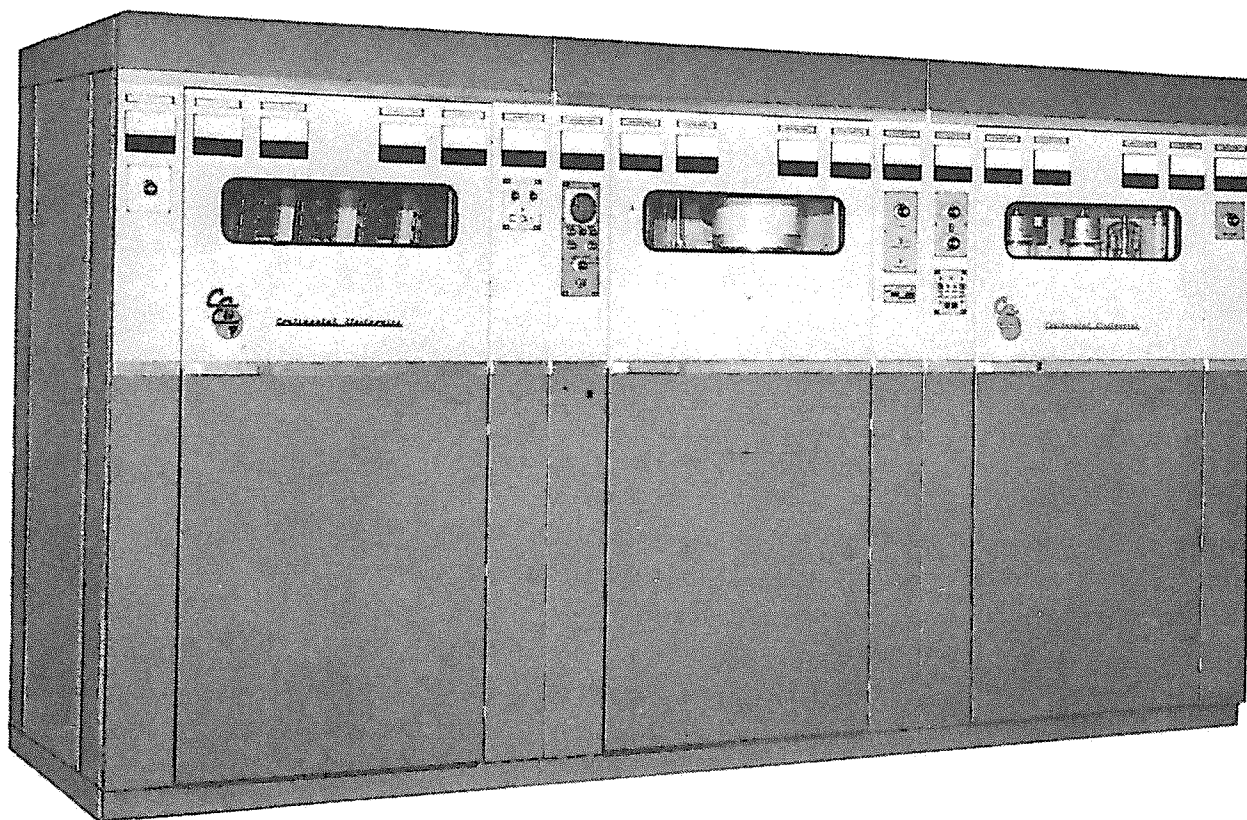


317C-2 AM BROADCAST TRANSMITTER

TRAINING MANUAL



80-1045



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SECTION 1 - DESCRIPTION

1-1. INTRODUCTION

This handbook contains instructions for the installation, operation and maintenance of the Continental Electronics Type 317C-2 50 kW AM Broadcast Transmitter. It is effective on S/N 202 and above.

The Type 317C-2 Transmitter can be tuned to operate on any fixed frequency between 535 and 1620 kHz.

The Type 317C-2 Transmitter consists of a main cabinet group and the associated High Voltage Transformer and Regulator cabinet (Figure 1-1 and 1-2).

The main cabinet group consists of three separate cabinets each of which is 48" wide, 54" deep and 78" high. These cabinets are located side-by-side and are bolted together. The right end cabinet housed the Driver and Power Distribution which is designated Unit 2. The center cabinet housed the Power Amplifier and is designated Unit 1. The left end cabinet houses the H.V. Rectifier and Harmonic Filter and is designated Unit 3. The H.V. Transformer and Regulator cabinet is designated Unit 4 and is generally located adjacent to the Rectifier and Harmonic Filter cabinet, although it may be located wherever the customer desires.

The Type 317C-2 Transmitter is completely self-contained, in that no external driver or exciter unit is required. Only an audio input, a transmitting antenna, and a source of three phase, primary power are required for operation.

Electrical parts lists and other supplementary data are supplied within this handbook.

Throughout the descriptive pages of this handbook, a symbol number, when referred to, will carry the unit number as a prefix to the symbol number in order to simplify location on one of the schematics or Electrical Parts Lists. Separate schematics and Electrical Parts Lists are used for each of the three units.

1-2. GENERAL DESCRIPTION OF CIRCUITRY

a. RF Circuits. Solid state circuitry is employed in the low level stages which consists of an oscillator, RF switch, RF amplifier and RF output. A 4-400C is used as a Driver Amplifier for the Final Power Amplifier. The final power amplifier configuration

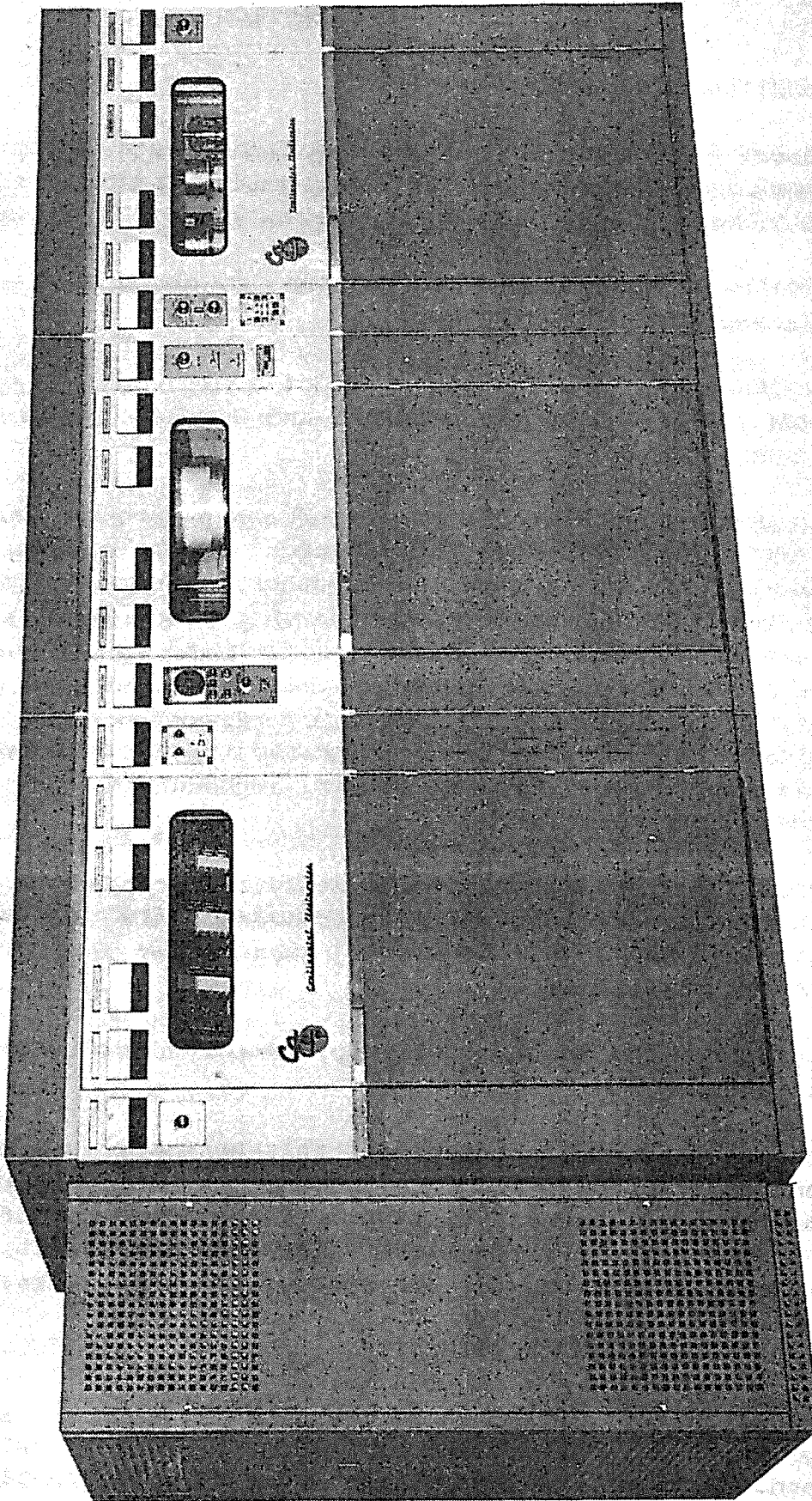


Figure 1-1. Type 317C-2 AM Broadcast Transmitter.

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is a combination of the screen-grid modulated amplifier and the high-efficiency Doherty amplifier.

Overall rf feedback is tapped from the output of the transmitter, rectified and applied as negative feedback to the first audio amplifier stage to reduce noise and improve linearity.

b. Tetrode Final Amplifier. The use of tetrode tubes in the final power amplifier stage offers many advantages:

- (1) A minimum of rf driving power is required, since a tetrode is inherently a high gain tube.
- (2) Modulator power requirements are greatly reduced. Constant rf excitation is applied to the control grid of the tetrode tube while audio modulation is applied to the screen grid. Since rf output is controlled linearly by screen grid potential, with relatively low values of screen current, an excellent method of modulation is possible with very little power being consumed in the modulator.
- (3) The screen grid is operated at ground potential with respect to the rf signal and serves as a shield between the control grid and the plate of the tube, thereby eliminating the necessity of a great amount of neutralization.
- (4) Slightly higher efficiency than that obtained from a high-level plate modulated transmitter is possible through the use of a tetrode tube in the high efficiency Doherty amplifier circuit.*

c. Screen Grid Modulation. Screen grid modulation as used in the Type 317C-2 Transmitter offers the following advantages:

- (1) Since the required modulation power is very low, small audio components may be used. Large transformers and chokes are not used in the resistance-coupled audio system. Harmonic distortion and distortion due to inter-modulation are very low, therefore better transmitter performance is realized.

*Patent Nos. U.S. - 3,314,024, Canada - 764,605, Great Britain - 1,044,479, France - 1,432,543.

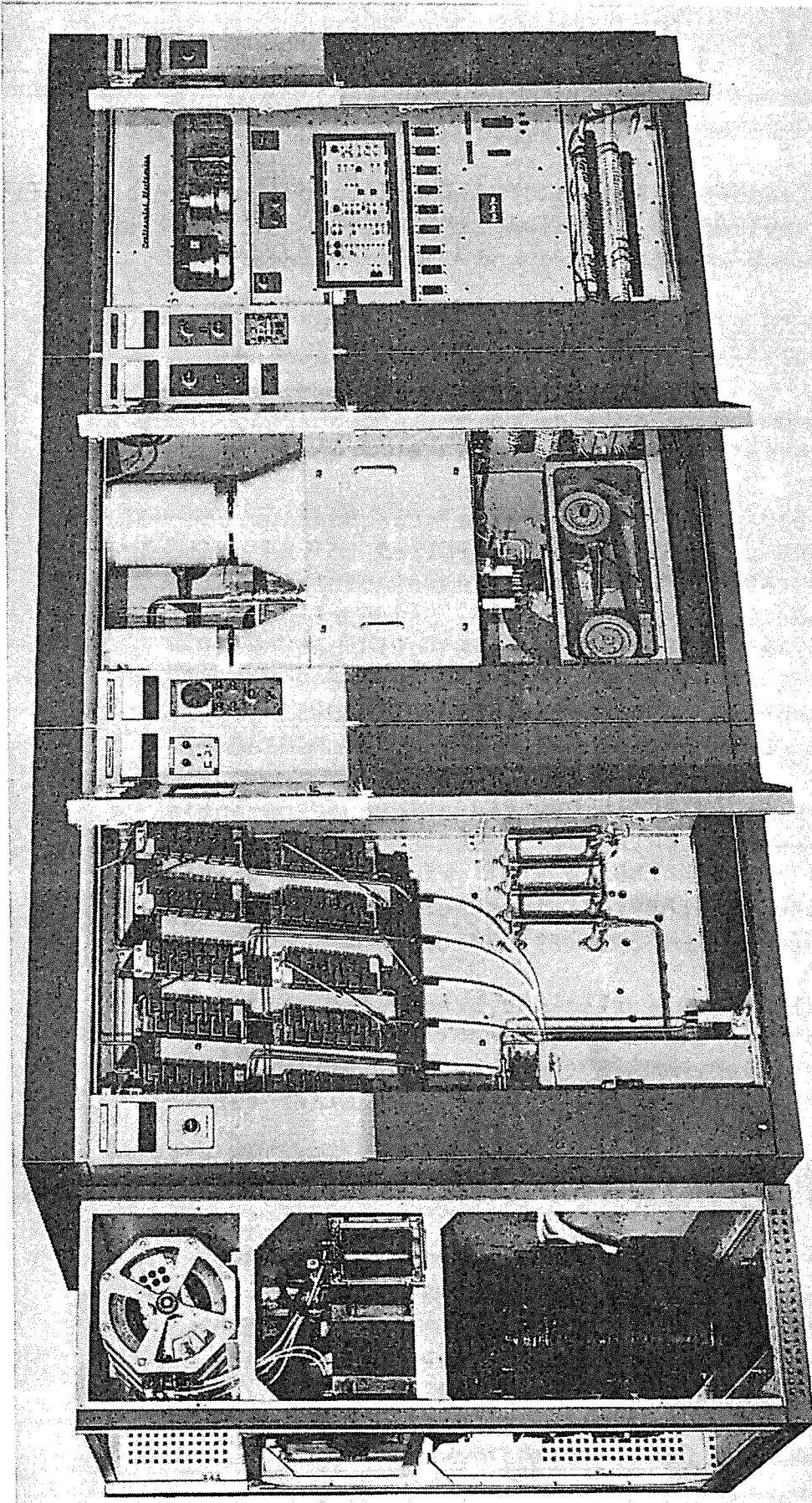


Figure 1-2. Type 317C-2 Front Doors Open

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- (2) Through the use of screen grid modulation, the audio and modulation system can be designed with full control of phase-shift characteristics, making possible the use of overall feedback in the transmitter. Transmitter performance is thereby further improved. Overall feedback can not be used in high-level plate-modulated transmitters.

d. Power Supplies. Semiconductor rectifiers are used in the high voltage, low voltage and bias power supplies, Semiconductor rectifiers require no warmup, and can be operated efficiently at temperatures below 32 degrees Fahrenheit. The semiconductor rectifiers produce a minimum amount of heat, can be packaged more compactly, and have very long life characteristics.

In unattended or remote operation, the semiconductor characteristics become even more attractive.

Since semiconductor rectifiers are used in the Continental Electronics broadcast transmitters, no damage will result when the equipment is turned on from a cold start.

Continental Electronics AM broadcast transmitters are also well suited for high ambient temperature operation and tropical climates.

1-3. OPTIONAL EQUIPMENT AND CIRCUITRY

The necessary circuitry for connection of optional equipment is provided in the Type 317C-2 Transmitter.

The Type 317C-2 can easily be connected to operate with any remote control, automatic logging and sub-audible telemetering equipment currently available.

The Type 317C-2 can be supplied with automatic Power Cutback to 25 kW or 10 kW.

The Type 317C-2 can be supplied for operation with 380V, 460V and 600 V, 3 phase, 50 Hz or 60 Hz primary power source.

1-4. TECHNICAL CHARACTERISTICS

The performance of the 317C-2 Transmitter meets, and in most cases, exceed the requirements of the FCC, DOC and CCIR. See Table 1-1.

TABLE 1-1. TECHNICAL CHARACTERISTICS

AF Input Impedance	150/600 ohms
* AUDIO DISTORTION:	Less than 2.5%, 20 to 10 KHz at 95% Modulation
AF FREQUENCY RESPONSE:	
* 0 to -0.5 dB	10 to 7500 Hz.
* 1.5 dB	15,000 Hz (Ref to 1000 Hz at 70% Modulation)
* CARRIER SHIFT:	2% or less at 100% Modulation
* PROGRAM INPUT LEVEL:	+10 dBm <u>+2.0</u> dB at 100%
* INTERMODULATION DISTORTION:	3.5% at 90% total modulation by SMPTE test method using 60 and 7000 Hz in 4:1 ratio
* PHASE RESPONSE:	$+2^{\circ}$ from 10 to 1000 Hz and phase linear to 30 kHz with output lagging 45° at 15 kHz.
TILT AND OVERSHOOT:	
* Clipped Sinewave:	3% variation in modulation percentage using 6 dB symmetrical clipping, 90% modulation 30 to 10,000 Hz.
Squarewave:	5% variation in modulation percentage, 60% modulation with squarewave frequencies from 30 to 7500 Hz.
* MODULATION CAPABILITY:	100% continuous at any frequency 20 - 10,000 Hz +125% Positive Peak with asymmetrical input.

TABLE 1-1. TECHNICAL CHARACTERISTICS - Continued

Noise, unweighted (below 100% Modulation at 1,000 cps)	60 dB
SPURIOUS & HARMONIC EMISSION:	-80 dB
Modulation Type	High Level Screen Grid/ Impedance Modulation
Type of Emission	A3
Frequency Range	535-1620 KHz
Frequency Stability	<u>+5</u> Hz
Output Impedance	40 ohm to 300 ohms (as specified by customer)
CARRIER POWER:	
Power Output Capability	60,000 watts
Power Rated	50,000 watts
Power Reduction	25kW or 10kW
Ambient Temperature	-4 ^o to 122 ^o F (-20 ^o to 50 ^o C)
Altitude	7500 feet (Higher by special order)
Power Supply	460 volts, 3 phase, 3 wire, 50/60 Hz (Other voltages optional)
* Power Consumption at 0% Modulation (100% Modulation)	82kW 120kW
Control Power External or Internal	120 VAC (Selected by wiring jumpers)
Power Factor	0.95 (approximately)
Overall Efficiency	Better than 60% at any depth of modulation
Permissible Combined Voltage Variation and Regulation	<u>+5%</u> Voltage <u>+2.5%</u> Frequency

TABLE 1-1. TECHNICAL CHARACTERISTICS - Continued

DIMENSION:

UNIT	WIDTH	HEIGHT	DEPTH
Power Amplifier Unit	48"	78"	54"
Driver and Power Distribution Unit	48"	78"	54"
Rectifier and Harmonic Filter Unit	48"	78"	54"
HV Transformer and Regulator Unit	24"	72"	46"
NET WEIGHT OF MAIN CABINET GROUP			4,891 lbs.
NET WEIGHT OF HV TRANSFORMER AND REGULATOR UNIT			1,990 lbs.
EXPORT SHIPPING			
Gross Weight			9,700 lbs. (4400 Kilos)
Size			800 cubic feet (22.65 cubic meters)

REMOTE CONTROL - See Table 2-1 for connection information

SECTION 4 - THEORY OF OPERATION

4-15. GENERAL CIRCUIT DESCRIPTION

The 317C-2 50 kW transmitter consists of a high efficiency screen modulated amplifier, RF driver and oscillator circuits, single ended cathode follower modulator and audio amplifier circuits, associated power supplies and control circuits. These are housed in a group of three cabinets which are placed side by side and bolted together. Another enclosure which contains the power amplifier plate transformer and associated switchgear can be placed either next to the rectifier/harmonic filter (Unit 3) cabinet or at any other location in the transmitter building. When installing this enclosure at locations other than next to Unit 3, Continental Electronics will supply special connecting cables to accommodate the extra length of cable runs. Figure 4-1.1 shows the layout and nomenclature of the transmitter assembly.

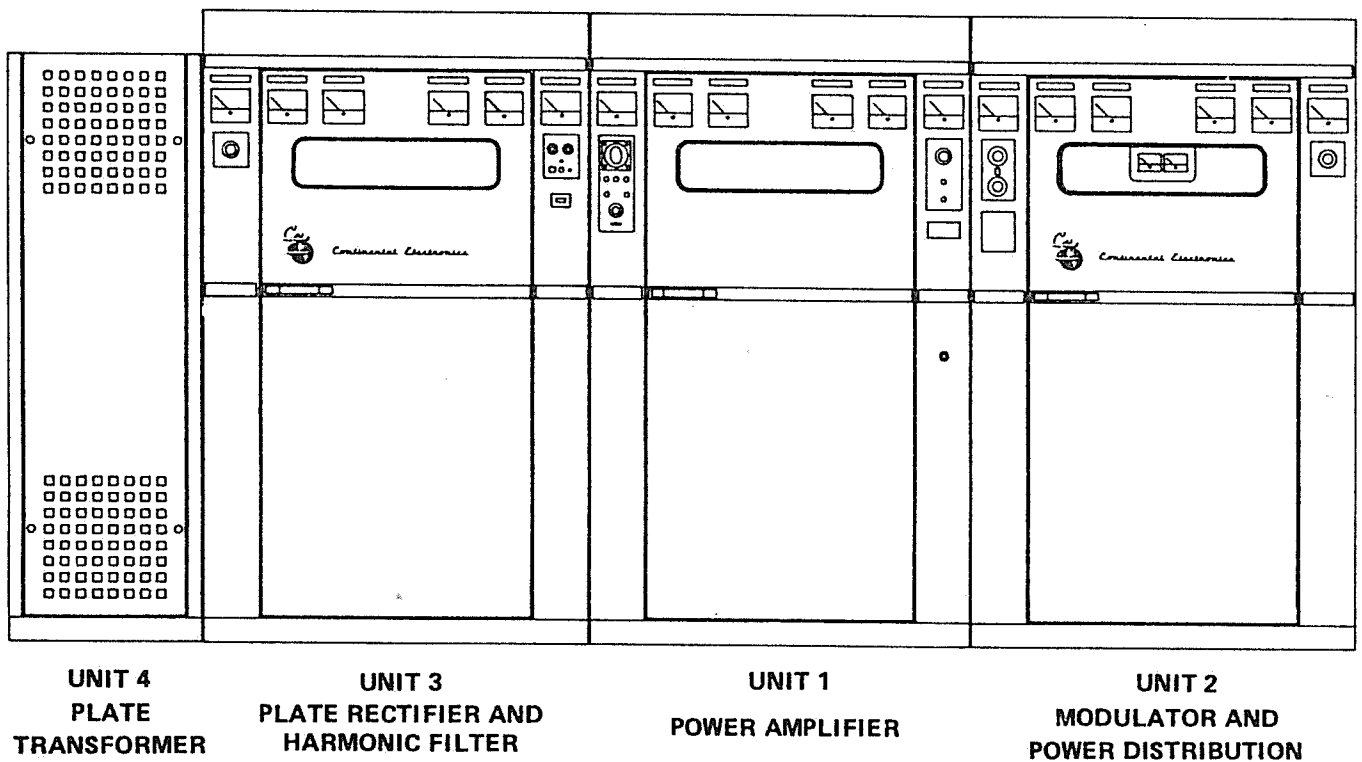


Figure 4-1.1 Type 317C-2 Transmitter Assembly

4-16. POWER AMPLIFIER CIRCUIT

The high efficiency screen modulated amplifier, which is a modification of the Doherty high efficiency linear amplifier, consists of two Type 4CX35000C air cooled tetrodes. One tube, referred to hereafter as the carrier amplifier or carrier tube, provides almost

all of the 50 kW carrier power when no modulation is applied. The other tube, referred to as the Peak Amplifier or Peak tube, is held near plate current cut-off in the absence of modulation. With positive-going modulation, the Peak tube is driven into plate current conduction so that at the positive peak of 100% modulation both tubes are contributing equal RF power into the load. Since with Amplitude Modulation the carrier level output RF voltage doubles at 100% positive modulation, the peak power output quadruples from 50 kW to 200 kW so that at this instant both tubes are putting out 100 kW. During the negative-going modulation, the Peak tube stays at cut-off and the output of the Carrier tube decreases in a linear fashion from 50 kW down to zero at the negative peak of 100% modulation.

The unique manner in which the outputs of these two tubes are combined is the basis of the Doherty amplifier principle in which the plates of the two tubes are connected together through a quarter wave or 90° network. In order for the Carrier tube to operate at Class C high efficiency at carrier level, it must be driven to saturation which means that more output power can be obtained only by either one of two means; by increasing the plate voltage (as in plate modulation) or by reducing the plate load resistance. The load resistance is reduced during positive modulation by the contribution of RF current into the load by the Peak Amplifier which would make it appear that the actual load resistance is increasing if the two tubes were connected directly in parallel. The 90° Interplate Network which separates the two plates inverts this apparent increase in load resistance so that, to the Carrier tube, the load would appear to be decreasing in resistance. The circuit is arranged so that at the positive peak of modulation, the load resistance at the plate of the Carrier tube is half its carrier level (unmodulated) value and equal to the Peak tube plate load resistance so that with both tubes being driven to saturation on the positive peak, their power outputs are equal. The screen modulation process and further information on the high efficiency amplifier is covered in the description of the modulator circuit.

4-17. DRIVER AND MODULATOR STAGES

Referring to the simplified schematic diagram, Fig. 4.2 (next page), the RF circuits begin with the RF Oscillator/Exciter Unit 2A1. This is a plug-in module located on the front of the Unit 2 cabinet. This Unit (2A1) contains two complete crystal oscillator circuits which are front panel or remotely selectable and also has provision for an external drive unit such as a synthesizer or stereo exciter.

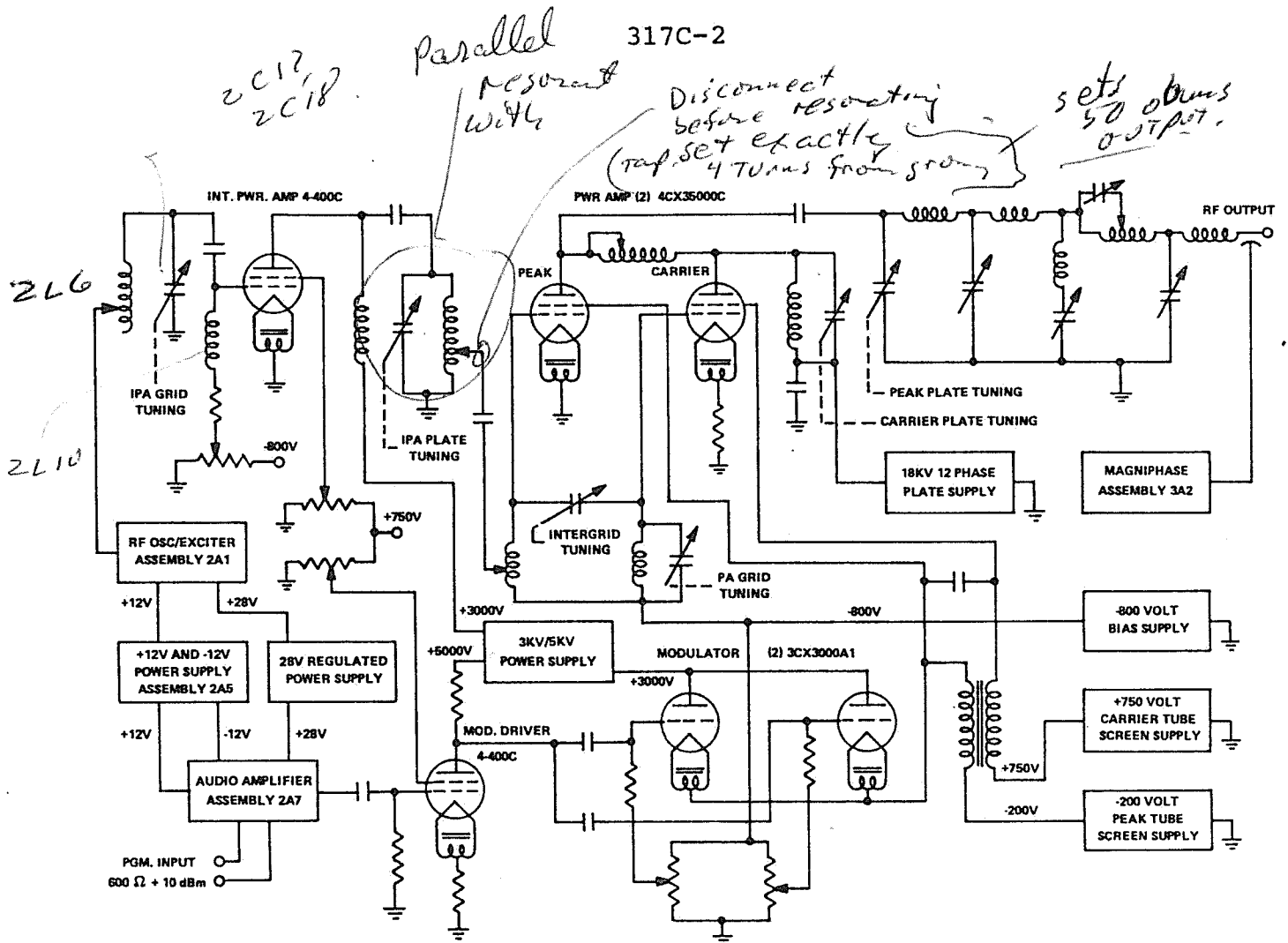


Figure 4.2 Simplified Schematic Diagram

The output of the 2A1 module (about 15 watts) is fed to the grid of the intermediate power amplifier tube (IPA) through a front panel adjustable tuning network. The 4-400C IPA tube operates Class C and puts out about 500 watts of RF drive to the Power Amplifier grid circuit. The IPA plate circuit is also tuneable from the front panel.

The Power Amplifier grid circuit is a 90° high-pass (phase advance) PI network. The phase advance circuit is used to compensate for the 90° phase retard Interplate Network. The PA grid network has adjustments for setting the 90° phasing and for setting the proper ratio of grid drive to the two PA tubes.

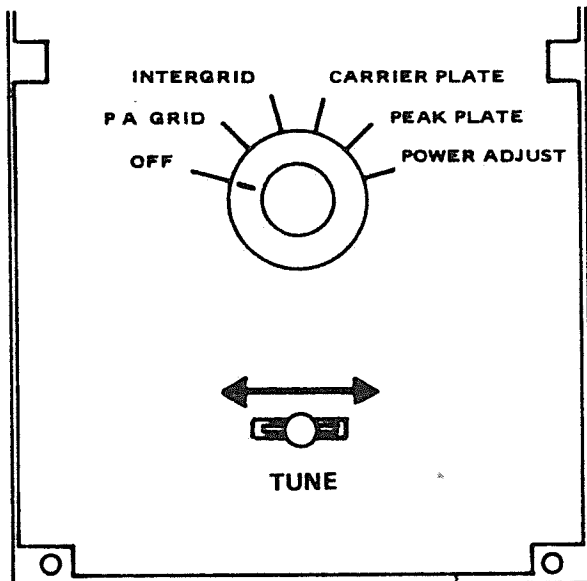
The audio amplifier line-up starts with the 2A7 Audio Amplifier module which plugs into the front of Unit 2. This unit performs a number of functions in addition to audio amplification and is described fully later in the text. The output from the 2A7 unit drives the grid of the 4-400C Modulator Driver tube. This is a Class A resistance coupled amplifier which provides the large output voltage

swing required for driving the cathode follower modulator.

The two Type 3CX3000A1 Modulator tubes are connected in parallel in a Class A cathode follower circuit. The output from the cathode circuit is from a specially designed modulation transformer which feeds the modulating audio to the screen grids of the Peak and Carrier power amplifier tubes.

4-18. POWER AMPLIFIER TUNING CIRCUITS

The 90° Interplate and Intergrid phasing which is required for proper operation of the PA circuit is tuned with the aid of a built-in phase monitor oscilloscope located on the front of the Power Amplifier (Unit 1) cabinet. The tuning elements (vacuum condensers) which affect the 90° phasing circuits and which tune the plate and grid circuits are driven by slow-speed tuning motors which are controlled from a selector switch and tuning lever switch on the oscilloscope. There are six positions on the selector switch (including an OFF position).



OFF Oscilloscope and tuning motor power off.

PA GRID - Sets 90° grid phasing.

INTERGRID - Sets grid drive ratio to peak & carrier tubes.

CARRIER PLATE - Resonates the plate circuit of the carrier tube.

PEAK PLATE - Sets the 90° plate phasing.

POWER ADJUST - Sets transmitter power output by raising or lowering plate and screen voltage.

The circuits are arranged so that when a tuning position is selected, the oscilloscope will display the waveform appropriate to that position and the TUNING lever switch will tune only the element which controls the waveform which is displayed on the oscilloscope. For instance, if PEAK PLATE is selected, the 'scope will display an upright ellipse depicting a 90° phase relationship and the TUNING switch when operated will tune the Peak plate tuning condenser which will control the 90° phasing. In this way, it is impossible to mis-

tune the Power Amplifier by looking at a phasing display and tuning a control which will not affect that display. The oscilloscope can also be used as an indicator of negative modulation depth.

4-19. LOW VOLTAGE POWER SUPPLIES

The output Power MOSFETs in the 2A1 RF Oscillator/Exciter module are powered from a 28 volt DC regulated power supply which operates from 115 VAC single phase power. The 2A5 module contains a +12 volt 1 amp supply for the control circuit modules and a +12 V split supply for the 2A7 Audio Amplifier. These are also powered from 115 VAC single phase. All other supplies except the 18 kV 12 phase plate supply are three phase full wave and are powered from the 230 volt 3 phase buss. These are:

Bias - A -800 volt supply which provides bias for the PA, Modulator and IPA tubes.

-200 V - The Peak Amplifier screen supply.

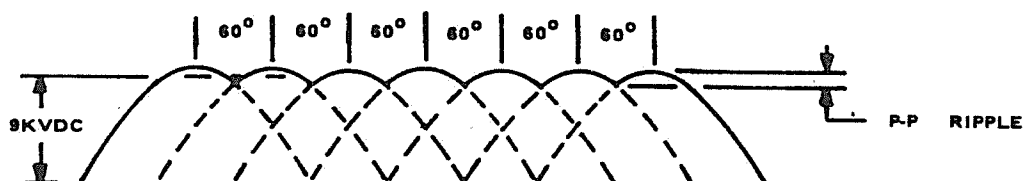
+750 V - The Carrier Amplifier screen supply. This also provides screen voltage for the IPA and Modulator Driver tubes and collector voltage for the output transistor in the 2A7 Audio Amplifier module which is zenered down to +120 volts.

+3000V - This is the plate supply for the Modulator and IPA tubes.

+5000V - The plate supply for the Modulator Driver tube.

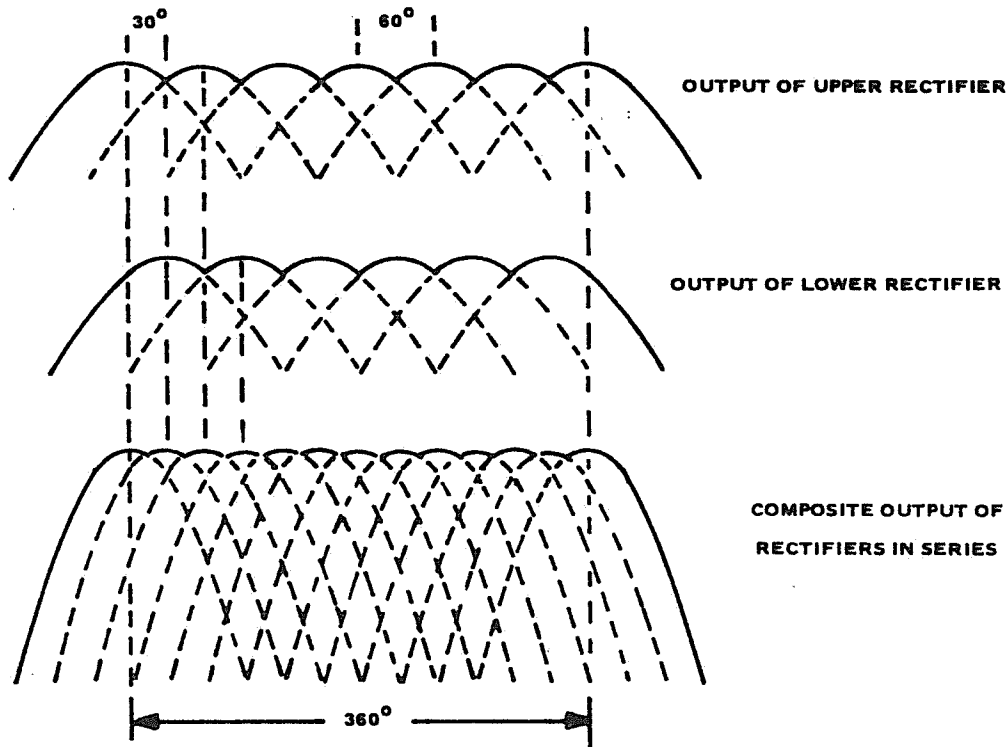
4-20. POWER AMPLIFIER PLATE SUPPLY

The 18 kV PA plate supply consists of two 9 kV 3 phase full wave bridge rectifiers in series with the phasing of the upper rectifier displaced by 30° relative to the lower rectifier. Commutation in each 3 phase full wave bridge will produce a DC output with six ripple peaks per cycle of primary voltage. These peaks will occur at 60° intervals ($360^\circ \div 6 = 60^\circ$) and therefore have a ripple frequency of $6 \times 60 = 360$ cycles.



The RMS level of the 360 cycle ripple is about 4% of the DC level (about 28 dB below DC).

By adding an identical 9 kV supply in series but with its ripple peaks displaced by 30° , the composite output voltage becomes:



The DC level is $9 + 9 = 18$ kV. There are 12 ripple peaks per cycle (hence the term 12 phase) so the ripple frequency is now $12 \times 60 = 720$ cycles and the ripple level is reduced from 4% to 1% (-40 dB) which precludes any necessity for a filter reactor.

The exclusion of the filter reactor enhances the ability of the power supply to deliver large Direct Currents for long periods (in hundreds of milliseconds) without a large drop in output voltage. The conventional power supply/filter circuit depends on the stored energy in the output filter condenser to provide the high instantaneous current. With the series filter reactor out of the circuit, the supply more closely resembles a huge battery bank having excellent voltage regulation. This in effect means that the power supply impedance is very low at low audio frequencies so that sine wave modulation down to 10 cycles at 100% modulation is now possible.

The power supply impedance versus frequency is now determined not by the ripple filter constants but by the plate transformer impedance (leakage reactance) which is inductive and which will resonate with the filter capacitance. This occurs at about 70 cycles. The curve

of impedance versus frequency is quite broad so that it produces no noticeable effect other than slightly higher distortion in the range from 50 to 100 cycles.

The 30° displacement of the ripple peaks of the two 9 kV rectifiers can be accomplished by several methods. Earlier transformers were wound with a delta connected feed to the lower rectifier and a wye connected feed to the upper supply. Since there are 30° difference in phase between corresponding wye and delta voltages in a 3 phase system, then the peaks of the wye connected rectifier will lag the delta rectifier by 30° . Later transformers use what is referred to as the extended delta winding on both the upper and lower rectifiers. In this arrangement, the coils are wound identically but the auto-transformer action and the arrangement of connections will provide the required 30° offset.

4-21. THREE PHASE POWER DISTRIBUTION

The primary power for the transmitter can be either 380, 480 or 600 VAC, 3 phase, 3 or 4 wire, 50 to 60 cycles. Whichever is used is routed through switchgear to the 18 kV plate transformer which has taps to accommodate different voltages. The primary voltage is also routed through a circuit breaker to a step-down transformer which provides a 230 volt, 3 phase feed for all other transmitter circuits. The step-down transformer also has taps to accommodate different primary voltages and has a tap on one of the 230 volt windings to provide 115 VAC single phase. The 230 volt 3 phase output is routed through a terminal board (2TB4) with jumpers which can be removed when a low voltage regulator is used on the 230 volt distribution buss, and is then tied to the line side of circuit breakers 2CB1 through 2CB9. These circuit breakers then feed low voltage power supplies, filament transformers, blower, etc..

4-22. TRANSMITTER OUTPUT NETWORK

The Harmonic Filter and Output Matching Network consists of a low-pass PI, L and Tee in series. The transmitter is normally supplied to feed 50 ohm coaxial line but can match any impedance between 25 and 250 ohms. A 90° Tee network transforms the 50 ohm load up to 100 ohms. If the load is something other than 50 ohms, the Tee network will still transform it up or down to 100 ohms with a phase shift of -90° . Referring to the simplified network diagram, Figure 1.3 (next page), the input Tee coil 3L4 has a portion of its turns resonated at the third harmonic.

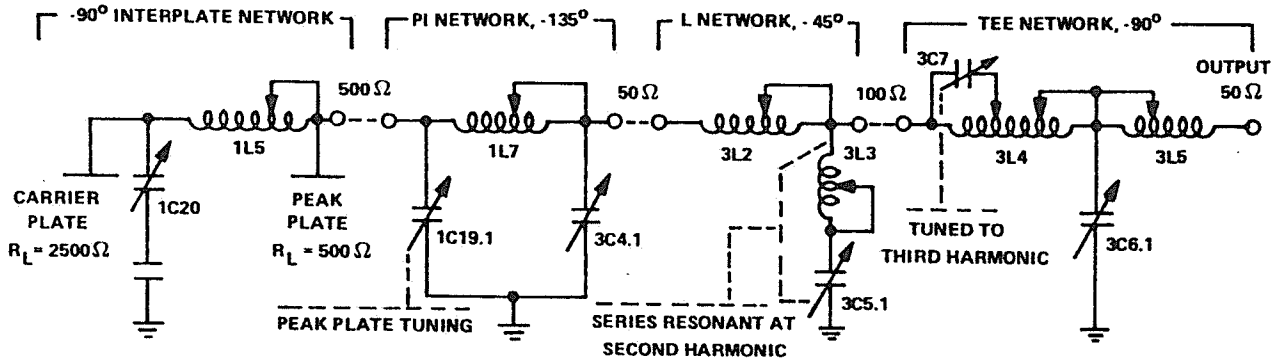


Figure 4.3 Simplified Schematic of Output Network

The L network consisting of series inductance 3L2 and shunt capacitive branch 3C5 in series with 3L3, transforms the 100 ohm resistance at the Tee network input down to 50 ohms with a phase shift of -45° . 3L3 in series with 3C5 is series resonant at the second harmonic and is capacitive at the carrier frequency.

The PI network consists of 3C4 in the Unit 3 cabinet and 1C19 and 1L7 in the Unit 1 (center) cabinet. This network transforms the 50 ohm input resistance of the L network up to 500 ohms which is the Peak tube plate load resistance. The PI network is tuned for a nominal phase shift of -135° although this will decrease at the low end of the band because of the decreasing "Q" of the tank circuit.

The 90° Interplate phasing network, although not considered as a part of the output network, will provide some harmonic attenuation because of its low pass configuration. This network is a PI circuit which is made up of series inductor 1L5 (Interplate coil), Carrier plate tuning condenser 1C20, and Peak plate tuning condenser 1C19. The 90° Interplate network transforms the 500 ohm Peak tube plate load resistance up to 2500 ohms at the plate of the Carrier tube.

4-23. CONTROL CIRCUITS

The Control circuit uses 115 VAC for operating contactor coils in the power circuits. The timing and counting and sequencing circuits use CMOS integrated circuits which ultimately drive transistor/relay logic or light emitting diode (LED) indicators. No incandescent lamps are used in the transmitter. All of the control, timing and sequencing functions are performed by the circuits contained in the plug-in modules 2A2, 2A3 and 2A4. Some other functions relating

to the Magniphase antenna protective circuit are performed in the 2A6 module. These circuits will cause an automatic reduction in Transmitter power in the case of excessive antenna VSWR. If the problem persists on reduced power, the Transmitter will shut down.

The MASTER on/off, PLATE on/off, REMOTE/LOCAL switching and indicating circuits are contained in the 2A8 assembly on the front of Unit 2.

The control circuit also contains a relay which will detect a loss or reduction of any one of the three phase voltages or an improper phase sequence and will shut down the Transmitter if this should occur.

4-24. LOCATION AND FUNCTION OF CONTROLS AND INDICATORS

Before going into detailed individual circuit descriptions, it is necessary to become familiar with the location and function of the various operating and tuning controls, meters and status indicating LEDs. The following pages deal with all of the controls, meters and indicators on the front of the three transmitter cabinets including those behind the non-interlocked front door of Unit 2. There are no hazardous voltages present behind this door so that it can be opened at any time. Since high voltage DC is present inside the front doors of Units 1 and 3, these doors are interlocked and are also equipped with mechanical grounding switches which short the hazardous voltages to ground when the doors are opened. There are no operating controls inside or on the rear panels of the cabinets and the meters which are mounted inside can be seen through the windows.

Figure 4.4 (next page) shows the location, symbol number and function of the transmitter meters. Figure 4.5, on the page following, shows the location and symbol number of the Unit 2 subassemblies which are referred to throughout the text. The controls and indicators on the subassemblies are then described. Following this is a graphic description of the RF tuning controls explaining how to use the oscilloscope for tuning the power amplifier.

Although there are no operating controls inside of the cabinets, there are some adjustable resistors and some variable tuning elements in the RF networks. These are all set during initial tune-up at the factory. The adjustment or setting of these components is covered further on in the text. See Figures 4-6 through 4-11.

<u>FULL SCALE</u>	<u>DESCRIPTION</u>
3M1	0-600 VAC
3M2	0-5 KVDC
3M3	0-10 KVDC
3M4	0-20 KVDC
3M5	0-50 AMPS RF
3M6	0-200 μ AMPS DC
1M1	0-1 AMP DC
1M2	0-10 AMP DC
1M3	0-500 MADC
1M4	0-500 MADC
1M5	0-15 VAC
1M6	Dual Scale
2M1	Dual Scale
2M2	0-1 AMP DC
2M3	0-500 VDC
2M4	0-1 KVDC
2M5	0-1 KVDC
2M6	0-300 VAC
2M8	0-1 AMP DC
2M9	0-1 AMP DC

<u>FULL SCALE</u>	<u>DESCRIPTION</u>
3M1	Primary Line Voltage (Switchable all 3 Phases)
3M2	+3000 Volt Modulator Plate Supply
3M3	+5000 Volt Modulator Driver Plate Supply
3M4	+18 KV Power Amplifier Plate Supply Voltage
3M5	0-1 MADC Meter Calibrated for RF Line Current
3M6	Magniphase Null Meter
1M1	Carrier Tube Screen Current
1M2	Power Amplifier Total Plate Current
1M3	Peak Tube Control Grid Current
1M4	Carrier Tube Control Grid Current
1M5	Peak or Carrier Tube Filament Voltage
1M6	Peak or Carrier Tube Cathode Current
2M1	Switchable Multimeter for Low Level Metering
2M2	Cathode Current of 4-400C IPA Tube
2M3	Peak Tube Screen Voltage (-200 Volt Supply)
2M4	Carrier Tube Screen Voltage (+750 Volt Supply)
2M5	Bias Supply Voltage (-800 Volt Supply)
2M6	230 Volt, 3 Phase Line Voltmeter
2M8	Left Modulator (V3) Plate Current
2M9	Right Modulator (V4) Plate Current

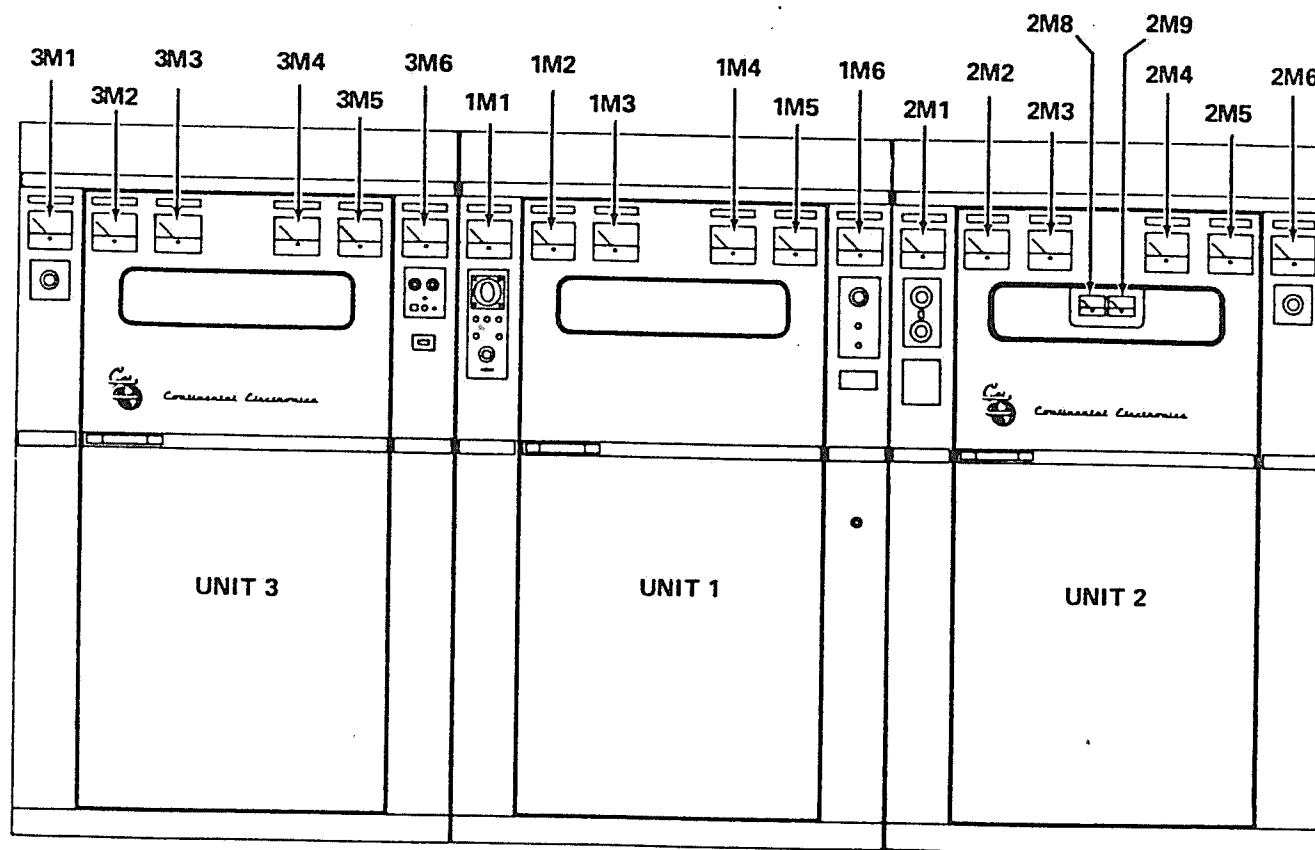
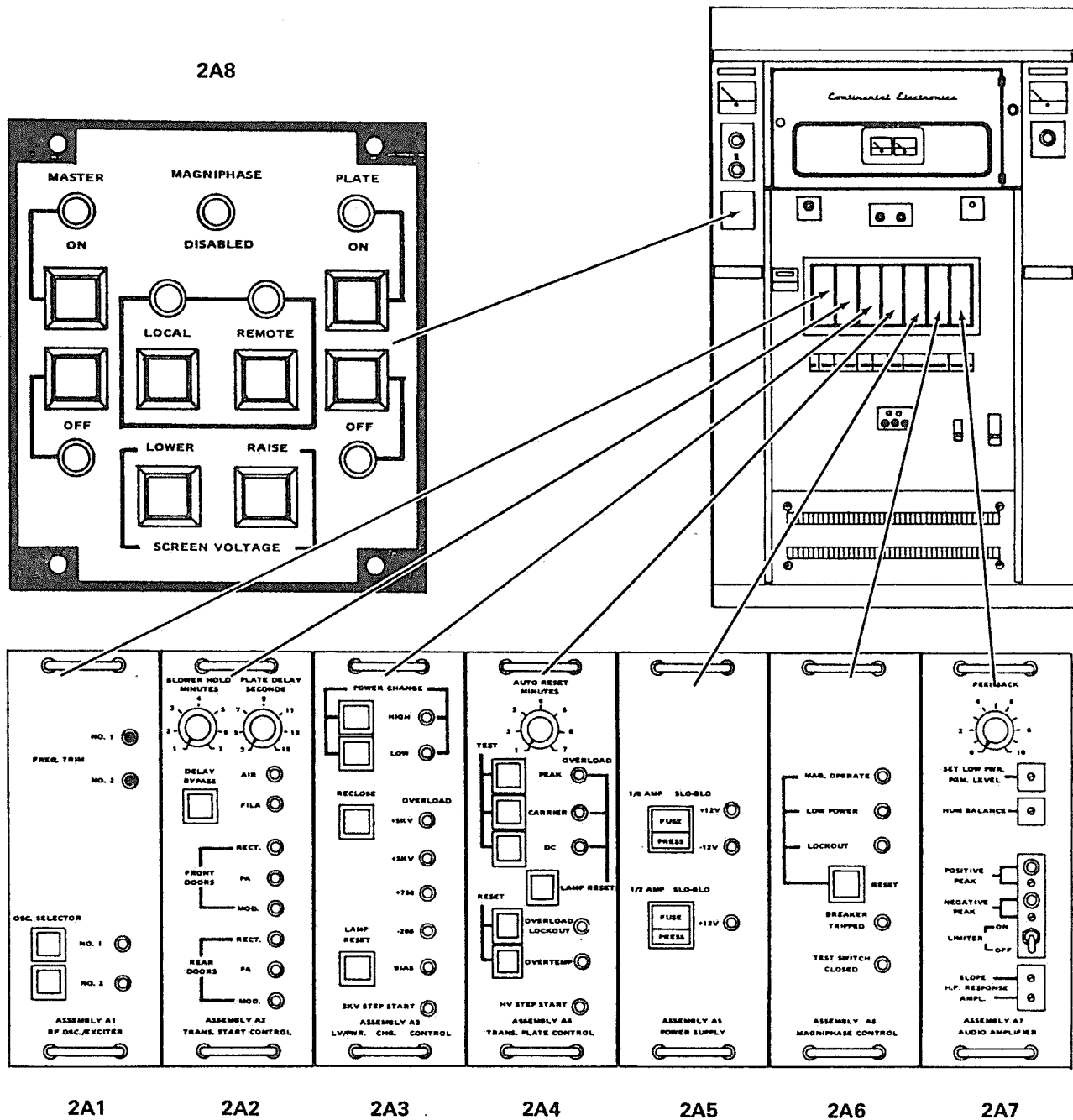


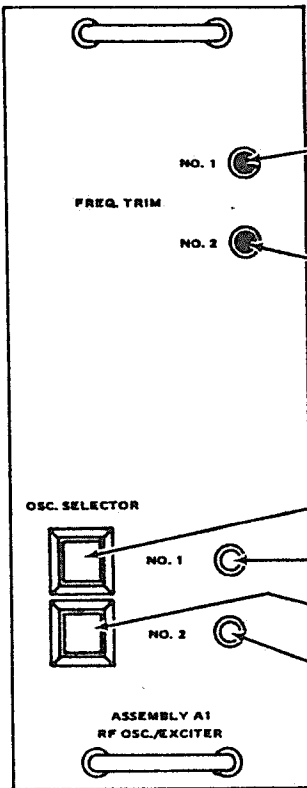
Figure 4-4. Identification & Location of Meters

2A8 (Control Unit) is removed by taking out four corner screws (nuts are captive in panel). After pulling away from front panel, wiring is disconnected by Jones plug on underside of assembly.



Subassemblies 2A1 through 2A7 are plug-in modules. Before unplugging or re-installing remove all DC power from solid-state circuits by manually turning off circuit breakers 2CB1 and 2CB2 located just below subassembly 2A1.

Figure 4.5 Location of Unit 2 Subassemblies



ASSEMBLY 2A1

Use insulated tuning tool (screw driver blade) to set carrier frequency when No. 1 oscillator LED is lighted.

Same as above when No. 2 oscillator LED is on.

NOTE: Output to frequency counter is from 2TB1-52 & 2TB1-53 (52 is ground).

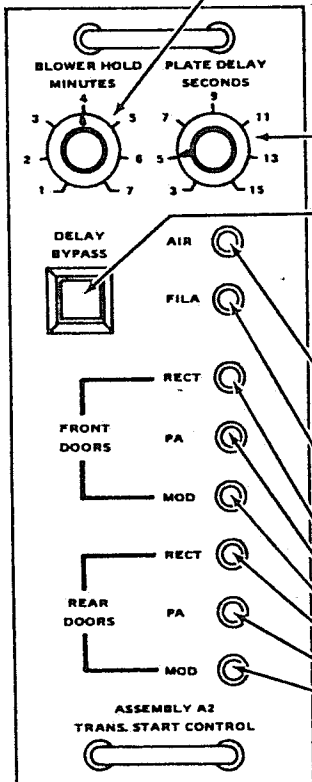
Blue button - push to select No. 1 oscillator.

Yellow LED lights when No. 1 osc. is selected.

Blue button - push to select No. 2 oscillator.

Yellow LED lights when No. 2 osc. is selected.

ASSEMBLY 2A2



On transmitter shutdown (MASTER OFF button pushed), the blower will continue to run after the filaments go off for the amount of time selected on this potentiometer.

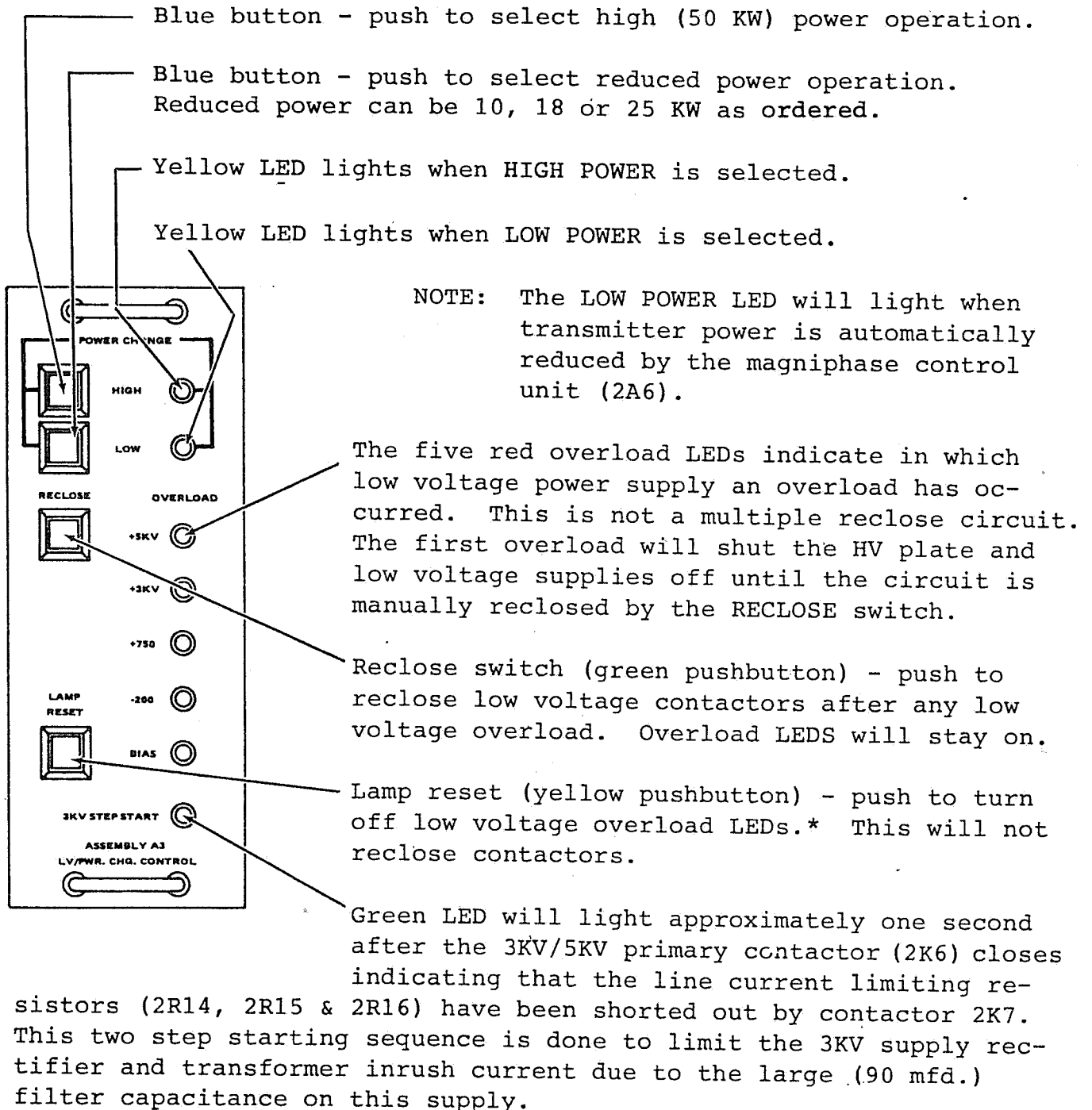
On transmitter start-up (MASTER ON button pushed), the low voltage supplies will come on and the transmitter will be ready for plate voltage in the time interval selected on this potentiometer. The time interval begins when the FILA LED comes on.

For on-site testing, the PLATE DELAY (above) time can be bypassed if you do not care to wait it out. This is a green pushbutton.

Green LED lights when air pressure switch in PA air plenum closes after blower start-up.

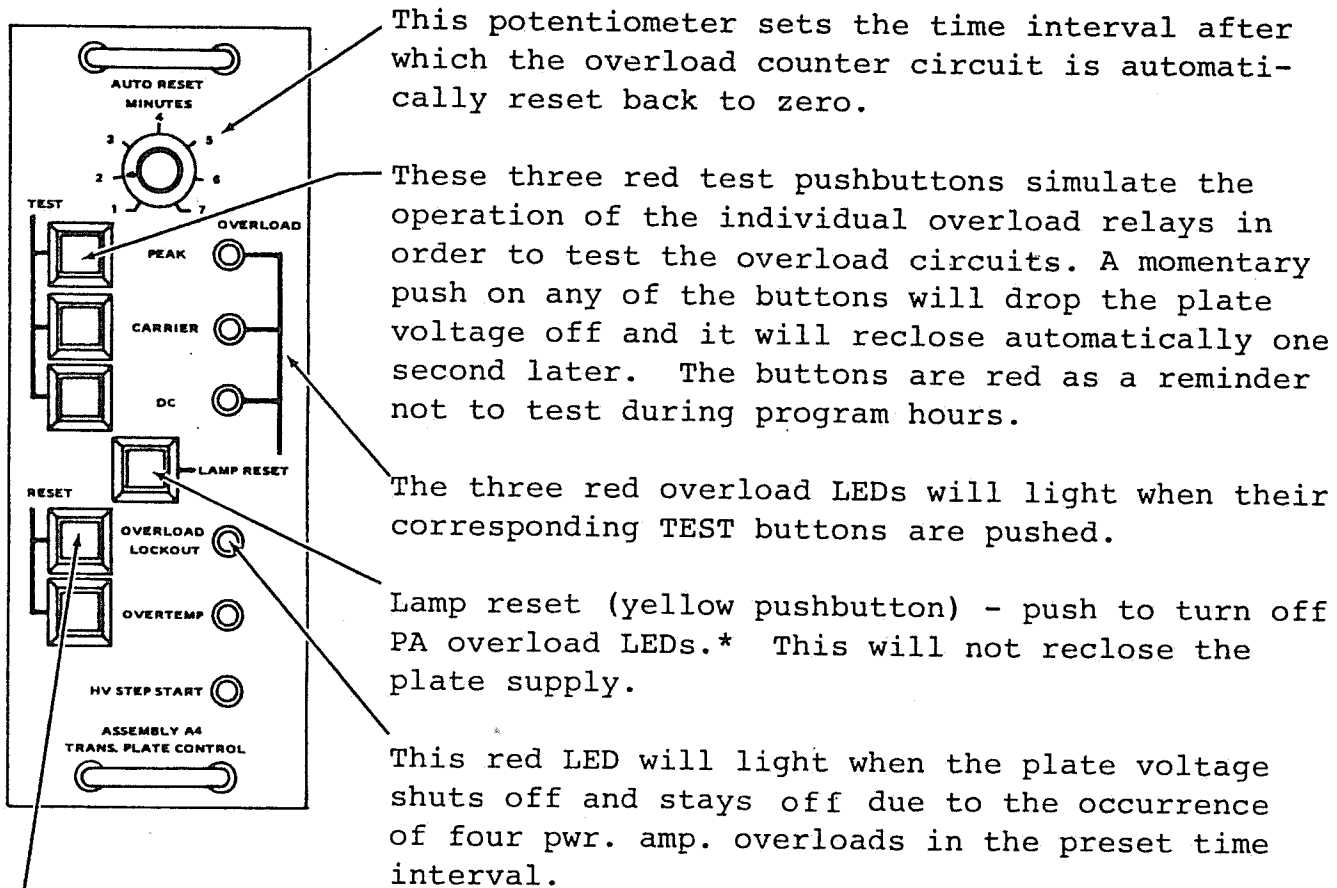
Green LED lights when filament contactors close.

The six door interlock LEDs (green) will light when the doors are closed.

ASSEMBLY 2A3

ASSEMBLY 2A4

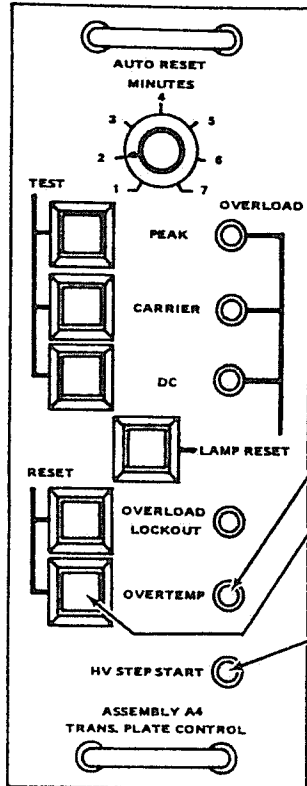
The power amplifier (peak tube, carrier tube and 18 KVDC plate supply) overload logic is a multiple reclose circuit. An overload in any of these three circuits will shut down the 18 KV plate supply. After a one second delay, the plate supply will automatically reclose. This will happen for three successive overloads in a pre-selected time interval. The fourth overload in that time interval will lock-out the plate voltage supply which will then have to be reclosed manually. The circuit which counts the number of overloads is automatically reset back to zero at the end of the preset time interval so that the overloads do not accumulate over a long time period.



Push this green button to reclose the 18 KV plate supply after lockout. It will turn off the red OVERLOAD LOCKOUT LED. It will not turn off the individual PA overload LEDs.

* These LEDs are not resettable by remote control. They can be extinguished only by pushing the LAMP RESET switch or by a momentary loss of primary power. Provision is made for 12 volt DC battery memory on these LEDs.

ASSEMBLY 2A4 (Continued)



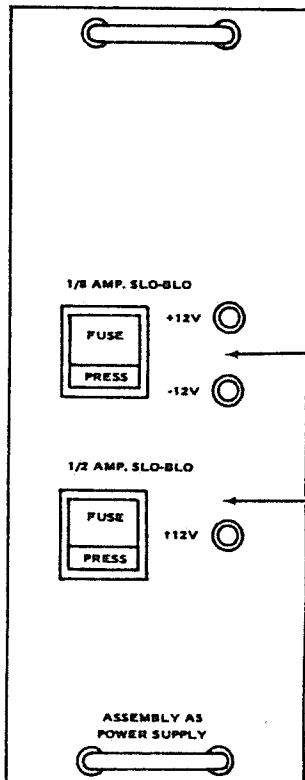
This red LED will light when the bi-metal thermo-switch located in the carrier tube exhaust air chimney operates. The transmitter HV plate supply will shut off at the same time. The LED cannot be turned off nor can the plate supply be reclosed until the thermoswitch cools enough for its contacts to close.

Push this green button to reclose the HV plate supply and turn off the OVERTEMP LED. If the plate will not come back on and the LED lights again when the button is released, it means that the thermoswitch has not cooled sufficiently.

Green LED lights 100 milliseconds after the PLATE ON button is pushed when the 3 phase vacuum contactor (4K1) closes. The RF excitation will come on at the same time the LED lights. The vacuum contactor shorts out the current limiting resistors in the HV plate transformer primary leads.

ASSEMBLY 2A5

This assembly contains three 12 volt DC regulated power supplies which come on as soon as the 3 phase primary power is applied to the transmitter.



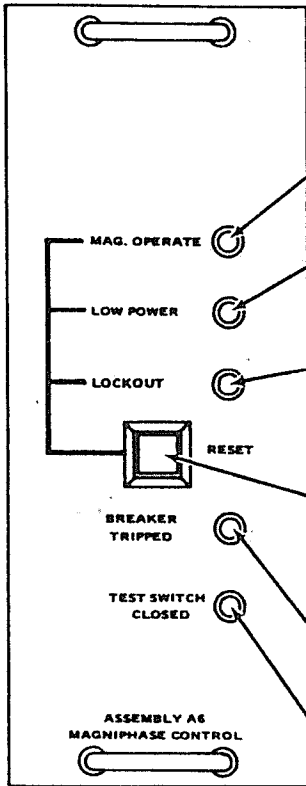
1/8 amp slo-blo fuse and green LEDs for ± 12 volt split supply. Remove fuse by pressing with thumb at point indicated.

1/2 amp slo-blo fuse and green LED for +12 volt, 1 amp control supply. Fuse removed same as above.

NOTE:

These supply voltages are metered on TEST METER 2M2 when the meter selector switch is in positions 8, 9 or 10.

ASSEMBLY 2A6



Red LED lights and stays on after magniphase operation.

Red LED lights when transmitter is automatically switched to low power because of four magniphase operations in a 2 minute time interval.

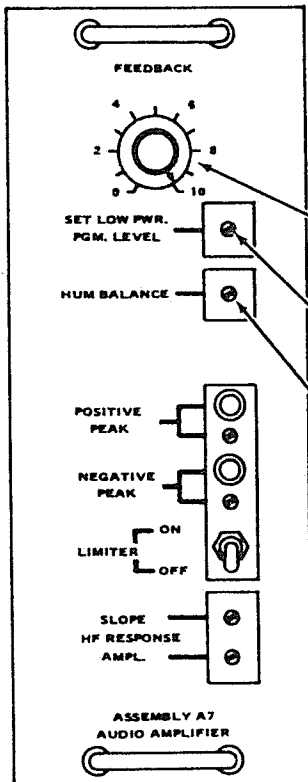
Red LED lights when transmitter plate voltage shuts down and stays off because of four magniphase operations in 2 minute time interval after having been automatically reduced to low power.

Push green button to turn transmitter plate voltage back on after magniphase lockout. The transmitter will come back on at low power and must be manually restored to full power. This RESET button will also extinguish the three red LEDs above it.

This red LED lights when plate breaker 2CB11 is tripped.

This red LED lights when the link switch which grounds the carrier tube screen grid is set to the test position.

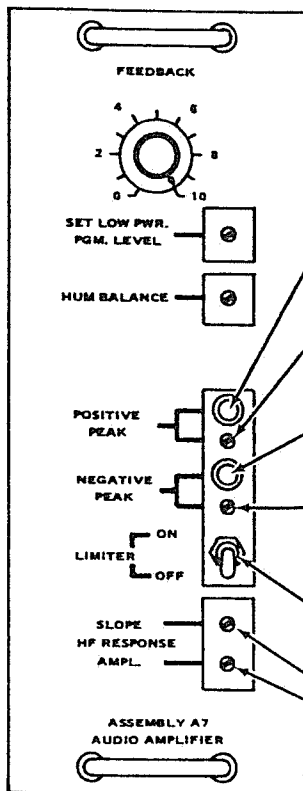
ASSEMBLY 2A7



Potentiometer adjusts amount of negative feedback applied to audio amplifier. It is normally set fully clockwise.

10 turn trimpot sets input program level on low power to match the level at full power.

10 turn trimpot is adjusted to minimize 120 cycle residual hum on carrier. The adjustment is made with the aid of a noise and distortion meter.

ASSEMBLY 2A7 (Continued)

When peak limiter is turned on, this yellow LED will flash on when positive peaks of modulation exceed the established threshold.

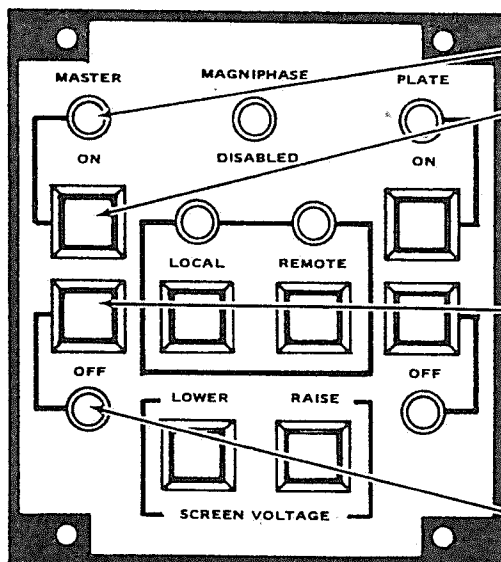
10 turn trimpot establishes the limiting threshold of the positive modulation peak. Turn clockwise to increase modulation peaks at a rate of about 1 dB per turn.

When Limiter is turned on, this yellow LED will flash on when negative modulation peaks exceed the established threshold.

10 turn trimpot sets the limiting threshold of the negative modulation peak. Turn clockwise to increase modulation depth at a rate of about 1 dB per turn.

Toggle switch turns peak limiter on or off.

These two ten-turn trimpots are used to adjust the shape of the audio high frequency response curve. Adjustment is by optimizing the shape of a high frequency square wave.

ASSEMBLY 2A8

MASTER ON LED lights green when MASTER ON switch (green button) is pushed. The blower will start. The filaments will come on and after the plate delay time, the low voltage and bias supplies will come on.

MASTER OFF (red button) when pushed will turn off the low voltage, bias supplies and filaments and keep the blower running for the amount of time specified on the 2A2 assembly.

MASTER ON LED will turn off and the MASTER OFF (yellow LED) will turn on.

ASSEMBLY 2A8 (Continued)

Push the LOCAL (yellow pushbutton) switch to prevent remote transmitter control.

NOTE: Below serial number 268, only remote plate control is prevented.

The red LOCAL LED will light when the LOCAL button is pushed. A red LED is used here as a reminder not to leave an unattended site in LOCAL control.

This red LED lights when the toggle switch on the magni-phase nulling unit (3A2) is in the DISABLE position. The red LED is a reminder not to leave the site with this protective circuit disabled.

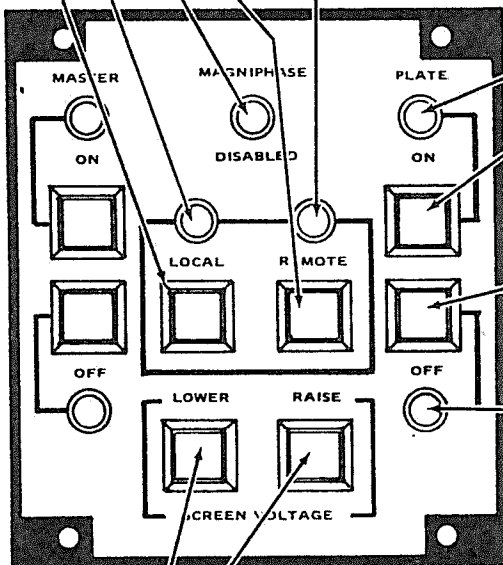
Push the REMOTE (yellow button) switch to enable remote transmitter control.

The green REMOTE LED will light when remote control is selected.

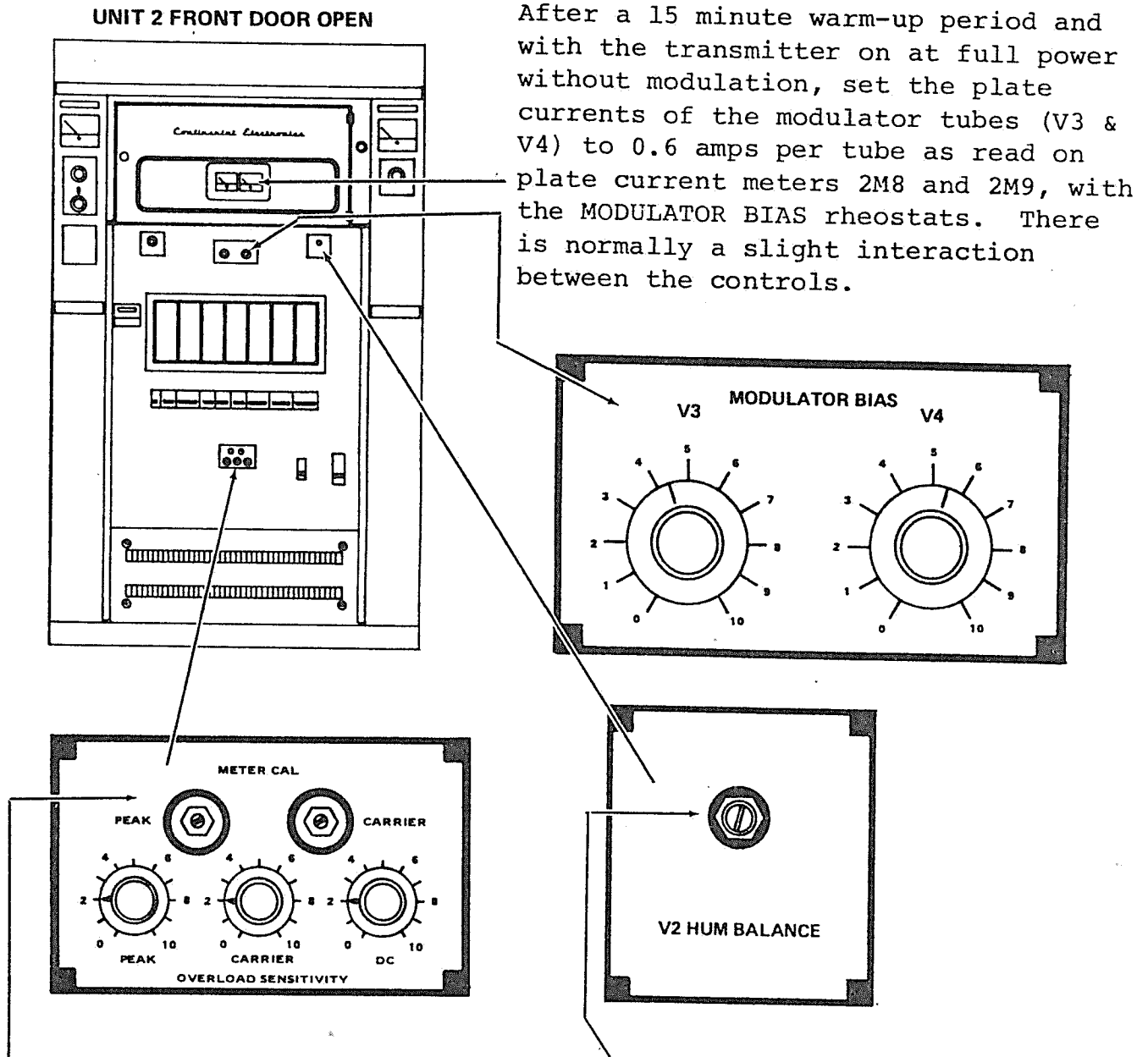
PLATE ON LED lights green when the PLATE ON switch (green button) is pushed. The 3 phase vacuum contactor (4K1) closes and RF excitation is applied 100 milliseconds later.

PLATE OFF (red button) when pushed will turn off the HV plate supply and remove RF excitation.

The yellow PLATE OFF LED will light when the PLATE OFF button is pushed. If the plate voltage is off and the PLATE OFF LED is not on, it means that a door is open or that some other interlock is holding the plate voltage off.



The screen voltage raise and lower pushbuttons (blue buttons) provide adjustment of the carrier tube screen supply voltage independent from the PWR. AMP. plate voltage.

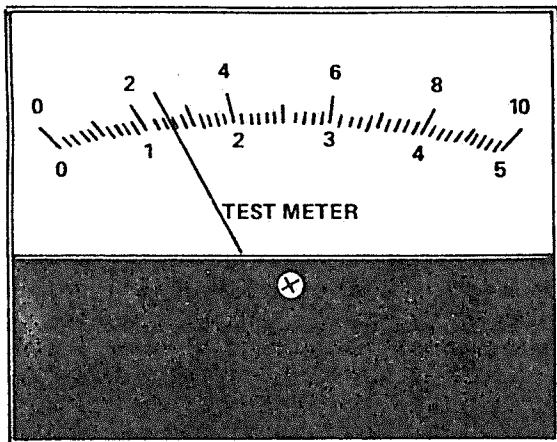


After a 15 minute warm-up period and with the transmitter on at full power without modulation, set the plate currents of the modulator tubes (V3 & V4) to 0.6 amps per tube as read on plate current meters 2M8 and 2M9, with the MODULATOR BIAS rheostats. There is normally a slight interaction between the controls.

The peak and carrier METER CALIBRATE controls (two upper controls with shaft locks) are factory set with a 1% DC ammeter to provide accurate indication of the peak and carrier tube cathode currents as indicated on the unit 1 TEST METER (1M6). The three OVERLOAD SENSITIVITY controls are normally set at 2 which will accommodate very high average program modulation.

The V2 HUM BALANCE rheostat sets the electrical center of the filament of the 4-400C modulator driver tube (V2). This adjustment will minimize the 60 cycle residual noise on the unmodulated carrier as measured with a noise and distortion meter. This adjustment should be checked when the modulator driver tube is replaced. The control shaft should be locked after the adjustment.

Figure 4-6. Unit 2 Inner Panel Controls



I_D RF DRIVER 0-1 amp. This is the drain current of the output MOSFETs in the 2A1 OSC/Exciter assembly. Typical reading is .4 to .6 amp.

IPA GRID CURR 0-50 ma. Grid current of the 4-400C IPA tube. Typical reading is 15 to 20 ma.

28V SUPPLY. Typical is 26.5-28V.

I_C AUDIO AMP 0-100 ma. This is the collector current of the output transistor (Q4) in the 2A7 audio amplifier assembly which is set to 36 ma. It may drift up to 40 ma and down to 35 ma.

V_{CC} AUDIO AMP 0-500V. This is the collector supply voltage for Q4 in the 2A7 assembly which is zenered down to +120V. Typical is 115 to 125 volts.

I_K AUDIO DRIVER 0-100 ma. This is the cathode current of the 4-400C modulator driver. Typical reading is 65-70 ma which is set by screen voltage resistor 2R7.

FEEDBACK RECT 0-10 ma. This is the emitter current of Q6 in the 2A7 audio amplifier assembly. Typical reading is 2.2-2.7 ma.

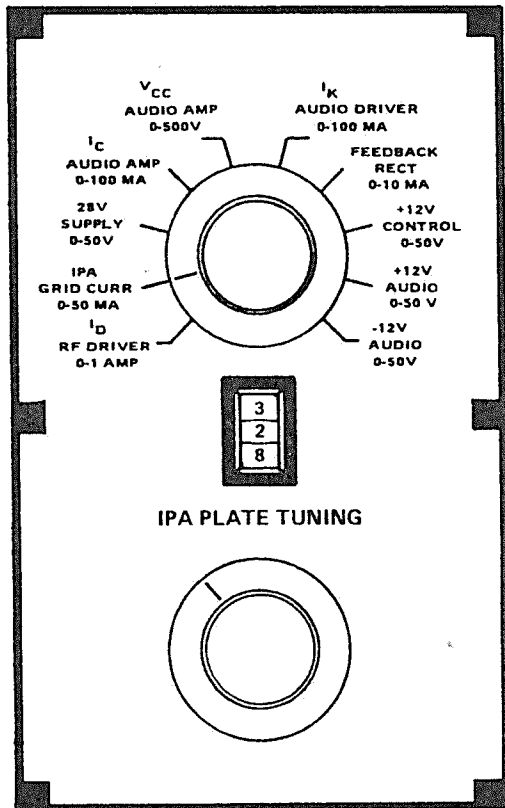
+12V CONTROL 0-50V. This is the regulated 12 volt 1 amp control

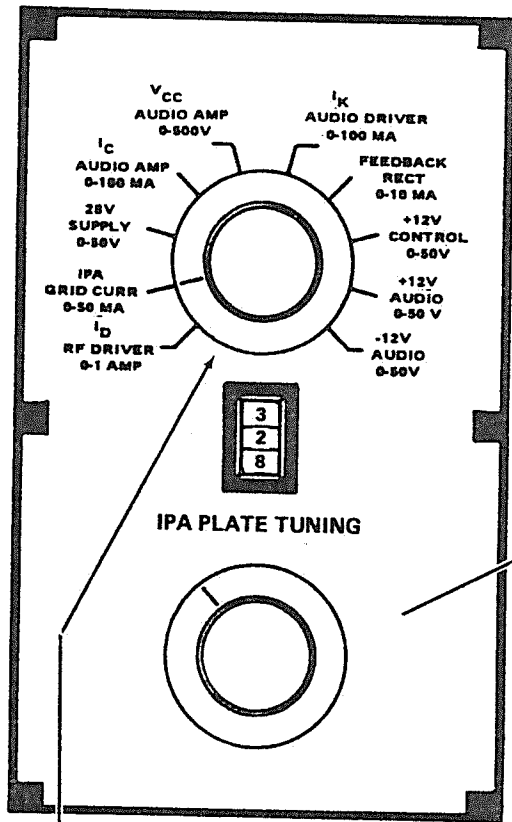
supply in the 2A5 assembly. Typical reading is 11.5-12.5 volts.

+12 AUDIO 0-50V. This is the positive side of the split 12 volt regulated supply in the 2A5 assembly. Typical reading is 11.5-12.5V.

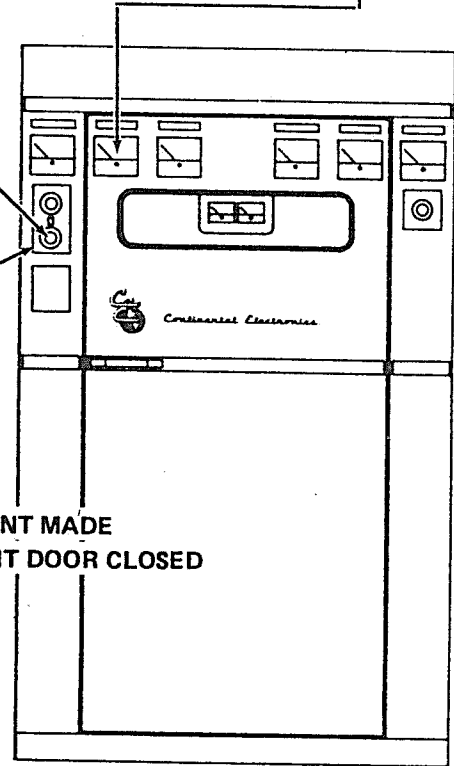
-12V AUDIO 0-50V. Negative side of the split supply. Typical reading is 11.5-12.5V.

Figure 4-7. Unit 2 Test Meter Position





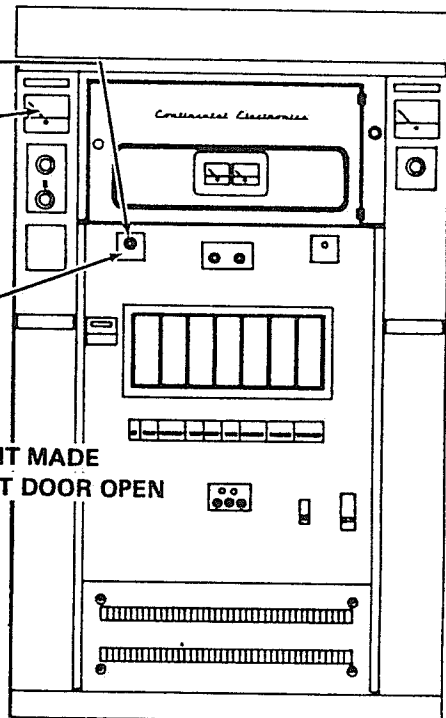
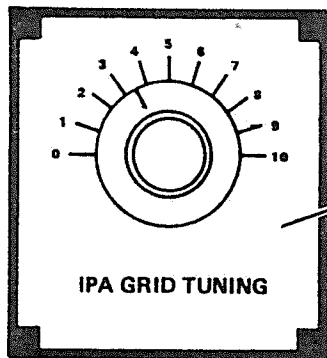
Adjust IPA PLATE TUNING for MINIMUM IPA cathode current as indicated on IPA CATHODE CURRENT meter 2M2.



ADJUSTMENT MADE WITH FRONT DOOR CLOSED

UNIT 2

With the test meter selector switch set at second position (IPA Grid Curr 0-50 ma.) tune IPA GRID TUNING control for a MAXIMUM indication on TEST METER 2M1.



ADJUSTMENT MADE WITH FRONT DOOR OPEN

The RF Driver Drain Current (position 1 on meter selector) will maximize at the same point.

Figure 4-8. Unit 2 Tuning Controls

The TEST METER transfer switch operates in conjunction with LM6. Typical readings are: (at full power and without modulation)

I_k PEAK 0-5 amp - .35 to .45 amp

I_k CARRIER 0-10 amp - 3.8 to 4.0 amp

The FILAMENT VOLTMETER switch operates in conjunction with LM5. Typical reading in either position is 9.4 to 9.6 volts.

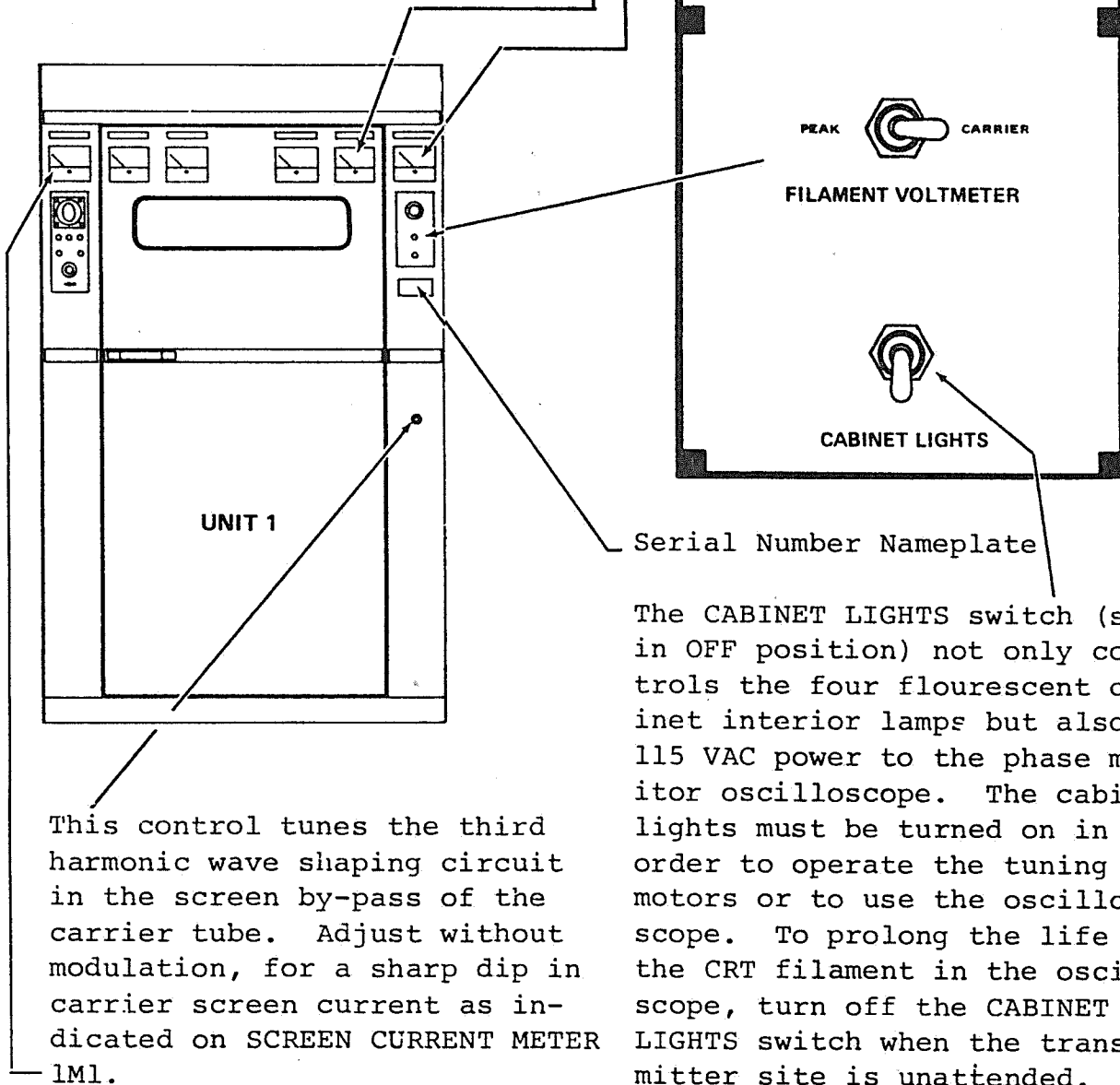
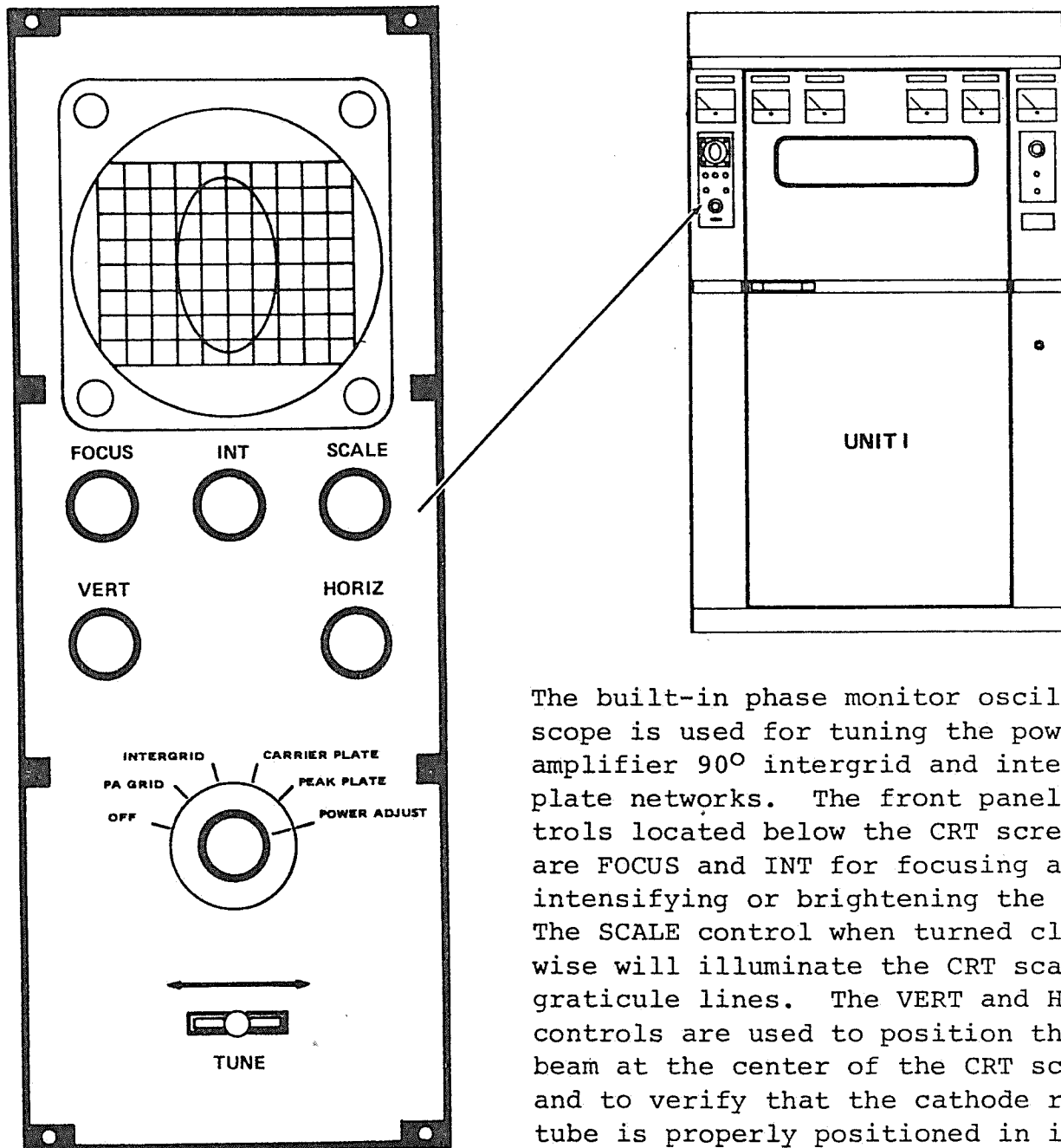
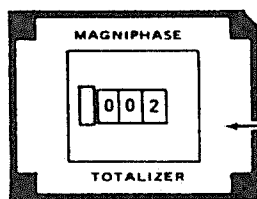
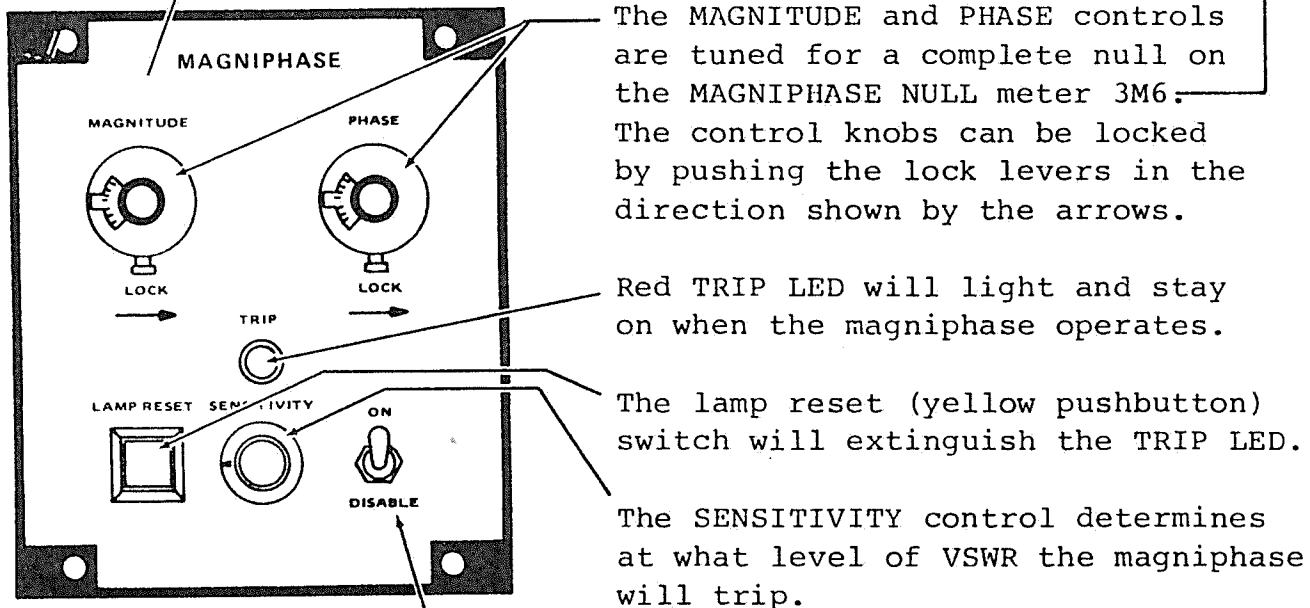
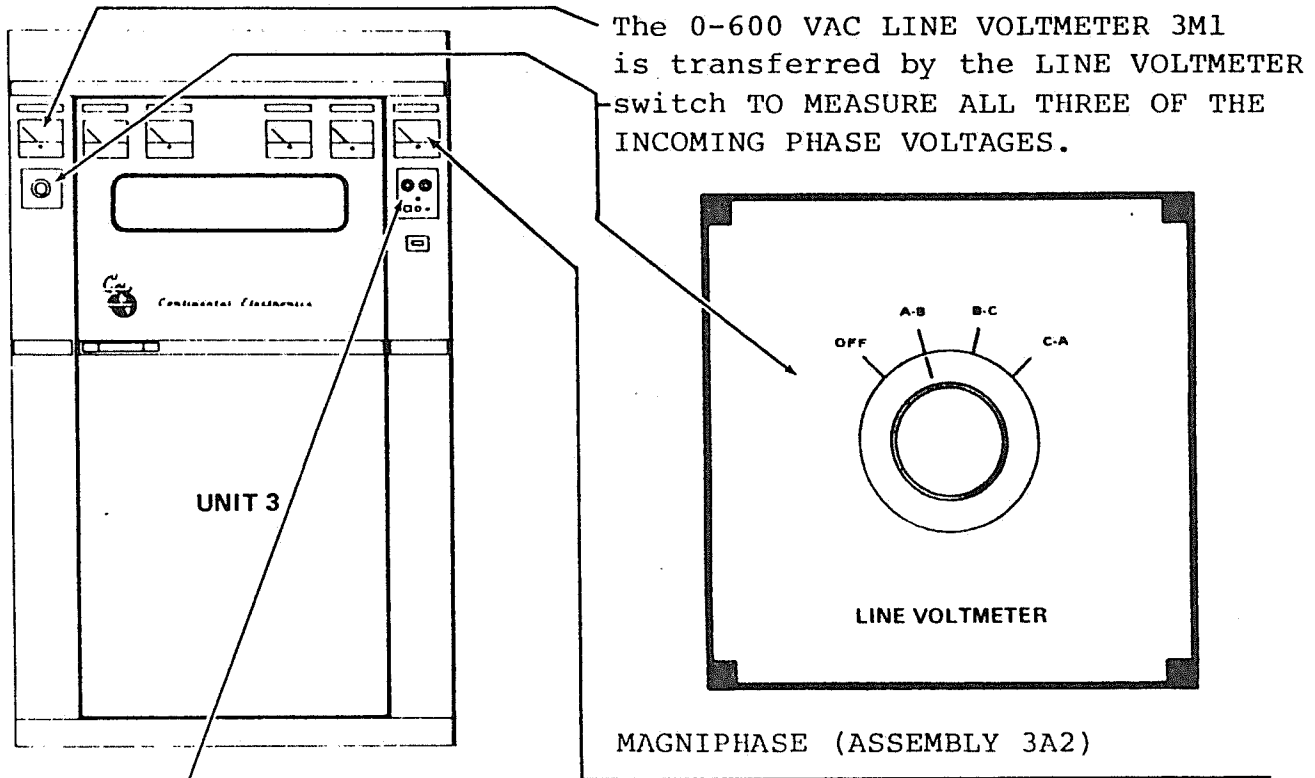


Figure 4-9. Unit 1 Controls



The built-in phase monitor oscilloscope is used for tuning the power amplifier 90° intergrid and inter-plate networks. The front panel controls located below the CRT screen are FOCUS and INT for focusing and intensifying or brightening the beam. The SCALE control when turned clockwise will illuminate the CRT scale graticule lines. The VERT and HORIZ controls are used to position the beam at the center of the CRT screen and to verify that the cathode ray tube is properly positioned in its socket by noting that the beam moves vertically and not at an angle when the VERT control is turned. The tuning selector switch will connect the RF voltage samples from the peak and carrier grid and plate circuits to the CRT deflecting plates appropriate to the position selected and will also connect the tuning motor which will affect the scope display to the TUNE lever switch. An astigmatism control (not shown) is located on the rear panel and is factory set to provide best edge focus. The line fuse is also located on the rear panel.

Figure 4-10. Unit 1 Oscilloscope



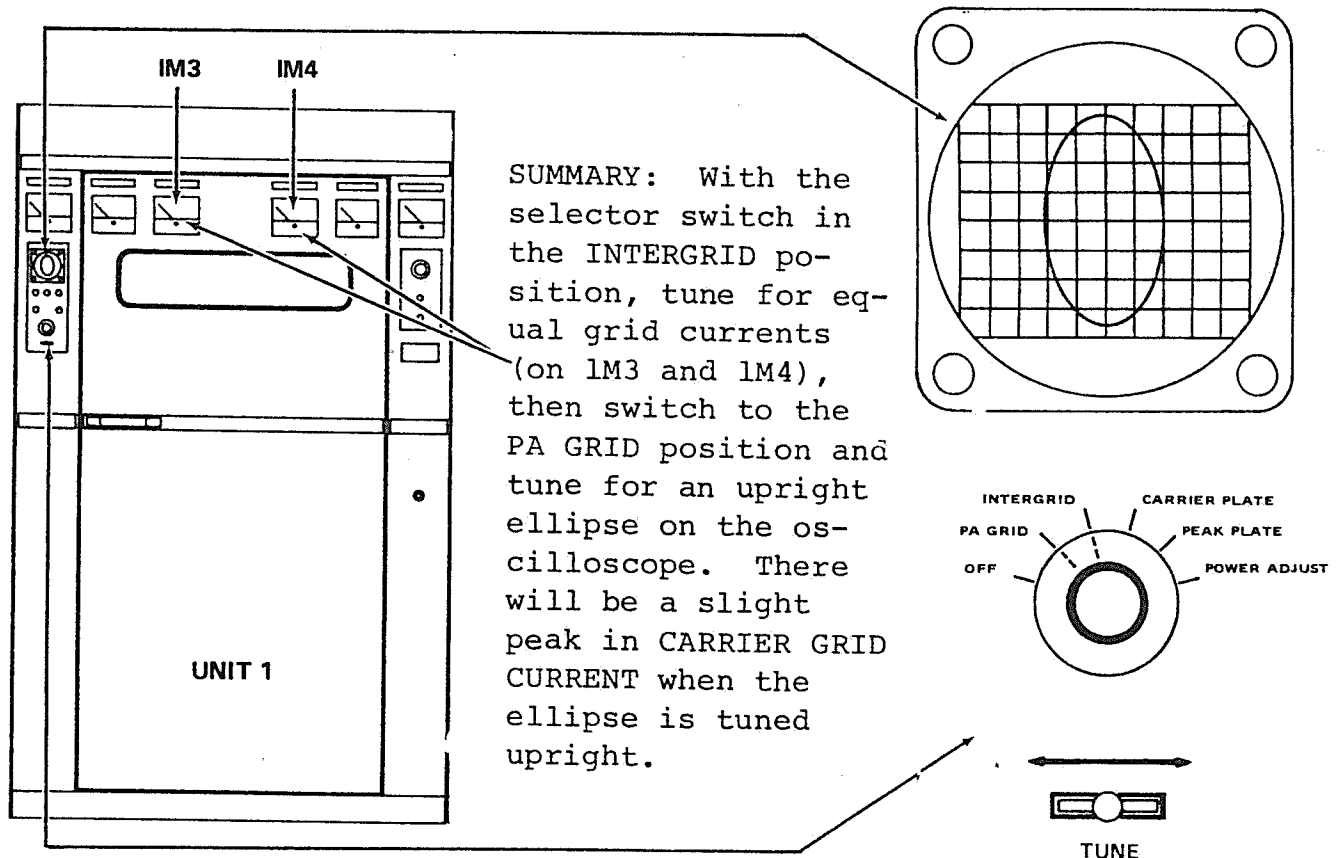
This toggle switch is used to disable the trip circuit while nulling or setting sensitivity.

Optional electro-mechanical counter totalizes up to 999 magniphase operations. It can be manually reset to zero at any time.

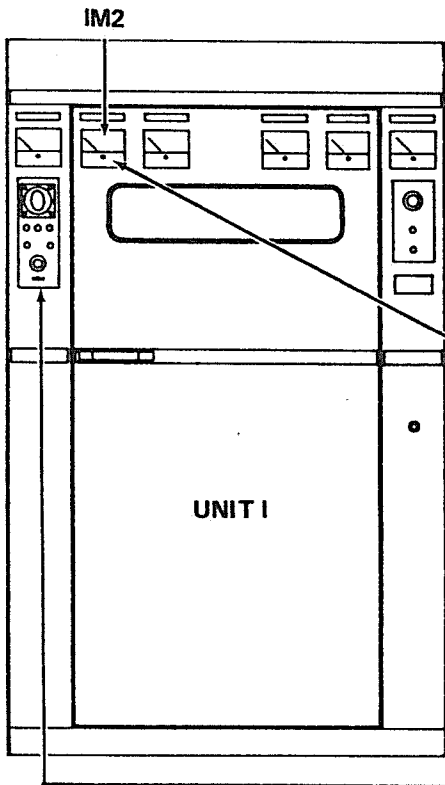
Figure 4-11. Unit 3 Controls

4-25. TUNING THE POWER AMPLIFIER GRID CIRCUIT

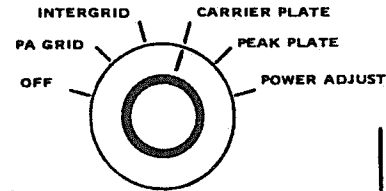
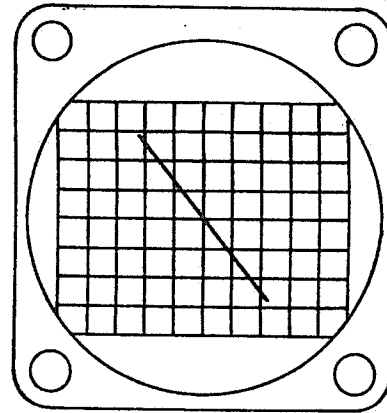
Proper 90° phasing of the power amplifier grid circuit is indicated by the vertically oriented ellipse on the oscilloscope when observing on either the PA GRID or INTERGRID positions of the tuning selector switch. The peak and carrier tube grid currents are normally made equal at about 150 ma per tube as indicated on the grid current meters IM3 and IM4. These conditions of equal grid current and 90° phasing are obtained by first switching to the INTERGRID position on the tuning selector and operating the TUNE lever switch while watching the GRID CURRENT meters IM3 & IM4. One direction of the TUNE switch will increase the PEAK GRID CURRENT (IM3) while decreasing the CARRIER GRID CURRENT (IM4). The other direction on the TUNE switch will reverse this action. The 90° upright ellipse will also lean to the right or left as the grid currents are going up and down indicating improper phasing. After obtaining equal grid currents on the intergrid tuning position, switch to the PA GRID position and tune for the upright ellipse. The grid currents will change slightly while tuning the ellipse upright in the PA GRID position which may necessitate a slight retuning of the INTERGRID circuit. The final adjustment should be the setting of the 90° phasing in the PA GRID tuning position.



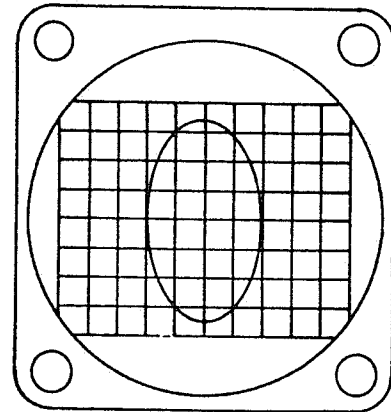
4-26. TUNING THE POWER AMPLIFIER PLATE CIRCUIT



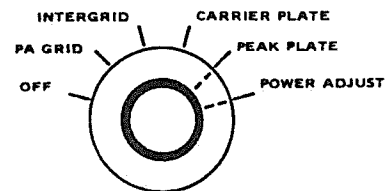
With the tuning selector switch in the CARRIER PLATE position tune for a closed diagonal line concurrent with a dip in TOTAL PLATE CURRENT as indicated on IM2. If the dip doesn't exactly correspond with the closing of the line, tune for the closed line which indicates the 180° phase comparison of carrier tube RF grid and plate voltage.



Proper 90° phasing of the power amplifier plate circuit is indicated by the vertically oriented ellipse on the oscilloscope when the tuning selector switch is in either the PEAK PLATE or POWER ADJUST positions. With the selector switch in the PEAK PLATE position, the ellipse will lean either left or right when the TUNE switch is operated and will change much slower than was noticed with grid circuit tuning. Proper tuning is with the ellipse upright.

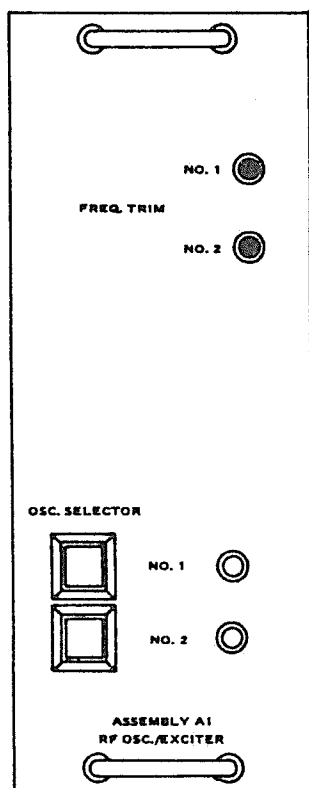


With the selector switch in the POWER ADJUST position, the 90° plate phasing pattern will be displayed and operation of the TUNE switch will raise or lower the output power by raising or lowering the plate voltage and carrier tube screen voltage. The ellipse will get larger or smaller as the power is raised or lowered but will not change its upright orientation. Push the TUNE switch to the right to raise power and left to lower power.



4-27. DESCRIPTION OF RF AND AUDIO CIRCUITS

RF OSCILLATOR/EXCITER MODULE (2A1) - (See Figure 4-12)



The OSCILLATOR/EXCITER assembly consists of the following circuits:

- a) Circuits for generating the carrier frequency from ovenless high frequency crystals.
- b) A circuit for conditioning external RF drive signals to CMOS square wave level.
- c) A circuit for gating the RF excitation on or off consistent with external commands.
- d) A power amplifier for driving the 4-400C IPA stage.

The carrier frequency is generated by an ovenless crystal which oscillates at from 4 to 10 times higher than the transmitter output frequency. The crystal is generally in the range of 5 to 7 Megacycles. The circuit is the MCL2061L TTL package. The SN7493 and SN7476 frequency dividers are also TTL and the complete circuit is operated from +5 volts which is zenered down from the +12 volt regulated supply. Two complete oscillator circuits are provided. The No. 2 oscillator is a complete duplicate of the No. 1 including the dividers and the 5 volt zenered supply. Selection of the No. 1 or No. 2 circuit is either by front panel push-button (2A1S1 or 2A1S2) or by remote control. The selector switches operate latching relay 2A1K1 which transfers the +12 volt supply to either the No. 1 or No. 2 zener circuit. The same contacts on 2A1K1 light LEDs that indicate which circuit is in use. The outputs of both oscillator circuits are fed to the SN7400 active combiner chip U7 which is operated from a separate 5 volt zenered supply. This circuit provides a single output from either of two sources without mechanical switching. The output is a 4 volt P-P square wave on carrier frequency. Each crystal is supplied with an air variable trimming condenser for setting the exact carrier frequency.

NOTE

When making this adjustment be sure to use an insulated tuning tool since the slot on the condenser rotor is in the RF circuit. The total range of the condenser may result in several hundred cycles of frequency change, so make the adjustment slowly.

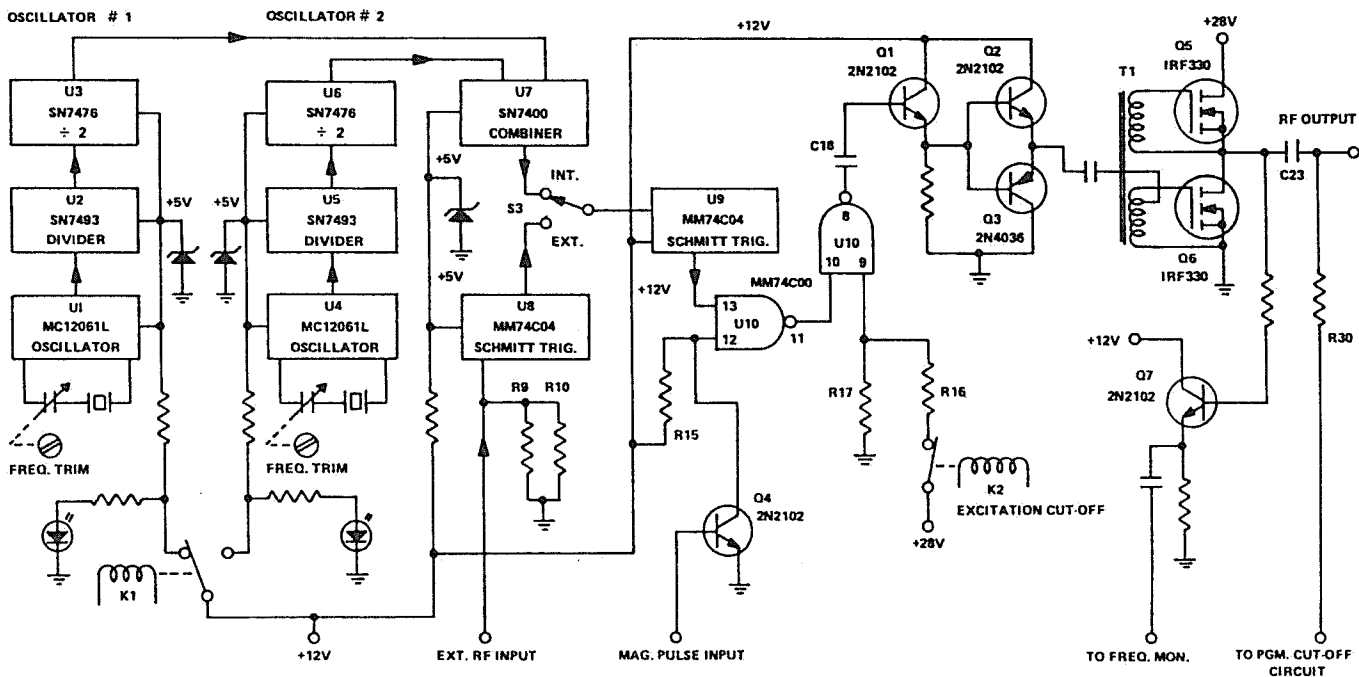


Figure 4.12 Simplified Schematic of Oscillator/Exciter Assembly

Provision is made for using an RF source other than the built-in crystal oscillator. This might be a high stability synthesizer, stereo exciter or utility load management device. The external source is fed via 50 ohm coaxial cable to 2TB1-54 and 2TB1-55 (54 is shield ground) which is fed to terminals 1 and 3 on 2A1. Two 100 ohm resistors in parallel (2A1R9 & R10) provide the necessary 50 ohm termination. The RF level from the external source should be from 2 to 6 volts P-P, either sine or square wave. This is fed to a CMOS Schmitt Trigger U8 which is operating from the same 5 volt zenered supply as the active combiner U7. The output of U8 is therefore a 4 volt P-P square wave, regardless of the input level or waveshape.

The outputs of the crystal oscillator (from U7) and the external source (from U8) are fed to 2A1S3, the INTERNAL/EXTERNAL selector switch. The output of S3 feeds another CMOS Schmitt Trigger U9 which

transforms the 4 volt P-P RF signals up to 12 volt P-P CMOS level.

The output of Schmitt Trigger U9 feeds one input (Pin 13) of CMOS Nand Gate U10. The other input (Pin 12) of the Nand Gate is held at +12 volts through resistor R15. The output (Pin 11) will then be a replica (except for inversion) of the input. The positive going Magniphase pulse fed to the base of Q4 will saturate Q4 which pulls Pin 12 of the Nand Gate down to near zero volts, thereby cutting off the RF output from Pin 11 for the duration of the Magniphase pulse.

The output from Pin 11 is fed to another Nand Gate input (Pin 10) of U10. The other input of this Nand Gate (Pin 9) is held at +12 volts by the +28 volts across resistance divider R16-R17. When the +28 volts is removed, such as by dropping out the high voltage vacuum contactor or by operating the excitation cut-off circuit, Pin 9 of the Nand Gate goes to zero volts which cuts off the output from Pin 8.

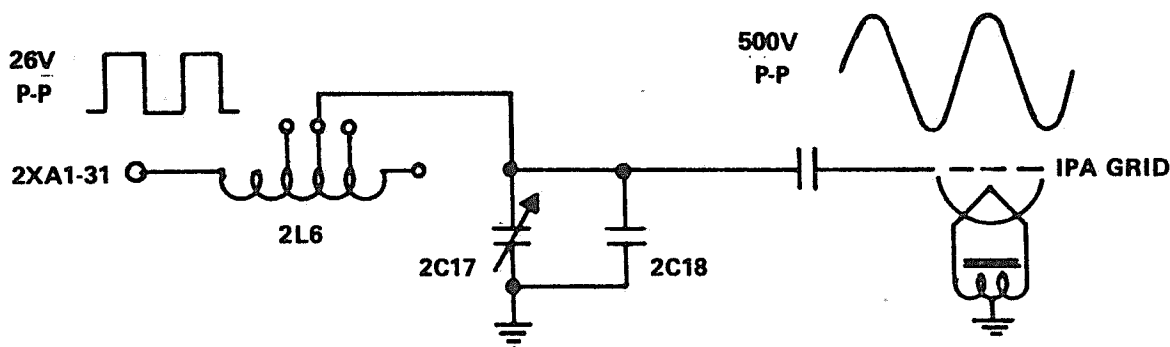
The RF output from U10 (Pin 8) is capacitively coupled to the base of emitter follower Q1 through C18. Q1 is a buffer stage between the CMOS output of U10 and the Complementary Symmetry Pre-Driver Q2 and Q3. Q1, Q2 and Q3 are all operated from the +12 volt supply.

The power output stage consists of power MOSFETs Q5 and Q6 in a totem pole configuration. Gate drive of proper amplitude and polarity is provided by the broadband Ferrite Transformer T1. The lower MOSFET (Q6) gets drive from the primary side of T1 with a slight voltage step-up due to auto-transformer action. Upper MOSFET Q5 receives the same drive amplitude but in opposite polarity from the secondary of T1. The +28 volt regulated supply provides drain voltage for the MOSFETs.

The output from the center point of the totem pole (drain of Q6) is a 26 volt P-P square wave which is fed through DC blocking condenser C23 out to terminal 31 of the PC board. It is then fed through a coupling network to the IPA grid. The output is also fed through a resistance divider and buffer transistor (Q7) to provide drive for a frequency monitor. Another sample of the output is taken from C23 through R30 to feed the program cut-off circuit in the audio amplifier. This operation of this circuit is covered in the description of the Audio Amplifier Module (2A7).

4-28. INTERMEDIATE POWER AMPLIFIER (IPA)

As explained in the description of the RF Exciter Module (2A1), the RF Output Stage is a totem pole arrangement of power MOSFETs. The output waveform is a 50% duty cycle square wave on the carrier frequency with a Peak-to-Peak amplitude of 26 volts. This square wave is fed out of 2A1 into an "L" Network consisting of series inductor 2L6 and shunt capacitance 2C17 (IPA GRID TUNING) in parallel with 2C18 (which is a frequency determined part). This network transforms the 26V P-P square wave up to 500V P-P sine wave to drive the grid of the 4-400C IPA tube.



When 2C17 (IPA GRID TUNING) is adjusted to maximize the IPA grid current, the circuit is resonated and so only a fundamental (sinusoidal) current flows in the network. This current maximizes at resonance and decreases on either side of resonance. The inductive input of the network prevents the flow of the odd harmonic currents of the square input waveform so that as the circuit is tuned through resonance, the loading on the Exciter output stage is maximized at resonance and decreases on either side. The DC drain current of the MOSFET totem pole is proportional to the fundamental RF current (the sinusoidal component) in the network and will therefore also maximize at resonance and decrease on either side. Because of this property of the coupling network (inductive input) no amount of mistuning can damage or overheat the MOSFETs. They are also immune to open or short circuit on the Grid side of the network since either condition would reduce the drain current to zero. The transformation ratio of the "L" coupling network is Factory set to provide a power output of from 12 to 15 watts to drive the IPA grid circuit. MOSFET efficiency is about 90% regardless of tuning or power output so that dissipation per device is always less than one watt.

IPA grid bias is a combination of fixed and grid leak bias. The fixed bias is set at about -125 volts by the slider on 2R2 in the bias supply bleeder.

NOTE

This adjustment is made with the H.V. PLATE and RF off. When the Transmitter is on at full power the fixed bias will increase from -125V to about -175 volts because of PA grid current flow in the bias bleeder.

The grid leak bias is developed by the DC grid current flowing through the grid loading resistors 2R42.1 - 2R42.4. The total resistance of 2R42 is 3000 ohms so that 15 ma of grid current will develop 45 volts of grid leak bias. Normal grid current is between 15 and 20 ma with MOSFET drain current between 400 and 600 ma.

Screen voltage for the IPA tube is set at about +500 volts by the slider on 2R6 which is in the bleeder network of the +750V Screen Supply.

NOTE

Since the +750 volt Supply is variable in output voltage the IPA screen voltage must be set when the +750 volt Supply is at its normal full power setting as indicated on the CARRIER SCREEN VOLTAGE meter (2M4). The slider on 2R6 can be set at +550 volts with RF and Plate off and will drop about 40 to 50 volts when the Transmitter is turned on.

Plate voltage for the IPA is taken from the +3000 volt Supply. The plate RF output network is a parallel resonant circuit consisting of 2L9 in parallel with IPA PLATE TUNING condenser 2C28. The RF output to the PA grid circuit is fed off a tap near the ground end of 2L9. The loading of the IPA plate circuit is adjusted by the position of the tap. Loading is increased by raising the tap up from the ground end and vice versa.

The proper amount of PA grid drive is obtained with the IPA plate circuit loaded to about 800 watts DC input power. IPA plate efficiency is about 70% which means that 560 watts is delivered to the PA grid circuit and 240 watts is dissipated as heat at the IPA plate. The 4-400C IPA tube has a plate dissipation of 400 watts and will begin to glow red in spots at about 250 watts dissipation. At 400 watts dissipation the plate will glow a bright cherry red all over. It is therefore quite normal for the IPA tube to show some anode color.

NOTE

During reduced power operation the IPA anode will show a full red glow. Plate dissipation rises to about 300 watts in this mode of operation because of the reduction in IPA screen voltage which reduces the plate efficiency.

The product of IPA cathode current (2M2) and 3000V supply voltage will equal about 900 watts at full power. The cathode current includes about 20 ma grid current and 20 ma screen current along with the plate current. In later model transmitters the 3000 volt supply voltage has been reduced to about 2700 volts so that IPA cathode current will be about 330 ma rather than 290-300 ma in transmitters with a 3100 volt supply.

4.29. TUNING THE IPA STAGE

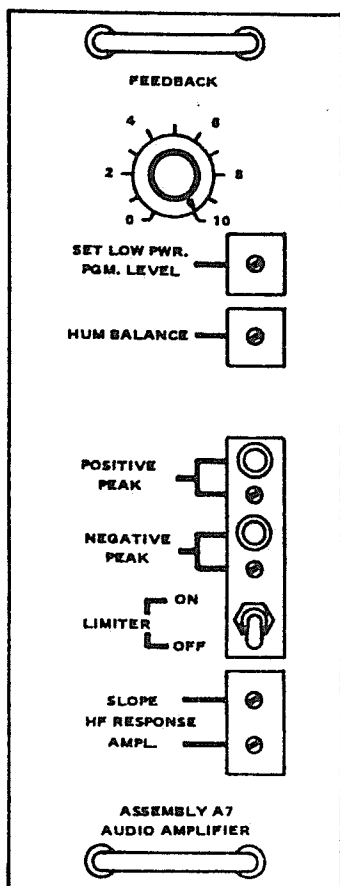
The IPA grid circuit is tuned by adjusting the IPA GRID TUNING control (2C17) for maximum grid current as indicated on TEST METER 2M1 with the Meter switch in the IPA Grid Curr 0-50 ma position. It will be noted that the MOSFET drain current (I_d RF Driver 0-1 amp on test meter switch) will peak up with the grid current.

The IPA plate circuit is tuned by adjusting IPA PLATE TUNING control (2C28) for minimum IPA cathode current as indicated on cathode current meter 2M2. It will be noted that the PA grid currents (1M3 and 1M4) will maximize at about the same point as minimum IPA cathode current. The difference between the tuning point of minimum IPA cathode current and maximum PA grid current will be less than one-tenth turn of the IPA PLATE TUNING control. Tune for minimum IPA cathode current.

NOTE

The average life expectancy of the 4-400C IPA tube is about 15,000 hours. A gradual loss of filament emission toward end of life will first become evident as a gradual reduction in PA grid current (1M3 & 1M4) and a drop-off in IPA cathode current (2M2). A reduction of 15-20% in PA grid current will have a detrimental effect on Transmitter performance so that when this is noted, it is time to put in a new IPA tube.

AUDIO AMPLIFIER MODULE (2A7)



The Audio Amplifier Assembly consists of the following circuits:

- a) Audio amplifier which transforms the balanced 600 ohm program feed to single ended with amplification from +10 dBm to 65 volts Peak-to-Peak.
- b) Provision for the mixing of negative feedback and hum cancelling signals into the audio amplifier.
- c) Provision for shaping the frequency response curve of the audio amplifier.
- d) A circuit for cutting off program audio in the absence of RF excitation.
- e) A Peak Limiter with controls for adjusting the limiting threshold for both positive & negative peak.
- f) An adjustable attenuator for setting program audio level for a low power operation.
- g) An envelope detector for deriving the negative feedback signal.

The balanced 600 ohm program feed comes in on Pins 15 & 16 on 2A7 and is terminated with a 17 dB, 600 ohm balanced "H" pad (R1 thru R6). Op amp U1 (NE5534N) operates as a Balanced Input Single Ended Output Amplifier with a gain of 19 dB. Its output level is therefore 9 volts Peak-to-Peak (2 dB above the +10 level of 7 volts P-P). U1 is powered from the +12V and -12V supplies and has a trim-pot (R12) for setting the output offset to zero volts DC.

NOTE

The output offset adjustment is made by connecting either a 'scope probe, DVM or multimeter having resolution down to + 10 millivolts from the lower end of R11 (which connects to output Pin 6 of U1) to ground. Adjust trimpot R12 for zero volts DC.

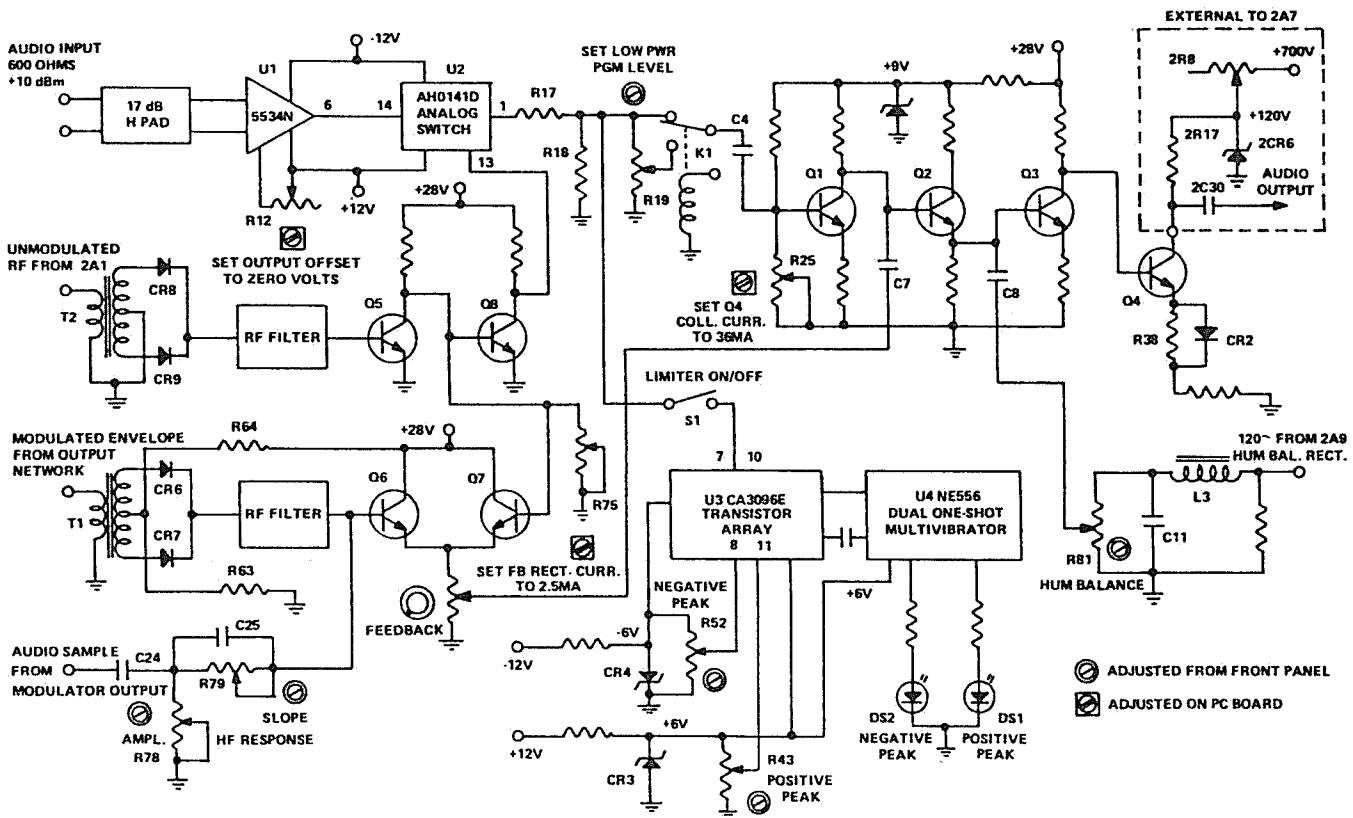


Figure 4.13 Simplified Schematic of Audio Amplifier

Op amp U1 has a typical Common Mode Rejection of 60 to 70 dB so that RF and/or 60 cycle hum which is induced in phase into the balanced input does not appear on the output (Pin 6).

4-30. ANALOG SWITCH

The output of U1 is fed directly into the input (Pin 14) of Analog Switch U2 (AH0141CD). U2 is also powered from the +12V and -12V supplies so that its input and output DC levels are at zero volts. The switch functions as a single pole single throw contact and is controlled (either on or off) by the voltage applied to Control Pin 13. When Pin 13 is positive, the switch is closed and audio fed into Pin 14 will come out of Pin 1 unchanged either in DC level or Peak-to-Peak audio level. With Pin 13 at zero volts DC (ground potential), the switch opens and no audio comes out of Pin 1. The DC level at Pin 1 stays at zero volts.

The Analog Switch functions to remove Program audio in the absence of RF excitation since without RF output the negative feedback signal would disappear, thereby raising the Modulator drive by 9 dB which would cause a Modulator overload. U2 operates at the

same speed as the Magniphase cut-off pulse (within microseconds) and since there is no DC output level change with switching there are no switching transients generated.

The Control Signal (on-off signal) for U2 is derived from the RF excitation signal in the following manner. A sample of unmodulated RF is taken from the 2A1 (RF Exciter) Module and fed via coax cable to Pin 5 on 2A7. Pin 5 feeds the primary of a toroidal RF transformer (T2) having a center-tapped-to-ground secondary. Diodes CR8 & CR9 provide full-wave rectification of the RF signal. The DC output of the rectifier is fed to the base of transistor Q5 (2N2102) through RF filter C21-R73-C22. This DC level is sufficient to hold Q5 in saturation so that its collector-to-ground voltage is essentially zero. Q5 collector is direct coupled to Q8 base which puts Q8 into a non-conducting state. In this condition Q8 has +10 volts DC on its collector because of voltage division of R15 and R16 from the +28 volt supply. The collector of Q8 is direct coupled to the control pin of Analog Switch U2 so that with RF excitation, the +10 volts on Q8 collector turns on (or closes) the Analog Switch.

When RF excitation is off, Q5 has no base current and becomes non-conducting which by inversion puts Q8 into saturation, dropping its collector voltage to almost zero which turns off (opens) the Analog Switch.

4-31. PEAK LIMITER

The output (Pin 1) of the Analog Switch is direct coupled to voltage divider R17 & R18 which attenuates the 9 volt P-P output to 3.5 VP-P. The shunt operating Peak Limiter is connected through LIMITER ON-OFF switch S1 to the junction of R17-R18. The Limiter is a shunt operating device because it alters the voltage division of R17-R18 by shunting R18 with a low resistance upon the initiation of either positive or negative peak limiting. The effective amount of resistance reduction of R18 is established by the components within the Limiter circuit and will produce a 2:1 limiting ratio; that is, for every 2 dB increase in audio input level beyond the limit threshold, the output will increase only one dB. This is a fairly soft clip and for this reason the Limiter shouldn't be used solely for the purpose of generating Program asymmetry. If used in this manner, the onset of negative peak limiting would have to begin at about 85% modulation in order to generate 125% positive peak modulation. Generation of asymmetry is best left to the station processing chain with the Transmitter Limiter used only to take care of Processor overshoots.

The transistors used in the limiter circuit are contained within the CA3096E integrated circuit (U3). This consists of two PNP and three NPN transistors on a common substrate with separate connectors for each one, U3 is powered from the +12V and -12V supplies after zenering down to plus and minus six volts (Zener diodes CR3 and CR4). The emitters of an NPN and a PNP transistor (Pins 7 and 10) are tied to R18 (through S1) with their collectors connected through collector resistors R45 and R54 to +6V and -6V respectively. Base bias is obtained from divider R51, R52 and R53 (negative peak) fed to NPN (Pin 8) and R42, R43 and R44 (positive peak) fed to PNP (Pin 11). The limiting threshold is set by the base bias trimpots (R52 for negative peak and R43 for positive peak). Program audio at R18 (emitters of limiting transistors) is swinging positive and negative relative to zero volts (ground potential) and when peaks exceed the base-emitter bias, the transistors conduct to saturation which clamps the peaks at the pre-determined levels.

The other three transistors in U3 are used to amplify the collector currents of the limiter transistors and derive negative going pulses to feed the peak flasher circuit U4.

U4 (NE556) is a dual 555 timer with both halves connected as one-shot multivibrators. The time constants of R59-C18 for negative peak and R60-C17 for positive peak establish a 100 millisecond pulse length for each one-shot. The negative going random length pulses derived from U3 are fed to the trigger Pins 6 and 8 of U4. The 100 millisecond positive output pulses of U4 are fed to positive & negative peak flasher LED's DS1 and DS2. The 100 millisecond "ON" time of the LED's will give a bright, well defined indication of even very short duration limiting of peaks. Because of normal circuit component tolerances, the LED's will light from 0.2 to 0.5 dB beyond the limiting threshold.

NOTE

The positive and negative peak limiting thresholds may be coarse adjusted with sine wave modulation, but the final adjustment must be made with program modulation. This is because of the normal reduction of power amplifier plate and screen supply voltage due to regulation with sine wave tone modulation. The clip threshold controls are 10 turn trimpots so that fine adjustments can be made about 1/4 turn at a time while watching the flashers on the modulation monitor. The adjustment rate is about 1 dB

per turn near 100% modulation. Turn the trimpots clockwise to increase modulation. If it is desired to let the positive peaks go unlimited, turn the positive peak trimpot (R43) clockwise about five turns from the 100% mod limit point or until you can hear the overtravel limit spring clicking inside the trimpot. The 2A7 module will have to be removed and taken to a quiet room for this adjustment. Remember that even the best multiturn trim-pots can be rendered inoperative by excessive rotation beyond the overtravel limit. Excessive might be defined as 20 turns in the same direction on a 10 turn pot.

432. FOUR STAGE AUDIO AMPLIFIER

The peak limited audio output at the junction of R17-R18 is tied to the normally closed contacts of relay K1. In parallel with R18 is a voltage divider consisting of R19 & R20. R19 is a ten turn trimpot which is used to set the required program level for low power operation. When relay K1 is energized on low power selection, the attenuated audio output from the slider of R19 is transferred to the audio amplifier input at C4.

C4 blocks the positive bias voltage of Q1 from the DC ground potential at R18. The coupling time constant is so long that there is no degradation of amplitude or phase response down to 5 cycle sine wave. Q1 through Q4 is a DC amplifier which serves a number of purposes:

- a) It provides a slight low frequency phase compensation.
- b) It serves as a mixer for injecting the negative feedback and hum cancelling signals.
- c) It provides a slight pre-distortion or pre-stretching of the positive peak.
- d) It increases audio level sufficient to drive the 4-400C modulator driver.

The first amplifier transistor, Q1, is a common emitter stage with a negative feedback circuit connected from collector to base. This feedback network consisting of C5 and R28 provides 6 dB of feedback starting at about 20 cycles. Below 20 cycles the feedback de-

creases so that the stage response rises slightly at low frequencies. This compensates the decreasing amplitude response of the modulator and precisely corrects the low frequency phase response.

The base bias network of Q1 which consists of R22, R23 & R25 is adjustable. Having this adjustment on the first stage will set the proper operating conditions for the succeeding three stages (Q2, Q3 & Q4) since they are all direct coupled.

NOTE

The Q1 bias trimpot R25, is adjusted to provide a collector current of 36 ma for Q4. Q4 collector current is measured on test meter 2M1, position 4, labeled - I_C AUDIO AMP 0-100 ma. Clockwise rotation of trimpot R25 will increase the collector current at a rate of about 4 ma per turn. The 36 ma setting will vary by ± 3 ma with temperature variations. Current below 26 ma will limit the depth of negative peak modulation while current above 46 ma will limit positive peak headroom.

Summing of the audio output of Q1 with the negative feedback signal takes place at the base of Q2. Q2 is an emitter follower with base bias derived from the direct connection to Q1 collector. This base bias is blocked from the DC level of the feedback circuit by C7. The summed output from the emitter of Q2 is direct coupled to the base of Q3, a common emitter amplifier. The output from the hum cancelling circuit is fed also to the base of Q3 through C8-R37.

The output of Q3 is direct coupled to the base of Q4, a common emitter amplifier. The collector voltage for Q4 is zenered down to +120 VDC from the +750 volt screen supply and is metered on TEST METER 2M1, position 5, labeled - V_{CC} AUDIO AMP 0-500V. The Peak-to-Peak collector voltage swing of Q4 is about 65 volts at 100% modulation. Since there is one inverting stage (the 4-400C modulator driver) following Q4, the negative peak at its collector corresponds to the positive peak of the modulation envelope.

The output of the 3CX3000A1 Modulator stage will exhibit a positive peak compression of about 3% due to the non-linear nature of its connected load. To compensate for this, the peak is pre-stretched by the action of R38-CR2 in the emitter of Q4. The emitter current of Q4 flowing through R38 produces a voltage drop of 0.6 volts across CR2 which puts it on the verge of conduction. When the base of Q4

is driven negative, CR2 is non-conducting so that there is no change in stage gain or output collector waveshape. On the positive half cycle of base drive the emitter current increases and flows mostly through CR2 rather than R38. This change in emitter degeneration increases the stage gain slightly which stretches the negative peak of the collector output waveshape. 180° inversion by the Modulator Driver then results in proper symmetry of the Modulator output waveshape.

4-33. HUM CANCELLING CIRCUIT

The residual AM noise on the unmodulated carrier is due almost entirely to filament hum from the 4CX35000C PA tubes. With 60 cycle primary power, the noise component will be 120 cycle. The uncorrected noise level of the PA tubes is generally from 40 to 45 dB below 100% modulation. 9 dB of negative feedback will reduce this to 49 to 54 dB. In order to avoid having to use an unreasonable amount of feedback (up to 20 dB), the 120 cycle hum is cancelled by injecting into the audio amplifier a separately derived 120 cycle sine wave which is 180° out of phase and equal in amplitude to the filament hum.

This 120 cycle sample is obtained by fullwave rectification of the 60 cycle primary voltage at a low level. Hum Balancing Assembly 2A9 has provision for sampling any combination of the three incoming phases and stepping the voltage down from 230 to 16 volts. The 120 cycle sample is fed from 2A9 to Pins 21 & 22 on the 2A7 module.

Because of the high leakage reactance of the PA filament transformers, the residual filament hum lags the 230 volt primary voltage from which it is fed by about 30°. To compensate this, the sample derived from 2A9 is fed to a low-pass filter consisting of L3 and C11 on 2A7. The filter performs two functions. First, it retards the phase of the 120 cycle sample by 30° and second, it filters out the harmonic components of the sample which would otherwise add to the filament hum. The filter is terminated by trimpot R81 which is used to adjust the amplitude of the hum balancing signal.

NOTE

Because of the manufacturing tolerances of filter components L3 and C11, it is sometimes necessary to decrease the filter terminating resistance to obtain the proper phase shift. On some units a resistor will be paralleled across trimpot R81 on the back of the PC board to accomplish this. If L3 or C11 are

ever replaced, the noise level should be checked for complete cancellation of 120 cycle component and if necessary R81 should be paralleled with 330 to 680 ohms, 1/4 watt.

4-34. NEGATIVE FEEDBACK CIRCUITS

A sample of the Transmitter RF output envelope is taken from a tap on the static drain coil (3L7) in the output network. This sample is fed via coax cable to toroidal RF transformer 2A7T1 on the Audio Amplifier. The RF transformer has a center-tapped secondary to provide a common biasing point for the rectifier diodes and to allow for full wave RF rectification. The diodes (CR6 & CR7) are biased into conduction by the positive voltage applied to the center tap of T1 from the resistive divider R63 and R64 which is connected across the 28 volt supply. The biasing of the diodes prevents clipping distortion of the rectified negative peak of the envelope as the RF level falls below the 0.6 volt conduction threshold of the diodes. Full wave rectification provides better RF filtering for a given filter time constant than would half wave rectification.

The resistance-capacitance filter following the diodes consists of C19, R65 and C20 which not only filters out the rectified RF pulses but also shapes the demodulated audio output response curve. The filter constant of R65 & C29 causes the audio output to decrease at a rate of about 3 dB per octave starting below 1000 cycles. If this were to be applied as negative feedback to the Audio Amplifier, the resulting Transmitter response would be the complement of this (rising high frequency response). In order for the Transmitter response to be flat, the feedback rectifier response must also be flat. This is accomplished by taking a sample of the Modulator audio output, shaping its response curve for an increasing high frequency response and mixing it with the envelope rectifier output. The Modulator sample is derived from the resistive divider made up of 2R38 (10K ohm) and 2R39.1, 2R39.2 & 2R39.3 connected from the Modulator output to ground. The audio sample is fed through RF choke 2L11 to Pin 11 on the audio amplifier 2A7. It is then hi-pass R-C filtered by C24, C25, R77, 78, 79 & 80 on the amplifier board. The output is added to the envelope detector output at the junction of R66, R67 & R68.

The reason for this feedback mixing and response shaping is so that rectified output envelope feedback is used only to reduce low frequency noise and correct for low frequency distortion. Envelope feedback is seldom effective in improving distortion at high audio

frequencies because of the difficulties encountered in controlling the closed loop phase response caused by antenna bandwidth asymmetry. In many cases the bandwidth problem can cause a wideband envelope feedback circuit to operate too close to the edge of the stability margin and require either a decrease in feedback level or a reduction in high frequency response or both. In order to provide a fixed level (9 dB) of feedback with a predictable stability margin regardless of antenna bandwidth, the high frequency audio out of the envelope detector is attenuated and replaced by a sample of modulator output high frequency audio which has a constant and suitably shaped phase response curve.

435. ADJUSTING THE RESPONSE SHAPE

As noted earlier, the output of the overall feedback circuit (which includes the envelope detector and modulator sample combined) must have a flat frequency response. The output of the envelope detector has a fixed 3 dB per octave high frequency slope rate determined by the low-pass RC filter R65-C20. The complementary high-pass response curve of the Modulator output sample which is to be mixed with it is adjustable from the front of the 2A7 Audio Amplifier by the HF RESPONSE trimpots labeled SLOPE and AMPLITUDE. These controls are adjusted for a flat frequency response with the aid of a high frequency square wave.

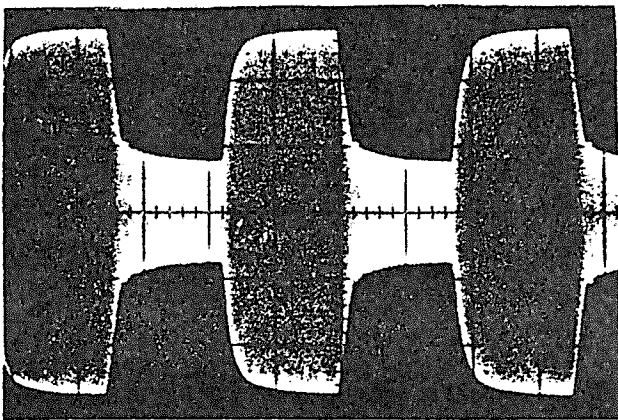
The adjustment is made with the transmitter on at full power and with the FEEDBACK control (2A7R75) in its normal (fully clockwise) position. The HF RESPONSE controls will have to be adjusted while watching the modulation envelope on an oscilloscope which can be placed in front of Unit 2. RF pickup for the oscilloscope can be taken from the modulation monitor samples on 2TB1-46 and 47 or 2TB1-48 and 49. Put the Unit 2 TEST METER selector switch in the FEEDBACK RECT 0-10 ma position. Modulate the transmitter with a 5000 cycle square wave at about 50% modulation.

NOTE

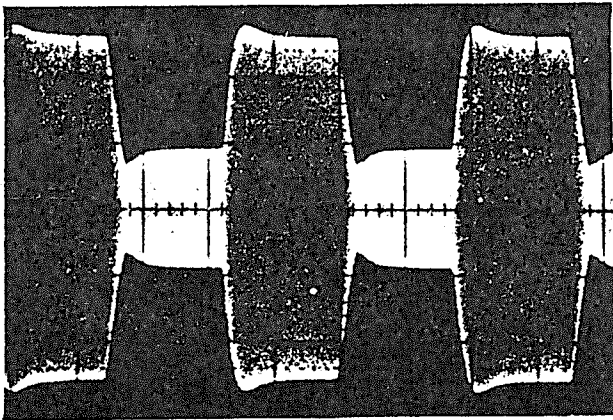
Since the input audio amplifier in the transmitter is direct coupled to the program line, the square wave generator must not have any DC on the output. The square wave should be 50% duty cycle and must swing equally positive and negative above and below zero volts (DC ground). If the generator has an output offset control, use it for this purpose.

The feedback rectifier current should be 2.5 MA (± 0.3 MA) and should be noted because the response trimpots when adjusted, will change the feedback rectifier current. The transmitter frequency and phase response is optimum when the 5KC square wave is free of tilt, ramp up or overshoot. The AMPLITUDE adjust trimpot should never have to move more than 1 turn (10 turn trimpot) from factory setting. The SLOPE trimpot will have the greatest effect on the square wave flat top.

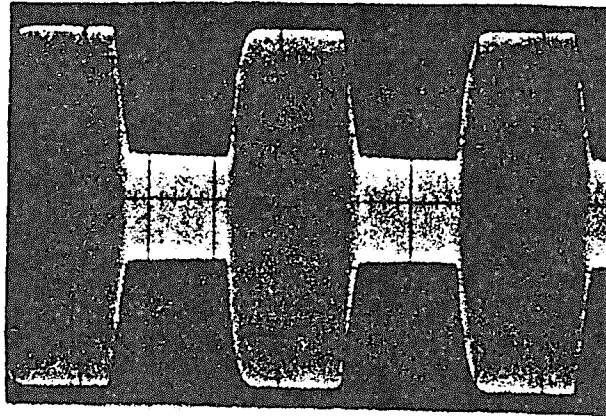
Observe the modulation envelope on an oscilloscope and if the square wave shows ramp-up, turn the SLOPE control clockwise about a half turn.



Conversely, if the envelope shows tilt, turn the SLOPE control about a half turn counterclockwise.



The final setting is one which gives a flat top free of ramp-up or tilt and with good rise time. There will be a slight ringing after the negative peak leading edge which is due to the inductance of 1L15 in the carrier amplifier screen circuit. The ringing, is not noticeable on the positive peak because of the damping effect of the large screen current and modulator plate current. On the negative peak the single ended modulator is swinging to plate current cut-off and the carrier screen current is zero so that there is very little damping effect.



Operation into a dummy load or into a very good antenna load will give results similar to the above waveform. Loads having poor side-band VSWR will produce ringing and possibly some overshoot to both the positive and negative peak. This situation cannot be improved with the response shaping trimpots. If for some reason the trimpots become grossly misadjusted, they can be returned to their original settings by adjusting for optimum square wave response consistent with the noted feedback rectifier current.

4.36. BALANCING OUT THE DC COMPONENT OF THE FEEDBACK SIGNAL

The properly adjusted composite feedback signal appearing at the junction of R66, R67 & R68 is fed through R68 to the base of Q6. In the absence of modulation, this is a DC voltage of about +3 volts produced by the envelope rectifiers CR6 and CR7. At 100% sinewave modulation, this +3 volt signal will increase to +6 volts at the positive peak and reduce to zero at the negative peak. The composite feedback signal is therefore the demodulated audio superimposed on a +3 volt DC level. At the emitter of Q6 this is reduced to about +2.4 volts because of the base-emitter voltage drop. The output from the emitter of Q6 is taken off the FEEDBACK control (R75) and capacitively coupled to the base of Q2. Capacitive coupling removes the DC component of the feedback signal and the coupling capacitance is sufficient to preserve low frequency square wave shape. With 2.5 MA of emitter current in Q6, the feedback level will be about 9 dB.

Any loss of RF excitation, such as during operation of the magniphase circuit, will reduce the DC level at the emitter of Q6 from +2.5 volts to zero because the feedback rectifier will have no RF drive. When excitation returns, the Q6 emitter voltage will go from zero to +2.5 volts. The length of the magniphase pulse is about 100 milliseconds so that during magniphase operations, Q6 would feed a square pulse of 100 millisecond duration back into the audio

amplifier at a level sufficient to cause Modulator overload. To prevent this, the DC component at Q6 emitter is held constant with or without RF excitation by the action of Q7 which is connected in parallel with Q6.

As explained earlier in this section on the description of the Analog Switch circuit, the collector of 2A7Q5 is held near DC ground potential while RF is on because of the saturation base drive on Q5 from the RF rectifier circuit (T2, CR8, CR9, etc.). The collector of Q5 is direct coupled to the base of Q7 so that with RF on, no current flows in Q7 (Q5 saturated). The emitter of Q7 is at +2.5 volts because it is connected directly to Q6 emitter. On loss of RF excitation, the base of Q6 goes to zero volts which cuts off Q6 emitter current. At the same time, Q5 goes from saturation to cut-off so that the base voltage of Q7 rises to a level pre-determined by the resistance divider R70-R72. R72 is a 10 turn trimpot and is set so that the base voltage of Q7 in the absence of RF excitation is the same as the base voltage of Q6 in the presence of RF excitation. When this is done, the voltage at Q6, Q7 emitter will be constant, with or without RF excitation.

NOTE

When making this adjustment, the Transmitter must be operating at full power. Put 2A7 into the extender card and remove modulation. Put the TEST METER switch into the FB RECT position and note the reading with the Transmitter on at full power (should be from 2.2 to 2.8 ma). Turn the PLATE off and note that the FB RECT meter reading is unchanged. If it changes, adjust trimpot 2A7R72 (lower center of 2A7 PC board) so that the meter reading is the same in either case.

4-37. SETTING LOW POWER PROGRAM LEVEL

The SET LOW PWR PGM LEVEL trimpot (2A7R19) can only be adjusted during low power operation and should be set with FEEDBACK fully on and with program modulation applied. If the Peak Limiter is used on full power it should also be ON during the LOW POWER PGM LEVEL adjustment. Set the trimpot while watching either an oscilloscope modulation envelope or the negative peak flasher on the modulation monitor. Adjust for negative peak amplitudes as close to 100% as those seen during full power operation.

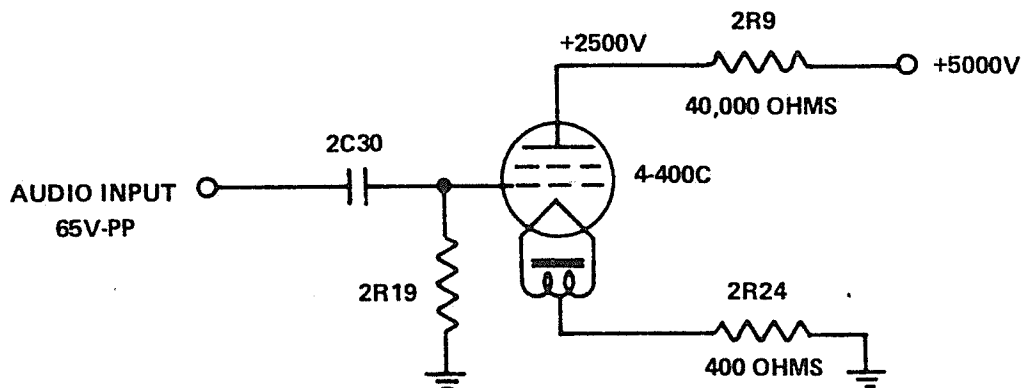
4-38. MODULATOR DRIVER STAGE

As noted earlier, the output from Q4 in the 2A7 Audio Amplifier module is about 65 volts P-P at 100% modulation. This output is capacitively coupled to the grid of the 4-400C Modulator Driver through 2C30. The coupling circuit has flat response down to 10 cycles. The 4-400C control grid operates at DC ground through grid resistor 2R19 and bias is provided by cathode resistor 2R24.

The Modulator Driver Stage is a Common Cathode Class A resistance coupled amplifier. The audio output voltage developed across the plate resistor is necessarily higher than the Modulator output voltage because the Modulator Stage is a cathode follower which has a gain of 0.8. At 100% modulation, the Modulator output is 2000 volts P-P so that with a gain of 0.8 the Modulator Driver must put out, $2000/0.8 = 2500$ VP-P at 100% modulation. To provide some head room above the 125% positive peak limit, both stages are designed for 150% modulation which for the Modulator will be, $1.5 \times 2000 = 3000$ VP-P, and for the Modulator Driver, $1.5 \times 2500 = 3750$ VP-P.

In Class A resistance coupled operation, the 4-400C will be linear over about 75% of its DC plate voltage. This dictates a plate supply voltage requirement of, $3750/.75 = 5000$ VDC. The 5 kV supply feeds only the Modulator Driver plate. The plate load resistance of 40,000 ohms (2R9) is sized to provide a high stage gain along with a reasonable plate dissipation.

The quiescent point of the resistance coupled Class A amplifier is typically placed so that the voltage drop across the tube is half the supply voltage so that the output voltage can swing symmetrically above and below the quiescent point. Discounting for now the small drop across the cathode resistor, the plate current necessary to



satisfy this requirement is, $2500V/40,000 \Omega = .0625$ amps. The plate current excursions necessary to swing ± 1875 volts (3750 volts P-P) will be, $1875V/40,000 \Omega = .047$ amps.

On the negative peak of the plate swing the plate current will be, $62.5 \text{ ma} + 47 \text{ ma} = 109.5 \text{ ma}$, at which time the drop across the plate resistor will be, $.1095 \times 40,000 = 4380$ volts.

On the positive peak of the plate swing the plate current will be, $62.5 \text{ ma} - 47 \text{ ma} = 15.5 \text{ ma}$, and the plate resistor drop will be, $.0155 \times 40,000 = 620$ volts.

The Peak to Peak swing across the plate resistor is then, $4380V - 620V = 3760$ VP-P.

Since there is no need to modulate 150% in the negative direction, the quiescent point is moved down by setting the plate current at 70 rather than 62.5 ma. This will drop 2800 volts across the plate resistor and leave 2200 volts across the tube.

NOTE

The 4-400C Modulator Driver operates with cathode bias only. The quiescent plate current is set at 70 ma by setting the screen voltage tap on 2R7 which is fed from the +750 volt supply. Remember that the +750 volt supply is variable so that this setting must be made when the Carrier Screen voltage (+750 volt supply) is at its full power setting. The 70 ma current is measured on test meter 2M1 with the selector switch in the IK AUDIO DRIVER 0-100 ma position.

Lowering the quiescent point also allows even more linear positive peak head room. The positive peak at the Modulator Driver plate corresponds to the positive peak of the Modulator output since the Modulator is a cathode follower and therefore has no 180° phase inversion.

The 400 ohm cathode resistor (2R24) serves two purposes. First, it develops the necessary cathode bias and second, it provides about 6 dB of cathode degeneration (feedback) by being unbypassed. The small (.02) mica cathode bypass condenser (2C29) has the effect of raising the gain very slightly above about 10 kc to compensate for the shunt capacitive loading in the plate circuit due to the Modula-

tor grid input capacitance.

In a high gain Class A amplifier using a directly heated tube like the 4-400C, the electrical center tap of the filament transformer is almost never sufficient to reduce filament hum to a -60 dB specification. For this reason the center point is made variable by connecting rheostat 2R21 across the filament and using its slider arm to establish the electrical center tap. The 47 ohm resistors in series with the rheostat restrict its adjustment range to provide a vernier control.

NOTE

The centering rheostat labeled V2 HUM BALANCE is adjusted from the front panel of the Modulator cabinet just below the Modulator Driver tube V2. The rheostat is adjusted to minimize the 60 cycle AM noise on the unmodulated carrier with the aid of a noise meter. Lock the rheostat control shaft after making the adjustment. This adjustment should be made after replacing the 4-400C Modulator Driver.

The plate dissipation of the Modulator Driver tube without modulation is the product of plate current and voltage. P (dissipation) = .07 amp x 2200V = 154 watts. This decreases only slightly during modulation because the plate efficiency is only about 10% at full output. It is not unusual for the anode to show a slight amount of color in spots. Because of the very small demand on filament emission the life expectancy is about 30,000 hours.

4.39. MODULATOR STAGE

Unlike Plate Modulation where the Modulator works into a constant load resistance determined by PA DC plate voltage and current, the Screen Modulator in the 317C-2 works into a load resistance that varies considerably over the modulation cycle. At zero modulation the load resistance is determined by screen voltage and current which for the Carrier tube screen is, $R = 700V / .25 \text{ amp} = 2800 \Omega$ (screen voltage divided by screen current). The load due to the Peak tube screen is infinite because without modulation the peak tube screen current is zero.

At the positive peak of 100% modulation, the Carrier tube screen voltage (instantaneous peak) is +1700 volts and the current is 2 amps.

The load at this instant (positive peak) is then, $1700\text{V}/2 \text{ amp} = 850\Omega$. The Peak tube screen grid conditions at this instant are: screen voltage +800V and screen current 1.0 amp. The load resistance is then, $800\text{V}/1.0 \text{ amp} = 800\Omega$.

The two loads in parallel then become, $R = 850 \times 800/850 + 800 = 412 \Omega$.

As the modulation swings in the negative direction, the Carrier tube screen current goes to zero at about 30% modulation and stays zero all the way down to carrier cut off. The Peak tube screen current is also zero during all of the negative peak so that the Modulator load resistance is infinite.

So the load on the Modulator swings from infinity on the negative peak down to 412 ohms on the positive peak. This bad situation is made somewhat better by the constant resistance load provided by the Peak tube grid modulating resistor 1R11 which might be anything from 1500 to 2500 ohms, depending upon its setting. The only Modulator circuit which will work into such a variable load is a cathode follower since its gain is dependent almost completely upon the amplification factor of the Modulator tube and only slightly by the load resistance.

The gain of a cathode follower using a tube with an amplification factor (μ) of 5 is found by:

$$\text{Gain (A)} = \frac{\mu R_L}{R_p + (\mu + 1)R_L}$$

The AC plate resistance (R_p) for the two parallel tubes is 100 ohms so the gain on the positive peak when $R_L = 400 \Omega$ is:

$$\text{Gain (A)} = 5 \times 400/100 + (6 \times 400) = 0.8.$$

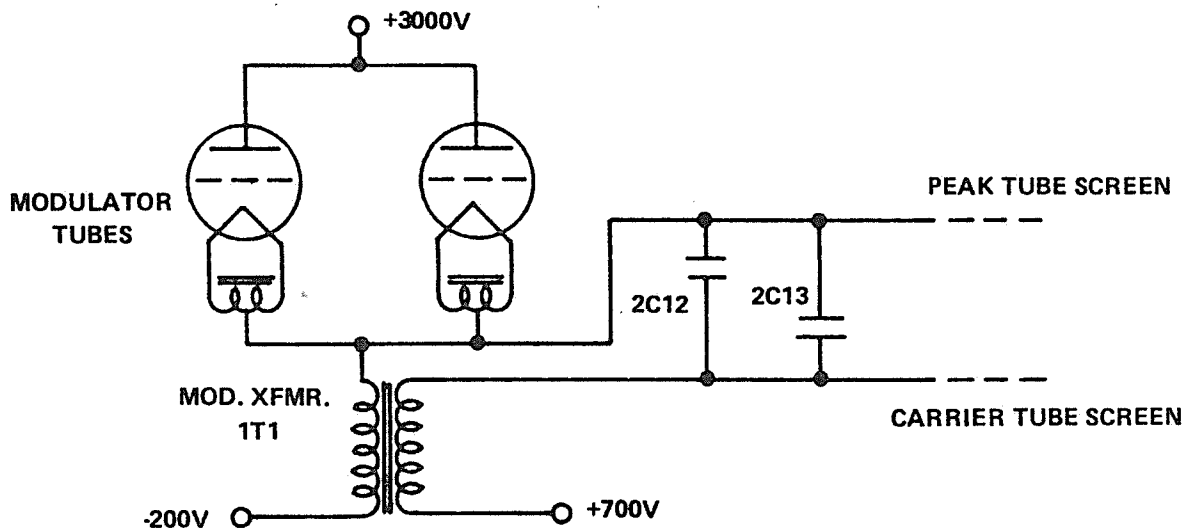
On the other extreme, when the load is infinite, the formula reduces to:

$$A = \frac{\mu}{\mu + 1} = .83$$

This means that if the Modulator is driven to an output of 830 volts peak with no load connected, the output would drop to only 800 volts peak when a 400 ohm load is connected. This 3.5% reduction of positive peak amplitude is compensated in the output stage of the 2A7 Audio Amplifier module by pre-stretching, as explained in that section.

The Modulator output voltage required for 100% modulation is determined by the DC screen voltage applied to the Carrier tube and the amount of negative screen voltage required to bring the Carrier tube down to plate current cut-off (100% modulation negative). At full power output the nominal screen voltage will be +700 VDC. This would have to be reduced to -300 VDC to cut off the plate current for a total excursion of 1000 volts. This would represent the sinusoidal voltage swing from carrier level down to the 100% negative peak of modulation. With a symmetrical sinusoidal Modulator output, the positive peak will take the screen voltage up 1000 volts from +700 to +1700 volts, which is the positive peak of 100% modulation. The total excursion from negative peak to positive peak is then from -300V to +1700V or a Modulator output swing of 2000 volts Peak-to-Peak at 100% modulation.

The Peak tube is held near cut-off by the -200 volts applied to its screen grid (-300 volts will result in plate current cut-off). The Modulator output is coupled to the two screen circuits which are operating at different DC screen voltages by isolating them with a modulation transformer. By placing the Modulator cathode at the same DC potential as the peak tube screen grid, this connection becomes a direct coupled circuit. The Carrier tube screen grid is then coupled to the Modulator by the modulation transformer.



The modulation transformer (1T1) voltage ratio (turns ratio) is 1:1 and the primary and secondary turns are laid adjacent to one another (bifilar) over the full multilayer winding. The leakage inductance of this type of winding is the lowest possible and also, since the primary and secondary voltages are equal, the voltage stress between windings reduces to simply the DC voltage difference

of 900 volts. The Carrier tube DC screen current that flows in the secondary winding is in the opposite direction to the Modulator DC cathode current which results in a partial cancellation of the DC flux produced in the core by the Modulator current. This results in a smaller core cross-sectional area for a given low frequency audio limit. The transformer is designed for flat sine wave response down to 10 cycles at 3000 volts Peak-to-Peak output. To assure a tilt-free 30 cycle square wave, condensers 2C12 and 2C13 are connected from primary to secondary.

The Modulator tubes are biased from a supply common to both the PA and IPA stages. The full bias voltage (-800 volts) is applied to the 3CX3000A1 Modulator grids through the MODULATOR BIAS adjust pots 2R35 and 2R36. The pots are in series with 2R37 to limit the range of adjustment from -800 to -530 volts.

NOTE

The MODULATOR BIAS adjust pots are used to set the Modulator plate current (as read on 2M8 and 2M9) to 600 ma per tube with the transmitter on at full power and without modulation applied. The Modulators are operated in Class A so that there is some warm-up drift upwards in Modulator plate current. For this reason, the adjustment should be made after at least a fifteen minute warm-up period.

It will be noticed that when the transmitter plate voltage is turned off, the Modulator plate currents will rise several hundred milliamperes from the 600 ma setting. This is because the bias supply voltage decreases in the absence of PA grid current. Although this seems to be the opposite of normal power supply regulation in which the supply voltage increases in the absence of load current, it must be remembered that in a grid bias supply the DC grid current cannot flow back through the rectifier (as is normally the case) but instead must return to ground through the bias bleeder resistance. If the bleeder resistance were to be sized such that the unloaded bleeder current is equal to the DC grid current, no current would be delivered by the rectifier when grid current is flowing. This is why the bias voltage increases when PA grid current is flowing.

The actual grid bias applied to the Modulator tubes is less than the negative voltage measured from the arm of the bias adjust pot to ground. If this voltage were to measure -650 volts, the

actual grid to cathode bias is -450 volts because the cathode is at -200 volts relative to ground. The cathode is actually about 20 volts less negative than the -200 volt supply voltage because of the IR drop in the primary of the modulation transformer. Since both Modulator tubes are drawing cathode current through this common winding, it will be noticed that the MODULATOR BIAS adjust pots interact slightly, that is as the plate current is increased in one tube, it decreases in the other. This is because the IR drop in the common winding from the increasing current in one tube is increasing the cathode bias on the other tube.

The life expectancy of the 3CX3000A1 Modulator tubes ranges from 10,000 to 20,000 hours averaging about 15,000 hours. The first sign of deterioration will be a reduction in positive peak modulation capability because of decreased filament emission. The taps on the filament transformers provide an adjustment of $\pm 2.5\%$ and $\pm 5\%$. The taps are set at the factory for operation at 7.3 volts (2.5% low). When loss of emission is evidenced, an attempt can be made to rejuvenate the filament by increasing the voltage to 5% above the nominal 7.5V (move wires to 218V primary tap) although this is seldom successful. New tubes should be set at 2.5% below nominal (primary wires on 236V tap). These tubes very rarely fail catastrophically due to filament damage or grid to filament short but if they should fail, the first indication would be a +3000 volt overload light on the 2A3 module.

NOTE

At least once a year the 3CX3000A1 Modulator tubes should be pulled out of their sockets so that the tru-arc retainer ring which compresses the inner filament connector on the socket can be inspected. If the ring becomes annealed it will no longer compress the tulip connector and the filament may actually go dark due to loss of filament current. If the ring will rotate freely around the tulip connector without any discernable compressive strength, it should be replaced. The replacement part is WALDES #5100-68 TRU-ARC RING. Stainless steel rings, if available, are preferable to beryllium copper. Either type should be available through machinery supply distributors. To replace the ring, remove the center contact by removing the 1/4-20 hex head bolt from the underside of the socket.

4-40. ANTENNA PROTECTION SYSTEM (MAGNIPHASE)-See Figure 4-14.

The Magniphase Antenna Protective System consists of the following three units:

- The transmission line coupler located below the transmission line end terminal at the rear of the left end (Unit 3) cabinet.
- The nulling and pulse generating unit (3A2) located on the front of the Unit 3 cabinet.
- The control unit (2A6) which plugs into the front of the right end (Unit 2) cabinet.

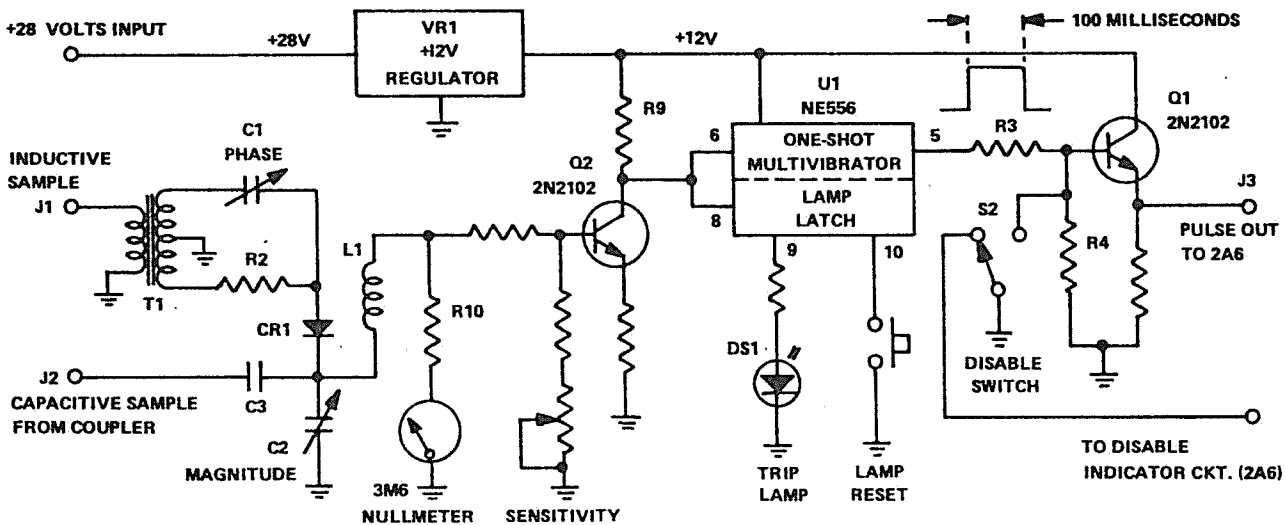


Figure 4-14. Magniphase Simplified Schematic, Unit 3A2

The transmission line voltage and current samples are derived from the capacitive and inductive pick-ups on the coupler unit. These RF samples are fed via coaxial cable to the 3A2 nulling unit. The voltage sample from the capacitive pick-up is fed in J2 to a capacitive divider consisting of C3 and MAGNITUDE adjusting condenser C2. The current sample from the inductive pick-up is fed in J1 to the transformer/phase shifter network T1, R2 and C1 (PHASE adjust control). The MAGNITUDE and PHASE controls are adjusted to provide a complete null (zero reading) on meter 3M6. This null is obtained when the two RF samples are of equal amplitude and in phase at both ends of diode CR1. In this case, the effective voltage across the diode is zero so that it draws no current. A transmission line or antenna fault will change the amplitude and/or phase of the samples which causes the diode to conduct through the RF

filter and base resistor network of Q2. Base current in Q2 will cause its collector voltage to swing down towards zero volts. The trigger pins (6 and 8) of dual timer U1 are driven by the negative-going collector voltage of Q2. One half of the timer is connected as a one-shot Multivibrator which generates a single pulse of 100 milliseconds duration when triggered. The other half of U1 is connected as a latch which drives TRIP LED DS1.

The 100 millisecond pulse is fed out of Pin 5 of U1 to the base of emitter follower Q1 through a resistive divider R3-R4. This divider allows the base of Q1 to be grounded by the OPERATE-DISABLE switch without grounding the output Pin 5 of U1. The pulse out of the emitter of Q1 is fed by coax cable to the Magniphase Control Unit 2A6 in the right end cabinet.

The sensitivity of the Magniphase unit can be varied to detect changes in transmission line VSWR as low as 1.2:1 to as high as 2:1. These numbers are approximate and will vary with frequency. With the SENSITIVITY control fully clockwise (maximum sensitivity) the trip point will be at about 20 to 30 on the null meter. At minimum sensitivity the trip point will be at about 70-90 on the meter. These points can be checked by disabling the cut-off pulse by switching S2 to DISABLE, removing modulation and tuning either the MAGNITUDE or PHASE controls until the red TRIP LED lights. The reading of the null meter at the point at which the LED turns on is determined by the setting of the SENSITIVITY control.

Most antenna systems will present a load to the Transmitter that changes with frequency. The amount of change will vary considerably from one system to another. When the Transmitter is modulated at 10 kc into a load that has considerable variation over a range of ± 10 kc from center frequency, it can be expected that the Magniphase null meter will read up-scale because of the change in phase and amplitude of the sideband currents relative to carrier. The sensitivity setting of the Magniphase unit will therefore be determined by load bandwidth. The best method for establishing an acceptable setting is to start at minimum SENSITIVITY and with normal programming and with Magniphase DISABLED, increase the SENSITIVITY until the TRIP light comes on due to high frequency program content, and then back it off slightly. The setting will have to accommodate the worst case (either day or night pattern) without nuisance tripping on program. Experience has shown that in most cases, a trip setting around 50 or 60 on the null meter will give good protection without a lot of false trips. In multi-tower directional systems having some of the towers lightly coupled into the Transmitter, there will be no protection because

even a short circuit at the base of these towers causes very little change in Transmitter load. If it is deemed necessary to protect these towers, then they can be fitted with their own Magniphase units.

441. MAGNIPHASE CONTROL UNIT (2A6) Figure 4-15.

The 100 millisecond pulse out of the Magniphase unit is fed into the 2A6 Control Unit and also into the 2A1 RF Oscillator/Exciter Unit where it is used to cut off RF drive over the length of the pulse. The operation of these circuits is covered in the description of the 2A1 RF Oscillator/Exciter Unit. The primary function of the 2A6 Control Unit is to control the Transmitter in response to excessive Magniphase operation. These control functions are arranged as follows:

- a) Four Magniphase cut-off pulses in a 90 second period will automatically switch the Transmitter to LOW power. The counter is automatically reset to zero every 90 seconds.
- b) If four more Magniphase pulses are counted in another 90 second period after having been switched to LOW power due to the above, the Transmitter plate voltage will shut off and stay off until manually reset.

After manually reclosing the plate supply, the Transmitter will come on at LOW POWER and will have to be manually switched up to HIGH POWER.

There are several schools of thought on the timing and sequence of this operation and the circuit is flexible enough to be readily changed. For instance, the concept of four operations in a 90 second period is based on the assumption that this is quite possible during a thunderstorm and that since low power operation automatically desensitizes the Magniphase circuit, the number of program interruptions would be decreased. At the same time the possibility of antenna damage because of reduced sensitivity is offset by the reduction in Transmitter power. While four operations in 90 seconds may be common in some localities, 15 or 20 in that period may occur in other parts of the world. For this reason, the 90 second time period can be shortened to what is deemed appropriate for the locale. This can be done by changing the value of 2A6R4 according to the following table. The timing tolerance will be about +20%, -10% because of the capacitance tolerance of timing condenser 2A6C4. R4 is located just above U1 at the top of the PC board.

TIME (seconds)	R4 (1/4 watt)
15	22k
30	47k
60	82k
90	120k

The reduction to LOW power feature can be defeated if desired by removing condenser 2A6C2, located just to the left of the LOCKOUT LED on the PC board. If this is done, the LOW POWER LED will still light after the first four Magniphase trips but the Transmitter will stay on at full power. The plate voltage will then shut off after four more Magniphase operations in the 90 second time period.

4.42. TESTING THE CONTROL CIRCUIT

The most practical way of generating a single Magniphase pulse is by shorting the output transmission line to ground. This can be done with a grounding stick at some point where the center conductor of the transmission line can be exposed. It is almost impossible to generate a single pulse by tuning the Magniphase out of the null past the trip point on the meter because of the fact that the pulse lasts only one-tenth of a second and resets in a few microseconds. Any attempt to flip the DISABLE switch on and off rapidly in this condition will generate multiple pulses because of the contact bounce in the switch. The switch would only have to be on for four hundred milliseconds to get four operations and reduce to low power. With a grounding stick it is possible to quickly brush the transmission line and get a single pulse. If the automatic reset time is reduced from 90 seconds the line can be shorted three times and then wait out the auto-reset time. It should then take four more operations to get a reduction to low power.

NOTE

Before shorting the transmission line, make sure that the DISABLE switch is in the ON position.

CIRCUIT OPERATION

The 100 millisecond pulse generated in the 3A2 unit is fed to the base of transistor Q1 in the 2A6 module. The collector of Q1 is directly connected to the trigger pins of U1 and U2. U1 is the 90 second interval timer and U2 is operated as a latch whose output

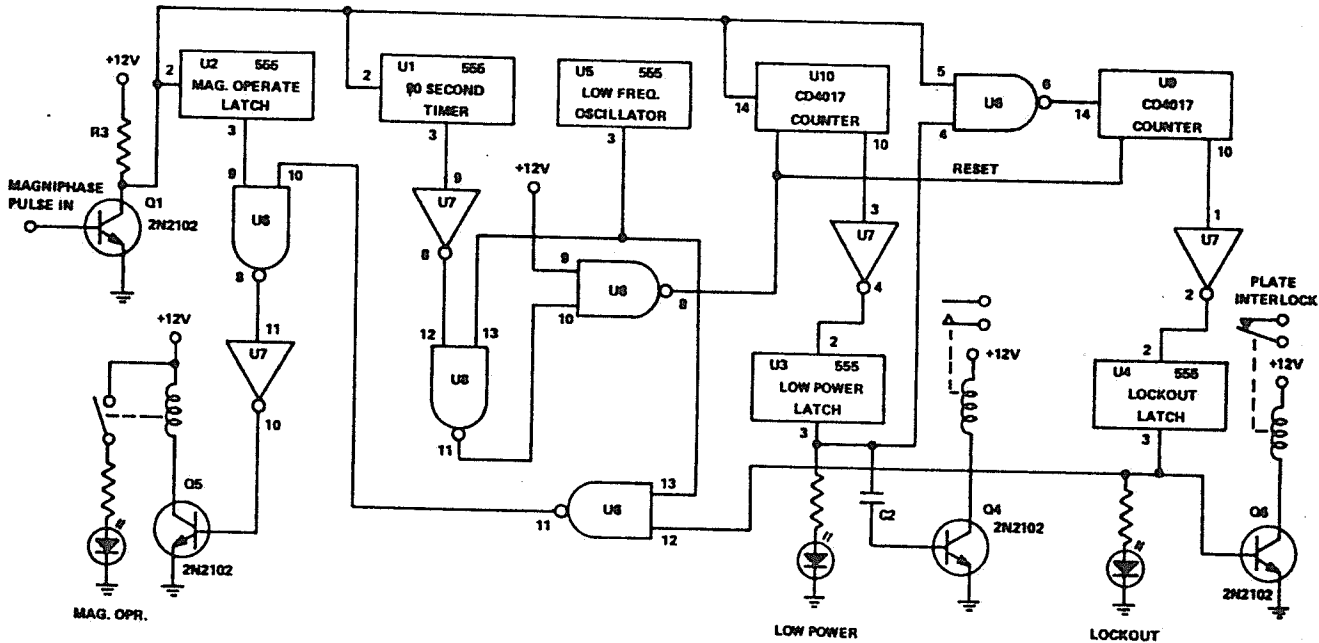


Figure 4.15 Simplified Schematic of Magniphase Control (2A6)

(Pin 3) goes from zero to +12 volts when triggered by Q1, at which time U1 starts the 90 second timing interval. The collector of Q1 is also connected to the clock input (Pin 14) of counter U10. If Q1 puts out four pulses in less than 90 seconds, the four-count output (Pin 10) of U10 will go from zero to +12 volts which drives the output (Pin 4) of inverter U7 down to zero volts. This latches up U3 whose output (Pin 3) goes from zero to +12 volts lighting the LOW POWER LED and pulsing the base of Q4 through coupling condenser C2. Q4 saturates for about 20 milliseconds giving a momentary closure of K6 contacts which is the same as pushing the LOW POWER button.

If Q1 puts out less than four pulses in the 90 second time interval, counter U10 is reset to count -zero by nand gate U8 Pin 8 which goes from zero to +12 volts 90 seconds after the first Magniphase pulse out of Q1. The reset pulse out of U8 Pin 8 is momentary due to the low frequency toggling of oscillator U5 which generates approximately a 2 cycle per second output from Pin 3.

When the Pin 3 output of LOW POWER latch U3 goes to +12 volts it enables nand gate U6 to feed Magniphase pulses out of its Pin 6 to Pin 14 (clock) of counter U9. Pin 5 of U6 gets pulses from the collector of Q1. If Pin 14 of U9 gets four pulses in less than 90 seconds its four-count pin (Pin 10) will go from zero to +12 volts which is inverted at Pin 2 of U7 latching up LOCKOUT latch U4. The

output (Pin 3) of U4 goes to +12 volts lighting LOCKOUT LED and opening the contacts of K5 which is driven by Q6. The contacts of K5 are in the plate voltage interlock circuit so that the plate drops off when K5 operates.

The first Magniphase pulse out of the collector of Q1 will latch up U2 driving its output (Pin 3) from zero to +12 volts which is fed through nand gate U6 (Pins 8 & 9) and inverter U7 (Pins 10 & 11) to the base of Q5 which closes the contacts on K7. One set of contacts lights the MAGNIPHASE OPR. LED on 2A6 and the other contacts give a remote indication by grounding connector Pin 16 on the PC board. When LOCKOUT latch U4 latches up and shuts off the plate voltage, it also enables nand gate U6 (Pins 11, 12 & 13) which allows the low frequency oscillator output to feed from U6 Pin 13 through U6 (Pins 8 & 10) and U7 (Pins 10 & 11) to Q5 causing K7 to switch on and off at the low frequency oscillator rate. The resultant flashing of MAGNIPHASE OPERATE LED 2A6DS1 will call attention to the fact that the Transmitter is off due to antenna problems.

OTHER CIRCUITS ON 2A6

In addition to the Magniphase control circuits, the 2A6 module contains other indicating and remote control circuits.

Relay 2A6K3 is energized when the DISABLE switch on the 3A2 Magniphase Unit is in the ON position. In the DISABLE position, normally closed contacts on K3 will cause the MAGNIPHASE DISABLED LED to light and will also ground connector pin 10 on the PC board which can be used for either remote or local status logic.

Relay K2 gives a remote indication of Transmitter overload by grounding connector pin 20 on the PC board. K2 will operate when the base of Q2 is driven positive by operation of any one of the eight overload functions (three on 2A4 Plate Control and five on 2A3 module). K2 is held energized after base drive is removed from Q2 because of its own seal-in contacts which are routed to ground through remote reset relay K1. The remote overload indication is then removed at the time the remote reset is operated.

Two other LEDs on the 2A6 module are used as reminders that the Transmitter is in the site testing mode because of the manual disabling of the HV plate supply (BREAKER TRIPPED LED) and the closing of the test link switch (TEST SWITCH CLOSED). Either of these operations will turn on Q3 which energizes K4 giving a remote indication by grounding connector pin 5 on the PC board.

4.43. . ADJUSTMENTS WHICH AFFECT TRANSMITTER PERFORMANCE

In addition to the many adjustments which have been noted in the circuit descriptions such as trimpot and tuning adjustments and setting of proper screen voltage and grid drive, there are three other circuit adjustments which, like the 90° phasing of the PA grid and plate circuits, are peculiar to the High Efficiency Screen Modulated Amplifier. These are:

- a) Setting the Carrier tube screen voltage.
- b) Tuning the Carrier tube third harmonic screen resonator.
- c) Setting the Peak tube grid modulation level.

These adjustments don't require ongoing maintenance and will only need attention after a power amplifier tube change and then only if there is a deterioration in transmitter performance.

4.43.1 ADJUSTING THE CARRIER SCREEN VOLTAGE

When the selector switch on the oscilloscope is in the POWER ADJUST position, the lever switch below it will raise or lower the Transmitter power by simultaneously raising or lowering the PA plate voltage and Carrier screen voltage. The gear reduction ratios on the two powerstat motor drive assemblies are chosen so that the screen voltage will change in a proportion to plate voltage change that will maintain a constant degree of Carrier tube saturation over the full range of plate voltage adjustment. Even though the two motors have no mechanical linkage, they will stay in synchronism because they are both slow speed stepping motors. They can get out of step if the drive shaft should slip on either of them and for this reason, they should be checked for slippage occasionally, depending on how much they are used. Slippage will show up as a change in screen voltage at the normal plate voltage setting.

The proper degree of Carrier tube saturation, which is set by screen voltage at a fixed level of grid drive and plate voltage, is determined by the amount of cross-over distortion generated by combining the Peak and Carrier amplifier outputs. The cross-over point is right at carrier level where the Peak tube is going into and out of conduction and the Carrier tube is going further into or out of saturation. If the Carrier tube is too deeply saturated (screen voltage too high) a cross-over bump will be noticeable on the modulation envelope similar to that of a Class B push-pull Modulator with

insufficient static current. If the Carrier tube is out of saturation (screen voltage too low) its output will increase linearly while the Peak tube is going into conduction and the envelope will show the opposite of the cross-over step. The non-linearity at this point will generate sufficient harmonic distortion to facilitate a technique for setting proper screen voltage. First, the modulation percentage should be low enough so that the harmonic distortion components are a large part of the Peak-to-Peak modulating audio, yet high enough so as not to be masked by hum & noise. Second, the modulation frequency should be high enough so that the cross-over distortion is not reduced by envelope feedback. Experience has shown that 25% modulation at 5000 cycles will satisfy both requirements.

The purpose of the following test procedure is to become more familiar with the Transmitter controls. It is assumed that the Carrier screen voltage is already properly set at the value recorded in the Factory Test Data and that the Transmitter is operating within all of its performance specifications.

- a) With the Transmitter running at full power, first check the noise level. It should be about 60 dB below 100% modulation. Nothing in the test set-up should limit noise readings to levels higher than -50 dB. This would include RF or cross-modulation from the Transmitter on the air or from the test equipment set-up.
- b) Modulate the Transmitter with 5000 cycle sine wave at 25% modulation and measure the harmonic distortion. It should be less than 2.5% (Transmitter specification limit), typically between 2.0 and 2.4%.
- c) If it is higher than 2.5%, raise the Carrier screen voltage by pushing the SCREEN VOLTAGE RAISE button on the 2A8 control panel while watching the distortion meter reading. If the distortion meter was reading around 3%, it should go down to 2.5% with about a 20 or 30 volt increase in screen voltage.
- d) If the distortion was less than 2%, then it is more than likely too high at 90% modulation at 7500 cycles and should be checked. The effect on the distortion at 90% modulation with changes in screen voltage can be checked at this time. However, the screen voltage setting which gives the best compromise on all aspects of performance, including inter-modulation distortion, plate efficiency and harmonic distortion.

tion is the setting which settles the 5000 cycle, 25% modulation distortion reading at about 2.2%. If it is more than 2.5%, raise the screen voltage. If it is less than 2%, lower the screen voltage. Remember that the distortion reading must change at a rate of about .5% for a 20 or 30 volt change in screen voltage.

This procedure should be performed whenever the Carrier tube is changed because of the possibility of variations in tube characteristics. The operating screen voltage with different Carrier tubes might range from as low as 650 volts to as high as 750 volts. Over this range the Carrier screen current may vary from 150 to 400 ma. The final verification of proper screen voltage setting is the distortion reading at 5000 cycle, 25% modulation. This is of course based on the assumption that everything else is properly adjusted and that the Transmitter is at full power.

4-43.2 TUNING THE CARRIER SCREEN RESONATOR

The screwdriver slot tuning adjustment located just below the paint color separation line on the right hand side of the center cabinet is the rotor shaft of an air variable condenser which tunes the screen grid of the Carrier tube to parallel resonance at the 3rd harmonic of the carrier frequency. The 3rd harmonic circuit consists of the shunt capacitive reactance of the screen by-pass condenser 1C6 in parallel with the net inductive reactance of blocking condenser 1C11 in series with 1L14 (which has the tuning condenser 1C37 in parallel with it). The tap on 1L14 is set to provide some tuning range above and below the 3rd harmonic. This circuit is isolated from the Modulator and the Peak tube screen by the series trap consisting of 1R13 in parallel with 1L15, which is located close to the 3rd harmonic circuit.

The purpose of this 3rd harmonic circuit is to reduce the DC screen current of the Carrier tube and still maintain the proper level of tube saturation and plate efficiency. Unlike the Tyler circuits (named for the inventor who pioneered their use) which place 3rd harmonic resonators in the grid and plate circuits in order to give a trapezoidal shape to the RF plate voltage waveform thereby increasing plate efficiency, this resonator squares up only the residual RF screen voltage and has nothing in the plate circuit to support a trapezoidal plate voltage waveshape. The reason for wanting to reduce the DC screen current is of course to reduce the demand on the modulator tubes.

Tuning this circuit has an influence on modulation linearity and for this reason, the circuit should be fine tuned with the aid of a distortion meter. Unlike the adjustment of the Carrier screen voltage which is made at 25% modulation, it is best to adjust this circuit at 90% modulation and then check it at 25% modulation. The modulation frequency should be 5000 cycles so that there is no cancelling effect due to negative feedback.

- a) With the Transmitter running at full power and with no modulation applied, the 3F (3rd harmonic) resonator should be tuned for minimum CARRIER SCREEN CURRENT (1M1). There is no mechanical stop on the tuning control and the condenser will go from minimum to maximum capacitance with 180° rotation of the tuning shaft so that there will be two minimum screen current points over 360 degrees of shaft rotation.
- b) Modulate the Transmitter at 90% with a 5000 cycle tone and measure the harmonic distortion. It should be around 1.5% (usually not less than 1% or more than 2%). Slowly tune the 3F resonator for minimum distortion while watching the distortion meter. This should occur very close to the dip in screen current.

NOTE

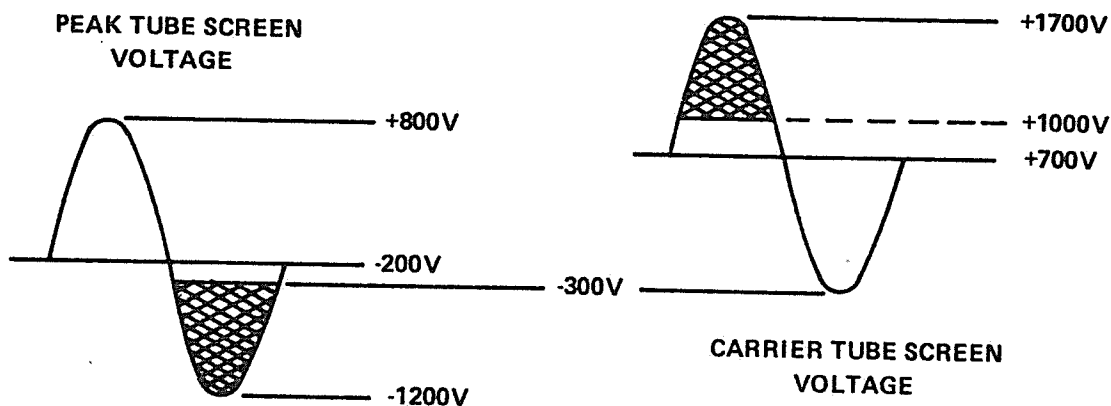
The dip will not be as noticeable with 90% modulation applied which is why the circuit is first tuned without modulation.

- c) Check the distortion at 5000 cycles and 25% modulation. It may be found that there is a point just slightly out of the dip which gives a better compromise between distortion at 25% and 90% modulation.
- d) Set the oscilloscope selector switch to the CARRIER PLATE position. Note that as the 3F resonator is tuned, the diagonal line on the scope will open or close. After dipping the screen current, the diagonal line should be closed by tuning the CARRIER PLATE.

Once set, this circuit should require no further attention. Tube changes will have no effect on the setting. The only reason that would necessitate re-tuning would be replacement of either the screen by-pass condenser 1C6 on the DC blocking condenser 1C11.

4-43.3 SETTING PEAK TUBE GRID MODULATION

As explained in the MODULATOR AND MODULATOR DRIVER description, the sinusoidal modulating audio voltage applied to the PA screen grids will swing the Carrier screen from +700 volts (approximately) up to +1700 volts on the positive peak of 100% modulation and from +700 V down to -300 V on the negative peak (carrier cut-off). The Peak-to-Peak audio swing is therefore 2000 volts (-300 V to +1700 V). The same level of modulating voltage is applied to the Peak tube screen which will then swing from -200 volts up 1000 volts to +800 volts on the positive peak of 100% modulation and from -200 volts down -1200 volts on the negative peak.



In order that both tubes deliver equal power at the positive peak of 100% modulation they need to be operating under identical conditions. The 90° interplate circuit equalizes the two plate load resistances at this point but from the above graph it is obvious that the screen voltages are not equal at crest. The instantaneous screen voltage on the Peak tube at 100% modulation is only +800 volts while on the Carrier tube it is +1700 volts. In practice, it would be sufficient to swing the Carrier tube up to about +1000 volts on the positive peak to keep it in saturation while its plate load resistance is decreasing. Any swing above +1000 volts is unnecessary and in fact could be clipped off with no detrimental effect. On the Peak tube modulating waveform the audio swing from -300 to -1200 volts could likewise be clipped off since the tube is cut-off during this time anyway. To do this of course would require separate direct coupled Modulators.

Since the Peak tube requires the same +1000 volts screen voltage on the positive peak but goes only to +800 volts, the effect of having +1000 volts can be attained by increasing the grid drive on the positive peak. This is accomplished by using a small sample of

the modulating voltage to modulate the control grid of the Peak tube. The modulating voltage is sampled from the screen of the Peak tube through blocking condenser 1C14 and applied to a resistive voltage divider consisting of 1R11 and 1R12. 1R12 is the Peak tube grid leak resistor and is always set for about 500 ohms resistance. In later transmitters, 1R12 is a fixed 500 ohm resistor. The amount of grid modulation is then controlled by the resistance setting of 1R11 which is mounted vertically to the left of the Peak grid coil 1L3 below the PA tubes. If the electrical characteristics of both the peak and carrier tubes are pretty closely matched, the total resistance of 1R11 will be used (adjusting slider set at bottom of resistor). If the Peak tube has less power gain than the Carrier tube (thereby requiring more drive) 1R11 will be set with about half its resistance shorted out. In the case of a Peak tube having higher gain than the Carrier tube, it would be better to switch the tubes and use the higher gain tube in the Carrier side. In making this determination, the things to look for are:

- a) If the carrier shift at 100% modulation is zero or positive with 1R11 set at maximum resistance, the Peak tube gain is higher than the Carrier tube and it would be best to switch the tubes.
- b) If the carrier shift at 100% modulation is more than 2% negative with 1R11 set at maximum resistance, move the slider on 1R11 up about 2 inches (decreasing resistance). The carrier shift should decrease to less than 2%.

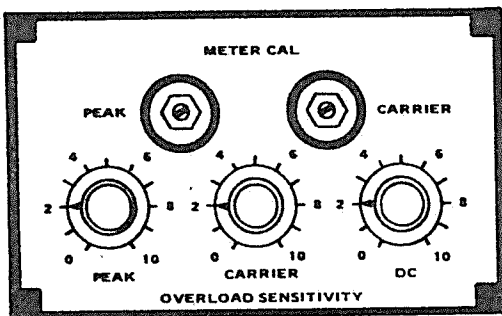
The slider on 1R11 should never be set to short out more than half of the resistance and this should really never be necessary. Doing this would not only unduly load the Modulator but would also overheat 1R11. The changes incurred in moving the slider from the bottom of the resistor to half way up are very slight. The carrier shift will be changed about 2% and the distortion at 5000 cycles 90% modulation will show about a 1% change. If this distortion is above 2%, the slider on 1R11 should be moved either up or down about 2 inches to reduce this to about 1.5%.

In order to become more familiar with the Transmitter, it would be a good idea during a maintenance period to observe the effect of changing 1R11 setting to see its effect on carrier shift and 5000 cycle distortion. Distortion will be obviously affected at other modulating frequencies but will be most noticeable at 5 kc or higher.

4.44. POWER AMPLIFIER OVERLOAD CIRCUITS

Each of the power amplifier tubes has an overcurrent relay in its filament center tap to ground connection. The 18 kV plate supply has the same type overcurrent relay in its negative connection to ground. These three overload relays, PEAK, CARRIER and DC have adjustable sensitivity controls located on the lower front panel of the Modulator cabinet.

The overload relays have 6 VDC coils which will operate on the average at about 4 volts DC. The coil resistance is 40 ohms so that the coil current at pick-up is about 100 ma DC. The coil of each relay is paralleled with a 120 ohm 2 watt resistor so that the net resistance of the parallel combination is $40 \times 120 / 40 + 120 = 30$ ohms. At 4 VDC the total current is $4V / 30 \text{ ohms} = 133 \text{ ma}$.



In series with each relay coil/resistor is a 50 ohm rheostat. These are the front panel sensitivity controls. At maximum sensitivity (fully clockwise or 10 on the dial scales) the rheostat is at zero resistance so that the relays will operate at 4 VDC. At minimum sensitivity (fully counter-

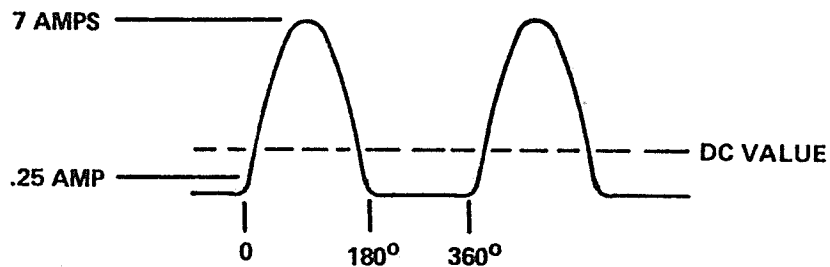
clockwise or zero on the dial scales), the full 50 ohms is in series with the 30 ohm coil/resistor circuit for a net total resistance of $50 + 30 = 80$ ohms. In order to put 133 ma of current into the 80 ohm series combination, the input operating voltage must be raised to; $E = .133 \times 80 = 10.66$ volts which would put 4 VDC across the relay coil.

The cathode current of each Power Amplifier tube is drawn through a 1.0 ohm resistor in its filament center tap to ground connection. The Peak and Carrier overload relay/rheostat circuits are connected across the 1 ohm resistors so that the net resistance to ground is now $30 \times 1 / 30 + 1 = .967$ ohms at maximum sensitivity and $80 \times 1 / 80 + 1 = .987$ ohms at minimum sensitivity. The cathode current necessary to develop 4 volts DC (at maximum sensitivity) will be $I_k = 4V / .967 \text{ ohms} = 4.14 \text{ amps DC}$ and at minimum sensitivity will be $I_k = 10.66V / .987 \text{ ohms} = 10.8 \text{ amps DC}$.

Without modulation the cathode current of the Carrier tube is about 4 amps DC which consists of 3.5 amps plate current plus about .35 amps screen current and .15 amps grid current. The Peak tube

cathode current is about 10% of this at about .4 amp which consists of .25 amps plate current and .15 amps grid current. The Carrier tube plate current varies in a sinusoidal manner with sine wave modulation so that at 100% modulation it will double from 3.5 to 7.0 amps at the positive peak and go down to zero at the negative peak. The average DC (as indicated by a DC ammeter) will therefore be 3.5 amps with or without modulation. The screen current is not sinusoidal so that there will be a slight change in the carrier cathode current as read on the PA TEST METER (1M6) when modulation is applied.

The Peak tube plate current at zero modulation is almost cut-off (about .25 amps). At the positive peak of 100% modulation it will be equal to the crest Carrier plate current of 7.0 amps. During the negative half of the modulating waveform the Peak tube plate current is cut-off so that over one full cycle of modulation the Peak tube plate current will resemble the output of a half-wave rectifier.



The average or DC value of the waveform will be $7/\pi = 2.23$ amps. The grid current of .15 amps and about .2 amps screen current will raise the DC cathode current of the Peak tube to about 2.6 amps at 100% modulation.

At modulating frequencies below about 50 cycles, the overload relays will respond to the instantaneous crest cathode current of about 8 amps per tube at 100% modulation so that the trip sensitivity will have to be set slightly above this. The minimum sensitivity settings for the Peak and Carrier overload relays is 10.8 amps which would correspond to the crest current at about 150% modulation.

NOTE

All three overload sensitivity controls should be set at 2.0 on the dial scales. This setting will allow proof testing down to 100% modulation at 10 cycles and no nuisance tripping with heavy program modulation.

The DC overload relay which is in the negative return lead of the 18 kV plate supply will have the crest value of both the Peak and Carrier plate currents ($7+7 = 14$ amps) so that the circuit sensitivity must be about half that of the tubes. This is done by putting the DC overload relay/rheostat circuit across a 0.5 ohm resistor rather than 1.0 ohm as is used in the PA tube cathodes. The PA overload circuits can be tested by two methods.

- a) The solid-state and logic circuits can be tested by momentarily pushing each of the three red test buttons on the 2A4 module.
- b) The overload relay/rheostat circuits and the solid-state circuits can be tested together by slowly increasing the overload sensitivity (turn controls clockwise) during low frequency tone or program modulation. With program they will trip at from 5.0 to 8.0 on the dial scales depending on program content. Either of these tests should be done only during maintenance periods since the overload operation will result in a momentary program interruption.

4-45. POWER AMPLIFIER OVERTEMPERATURE CIRCUIT

An overtemperature cut-off switch is used to protect against excessive anode radiator temperature rise on the 4CX35000C PA tubes which would result from partial restriction of PA cooling air either by clogged inlet filters or by excessive back pressure in the exhaust duct. The thermally actuated bi-metal switch is located beside the exhaust air duct of the Carrier tube. The hot exhaust air is partially deflected into the switch through three holes in the top of the cylindrical duct which is raised or lowered over the Carrier tube anode radiator.

NOTE

Take care during installation or subsequent maintenance that the two cylindrical exhaust ducts are not interchanged or improperly oriented. If in doubt about proper orientation, raise the right duct (Carrier tube) and look up inside it to see that the top baffle and the three side holes are toward the overtemperature bi-metal switch element (1S5). The ducts are labeled LEFT FRONT and RIGHT FRONT on transmitters above serial number 255.

The volume of air moving through each Power Amplifier exhaust duct is about 700 CFM. The total heat generated by the Carrier tube will be about 13 kW; 10 kW from plate dissipation and 3 kW from filament heat. Grid and screen dissipation is negligible. The exhaust air temperature rise will be:

$$\begin{aligned}\Delta T(^{\circ}\text{F}) &= \frac{3170 \times 13 \text{ kW}}{700 \text{ CFM}} \\ &= 60^{\circ}\text{F}\end{aligned}$$

The air flow requirements tabulated by Eimac on the 4CX35000C data sheet are based on maintaining a maximum anode core temperature of 225°C with 40°C (104°F) inlet air. The blower in the Transmitter will deliver sufficient air flow to maintain this with up to 16 kW of plate dissipation at an inlet temperature of 50°C (122°F). The exhaust air temperature at which the thermostatic contacts should close would then be 122°F (max ambient) + 60°F (temp. rise) = 182°F. At this exhaust temperature the anode core will still be below the 225°C maximum.

The compressive bi-metal spring contact in the thermostatic switch will respond at a rate of approximately 100°F per turn of the adjusting knob. Clockwise rotation will increase the temperature setting. To establish a 182°F overtemp trip setting in an 82°F ambient would mean turning the knob 1 turn clockwise.

The overtemperature thermostatic switch can be checked for proper operation and maintained in the following manner.

- a) If the Transmitter has been running, turn off the PLATE and MASTER switches and allow the thermostatic switch to cool down to room temperature by setting the blower holdover for the full seven minute rundown period.
- b) When the blower stops running turn the thermostatic switch knob slowly counter-clockwise (when viewed from knob end) while watching the OVERTEMP LED on the 2A4 module. Stop turning just at the point where the LED turns on.
- c) If you wish to adjust the overtemperature trip setting based on the yearly maximum expected site temperature, turn the knob clockwise (from the LED "on" point) an amount corresponding to:

$$N = \frac{T(\text{max}) - T(\text{amb}) + 80}{100}$$

where:

- N = number of turns of knob
- T(max) = maximum summer temp. (°F)
- T(amb) = present ambient temp. (°F)
- 80 = exhaust air temperature rise plus a 20° tolerance factor for the thermoswitch and actual airflow.

For example, if the maximum summer temperature is 100°F and the present ambient is 50°F, the number of clockwise turns will be:

$$N = \frac{(100 - 50) + 80}{100} = 1.3 \text{ turns}$$

It wouldn't be necessary to readjust the thermoswitch in winter months since exhaust air temperature is the prime consideration. If the air flow were to be restricted to half its normal volume, the temperature rise would double which would still maintain a safe anode core temperature in an ambient 60°F cooler than the ambient in which the thermoswitch was set.

After the thermoswitch has been set, push the OVERTEMP RESET button on the 2A4 module to extinguish the LED.

NOTE

Remember that the overtemperature relay in the 2A4 module is latched up by its own seal-in contacts and won't unlatch when the thermoswitch contacts open as the knob is turned clockwise or as the bi-metal element cools down. Once latched up, the LED will stay on until the seal-in circuit is opened by pushing the OVERTEMP RESET button on the 2A4 module. If this point is forgotten, it would seem natural to keep on turning the thermoswitch knob until the OVERTEMP LED goes out. On switches which have no mechanical stop on the adjusting screw, this could damage or ruin the bi-metal element.

446. OSCILLOSCOPE RF SAMPLES, Figures 4-16 and 4-17.

The phase monitor oscilloscope is used for adjusting the 90° intergrid and interplate circuits. In order to do this, the horizontal and vertical deflecting plates in the cathode ray tube must be driven by RF voltage samples from the grid and plate circuits of the Peak and Carrier tubes. Deflection sensitivity of the CRT is about 50 volts per inch of beam deflection for the horizontal plates and about 40 volts per inch for the vertical plates (vertical sensitivity is greater because the vertical deflecting plates are closer to the electron gun). The RF grid voltage is about 2000 volts peak-to-peak superimposed on the DC bias voltage and the RF plate voltage is about 32,000 volts peak-to-peak superimposed on the DC plate voltage. In order to be used on the CRT deflecting plates, these high voltages will obviously need to be attenuated. The attenuating circuit has two basic requirements. First, it must not introduce phase shift and second, it should remove the DC component of grid and plate voltage. Only a capacitive divider will satisfy both requirements.

The RF voltage waveforms at the grid and plate of the Peak and Carrier tubes are sinusoidal because of the harmonic filtering effect of the grid and plate tank circuits. However, the filtering isn't sufficient to attenuate the harmonics to the extent necessary for providing an undistorted elliptical display on the oscilloscope. RF harmonics will appear as bumps or ragged edges on the ellipse. To remove these harmonics, the attenuated samples from the capacitive

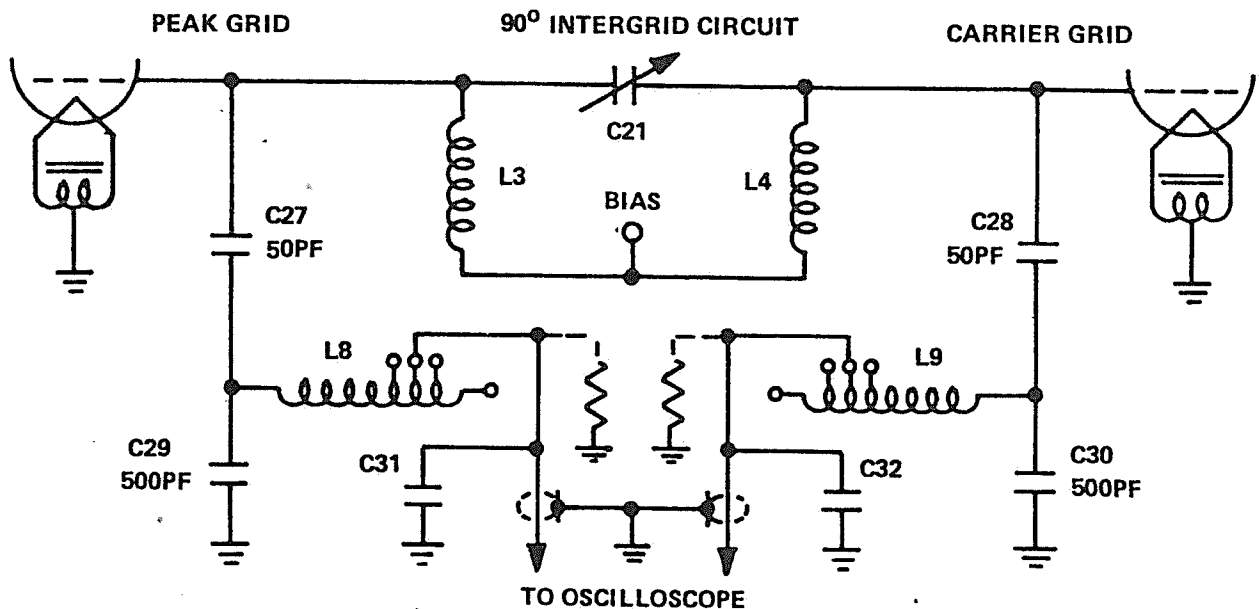


Figure 4.16 Simplified Schematic of PA Grid Circuit

dividers are fed through low pass filters before being applied to the deflecting plates. There are four RF samples to be filtered (grid and plate of the Peak tube plus grid and plate of the Carrier tube). The two grid sample filters (located under the shelf between the PA tubes) are similarly constructed but differ in some respects to the two plate sample circuits which are also similar to each other.

The capacitive voltage dividers for the grid voltage sampling consist of C27 in series with C29 for the Peak tube grid and C28 in series with C30 for the Carrier grid. The capacitance ratio is 10:1 (500 pf to 50 pf) so that the voltage across C29 and C30 is one-tenth the RF grid voltage or about 200 volts peak-to-peak. The series inductive element of the low pass filter is L8 for the Peak grid sample and L9 for the Carrier grid. These inductors have taps for selecting the proper inductance for the transmitter operating frequency and for adjusting the amplitude of sample voltage fed to the CRT deflecting plates. The shunt condensers connected to the output end of the filter (C31 and C32) are used in conjunction with the taps on L8 and L9 for setting sample amplitude and for greater harmonic filtering. These low pass filters are unterminated (the 'scope input is about 500,000 ohms) so that they will have either zero or 180° phase shift depending upon the reactance of the filter components. The filters are set at the factory below the resonant point (180° phase shift) because of the greater harmonic attenuation. There will be no errors in the oscilloscope displays as long as all four samples have the same 180° phase shift.

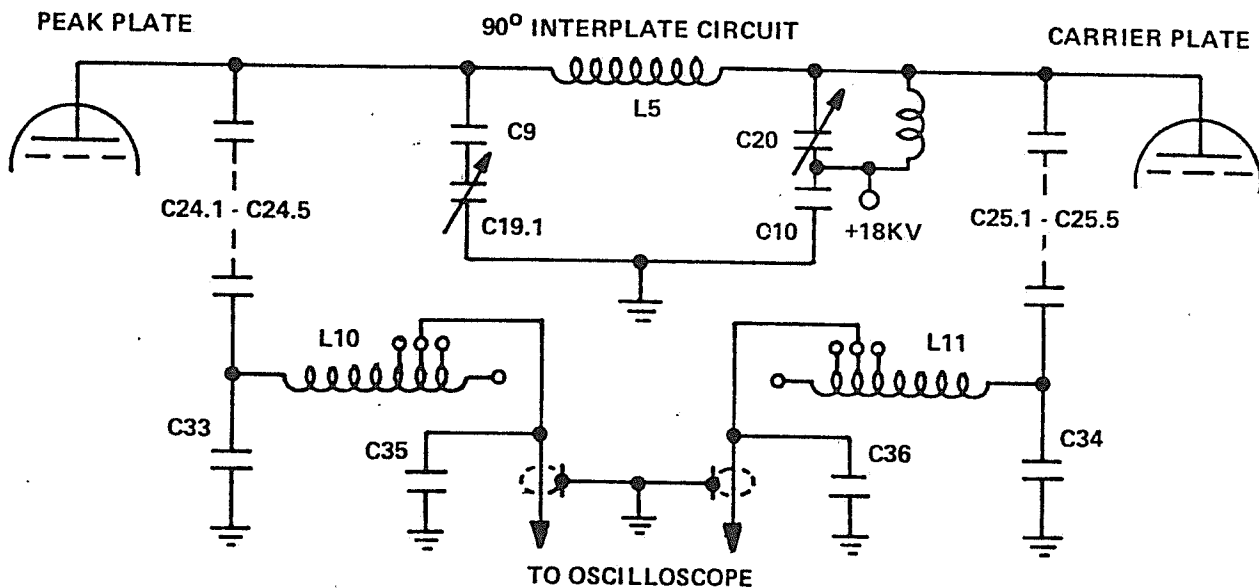


Figure 4.17 Simplified Schematic of PA Plate Circuit

The plate circuit sampling filters, because of their location near the plates of the tubes and necessity for shielding, will sometimes have slightly less than 180° phase shift depending upon frequency and the setting of the tap on the filter coil. If, for instance, these filters have 170° phase shift, then the grid circuit filters must likewise be set for 170° . The resistors shown dotted in on the oscilloscope end of the grid circuit filters are used for this purpose when necessary.

The capacitive voltage dividers in the plate circuit must not only block the 18 kV DC plate voltage but must also provide a much higher division ratio than the grid circuit dividers. The DC voltage and the biggest part of the RF voltage is dropped across the series assembly of five ceramic condensers, C24.1 through C24.5 on the plate of the Peak tube and C25.1 through C25.5 on the Carrier plate. Each of these condensers have 100 pf capacitance and a voltage rating of 15 kV so that each assembly of five condensers will have 20 pf capacitance and will withstand 75 kV.

The capacitance at the grounded end of the dividers is usually set at about 4000 pf at the Carrier plate (C34) and about 2000 pf at the Peak plate (C33) giving division ratios of $4000/20 = 200$ and $2000/20 = 100$. The 90° interplate network has a resistance transformation ratio of 5:1 (2500 ohms at the Carrier plate to 500 ohms at the Peak plate) and so will have a voltage ratio of $\sqrt{5}:1 = 2.24:1$ which means that the RF voltage at the plate of the Peak tube will be $1/2.24 = .45$ times the RF voltage at the plate of the Carrier tube. The output of the capacitive divider at the Peak plate is twice the Carrier divider output so that the two sample voltages are then roughly equal. If the CRT horizontal and vertical deflection sensitivities were equal, the two voltages 90° out of phase would give a circular display. However, since the vertical sensitivity is greater, the display will be a vertically oriented ellipse.

The taps on the low pass filter coils (L10 and L11) are used for setting the filter for 180° phase shift and also for adjusting the size of the 'scope display.

NOTE

Because of layout constraints and the large physical size of components, it is sometimes impossible to remove all of the RF harmonics from the plate voltage samples, especially the harmonics in the 10 to 20 megacycle range.

These will appear on the 90° interplate ellipse (PEAK PLATE and POWER ADJUST positions on 'scope selector switch) as jagged points on the upper right portion of the ellipse which represents the positive peak of the two plate samples. These jagged edges will become more noticeable when modulation is applied.

The 90° interplate ellipse is set in factory test to about six units vertically on the oscilloscope graticule and about four units horizontally. The graticule lines are on one-quarter inch centers. The actual size of the ellipse will vary with power output since the RF plate voltage changes with power level. It is not always possible to set the size to exactly six units high and four wide because of the lack of vernier control. Assuming an ellipse of these proportions and bearing in mind that the vertical deflection is due to carrier tube RF plate voltage, the 'scope can be used to measure modulation percentage by noting the reduction in vertical amplitude during modulation. For example, if the vertical size is 6 units without modulation and the inner ellipse is reduced to 3 units when modulation is applied then the modulation depth is 50%. If the modulation is increased until the inner ellipse becomes a small green dot on the center of the pattern, the modulation depth is 100%.

As mentioned elsewhere in the text, the Carrier tube is near saturation without modulation applied and so its RF plate voltage can increase only slightly with modulation. This can be seen by noting that the vertical amplitude of the ellipse increases very little with modulation. On the other hand, the horizontal deflection, which is due to Peak tube RF plate voltage, will double at 100% positive modulation since the full modulation envelope appears at the Peak tube plate. A better understanding of the operation of the High Efficiency Screen Modulated Amplifier can be gained by keeping in mind that the oscilloscope pattern is a visual voltmeter display of the two RF plate voltages 90° out of phase.

In the factory test the 90° intergrid ellipse is generally made smaller or in some other way different from the interplate ellipse in order to distinguish between the two at a glance. The intergrid ellipse is displayed in both the PA GRID and INTERGRID positions on the 'scope selector switch. During modulation there is some thickening or widening of this display due to the control grid modulation applied to the Peak tube. The display is quite different from the

modulated interplate ellipse, however, because the grid is modulated only about 20 to 25% and the modulating audio is superimposed on the RF waveform instead of causing amplitude modulation of the RF drive. This superimposed audio component, which varies the grid bias at an audio rate, will cause a lateral or diagonal displacement of the elliptical intergrid pattern during modulation.

The 90° interplate ellipse can be used to monitor the condition of the antenna or common point load by noting any deviation from the normal elliptical display. For instance, if the normal presentation is six units high and four units wide and something happens to the load to make it taller and thinner it would mean that the Peak tube load resistance has decreased which because of the inverting action of the 90° interplate network would increase the Carrier tube load resistance. This condition would also be accompanied by a decrease in TOTAL PLATE CURRENT, a decrease in power output and an increase in CARRIER TUBE SCREEN CURRENT. On the other hand, if the ellipse became shorter and wider (tending toward a circular display) due to a load change it would mean that the Peak tube load resistance has increased which by inversion would decrease the Carrier tube load resistance. In this condition, the plate current will increase, the Carrier tube screen current will decrease and the power output will probably not change or will decrease slightly. All of these observations are based on the fact that the normal ellipse which is six units high and four units wide represents a 5:1 resistance ratio in the 90° interplate network (or 2.24:1 voltage ratio). A taller, thinner ellipse means a higher resistance (and voltage) ratio while a shorter, wider ellipse means a lower ratio. If the horizontal and vertical dimensions are unchanged but the ellipse is leaning to one side or the other due to load change then it means that the plate loads on both tubes have become reactive. This condition can be remedied by tuning (in the PEAK PLATE position on the 'scope selector) for an upright ellipse. This will then retune both plate loads to a non-reactive condition.

The best indicator of load change is, of course, the MAGNIPHASE NULL meter. However, the oscilloscope display can be used to interpret the nature of the load change insofar as it affects the loading of the Power Amplifier tubes.

The accuracy of the 90° phase display depends not only upon the factory setting of the RF sample harmonic filters but also upon the fact that the cathode ray tube is properly oriented in its socket and shield assembly. This can be quite easily checked by noting that the dot moves vertically up and down the graticule line when the VERTICAL position pot is turned.