the high amplitude spot in terms of degrees before or after the pip.

f. Flip POWER switch to OFF and locate the high point on the wheel.

g. While supporting the motor shaft with an upward pressure with the hand, tap center of high portion of wheel with wood or plactic handled screwdriver.

h. Repeat steps e. through g. until the 30 cps modulation is reduced to minimum. Tighten screws on tone wheel with screwdriver.

i. Measure the amplitude modulation by method in figure 6-2.



$$\% \text{ Modulation} = \frac{(A - B)}{(A + B)} (100)$$

A = distance between maximum points of deflection

B = distance between minimum points of deflection

Figure 6-2. Oscilloscope Pattern for Measurement of Amplitude Modulation

j. The percent amplitude modulation must be less than 5%. If this condition cannot be met, a new wheel must be installed and the procedure repeated (paragraphs 6-11 through 6-13, step c.).

k. Loosen the holding screws on the 9960 FM tone wheel slightly. Tighten snugly with right angle screwdriver -- enough to hold wheel firmly but loose enough to allow adjustment by tapping with rubber or plastic mallet.

l. Set SPECIFIC SIGNAL SELECTOR to 9960 FM. With scope adjusted as described in steps d. and e., each space is equal to 10° on the tone wheel. Using the pip (caused by wire on wheel) as a reference point, locate high amplitude spot in terms of degrees before or after the pip.

m. Turn POWER switch to OFF, locate the high point on the wheel, and tap lightly with a rubber mallet to move the high point toward the center of shaft.

n. Rotate wheel by hand to determine whether it spins freely, turn POWER switch to ON, and observe oscilloscope pattern again.

o. Repeat steps l., m., and n., until amplitude modulation is reduced to minimum.

p. Turn POWER switch to OFF and tighten screws securely.

q. Turn POWER switch to ON and measure amplitude modulation by method in step i. Be sure to use narrowest verticle width of pattern as distance "B" -- regardless of whether it is at the dip of the 30 cps modulation envelope (could possibly be some peculiar pip or distortion in the envelope other than the 30 cps that gives the maximum amplitude modulation).

r. Measure amplitude modulation of Calibration Signal output at the back of the 479S-3 by method in step i. If AM is less than 5%, remove iron wire from each wheel.

s. If either the 9960 FM or the Calibration Signal has more than 5% amplitude modulation the 9960 FM tone wheel must be removed and replaced and the AM-removal procedure repeated.

6-18. PHASE ADJUSTMENT OF 9960 FM AND CALIBRATION SIGNAL, AND FINAL ADJUSTMENT OF VOLTAGE.

NOTE

The AM must be minimized (see paragraph 6-14) before phase adjustment is performed.

6-19. TEST SETUP. Connect the 479S-3 to the oscilloscope as shown in figure 6-3.

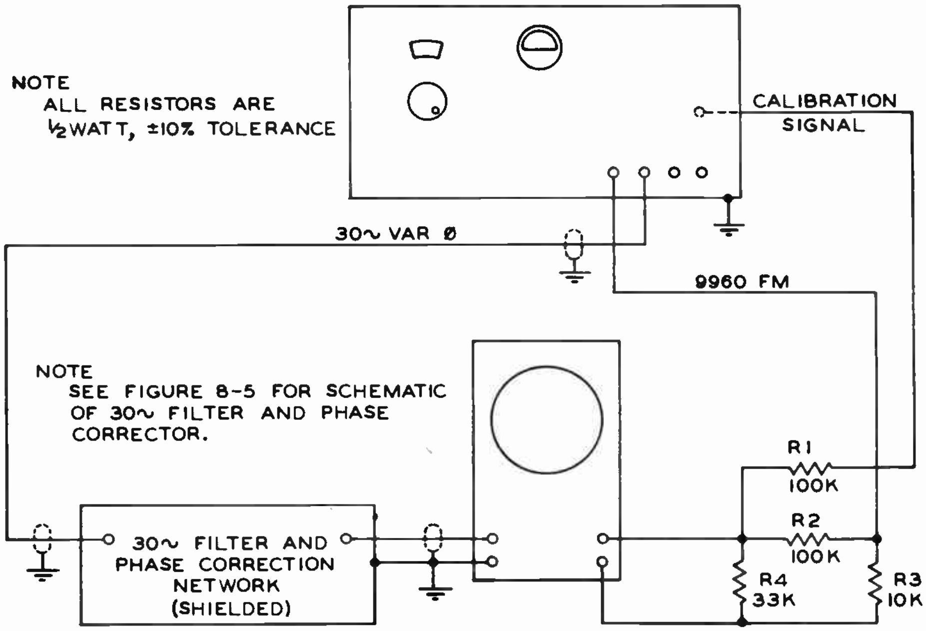


Figure 6-3. Test Set-Up for Phase Relationship, 9960 FM and Calibration Signal

6-20. TEST PROCEDURE.

a. Obtain an approximate 180° relationship between the 9960 FM and Calibration Signal by aligning pole faces of the two pickups opposite the two small holes on tone wheel. To do this, loosen the two screws which hold Calibration Signal magnet holder to long support arm, and adjust magnet holder vertically. Hold tone wheel so that one hole is opposite 9960 FM pole face while Calibration Signal pole face is being adjusted to other hole. Adjustment should be made as accurately as eye permits.

b. Tighten the two screws and rotate tone wheel by hand to insure that it will not contact the pole faces.

c. Turn POWER switch ON and set FUNCTION SELECTOR to SPECIFIC SIG. and SPECIFIC SIGNAL SELECTOR to 9960 FM.

d. Reduce horizontal gain setting so all envelopes are visible on screen.

e. Rotate PHASE ANGLE SELECTOR so that two widest envelopes are located behind each other and in center of screen (see figure 6-4). Envelopes will probably differ in size but are recognized by their wider size.

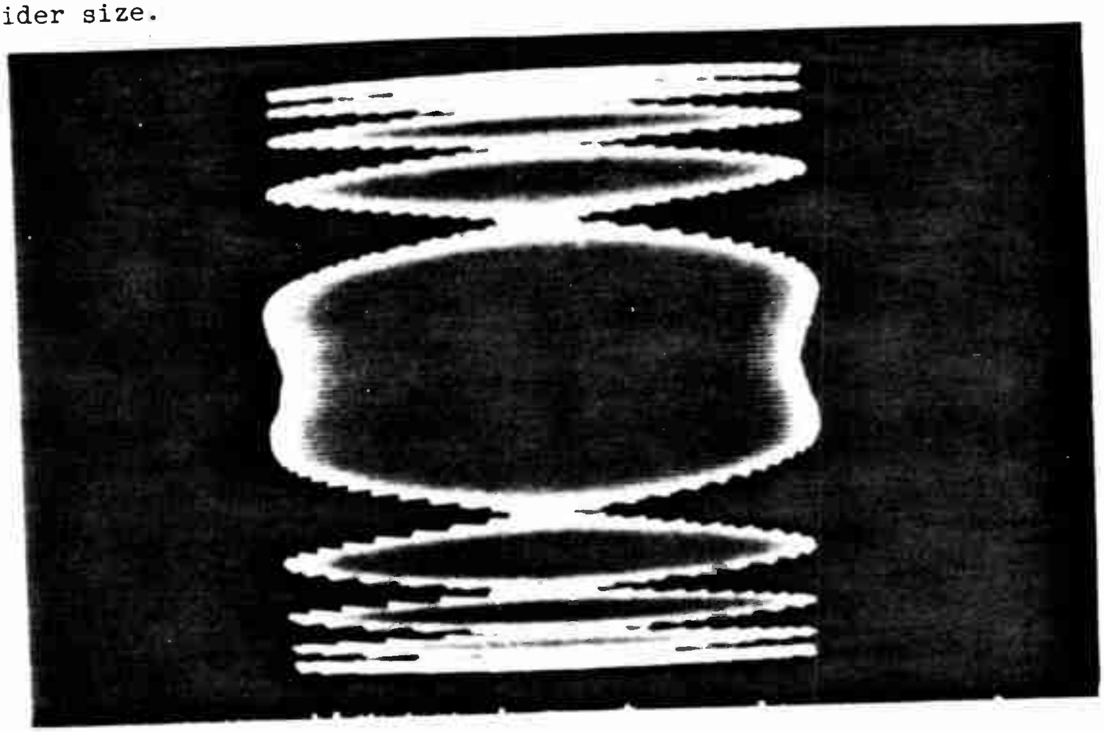


Figure 6-4. 180° Line-Up of Complete Pattern

f. Loosen same two screws (step a.), just enough to permit slight movement of the Calibration Signal magnet holder. Minutely adjust magnet holder up or down to obtain accurate size symmetry of the two large envelopes (see figure 6-5). (Adjustment required should be very small since a close approximation was obtained in step a.). The two signals are now 180° apart in phase. Tighten screws. If tightening screws upsets accuracy of adjustment, the effect must be anticipated by a slight compensating misadjustment so that 180° relationship will be correct when screws are tightened.

g. With test setup as in paragraph 6-13, adjust pickup voltages to 3.1 volts following the procedure of steps f. through j. (paragraph 6-13). Re-check the 180° relationship.

h. Tighten the locking set screws and back out the adjusting set screws a few turns.

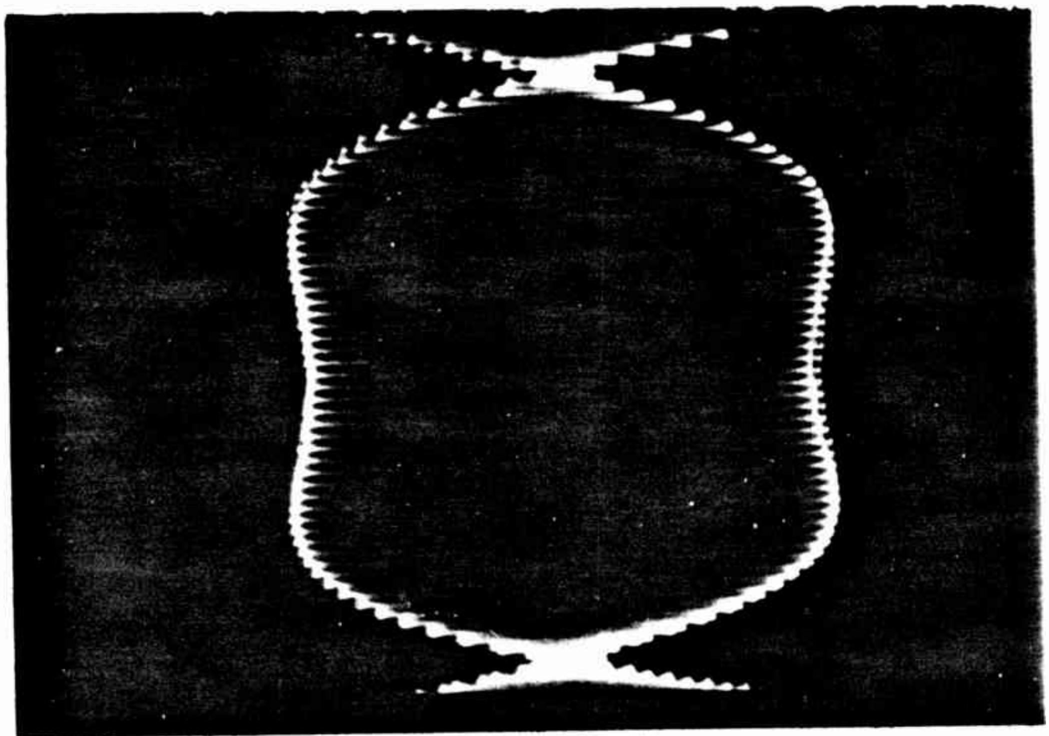


Figure 6-5. Interference Pattern for 180° Line-Up of FM Pickups -- Dial Setting "0"

i. All locking set screws must be set with blue glyptal. To do this, remove only one screw at a time, apply glyptal to the screw, replace screw, and tighten very firmly. Now remove the next set screw from the magnet holder, apply glyptal, replace, and tighten firmly. Repeat the process on all three magnet holders.

SECTION VII

OVERHAUL OF MECHANICAL COMPONENTS

7-1. REMOVAL OF BASE CASTING FROM BRACKET AND FRONT PANEL. See paragraph 6-4.

7-2. REMOVAL OF FM TONE WHEEL ASSEMBLY.

a. Loosen both set screws of rubber coupler between motor and tone wheel and slide coupler toward motor as far as it will go (rotating motor shaft by hand while sliding coupler may aid movement). Coupler should be clear of tone wheel shaft while sliding.

b. Remove screws shich hold down bearing caps No's. 4 and 5 on tone wheel bearings (bearing-cap numbers are stamped on caps).

c. Remove bearing caps by grasping front and rear with fingers and pulling straight up. If caps do not release easily, a slight amount of rocking while lifting may help. Prying cap with screwdriver tip--each end alternately--may be necessary. Use only slight pressure and small movements alternately to prevent bending of locating pins.

d. Remove Tru-Arc rings while holding down wheel.

e. Rotate tone wheel until coupler between wheel and 30 cps VAR Ø generator has left-hand slot of its central member vertical.

f. Grasp central and right members of coupler with fingers and other end of tone wheel shaft with other hand. Lift straight up to remove tone wheel assembly.

g. To remove bearing and hub assembly, remove the three screws which hold hub to wheel and withdraw bearing-and-hub assembly from hole in wheel.

h. Replacement of 9960 FM tone wheel assembly is done in reverse order of removal procedure. Removal of tone wheel assembly destroys zero calibration and removal of tone wheel from hub destroys amplitude modulation adjustment If hub-and-bearing assembly was removed, see paragraph 6-14 for description of AM removal prior to insertion into position of tone wheel assembly. Zero calibration (see paragraph 8-11) must be done after the tone-wheel assembly has been properly coupled back into the generator line-up.

7-3. REMOVAL OF 30 CPS VAR Ø GENERATOR.

a. Remove screws which hold terminal board (TB-103) to rear of dial-drive assembly.

7-3. REMOVAL OF 30 CPS VAR Ø GENERATOR. (cont.)

b. Remove the six screws on bottom of base casting which hold down dial-drive assembly.

c. Remove bearing caps No's. 2 and 3.

d. Position couplers on each end of shaft so generator can be lifted with ease (will probably require set screws on one coupler be loosened and coupler slipped to another position).

e. Remove generator.

f. Replacement of generator is in reverse order of removal procedure.

g. See paragraph 8-11 for zero calibration procedure since removal of generator destroys zero calibration.

7-4. REMOVAL OF 30 CPS REF Ø - 90° Ø GENERATOR.

a. Disconnect generator leads at terminal block (E-102).

b. Remove bearing cap No. 1.

c. Remove generator.

d. Replacement of generator is in reverse order of removal procedure.

7-5. REMOVAL OF 90 CPS - 150 CPS GENERATOR.

a. Disconnect generator leads at terminal block (E-105).

b. Loosen coupler set screw.

c. Remove the three screws which hold generator to hanger using small right-angle screwdriver provided.

d. Remove generator.

e. Replacement is in reverse order of the removal procedure.

f. See paragraph 8-11 for zero calibration procedure since generator removal destroys zero calibration.

7-6. BEARINGS. The shaft bearings, O-121 and O-122, (see figure 7-1) are factory-sealed with lubricant for the life of the bearings.

7-7. END THRUST (END "PLAY"). This condition is held to a minimum by thrust washers H-103, H-104, H-105 (see figure 7-1) in conjunction with retainer rings (No's. 66 and 74 in sequence breakdown). Equally important factors in mechanical snugness are the shaft couplers (two types--flexible and metal).

7-8. REMOVAL OF DIAL DRIVE ASSEMBLY.

a. Remove the screw at the potentiometer board.

b. Remove the four screws holding rear terminal board (TB 103) to rear of dial drive assembly.

c. Remove the six screws at under side of base casting.

d. With base casting resting in normal flat position, lift out dial drive assembly.

7-9. DISASSEMBLY OF DIAL-DRIVE MECHANISM.

7-10. Figure 7-2 includes a procedure for disassembly in numberical sequence.

7-11. MISCELLANEOUS. Snug fitting for the elimination of black-lash is provided by the sufficient meshing of teeth between gear 0-103 and gears 0-106 and 0-107 (see figure 7-2). At least three teeth should mesh. Also important is spring 0-108. Its tension pulls gear assembly 0-102 into snugness with the driven gear on the 30-cycle, variable-phase generator.

SECTION VIII

ALIGNMENT, CALIBRATION AND TESTS

8-1. CALIBRATION OF PHASE ANGLE SELECTOR DIAL WITH INTERFERENCE PATTERN.

8-2. In order to calibrate the Phase Angle Selector dial, a scope display is known as the "interference pattern". It is obtained by mixing the two 9960 FM signals and presenting this signal to the horizontal amplifier while applying the 30 cps VAR Ø signal to the vertical amplifier. By rotating the Phase Angle Selector, the pattern used for calibration is obtained (See figure 8-1). This pattern is found only when the 30 cps on the 9960 FM tone wheel and the 30 cps VAR Ø signal are out of phase by 90° or 270°. Thus, calibration of the dial is accomplished at the correct point or 180° from the correct point. The ambiguity is eliminated by introducing a known phase of 30 cps AM onto the 9960 FM signal and comparing this with the 30 cps variable phase signal.

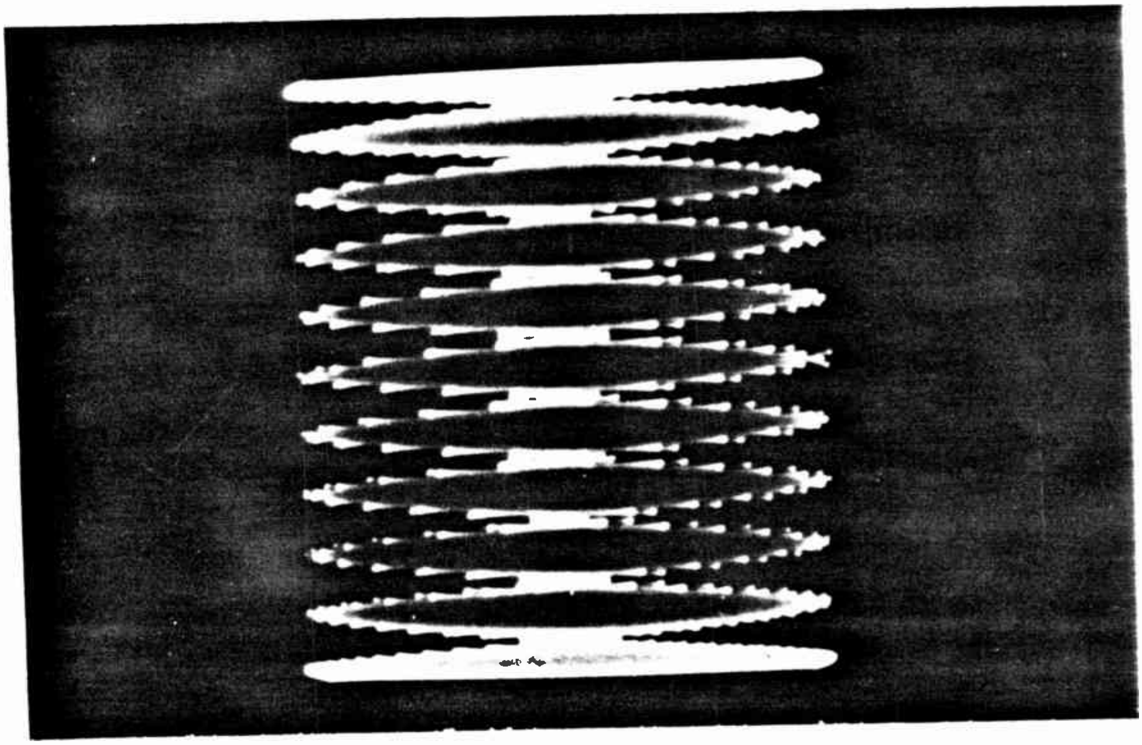


Figure 8-1. Interference Pattern for Zero Calibration at 90°

8-3. GENERAL TEST SET-UP. In order that the calibration is accomplished correctly, the phase angles being compared at the deflection plates of the scope must be the same as the phase angles of the modulator. Also, the distortion of the signals presented at the deflecting plates must be of very small magnitude, especially in the case of the 30 cps signals including the 30 cps on the FM tone wheel. The 30 cps VAR Ø signal is passed through a filter to reduce the distortion, but this cannot be done with the FM signal. However, the tone-wheel teeth are located very accurately, which results in very little 30 cps distortion. Since small phase shifts can be expected in oscilloscopes, and since filtering the 30 cps VAR Ø will result in phase shift, a system must be provided to control the phase shift of the signal so that the phase angle will be correct at the deflecting plates. This is accomplished by using networks of resistance and capacitance of the right amounts. Generally, the phase shift of the 9960 FM signal is of little consequence since 33° of phase shift at 9960 cps would result in only 0.1° of phase shift in the 30 cps from the tone wheel. A block diagram of the test set-up used in calibration is shown in figure 8-2.

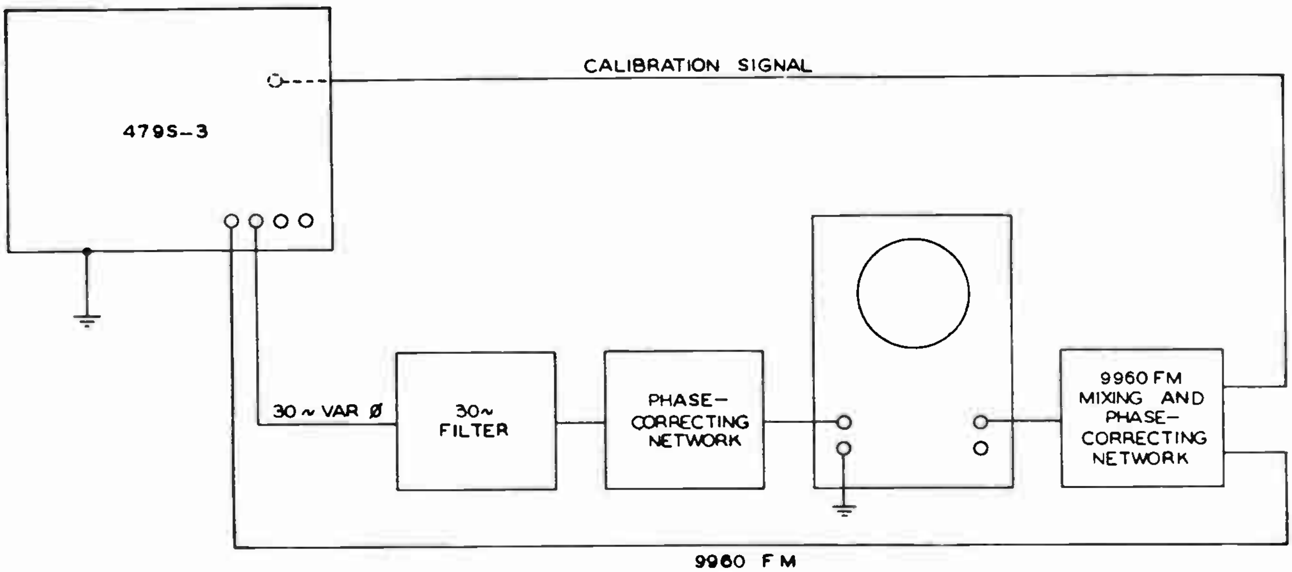


Figure 8-2. Arrangement for Calibration by Interference Pattern

8-4. A check should be made of the horizontal amplifier of the scope used to insure that phase shift in the region of 9960 cps does not exceed 30°. If the phase shift is excessive, it may be reduced to zero by the use of a phase-shifting network composed of a series resistance and a capacitor-to-ground (or vice versa) following the mixing network. The impedance of this combination should be at least ten times as great as that of the mixing resistor which is paralleled by the R-C network. This will insure that the horizontal deflection voltage will be reduced by a minimum amount from the loading effect of the phase-shifting network.

8-5. The phase shift of the 30 cps VAR ø, which occurs between the modulator and the deflecting plates, must be reduced to exactly zero degrees or 180° Any phase shift of this sort which is not removed will result in degrees of error in the dial calibration. Again, this phase shift may be removed by the use of one or more R-C combinations either before or after the 30 cps filter. Figure 8-3 shows a block diagram of the general test set-up required to remove the undesired phase shift.

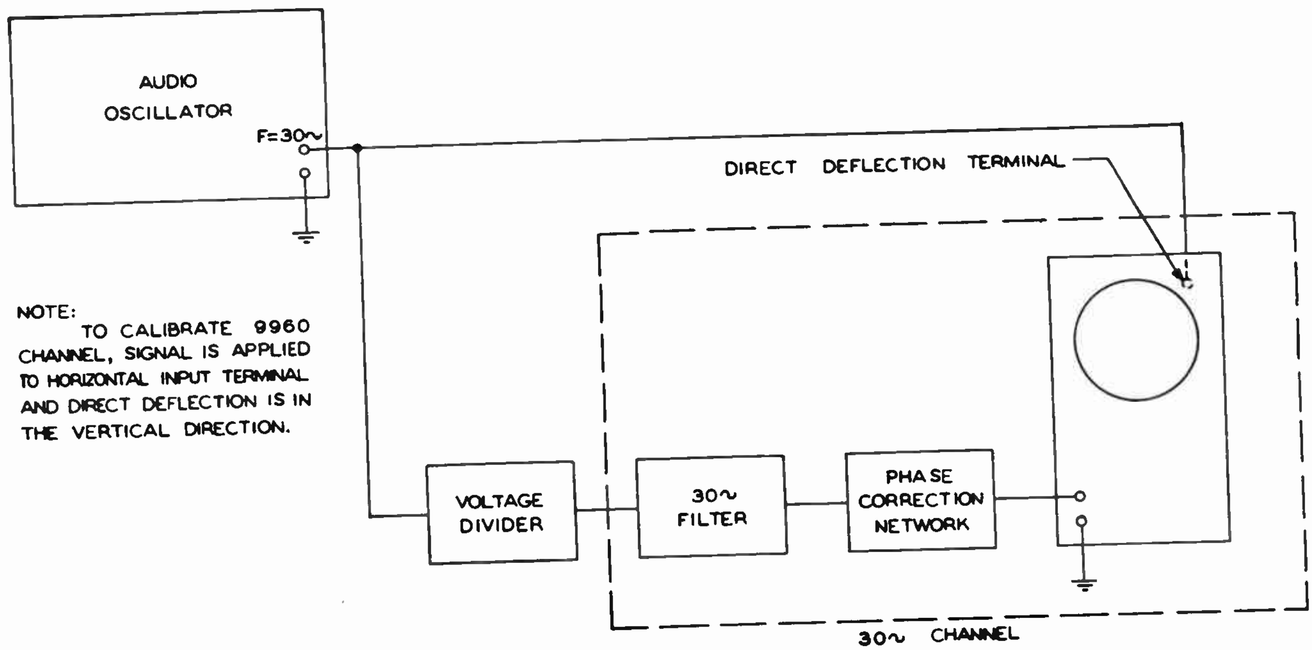


Figure 8-3. Arrangement for Calibration of 30~Channel

8-6. The audio oscillator used must be able to deliver a minimum of 100 volts into 3500 ohms with less than 1% distortion at 30 cps. This is necessary since the high voltage is used to deflect the scope beam directly without the aid of amplifiers. The low impedance load on the oscillator is used to insure that no phase shift occurs across the dropping resistor of the voltage divider due to reactive loading by the filter or phase-shifting network. Thus, the phase angle of the signal applied directly to one set of deflecting plates is the same as that applied to the channel invlolving the filter, phase-shifter, and amplifier. The problem of reducing the phase shift between the modulator and deflecting plates to zero degrees now resolves itself into (1) causing the oscillator to operate at the appropriate frequenc (30 cps or 9960 cps) (2) adjusting the oscillator output until the voltage at the input to the channel is of the same magnitude as the input voltage obtained from the modulator, and (3) adjusting the capacity or resistance of the phase-shifting network until the in-phase condition is obtained on the scope screen (closed trace from lower left to upper right of the screen). Once the phase shift has been removed the system is ready for use in calibration of the modulator.

8-7. FACTORS AFFECTING THE ACCURACY OF CALIBRATION. The important considerations when using the "interference pattern" are that (a) the phase shift be removed from the channels being used (b) that the distortion and "pick-up" be kept to a minimum, and (c) that the phase-measuring sensitivity of the system be great enough to readily discern the correct calibration within 0.1°.

8-8. PHASE-SHIFT REMOVAL. As previously indicated, the phase shift through the VAR Ø channel must be reduced to zero and the phase shift through the FM channel must be reduced to 30° and preferably less. Certain conditions are detrimental in the calibration procedure for obtaining the correct reduction of the phase shift. Particularly noteworthy are the following factors: (1) Some scopes change the phase of a signal when the attenuators (coarse or fine) are changed. Therefore, the 30 cps channel calibration should be performed with the attenuator settings in the positions which will be used in the modulator calibration. (2) Filters using inductance may change the phase shift through them when the level of the input voltage is changed. Therefore, the input voltage to the 30 cps VAR Ø channel should be the same during the calibration of the channel (channel involving filter, phase-shifter, and scope) as that used during the modulator calibration. (3) Some scopes change the phase shift through them when the line voltage changes. Therefore, it is advisable to operate the scope from a regulated supply such as a regulating transformer. (4) The phase shift through the filter, the phase-shifter, or the scope is a function of the frequency. Therefore, it is important that the frequency of the audio oscillator be exactly the same as that of the 30 cps VAR Ø from the modulator. Since the VAR Ø is synchronous with the line frequency, the oscillator frequency can be checked on the scope against the line frequency.

8-9. DISTORTION AND "PICK-UP". Although distortion does not have to be reduced to zero in all cases, it is desirable that it be minimized without impairing the measuring sensitivity of the system due to loss in voltage. Pick-up of the 60 cps line frequency can usually be eliminated by the use of shielded or very short leads, a common ground in the system, good filtering in the plate supply of the scope, and so on. It is a good policy to measure all voltages with a vacuum-tube voltmeter, but it is advisable to remove the voltmeter from the circuits when actually measuring or calibrating phase angles--otherwise 60 cps may enter into the signal. When calibrating the 30 cps channel, the picture should be a straight line if no distortion or pickup exists. If pickup is present it may be differentiated from second-harmonic distortion by tuning the audio oscillator slightly away from 30 cps. Presence of pickup will then cause the trace to slowly open and close. Evidence of distortion or pickup when calibrating the 30 cps channel will be found in small loops (see figure 8-4.)

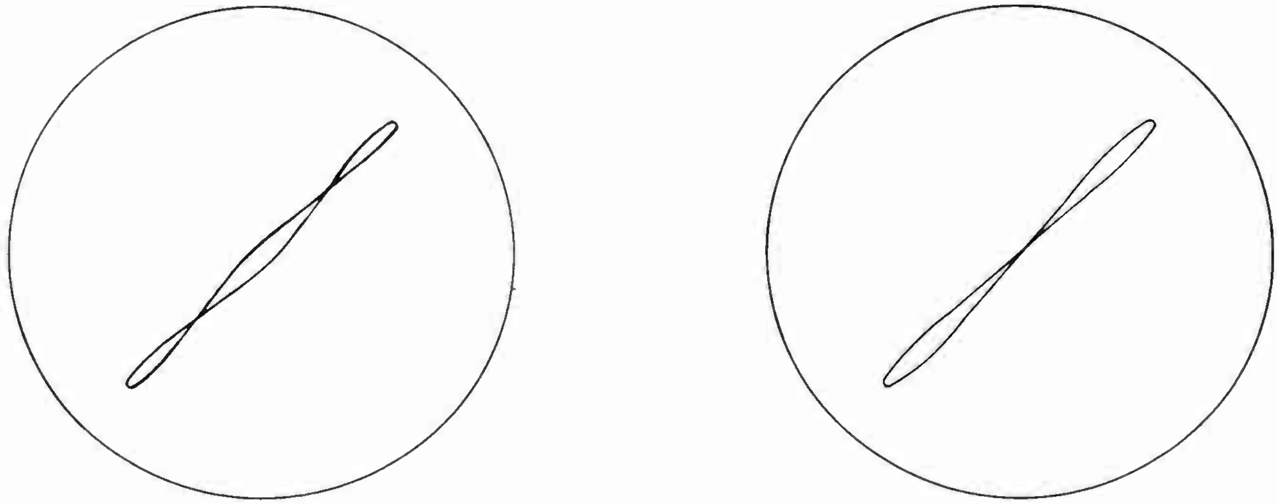


Figure 8-4. Examples of Distortion on Signal when Signal in Phase with Reference Signal of Same Frequency

8-10. If the loops are due to distortion, such distortion originates in the scope or in the oscillator. If a measurement of the oscillator output signal under operating conditions of load and level shows more than 1% distortion, the oscillator should be suspected. Possibly the test can be expedited by substituting another scope. However, neither of these tests can be regarded as the source for conclusive evidence. Distortion should be checked in the instruments according to the manufacturer's instructions. It is of no use to measure the distortion on the deflecting plates of the scope under conditions of high gain since only the on-screen portion of the signal is undistorted. The majority of the wave form is clipped when full amplifier gain is used and the actual signal on the deflecting plates approximates a square wave.

WARNING

High supply voltages exist in the oscillator, and extremely high voltages exist in the scope. These voltages should be treated with extreme caution.

8-11. The necessity for filtering the 30 cps VAR ϕ signal can be seen when it is realized that 2% of an odd harmonic which is 90° or 270° out of phase with the VAR ϕ signal would cause an error of approximately 0.65° in the modulator calibration. An even harmonic of 10% or less will cause misalignment of most envelopes in the "interference pattern", but will not disturb the alignment of the center peaks of the center envelopes. With good filtering of the VAR Ø signal, there should be good envelope alignment and peak alignment from end to end of the pattern.

8-12. PHASE-MEASUREMENT SENSITIVITY. In the process of filtering and phase correcting in the 30 cps channel, it is quite possible to have losses in the 30 cps signal great enough to cause the sensitivity of calibration to be less than desired. For proper sensitivity it should be possible to align the center peaks of the center envelopes so that if the 30 cps VAR Ø is varied plus or minus 0.1° from the aligned point the misalignment of these two peaks should be readily discernible.

8-13. NECESSARY TEST EQUIPMENT AND PERFORMANCE REQUIREMENTS.

8-14. OSCILLOSCOPE. This is one of the most important instruments used in the calibration of the MD-83A. It must be of high quality with respect to stability, gain, lack of distortion and power-supply ripple.

8-15. Stability is required in order that no additional phase shift appears in the scope between the time of 30 cps channel calibration and subsequent modulator calibration. Lack of stability could result from poor design and poor tubes or other components as well as intermittent connections. If the calibration is performed in a locality where the line voltage is likely to change in magnitude, it is advisable to operate the scope from a regulating transformer even though the scope is of high quality.

8-16. High gain is necessary to provide sensitivity to the measuring system.

8-17. The lack of distortion and of power-supply ripple is also necessary since a straight-line trace is required for accurate calibration of the 30 cps channel.

8-18. The scope used must also have the deflecting plates available in order that the beam may be deflected directly. Accordingly it should be noted that on some scopes the direct deflection terminals do not connect directly to the deflecting plates but go through an R-C coupling network first. This is true of the Dumont 304 and 304-H scopes which are very reliable for this purpose. The phase shift encountered in either of these scopes between the direct input terminals and the deflecting plates is approximately 0.065° at 30 cps. By paralleling the coupling capacitor with 5 uf or more, this phase shift can be reduced to essentially zero. It is advisable to consult the schematic diagram of the scope to be used in order to ascertain whether additional capacity will be required.

8-19. AUDIO SIGNAL GENERATOR. The signal generator must be a stable piece of equipment capable of operating at high output with very low distortion. As mentioned previously, the signal generator is required to deliver a minimum of 100 volts into 3500 ohm with less than 1% distortion at 30 cps. It must also be capable of operating at 10,000 cps in order to measure the phase shift in the scope at this frequency. However, distortion and voltage requirements for this check are not so stringent.

8-20. 30 CPS FILTER.

8-21. This item must also be stable with respect to phase shift through it. Generally, this is no problem as it likely will be constructed of inductors, resistors and capacitors only. The input impedance of the filter should not be less than 10,000 ohms and should preferably be 20,000 ohms or greater. This value is to prevent undesired phase shift in the 30 cps VAR Ø signal due to loading of the VAR Ø generator. A 10,000-ohm load will cause an undesired shift in the VAR Ø signal of approximately 0.1° and loads of smaller impedance can cause much greater phase shifts. It is necessary that the filter and the phase-correction network have an insertion loss of not greater than 30 db at 30 cps and that the 3rd and 5th harmonics be attenuated by at least 20 db greater than the fundamental. If any other harmonics cause misalignment of peaks in the pattern, they should be attenuated accordingly.

8-22. Furthermore, the phase-shift through the filter plus the phase-correction network as a function of frequency should change very slowly in the neighborhood of 30 cps. This is to obtain stability in the calibration method by preventing small phase shifts due to very small variations in line frequency over a period of time. A reasonable figure of maximum change in phase shift versus frequency is 4° from 29 cps to 31 cps as measured at the output of the filter plus phase correction network.

8-23. POWER-LINE FREQUENCY SOURCE. Usually the line frequency obtained from commercial power lines in the U. S. is very constant. However, it will occasionally vary somewhat and this could be a source of trouble. Since no control can be exercised over the line frequency, the alternatives are to monitor the line frequency with an accurate standard or to repeat the scope and modulator calibrations to serve as a check on the original calibration. Monitoring the frequency is the least desirable of the two since it requires an expensive standard such as a 60 cps tuning fork. If the monitoring method is used, the allowable tolerance in frequency change between the time of scope calibration and that of generator calibration will have to be determined from a knowledge of the phase shift vs. frequency characteristic of the 30 cps channel and the degree of calibration accuracy desired. If the first calibration is to be checked by repeating the calibration procedure, the difference in calibration can be read directly on the PHASE ANGLE SELECTOR dial.

8-24. EXAMPLES OF EQUIPMENT THAT MEET PERFORMANCE REQUIREMENTS.

a. Audio signal generator, Hewlett-Packard Model 205AG.

b. Cathode Ray Oscillograph, DuMont Type 304 or 304-H.

c. Constant voltage transformer, Sola Type 30806 or 5004, 120 VA capacity.

NOTE

The previously described test equipment is not the only suitable test equipment for this purpose. However, the requirements for the equipment that have been discussed should be adhered to in selecting and utilizing equipment.

d. See figure 8-5 for filter and phase-correction network.

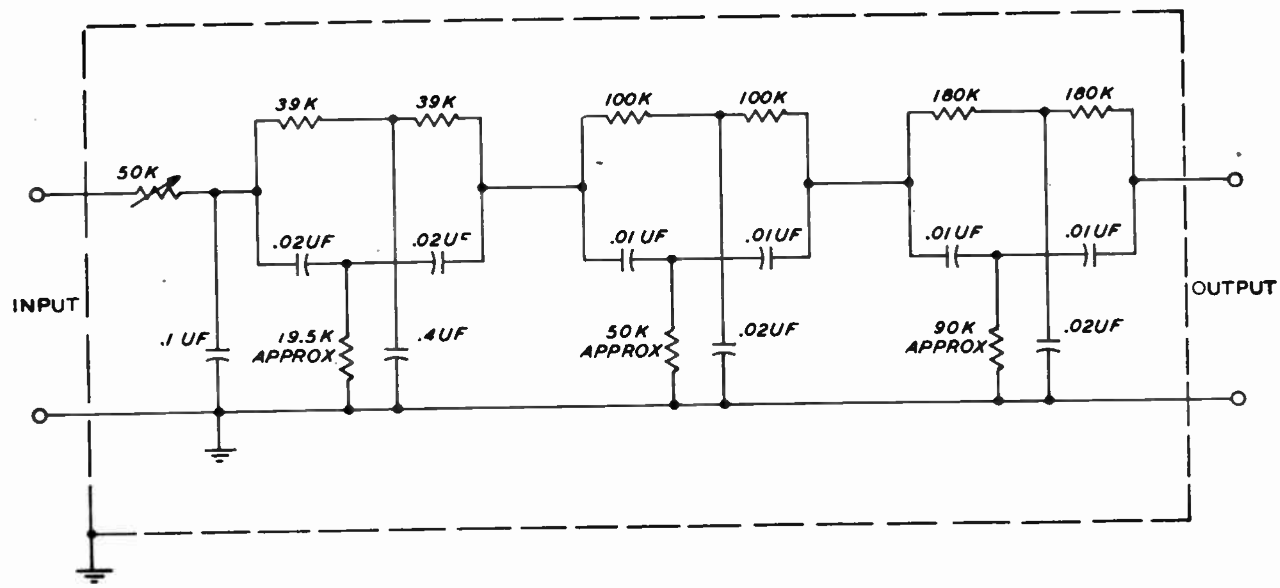


Figure 8-5. 30 cps Filter and Phase-Correction Network

NOTE

1. All resistors can have a tolerance of ±10% and a rating of 1/2 watt. All capacitors can have a tolerance of ±10% and the voltage rating can be very low.

2. Each rejection filter section must be tuned for greatest rejection at the appropriate frequency. Frequency can be determined by comparing against the power frequency.

3. The resistor and/or capacitor connected to ground in each section must be adjusted to change the tuning. Typical figures of rejection are as follows:

210 ~ Section Only	150 ~ Section Only	90 ~ Section Only	3 Sections in Tandem
30 ~ -3db	30 ~ -6db	30 ~ -9db	30 ~ -20db
210 ~ -34db	150 ~ -41db	90 ~ -41db	90 ~ -64db
			150 ~ -64db
			210 ~ -62db

4. The entire circuit as shown in figure 8-5 must be shielded and grounded to prevent pickup from the power line.

8-25. STEP-BY-STEP CALIBRATION PROCEDURE.

1. Remove Generator from the instrument case, remove casting from bracket and front panel, and re-connect plugs for normal operation (see paragraphs 6-3 and 6-4 for procedure).

2. Connect Generator through networks as shown in figure 8-6. Set FUNCTION SELECTOR to SPECIFIC SIG. and SPECIFIC SIGNAL SELECTOR to 9960 FM.

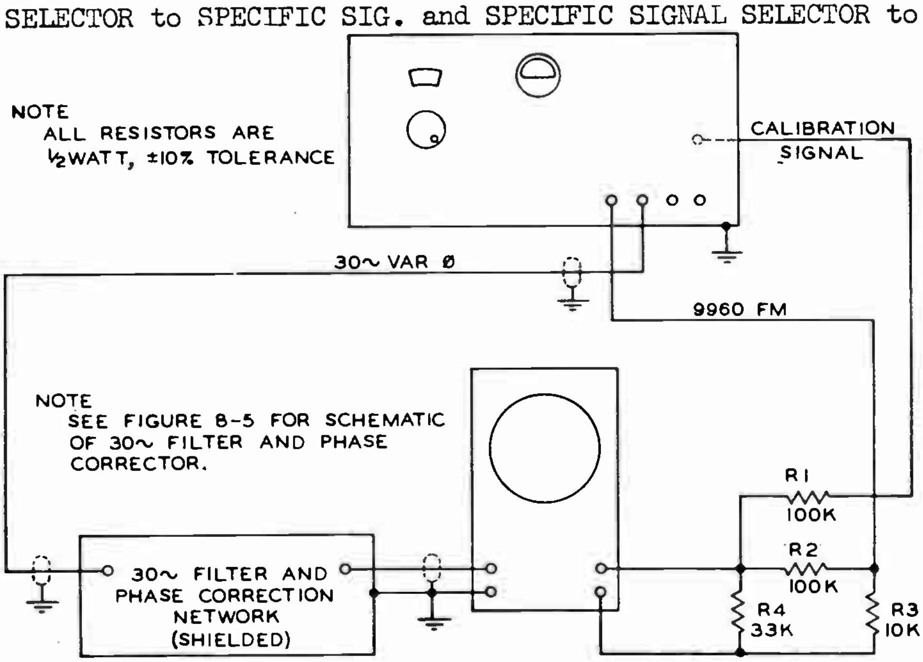


Figure 8-6. Generator Connections for Interference Pattern

3. Check 180 phase relationship between 9960 FM and Calibration Signal as described in paragraph 6-40.

4. Remove Generator connections from networks to scope and turn scope OFF.

WARNING

Do not touch any of the terminals at the rear of the scope while the power switch is ON.

5. Prepare horizontal amplifier for direct deflection. See figure 8-7.

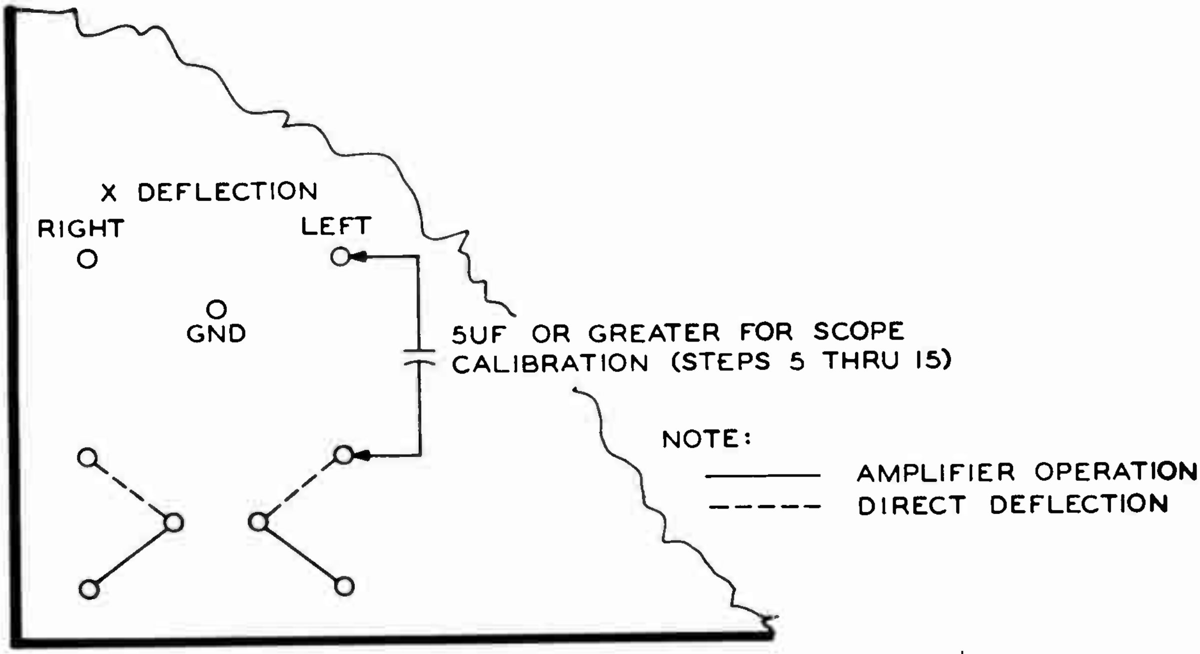


Figure 8-7. Portion of Rear Terminal Board of 304 Scope (Dumont) Showing Amplifier and Direct Connections

6. Reduce output of audio oscillator to zero.

7. Connect audio oscillator to scope. See figure 8-8.

8. Turn scope ON.

9. Measure output voltage at 30~ VAR Ø jack of 479S-3 with vacuum-tube voltmeter.

10. Connect vacuum-tube voltmeter across filter input, set frequency of audio oscillator to approximately 30 cps, and adjust output voltage until vacuum-tube voltmeter reads same as in step 9.

11. Disconnect the vertical scope input from phase correction network and connect LINE-FREQ TEST SIGNAL terminal on front panel of scope to vertical input. Adjust frequency of audio oscillator very accurately to obtain steady pattern.

12. Reconnect vertical input to phase correction network, and increase vertical scope gain to maximum.

13. Close trace by adjusting potentiometer R_X of phase correction network.

14. If picture is a very staight line (emphasized in the previous general discussion) obtain correct adjustment of potentiometer R_X by opening trace an equal amount with a high and low setting of potentiometer and thereby determine a medium setting.

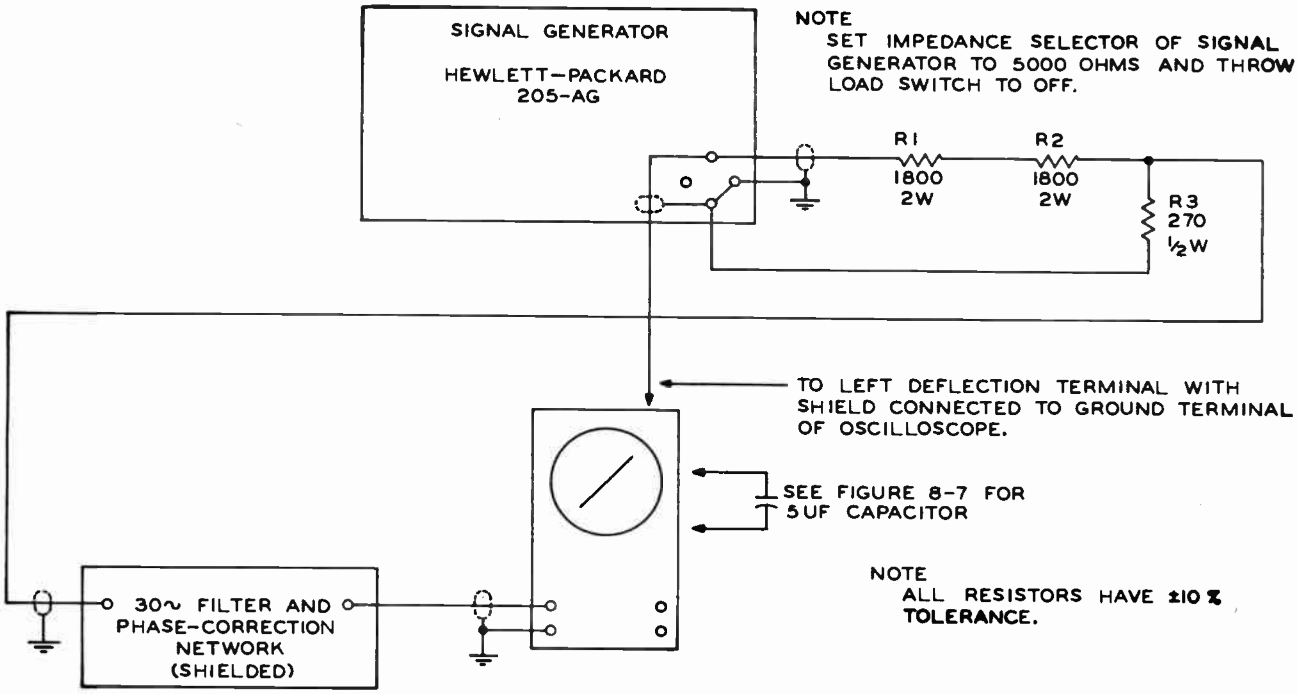


Figure 8-8. Circuit For 30 CPS Channel Calibration

15. Turn scope OFF, reduce oscillator output to zero, and discharge large condenser at rear of scope before touching any other connections.

16. Prepare scope for amplifier operation again and connect 479S-3 to scope as shown in figure 8-6.

17. Turn scope on, rotate PHASE ANGLE SELECTOR knob until picture agrees with that in figure 8-1. (Level of one of 9960 FM signals may have to be adjusted to obtain this.)

18. Increase vertical scope gain to maximum, locate center envelope of pattern, adjust level of one of 9960 FM signals to obtain a fine null between envelopes, and rotate PHASE ANGLE SELECTOR to obtain good envelope and peak alignment on center envelope. A look at the other patterns should disclose reasonably good peak-to-peak alignment throughout.

19. With the aligned pattern on the screen, loosen the two set screws which hold vernier (inner) dial to shaft and rotate dial until zero-mark lines up exactly with etched line on dial glass. (Eyes should be at least a foot away from glass to eliminate parallax.) Hold vernier dial in place

and tighten set screws carefully, being sure dial position does not change in the process. (Threads of set screws should be coated with glyptal before tightening.)

20. Remove Calibration Signal from scope, connect the 30~ VAR Ø directly to the vertical scope input (by-pass the filter--phase-correction network), and connect a 560-ohm (1/2 watt) resistor directly across MOD OUTPUT jack. Rotate PHASE ANGLE SELECTOR dial until following picture is presented. (MASTER ATTENUATOR should be full clockwise.)

21. Unless line frequency has been monitored throughout, procedure should be repeated from step 4 through step 18 for a check on the calibration.

8-26. ADJUSTMENT OF 30 CPS REF Ø GENERATOR.

8-27. TEST SETUP. Connect an AC VTVM to the horizontal input and the 30 cps VAR Ø jack to the vertical input of the scope. Operate scope from the Sola transformer.

8-28. TEST PROCEDURE.

1. Connect upper-vertical input terminal to upper-horizontal input terminal. Connect a capacitor decade box across a pair of jumpers for either amplifier at rear of the scope. Capacitors should have minimum voltage ratings of 400 V d.c. and 220 V a.c.

2. Center trace (which is approximately a straight line) by turning vertical amplifier OFF (step attenuator switch on panel) and positioning trace so it coincides with the center horizontal line on co-ordinate screen; turn vertical amplifier ON and horizontal amplifier OFF and position trace so it coincides with the center vertical line on co-ordinate screen.

3. Turn both amplifiers ON. Trace should now intersect center of co-ordinate screen. Increase gain of one amplifier and re-position trace if necessary so that it intersects center of screen. Increase gain of other amplifier in same manner. Alternately adjust amplifiers until maximum gain of one amplifier is being used and trace is at angle of approximately 45°.

4. Vary capacitor decade to close trace in center of screen. Note 30 cps VAR Ø voltage and remove connection between horizontal and vertical inputs.

5. Connect 30 cps REF Ø jack to horizontal input and adjust its level to agree with VAR Ø level noted in step 4. Rotate PHASE ANGLE SELECTOR to 0.0°.

6. Loosen bearing cap which clamps REF ∅ generator and rotate generator to obtain closed trace indicating in-phase condition with VAR ∅ generator. Avoid obtaining the 180° condition. One part of coupler may have to be slipped by 180° since REF ∅ generator leads may prevent in-phase condition from being obtained.

7. Tightening down clamp will likely open trace a small amount; if so, this effect will have to be anticipated and allowance made in adjustment so that tightening clamp will produce in-phase condition.

8. When adjustment is completed, it should be checked by removing REF ∅ signal and connecting horizontal input to vertical input. If trace is closed the adjustment is correct. If trace is open, close by varying capacitor decade, and reconnect REF ∅ generator and readjust.

9. Connect 30 cps 90° ∅ jack to horizontal input and rotate PHASE ANGLE SELECTOR to approximately 90°. The in-phase condition must appear somewhere between 89.0° and 91.0°. Be careful again that the 180° phase relationship is not found here. If the 180° condition is found, leads of REF ∅ and 90° ∅ signals from the generator have been interchanged. If in-phase condition appears outside of tolerances, the two-phase generator must be replaced.

8-29. PERFORMANCE CHARACTERISTICS.

8-30. All voltages do not vary more than ±5% of their preset value, and the variable phase does not vary more than ±0.2° of its pre-set reference phase under any combination of the following service conditions:

a. Temperatures ranging from -40° C to 55° C

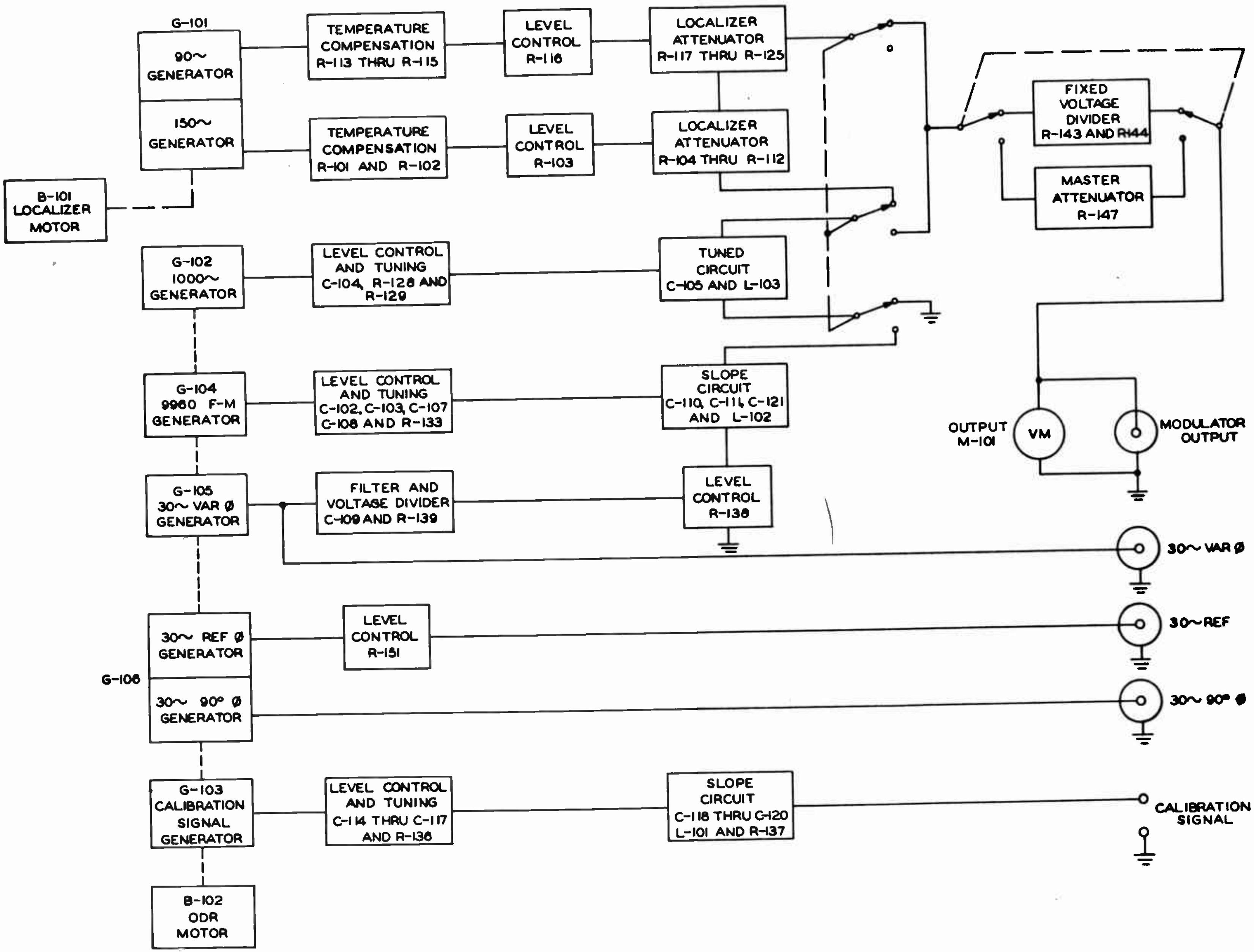
b. Altitudes up to 10,000 feet

c. Vibration varying from 10 to 33~ for 45 minutes

d. Vibration varying from 10 to 55~ for 45 minutes

e. Vibration at the four most severe resonant frequencies for three minutes each

8-31. The 45-minute tests are composed of 15 minutes of vertical vibration and 15 minutes of horizontal vibration in each of two directions--parallel and at right angles to the major axis. Total excursions are .06 inches from 10 to 33~ and .03 inches from 10 to 55~ and at fixed frequencies.



Block Diagram, Figure 10-1

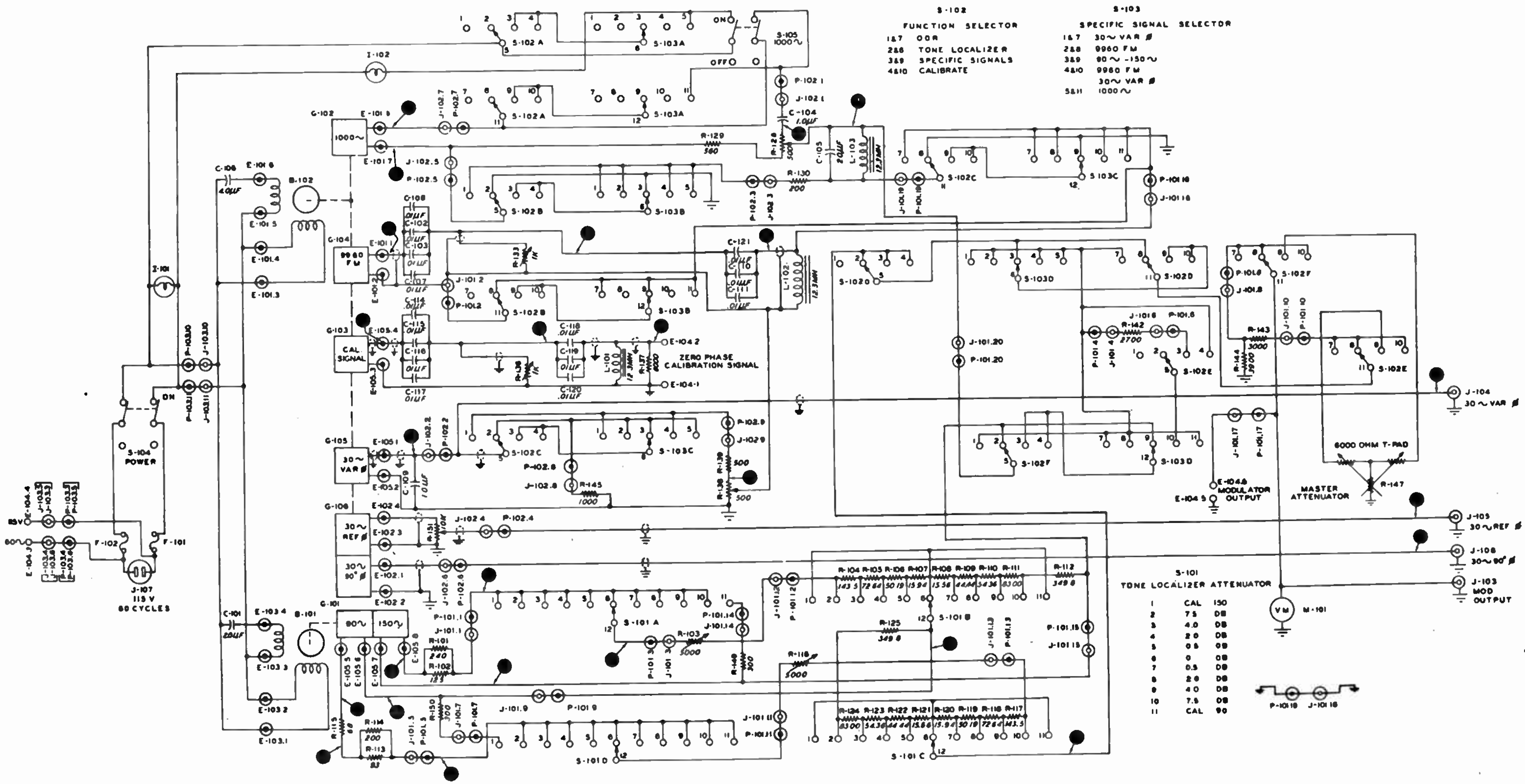


Figure 10-3. Schematic with Test Points

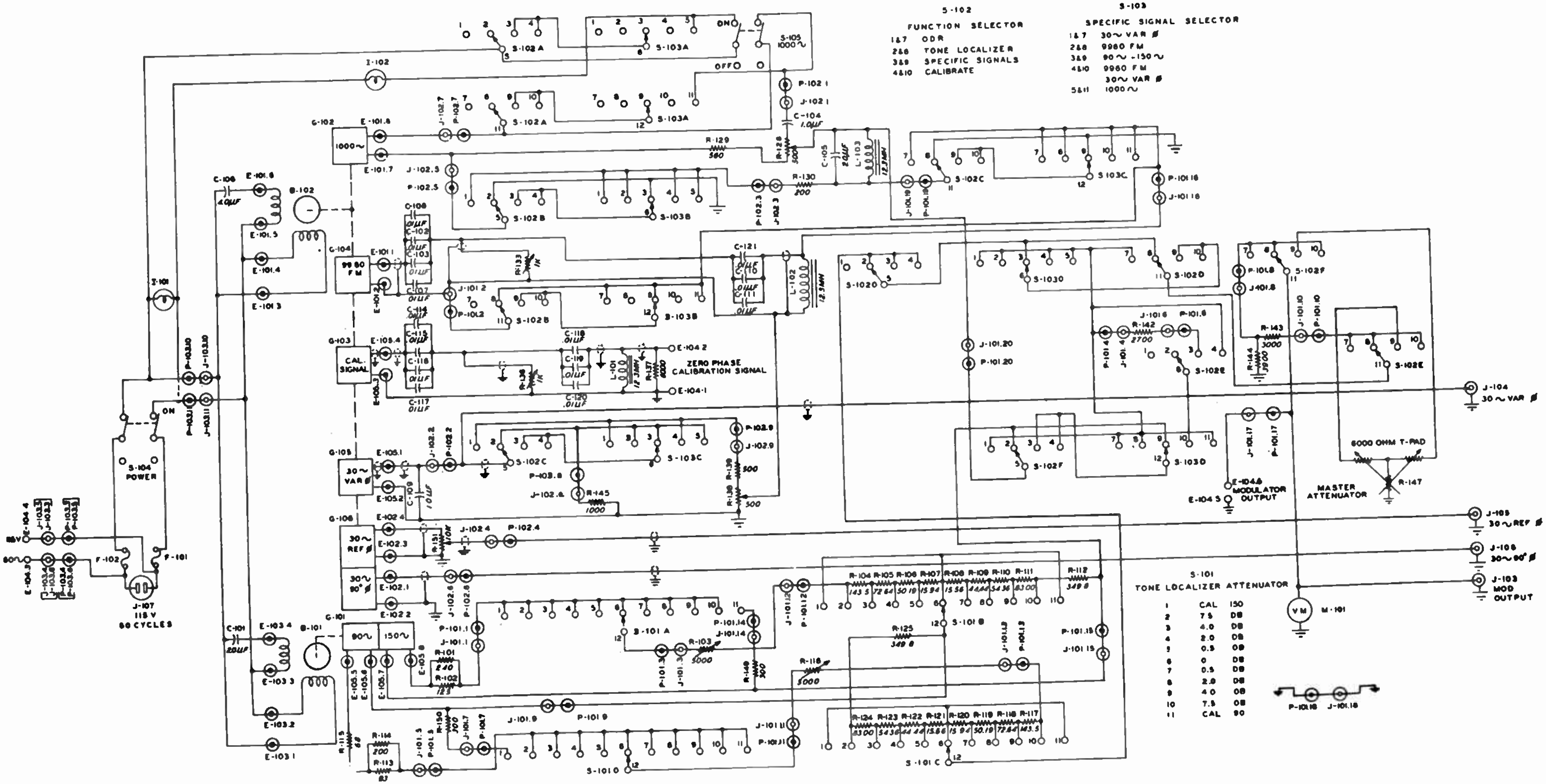


Figure 10-4. Overall Schematic