



USE OF TRIODE-CONNECTED TETRODES AS GROUNDED GRID AMPLIFIERS

The tetrode tube may be connected for hi- μ triode operation by placing the grid and screen elements at the same dc and signal potential (figure 1). Low- μ triode operation may be approximated by connecting the screen to the plate (figure 2). This connection is not recommended for grounded-grid operation, as the tube amplification factor is extremely low and screen dissipation is high.

Hi- μ triode connection, however, offers several advantages for SSB operation. No grid bias or screen power supplies are needed and the drive level of the grounded grid stage is compatible with the power output of the modern sideband exciters. Finally, neutralization is not required in a properly designed HF amplifier.

Certain tetrodes do not perform well when connected in the grounded grid circuit of figure 1. These tubes are characterized by high perveance, together with extremely small spacing between the grid bars, and between the grid structure and the cathode. Thus, while performing in excellent fashion in a grid driven circuit, this family of tubes is unsuited for grounded grid operation. Tubes of the 4-65A, 4X150 (which includes the 7609), 4CX250 (which includes the 8930), 4CX300, 4CX350, 4CX1000A, and 4CX1500 families are in this class.

For proper operation of a high-perveance tetrode the screen requires a much larger voltage than the control grid. When the electrodes of the tubes are tied together the control grid tends to draw very high current and there is grave risk of destroying it. For example, in grounded grid configuration, the control grid current of the 4X150A is 1.3 amperes at the positive peak of the driving cycle and the peak screen current is 0.5 amperes. At the same instant, the peak plate current is only about 0.8 amperes. In other words, the plate is getting only a third of the current emitted by the cathode instead of nearly all the current! By any standards, such a triode is unsatisfactory. Under these conditions the grid dissipation is about one thousand times as great for the high- μ -connected configuration as it is for the tetrode-connected tube.

The best way to operate tetrodes such as the 4X150A/4CX250B family or the 4CX1000A in a cathode driven linear amplifier is to ground the grid and screen through bypass capacitors and to operate them at their rated dc voltages, as shown in figure 3. The grid dissipation drops to normal when this is done and stage gain is greatly increased. The screen dissipation is nearly the same as in the normal tetrode connection. Good stage gain can be obtained with this circuit because the driver does not have to supply large screen and grid losses. If it is desired to dissipate excess driving power, it should be expended in a resistive load (figure 4).

Tetrodes such as the 4-125A, 4-250A, 4-400A and the 4-1000A are suitable for connection as grounded grid triodes because of their favorable current division characteristic. In the case of the smaller tubes, maximum power capability is limited by maximum grid dissipation.

The following ratings apply to these tubes for triode connected, grounded grid service:

OPERATING CHARACTERISTICS, EIMAC TETRODES, GROUNDED GRID CONFIGURATION

4-125A (VOICE CONDITIONS)

	2000	2500	3000	Vdc
Dc Plate Voltage				
Zero-signal dc Plate Current *	10	15	20	mAdc
Single-Tone dc Plate Current	105	110	115	mAdc
Single-Tone dc Screen Current	30	30	30	mAdc
Single-Tone dc Grid Current	55	55	55	mAdc
Single-Tone Driving Power	16	16	16	W
Driving Impedance	340	340	340	Ohms
Load Impedance	10,500	13,500	15,700	Ohms
Plate Input Power	210	275	345	W
Plate Output Power	145	190	240	W

4-400A (VOICE CONDITIONS)

(ratings apply to 4-250A, within plate dissipation rating of 4-250A)

	2000	2500	3000	Vdc
Dc Plate Voltage				
Zero-Signal dc Plate Current *	60	65	70	mAdc
Single-Tone dc Plate Current	265	270	330	mAdc
Single-Tone dc Screen Current	55	55	55	mAdc
Single-Tone dc Grid Current	100	100	100	mAdc
Single-Tone Driving Power	38	39	40	W
Driving Impedance	160	150	140	Ohms
Load Impedance	3950	4500	5000	Ohms
Plate Input Power	530	675	990	W
Plate Output Power	325	435	600	W

4-1000A (VOICE CONDITIONS)

	3000	4000	5000	Vdc
Dc Plate Voltage				
Zero-Signal dc Plate Current *	60	80	110	mAdc
Single-Tone dc Plate Current	700	680	650	mAdc
Single-Tone dc Screen Current	105	80	55	mAdc
Single-Tone dc Grid Current	170	150	115	mAdc
Single-Tone Driving Power	120	110	90	W
Driving Impedance	104	106	110	Ohms
Load Impedance	2350	3200	4600	Ohms
Plate Input Power	2100	2700	3250	W
Useful Output Power #	1320	1790	2050	W

Useful output power is that which is delivered to the load. It is lower than plate output power because of the losses in the plate tank and amplifier output coupling circuits.

* Zero-signal dc plate current will vary significantly from tube to tube.

In all cases, grid current should be monitored. This may be accomplished by grounding the control grid through a 1-ohm composition resistor, bypassed by one or more .01 MFD disc ceramic capacitors (figure 5). The network serves to hold the control grid very near ground potential. Grid current is monitored by measuring the voltage drop across the 1-ohm resistor. The indicating meter is calibrated in terms of grid current. For example, to have a meter range of 100 milliamperes, the series meter resistor plus the internal meter resistance should equal 100 ohms.

For voice operation, plate or grid current (as read on the meter) will reach a peak value less than the single tone meter reading. Under average conditions, voice current peaks should be approximately one-half the indicated single tone current. For example, a single tone plate current of 300 ma is approximated by voice meter peaks of 150 ma. Driving the voice meter peaks to equal the value of single tone current will result in severe overload distortion.

Use of a high-C tuned cathode circuit in any grounded grid amplifier is mandatory if maximum amplifier efficiency, minimum TVI and lowest intermodulation distortion products are desired. The circuit need only have a Q of 2 or so.

For more information on grounded grid amplifiers and for amplifier design information, refer to the "Radio Handbook," 22nd edition, published by Howard W. Sams Co., 4300 W. 62nd St., Indianapolis, IN 46268.



GROUNDED SCREEN OPERATION OF TETRODE AMPLIFIERS

One of the design problems encountered in tetrode amplifiers is ensuring that the screen element of the tube is at rf ground even though a dc potential is applied to it. The problem arises because the perfect screen bypass capacitor has not yet been invented. Even the best capacitor contains residual inductance which (when added to the inductance of the screen lead of the tube) inhibits neutralization and encourages VHF parasitics. One solution to this problem is to eliminate the screen bypass capacitor by rearranging the circuit.

Figure 1 shows the conventional dc return paths wherein all power supplies are returned to the grounded cathode of the stage. Meters are placed in the common return leads, and each meter reads only the current flowing in the particular circuit.

The dc ground connection is removed from the cathode in figure 2 and placed at the screen terminal of the tube. Circuit operation is still the same as all power supply returns are still made to the cathode of the tube. The only change is that the screen rf ground and dc ground are now the same. The cathode circuit is at a negative potential with respect to the chassis by an amount equal to the screen voltage. Also, the return of the high voltage plate supply and the grid bias supply are now negative with respect to ground by the screen potential. The cathode is bypassed to ground, as shown.

A practical version of this circuit is shown in figure 3. The grid bias and screen supplies are incorporated in the amplifier and terminals are provided for positive and negative connections to the high voltage supply. A "tune-operate" switch is added which removes the screen potential for tune-up purposes. The negative of the plate supply "floats" below ground by the value of the screen voltage. A resistor is placed across the plate milliammeter as a safety device to prevent the circuit from being accidentally opened by chance failure of the meter. Note that the cathode bypass capacitor must be rated to withstand the full screen voltage.

Operation of this circuit is normal in all respects and it may be applied to any form of tetrode amplifier with good results.

Another version of this circuit is shown in figure 4. The screen supply is placed between the cathode and ground, and the supply must be capable of passing the dc plate current. The screen current is thus "swamped" by the plate current. Aside from the extra complication of high current screen supply, the advantage of an extremely stable screen voltage source is gained, plus the fact that the screen potential is added to that of the plate power supply. The plate voltage, therefore, is the sum of the plate and screen supply voltages.

Screen current and plate current should be monitored separately, because screen current is still the best indicator of loading in a tetrode amplifier stage, and also because the screen dissipation rating must be observed.

The resistors "R" serve to tie the plate and screen supplies to ground in the event of meter burn-out. The resistors are just large enough so that they do not materially affect the accuracy of the meters. The grid meter and power supply are "off ground" by the amount of the dc screen voltage and must be adequately insulated.

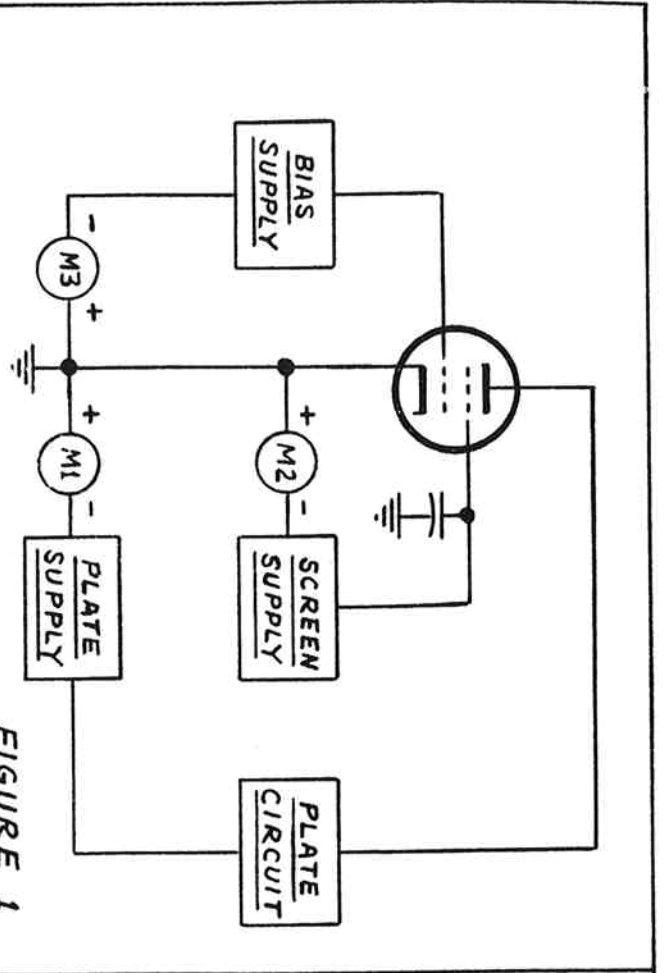


FIGURE 1

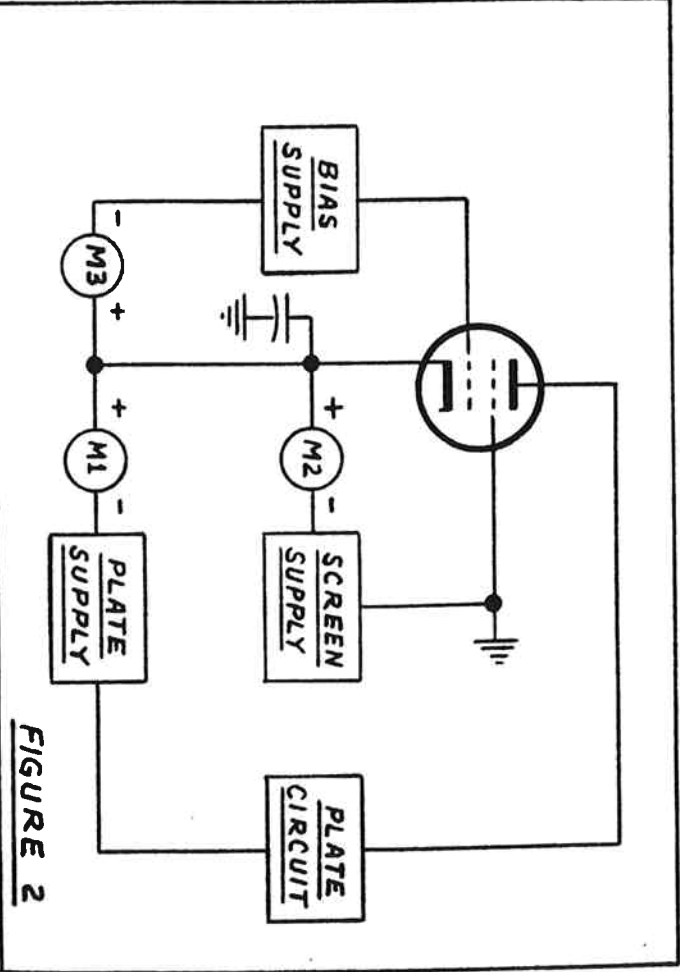


FIGURE 2

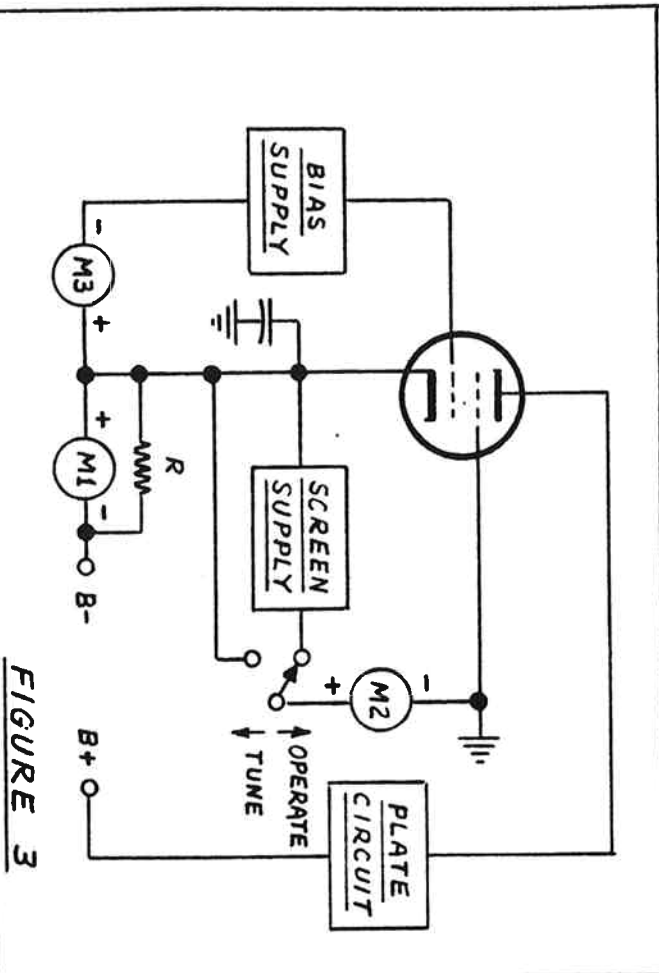


FIGURE 3

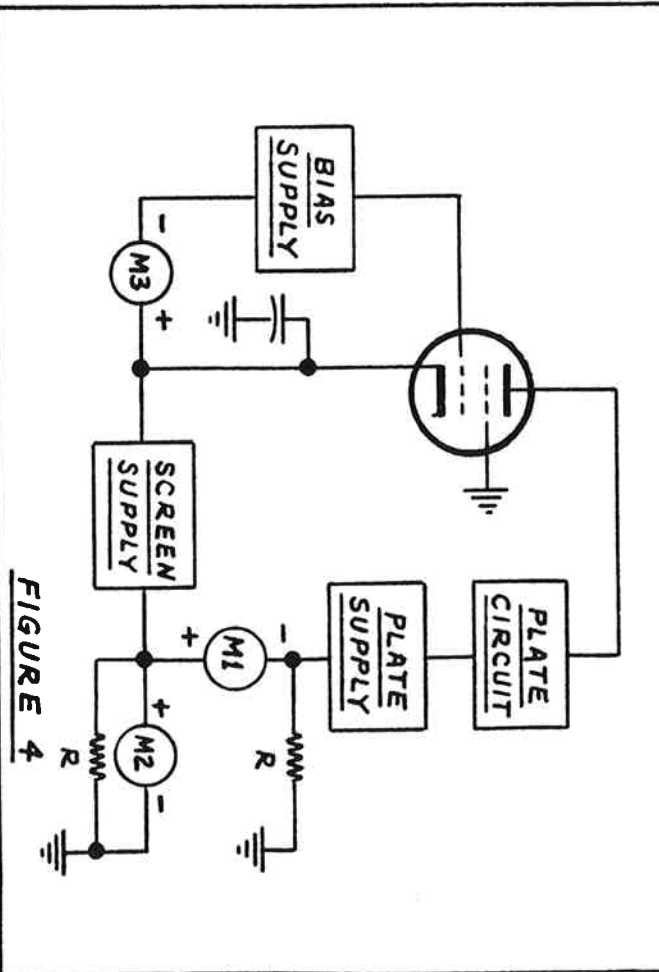


FIGURE 4

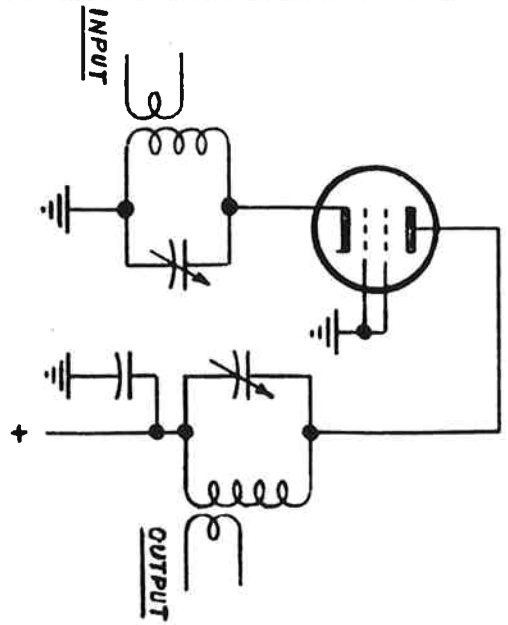


FIGURE 1

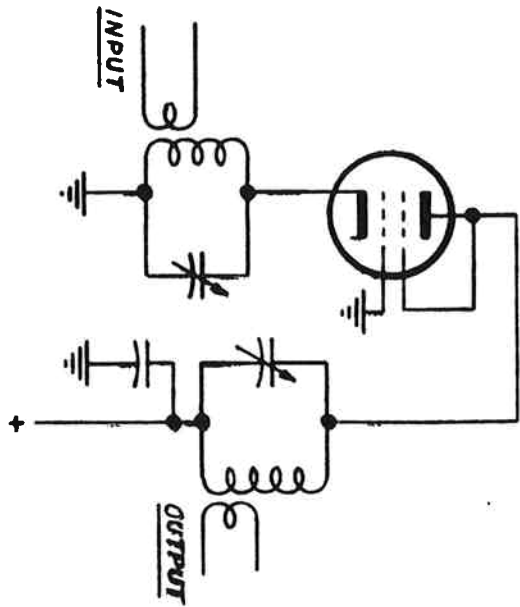


FIGURE 2

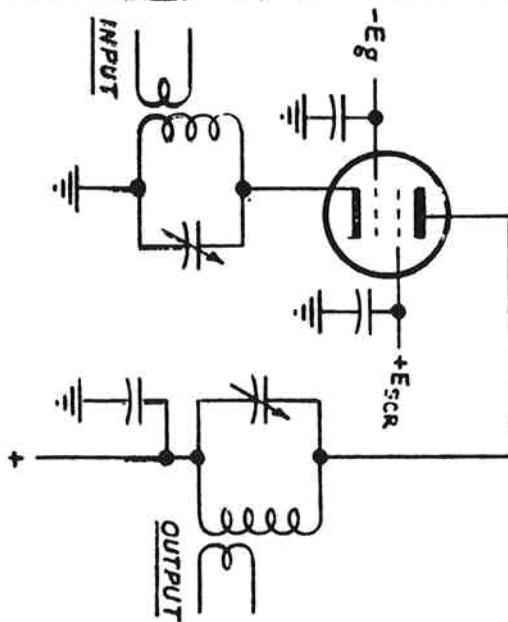


FIGURE 3

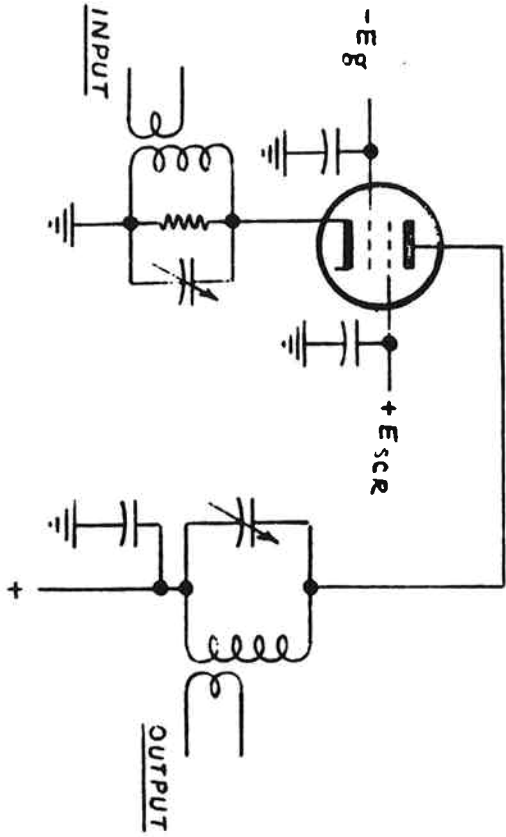


FIGURE 4

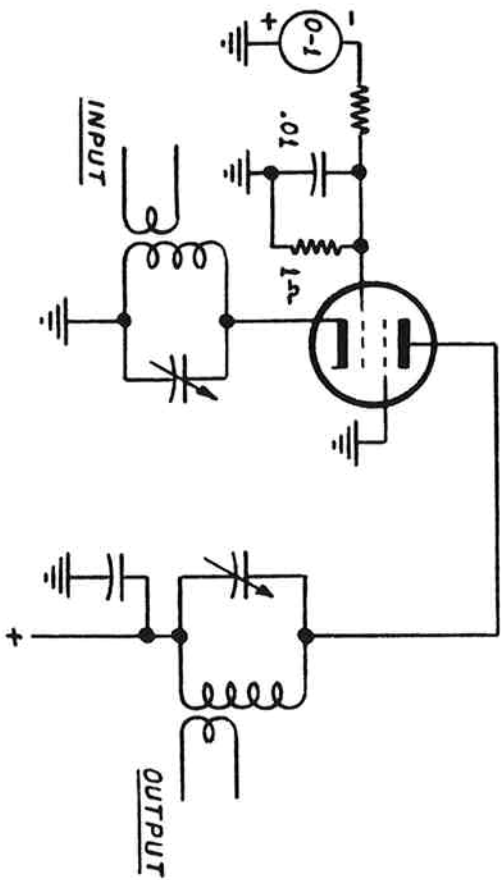


FIGURE 5



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THE 3-400Z and 3-1000Z FOR AMATEUR SERVICE
by William I. Orr, W6SAI

The EIMAC 3-400Z and 3-1000Z are zero bias triodes designed for grounded grid service in the high frequency spectrum. The tubes are rated at 400 and 1000 watts plate dissipation, respectively. No external bias supply is required over the plate potential operating range of 2000 to 3000 volts.

These tubes are especially suited for single sideband operation in the amateur service. Costly and bulky screen and bias supplies are not required. The tubes are small and rugged, and are designed to fit into modern, compact transmitter design. Best of all, the 3-400Z and the 3-1000Z provide improved linearity and a reduction of bothersome intermodulation products when operated in an approved circuit.

The 3-400Z is rated to 1000 watts PEP input, and the 3-1000Z is rated to 2000 watts PEP input. These ratings are established at moderate plate potentials, and result in third-and high-order product distortion figures better than -35 decibels below maximum output!

Preliminary operating data for these tubes is given in figure 1, and suggested circuits are shown in figures 2 and 3.

Circuitry for the 3-400Z

A simple operational circuit for the 3-400Z is shown in figure 2. The input circuit comprises a high-C tank (L1-C1), with excitation applied at a point which matches a 52 ohm driving source. The coil is bifilar wound, with the filament voltage applied to the tube via the coil. The grid of the tube is at ground potential for both d-c and r-f. The plate circuit consists of a pi-network (C5-L2-C6) with the output voltage monitored by a simple diode voltmeter.

The Cathode Circuit

Capacitors C3 and C4 form part of the cathode tuned circuit and comparatively high values of r-f current flow through them. The specified capacitors are satisfactory for the 3-400Z tube in continuous service, and will serve for the 3-1000Z in intermittent duty. These two capacitors should be grounded to a common point at the rotor of capacitor C1. Capacitor C2 carries the full excitation current and should be a transmitting type, as specified.

Although specifically designed for class B service, the 3-400Z may be operated as a class C power amplifier or oscillator or as a plate-modulated radio-frequency power amplifier. One can take advantage of the zero bias characteristic of the 3-400Z in class C amplifiers operating at plate voltages below 3000 volts by employing only grid-leak bias. If driving power fails, plate dissipation is then kept to a low value because the tube will be operating at the normal static zero bias conditions. Operating conditions are listed below:

MAXIMUM RATINGS	Class C Amp. or Osc.	Class C Plate-Modulated
D C PLATE VOLTAGE	4000 VOLTS	3000 VOLTS
D C PLATE CURRENT	350 MA	275 MA
PLATE DISSIPATION	400 WATTS	270 WATTS
GRID DISSIPATION	20 WATTS	20 WATTS
TYPICAL OPERATION		
D C Plate Voltage	3000 volts	3000 volts
D C Plate Current	333 m A	245 m A
D C Grid Voltage	-75 volts	-90 volts
D C Grid Current	130 m A	100 m A
Grid Driving Power	25 watts	18 watts
Plate Output Power	730 watts	550 watts

Air Sockets and Chimneys for the 3-400Z and 3-1000Z

In order to properly cool the seals and envelope of the 3-400Z and 3-1000Z, use of the EIMAC Air System socket is recommended. The SK-400 and SK-500 sockets are satisfactory; however, the new series SK-410 and SK-510 sockets are recommended for new equipments. These modernized sockets feature low cost, lighter weight design and simplified mounting. Low lead inductance insures proper tube operation.

The SK-410 socket may be used with the 3-400Z, 4-250A, 4-400A series tubes, in conjunction with the SK-416 chimney (for the 3-400Z) or the SK-406 chimney (for the 4-250A or 4-400A). The SK-510 socket may be used with the 3-1000Z (with the SK-516 chimney) or the 4-1000A (with the SK-506 chimney). See tube data sheet for air flow and full cooling information.

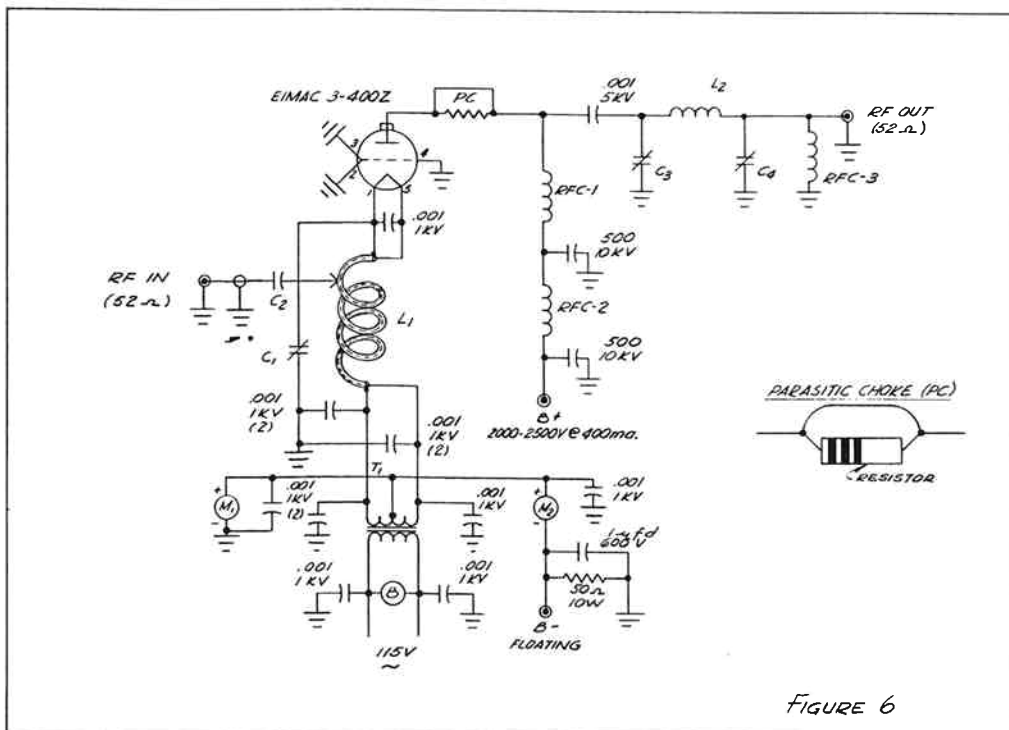


FIGURE 6

Using the 3-400Z on 50 MHz

The 3-400Z is rated for maximum service to over 100 MHz and makes an excellent grounded grid linear tube for 6 meter band. A suitable circuit for this service is shown in Figure 6. Neutralization is not required and the amplifier is stable and free of parasitics. A standard tuned cathode input and pi-network output circuit are used, with the grid and plate current meters placed in the d-c ground return. The power supply shown in Figure 3 can be used with this amplifier.

The amplifier may be built on a 10" x 14" x 3" aluminum chassis-box. Cathode circuit components are mounted within the box, with the plate circuit components placed atop the box. A complete cabinet, or enclosure should be built atop the chassis using perforated aluminum sheet. This will contain the various harmonics and reduce coupling between input and output circuits. The three grid pins of the 3-400Z socket (EIMAC type SK-410) are grounded directly to the chassis by means of wide copper straps passing through the adjacent socket slots. The straps (cut from flashing copper) are soldered to the socket pins, then bolted to the chassis directly next to the socket. Tuned cathode circuit L1/C1 is mounted close to the socket to insure short leads. The "cold" end of the bifilar filament coil (L1) is bypassed with two ceramic capacitors in parallel on each lead to bypass any r-f current flowing at this point. Input tuning capacitor C1 is mounted to the chassis in close proximity to the tube socket. All leads should be short and direct. Coupling capacitor C2 is placed near the tuned circuit and the lead from C2 to the input connector may be a length of 52 ohm coaxial cable.

The blower is mounted to the chassis, forcing air into the box which escapes via the tube socket and chimney.

FIGURE 1 Operating Data For EIMAC 3-400Z and 3-1000Z

3-400Z

Filament: 5 volts @ 14.5 amperes

Socket: EIMAC SK-400 Air System Socket

Cooling: Radiation and forced air

Maximum Operating Temperatures: Base, 200° C; Plate seal, 225° C

Typical Operation for minimum distortion products with 1 kw PEP input

DC Plate Voltage - - - - -	2500 volts
Zero Signal Plate Current - - - - -	73 mA ¹
Single Tone d-c Plate Current - - - - -	400 mA
Single Tone d-c Grid Current - - - - -	142 mA
Two Tone d-c Plate Current - - - - -	274 mA
Two Tone d-c Grid Current - - - - -	82 mA
Useful Power Output (PEP) - - - - -	560 watts
Resonant Load Resistance - - - - -	3450 ohms
Intermodulation Products - - - -	Typically more than -35 decibels below PEP level

Plate Voltage: 7.5 volts @ 21.3 amperes

Socket: EIMAC SK-500 Air System Socket

Cooling: Radiation and forced air

Maximum Operating Temperatures: Base, 200° C; Plate Seal, 225° C

Typical Operation for minimum distortion products with 2 kw PEP input

DC Plate Voltage - - - - -	2500 volts
Zero Signal d-c Plate Current - - - - -	162 mA
Single Tone d-c Plate Current - - - - -	800 mA
Single Tone d-c Grid Current - - - - -	254 mA
Two Tone d-c Plate Current - - - - -	550 mA
Two Tone d-c Grid Current - - - - -	147 mA
Useful Power Output (PEP) - - - - -	1050 watts
Resonant Load Resistance - - - - -	1700 ohms
Intermodulation Products - - - - -	Typically more than -35 decibels below PEP level

Figure 2: Grounded grid circuitry eliminates expensive bias and screen supplies required with grid driven circuitry. Good tube linearity, plus use of tuned cathode circuit results in low distortion, high power sideband amplifier.

Parts List:

- C1 -- 1000 pF (Three gang b-c variable, with sections connected in parallel. J.W. Miller #2113).
- C2 -- .01 μ F, mica. 1200 volt. Aerovox type 1446.
- C3 -- .01 μ F, mica. 500 volt. Aerovox type CM-30B-103.
- C4 -- same as C3.
- C5 -- 3500 volt rating. Effective tuning capacity; 2.5 pF per meter.
- C6 -- 500 volt rating. Effective tuning capacity; 25 pF per meter.
- L1 -- See text. Resonates to operating frequency with C1 setting of approximately 13 pF per meter. Approximate dimensions are: 80 meters, 10 turns, 1-5/8" i.d., 3-1/4" long, tap 6 turns from ground. 40 meters, 6 turns, as above, 2" long, tap 3-1/2 turns from ground. 20 meters, 4 turns, as above, 1-1/4" long, tap 2 turns from ground. 15 meters, 3 turns, as above, 1" long, tap 2 turns from ground. 10 meters, 1 turn, as above, tap 1/2 turn from ground. Make of 1/4-inch copper tubing, threaded with #12 insulated wire.
- L2 -- Make of 1/4-inch copper tubing, 3" i.d. To resonate to frequency with settings of C5 and C6 as specified above.
- M1 -- 0-750 mA M2 -- 0-1 mA M3 -- 0-1 mA
- R1 -- Internal resistance of meter M3 plus R1 totals 550 ohms. Meter reads 0-500 mA, full scale.
- T1 -- 5 volts at 14.5 amperes. Chicago type F-516.

RFC1 -- HF choke. B & W type 800.

RFC2 -- VHF choke. Ohmite Z-144.

PC -- Three 100 ohm, 2 watt composition resistors in parallel; shunt coil is 3 turns, 1" diameter, length of resistors.

B -- 115 volt blower. Minimum of 15 cubic feet per minute. Ripley #82.

FIGURE 3

T1 - 2900-0-2900 volts @ 500 mA CCS. 115-230 volt primary. 1600 VA capacity. Chicago #P-2126.

T2 - For 866A tubes: 2.5 volts @ 10 amp. 9 kV insulation. Chicago #F-210H.

For 872A tubes: 5 volts @ 15 amp. 10 kV insulation. Chicago #F-520HB.

CH1 - 10 Henries @ 500 mA. Resistance 40 ohms. Chicago #R-105

RYL - DPST relay. Potter & Brumfield PR7AY, with 115 volt a-c coil.

Note: 866A rectifier tubes may be used with 3-400Z. Use 872A rectifier tubes for 3-1000Z. Xenon type 3B28 may be substituted for 866A, and 4B32 for 872A.

FIGURE 4

Pi-network circuit for 3-1000Z

C1 - 1250 volt, transmitting-type mica capacitor. Aerovox type 1446 or 1651-L. Two capacitors may be connected in parallel to obtain odd values of capacitance.

80 meters:	1000 pF	15 meters:	150 pF
40 meters:	450 pF	10 meters:	100 pF
20 meters:	220 pF		

C2 - Same as C1. Capacitance as follows:

80 meters:	900 pF	15 meters:	90 pF
40 meters:	375 pF	10 meters:	30 pF
20 meters:	150 pF		

C3 - Same as C1. 0.02 μ F

L1 - May be made of B & W Miniductor coil stock, as follows:

80 meters:	2.5 μ H	15 turns, 1" diameter, 8 turns per inch. (B & W #3014).
40 meters:	1.1 μ H	8 turns, same as above.
20 meters:	0.55 μ H	7 turns, 3/4" diameter, 8 turns per inch. (B & W #3010).
15 meters:	0.37 μ H	6 turns, same as above.
10 meters:	0.3 μ H	6 turns, 1/2" diameter, 8 turns per inch. (B & W #3002).

Network may be adjusted by shorting capacitor C2 and trimming coil L1 until L1-C1 resonates to center of band of operation, or by making C2 variable and adjusting for maximum grid drive.

B - 115 volt, 60 cycle blower. Ripley #81. 45 cubic feet per minute.

RFC1 - 30 ampere bifilar filament choke. Barker & Williamson FC-30

Note: An alternative arrangement is to eliminate the bifilar filament choke and substitute a low-capacity filament transformer. (7.5 volts at 21.3 amperes). A suitable transformer is made by Transformer Technicians, Inc., 2608 No. Cicero Avenue, Chicago, Ill. (Type #TTI-4173).

