amateur service newsletter
W6SAI

A HIGH POWER LINEAR AMPLIFIER USING THE NEW EIMAC 3-1000Z

The Eimac 3-1000Z is a compact power triode designed for zero bias, class B r.f. and audio application. Grounded-grid operation is attractive as a power gain as high as twenty can be obtained in a cathode driven circuit. At a plate potential of 2500 volts, two kilowatts PEP input may be run, with intermodulation distortion products -35 decibels or more below maximum PEP level.

Shown in the drawing is the schematic of an all-band (3.5 - 29.7 Mc) amplifier designed around the 3-1000Z. A tuned cathode circuit is employed to achieve minimum distortion and ease of drive (1), and the popular bandswitching pi-network output circuit is used to match coaxial antenna feed systems.

The amplifier may be driven by any sideband exciter having a power output of approximately 65 watts. Drive is monitored by a grid current meter placed across a low impedance r.f. shunt located between grid and ground at the tube socket. The plate current meter is placed in the B-minus lead to the power supply. A simple diode voltmeter is used to indicate relative r.f. output, and is used for tuning purposes. During standby periods, the 3-1000Z is biased close to cutoff by the 50K resistor in the filament return circuit. The resistor is shorted out by the external VOX relay, grounding the center-tap of the filament transformer.

The new Eimac SK-510 Air-System Socket and SK-516 Chimney are recommended for use with the 3-1000Z. The older SK-500 socket may be used, provided care is taken to see that the contact pins move freely about, and do not place lateral strain on the tube pins. Flexible leads should be used with either socket to allow free pin movement.

At a plate potential of 2500 volts, peak plate meter current will be about 400 ma. under voice conditions, and grid current will approximate 125 ma. With carrier injection, the amplifier should be loaded to the single-tone operating conditions shown in the data sheet.

The amplifier may be constructed on a 14" x 17" x 4" aluminum chassis. The tuned input circuit and filament components are mounted below deck, and the plate circuit components atop the chassis. The chassis is pressurized by the addition of a bottom plate, and air forced into the chassis by a "squirrel cage" blower is exhausted through the air socket. The plate circuit components and tube are enclosed in a TVI-proof screen made of perforated aluminum sheet. Overall height of the amplifier is 14½".

(1) "The Grounded Grid Linear Amplifier", QST, August 1961, page 16.

3-1000Z LINEAR AMPLIFIER--PARTS LIST

C1--Three gang b.c. capacitor with sections in parallel. J. W. Miller #2113.

C2--500 $\mu\mu$fd., 10 KV. Jennings Radio Co. #UCSL-500 variable vacuum capacitor.

C3--1500 $\mu\mu$fd., 0.03" spacing. Barker & Williamson #51241.

L1--(See drawing) Mounted beneath chassis in close proximity to tube socket.

L2--Filament choke. Barker & Williamson FC-30. Windings connected in parallel.

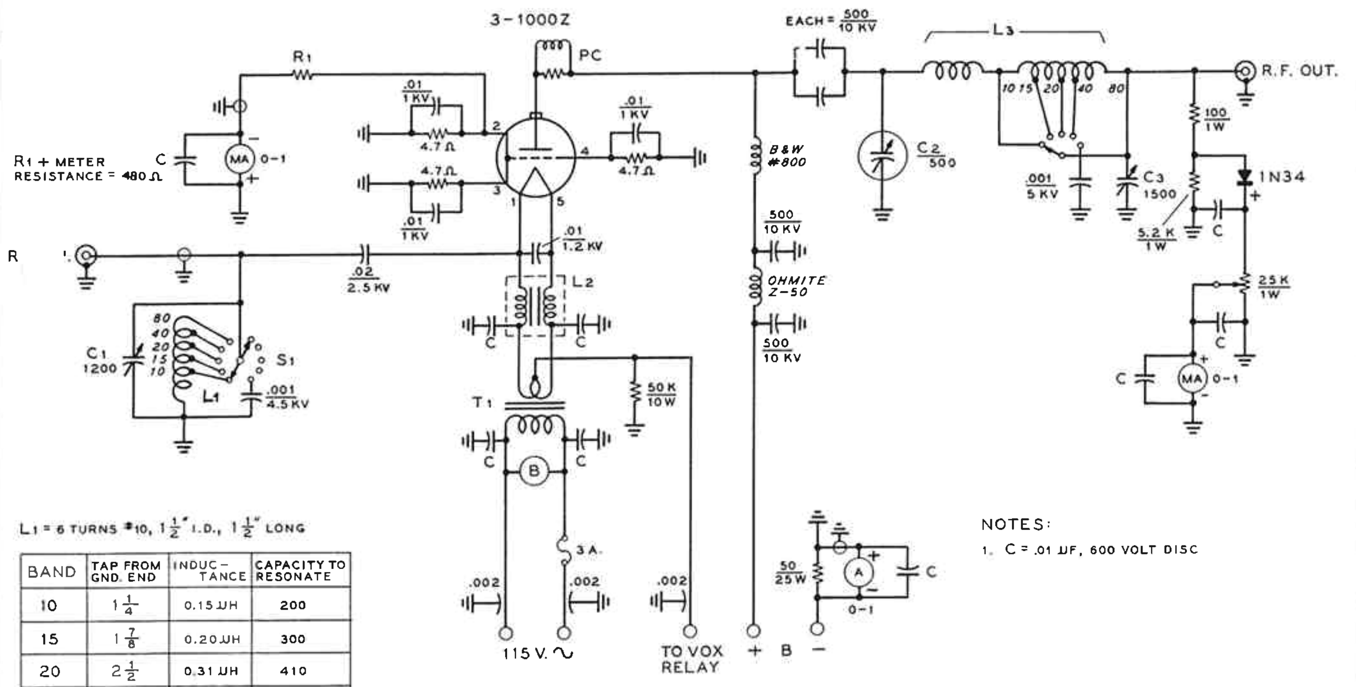
L3--Barker & Williamson #852 all-band coil assembly.

PC--Three 150 ohm, 2 watt composition resistors in parallel, shunted by three turns #12, 3/4" long.

T1--7.5 volts at 22 amperes. Stancor P-6457.

Blower: 20 cubic feet per minute, or greater. Dayton #1C-180, or Ripley #81.

G1 Meter: 0-1 d.c. milliammeter (55 ohms internal resistance), with multiplier. Full scale reading is 300 ma.



L1 = 6 TURNS #10, 1 1/2" I.D., 1 1/2" LONG

BAND	TAP FROM GND. END	INDUCTANCE	CAPACITY TO RESONATE
10	1 1/4	0.15 µH	200
15	1 7/8	0.20 µH	300
20	2 1/2	0.31 µH	410
40	4 1/8	0.62 µH	825
80	6	1.25 µH	1650

The 4-1000A in Grounded Grid

Fig. 1—K9LKA's kilowatt 4-1000A grounded-grid amplifier. Meters across the top of the panel are, from left to right, for plate voltage, relative r.f. output, plate current and grid current. The bandswitch control is in the center, flanked by the plate tuning control and capacitor switch S_2 on the left, and the output loading control on the right. Along the bottom are the filament switch, panel lamp and fuse; r.f.-indicator sensitivity control, and the input tuning control.

Most high-power triodes available at surplus prices do not have a sufficiently high amplification factor to permit zero-bias operation. Tetrodes may be converted to high-μ triodes by connecting the screen to the control grid. However, in the case of most tetrodes, this connection results in excessive control-grid dissipation at the driving-power level required to obtain normal rated output. The 4-1000A is one of the few exceptions to this rule[1] and is also one that is available in usable condition at relatively low cost from a number of sources. The triode connection results in considerable circuit simplification, especially in grounded-grid operation, since regulated bias and screen supplies are eliminated and neutralization is not required.

Zero-Bias Triode Operation in a 1-Kw. Linear

By LARRY KLEBER,* K9LKA

MANY construction articles describe radio gear that is almost impossible to duplicate with facilities available to the ordinary ham because of unusual mechanical requirements. Complicated gearing, chain drives or special metal shapes that require power tools found only in machine shops sometimes cause an otherwise excellent article to be passed by. In addition to the mechanical problems, cost is frequently completely out of reach for the would-be constructor.

Here is a kilowatt linear amplifier covering 10 through 80 meters that has several features to recommend it to the fellow who wants to increase power. First of all is the cost. Using all new parts, except the meters which are readily available from used- or surplus-equipment sources, the total expenditure will be less than $150 plus the cost of the tube. If you are willing to do some horse trading, scrounging and junk-box raiding, you can do it for considerably less. Type 4-1000As from broadcast or police radio transmitters are readily available at prices from $20 to $50. Surplus JAN tubes are listed by several *QST* advertisers, and they are regularly offered in Ham-Ads. Remember, the Eimac 4-1000A is built like a Mack truck and, once you have acquired one of these tubes in good condition, you can expect years of satisfactory service if you don't abuse it by overdriving the grid. That is why a grid-current meter is mandatory.

Secondly, construction is extremely simple. All mechanical work can be performed with ordinary hand tools. An electric drill will cut the con-

* 922 Whitney Blvd., Belvidere, Illinois.

[1] The Eimac data sheet on the 4-1000A as a grounded-grid triode qualifies this by adding, ". . . if a plate voltage of at least 3000 volts is used." — Editor.

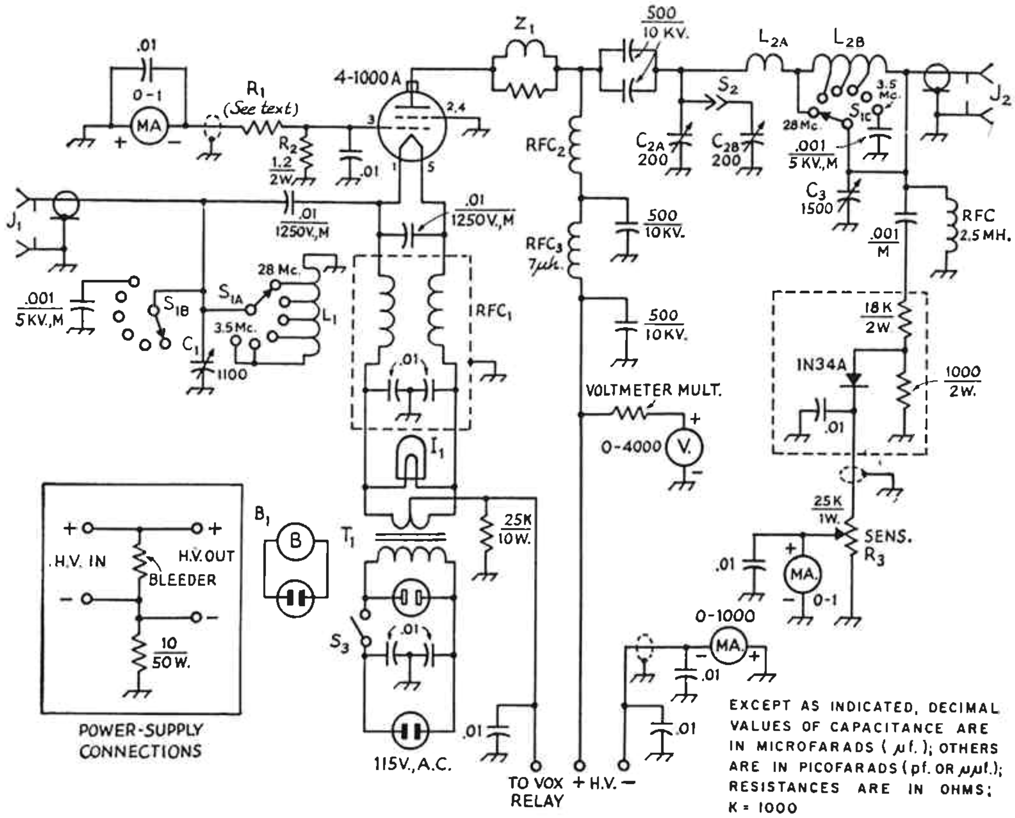


Fig. 2—Circuit of the 4-1000A grounded-grid amplifier. The 500-pf. 10-kv. fixed capacitors are TV doorknob type; others are 1-kv. disk ceramic, except M indicates mica.

B_1—Centrifugal blower, 60 c.f.m. at 0.6-inch static pressure (Ripley 8472).

C_1—Triple-section broadcast-replacement-type variable, 365 pf. or more per section, sections connected in parallel.

C_2—Dual air variable, 200 pf. per section, 7000 volts (Johnson 152-503/200CD70).

C_3—Air variable, 0.03-inch plate spacing (Cardwell PL-8013 or B & W 51241).*

I_1—6-8-volt panel lamp.

J_1, J_2—Chassis-mounting coaxial receptacle (SO-239).

L_1—6 turns No. 10, 1½-inch diam., 1½ inches long, tapped at 1¼, 1⅞, 2½, and 4⅛ turns from ground end.

L_2—Approximately 14 μh., tapped at 7, 3.5, 2.5 and 1.75 μh. (Barker & Williamson 850A band-switching inductor).

R_1—Approx. 27 ohms; see text.

R_2—Made up of four 4.7-ohm ½-watt carbon resistors in parallel.

R_3—Linear control.

RFC_1—30-amp. bifilar filament choke (B & W FC30A).

RFC_2—Solenoid r.f. choke (B & W 800).

RFC_3—Solenoid r.f. choke (Ohmite Z-50).

S_{1A-B}—Single-section double-pole six-position ceramic rotary switch, 60-degree index (CRL 2551).

S_{1C}—Heavy-duty single-pole six-position rotary switch (part of L_2 coil assembly, modified as described in the text).

S_2—See text.

S_3—S.p.s.t. toggle switch.

T_1—7.5-volt, c.t., 21-amp. filament transformer (Stancor P-6457, Chicago F-725).

Z_1—2 turns No. 8, ½-inch diam., shunted by three 150-ohm 1-watt carbon resistors in parallel.

* The Cardwell capacitor is listed in the 1963 Allied catalog. The B & W capacitor, which is identical, is not stocked by B & W as a retail item, and may or may not be available at any particular time, depending on manufacturing needs. It is advisable to check with B & W before ordering from this source.

struction time considerably, but it is not an absolute necessity. The meter holes can be cut with a bit brace, or with a hand drill and file. Best of all, every single component is standard merchandise and is readily available. Your favorite ham supplier may not have every item in stock, but he should be able to get any of them for you in a hurry.

Triode Operation

The 4-1000A may be connected for high-μ triode operation by placing the grid and screen elements at the same d.c. and signal potentials; in this case, both are grounded. This connection offers several advantages for sideband operation. First, no grid-bias or screen-voltage power supplies are needed. In addition, the drive level of this grounded-grid stage is compatible with the power-output level of modern sideband exciters. Finally, neutralization is not required.

The Circuit

The circuit of the amplifier is shown in Fig. 2. Excitation is fed to the filament through a 0.01-μf. 1250-volt (working) mica capacitor. A ceramic capacitor is not suitable for coupling since it will not stand the current. The cathode coupler, consisting of C_1 and L_1, does an excellent job of input matching. RFC_1 is the new B & W FC-30A bifilar filament choke which is more efficient than the earlier type FC-30. With the center tap of the filament transformer returned to ground through an extra pair of contacts on the VOX or antenna relay, the no-signal resting current will be approximately 60 ma. with 3000 volts on the plate. With the relay contacts open on standby, the 25K bias resistor drops the plate current to a negligible value.

A B & W type 850-A coil-switching unit is used in the pi-network output circuit. The type 852, incidentally, is not suitable for use with the 4-1000A, since it is designed for a much lower plate load impedance. Its use would not only require much higher input and output capacitances, but would also result in an abnormally high-Q circuit in this amplifier. Instead of an expensive vacuum variable for the tank capacitor, C_2 is a split-stator air unit with 0.175-inch plate spacing. To reduce the minimum circuit capacitance on the higher-frequency bands, one section of the dual capacitor is used for 10, 15, and 20 meters; the second section is switched in parallel with the first for the lower frequencies.

The variable output capacitor C_3 is a 1500-pf. unit with 0.03-inch plate spacing. This provides sufficient capacitance for the phone end of the 80-meter band. However, more capacitance will usually be required for the low-frequency end of this band, and this is provided by connecting a fixed 0.001-μf. mica capacitor in parallel with C_3 in the last position of S_{1C}.

Parasitic Suppression

Several different makes of chokes were tried at RFC_2 in conjunction with many different resistance-inductance combinations in the v.h.f. suppressor Z_1. However, it was found practically impossible to completely eliminate parasitic oscillation on all bands until the B & W type 800 choke was tried.

Metering

Grid current is monitored very simply. The control grid is grounded through four 4.7-ohm ½-watt composition resistors in parallel, bypassed by a 0.01-μf. disk ceramic capacitor. The RC combination serves to hold the control grid very close to ground potential. Grid current is monitored by measuring the voltage drop across the resistors with the 1-ma. grid meter, calibrated 0–300 ma. full scale, and a series resistor.

A simple way to determine the value of the series resistor R_1 is to place a regular milliammeter with a scale of 200 ma. or more from the VOX relay terminal to ground. Apply excitation, and substitute resistors at R_1 until both meters have the same deflection at 150 ma. As an example, the Weston Model 301, 1-ma. meter requires a 27-ohm series resistor.

Plate current is measured by a 0–1-amp. d.c. meter shunted across a 10-ohm resistor in the negative high-voltage lead. This resistor is incorporated in the power supply, not in the amplifier itself. The 50-watt rating gives an ample safety factor, since the power dissipation would not exceed a few watts should the ammeter open up. Notice that the negative terminal of the supply must not be grounded except through the 10-ohm resistor.

A plate voltmeter has a definite place in this amplifier, or in any other amplifier where the d.c. input runs 900 watts or more, since it is required by FCC regulations. Even if you run less than 900 watts, it is reassuring to know exactly what your input is at all times.

To continuously monitor the r.f. output level of the amplifier and to aid in efficient tuning, a simple r.f. voltmeter has been incorporated in the circuit. Absolute readings are not necessary, so provision has been made for varying the sensitivity by adjustment of R_3.

Component Modification

Some of the components require minor modification before mounting. The last rotor plate and the last stator plate of the rear section of the tank capacitor C_2 are removed. This is section C_{2A} in the diagram, which is used alone on the higher frequencies. The operation is simple and requires no special tools. The alteration reduces the minimum capacitance to permit a more favorable Q on 10 meters. To further reduce the minimum circuit capacitance, the stators of C_2 are moved farther away from the chassis by mounting the capacitor in an inverted position; that is,

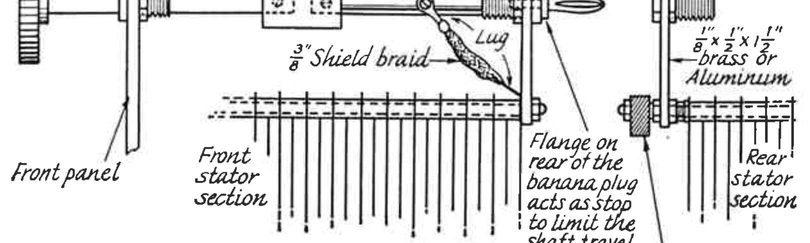


Fig. 3—Sketch showing details of the tuning-capacitor switch, S_2. The stator sections are connected in parallel when the panel control knob is pushed to engage the plug in the jack.

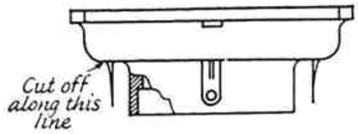


Fig. 4—Sketch showing how the lower portion of the tube socket is cut off.

with the stators on top. The mounting feet of the Johnson capacitor are easily moved to permit mounting in this manner, since the capacitor frame has duplicate mounting holes.

Fig. 3 shows the device used for S_2. Similar metal brackets are attached to adjacent ends of the stator-assembly rods of the dual capacitor. The bracket on the rear end of the front capacitor section (C_{2B}) carries a ¼-inch panel bearing through which a 3-inch length of ¼-inch brass rod slides. One end of this rod is drilled and tapped to accept the threaded shank of a banana plug. The other end of the brass rod is coupled to a 3⅛-inch length of ¼-inch bakelite rod which passes through another bearing in the panel to the control knob. The shaft coupler should be of the rigid type, either metal or ceramic. To assure good contact between the stator of C_{2B} and the banana plug, a piece of ⅜-inch flexible copper braid is used to connect the two directly, rather than to depend on the sliding contact at the bearing.

The banana jack is mounted on the other bracket. Be sure that the two brackets are drilled identically so that the plug and jack may be lined up accurately.

One other slight modification was made in the capacitor before mounting. A small triangular bracket was mounted inside the rear frame plate, that is, between the capacitor sections. This was fastened in place using the same screws which hold the ceramic stator bar against the frame plate. The upper point of the triangle extends sufficiently above the frame plate to allow mounting a 1-inch ceramic pillar. After the components were mounted on the chassis, the open end of the 10-meter section of L_3 was removed from the coil assembly, turned end for end, and fastened between the ceramic end plate and the ceramic pillar. A short length of ¼-inch copper tubing, also fastened to the ceramic pillar, connects the coil to one side of the blocking capacitors. Another short length of tubing connects the rear stator terminal of C_{2A} to the same point.

It will be noted that the 0.001-μf. fixed output capacitor requires an additional switch position. Fortunately, this is not difficult to provide, since there is already a hole for an extra stationary contact in the ceramic end plate of the B & W coil unit. All that is necessary is to obtain a switch contact from B & W [2] for one dollar (or make a reasonable facsimile) and mount it in the spare hole.

The socket for the 4-1000A is Eimac's new plastic type SK-510 (amateur net $6.50). It is designed primarily for duct connection to a blower. For the pressurized-chassis ventilating system used here, you can improve the air flow by cutting off the "nose" of the socket with a hacksaw, as shown in Fig. 4. Remove the socket contacts while this operation is performed, to avoid damaging them. Use extreme care in sawing. Although the socket is made of a tough plastic, unusual stress or strain may cause it to break.

You will note that the socket has slots next to the pins, right in the side of the molded fixture. To ground the two screen leads, pass a ¼-inch copper ground strap through the slot and solder it to the bottom of the screen contact inside the socket; then ground the strap to the chassis at the point where it emerges from the socket. The grid bypass capacitor should be installed in the same manner. One lead passes through the slot and is soldered to the bottom of the grid contact, while the other lead is grounded to the chassis. The leads should be only ¼-inch long.

Construction

The 14 × 17 × 4-inch chassis is made up of a pair of SeeZak [3] R414 rails (4 by 14 inches), a pair of R417 rails (4 by 17 inches), and two P1417 panels (14 by 17 inches). Standard 13 × 17×4-inch chassis are readily available, of course, but the extra inch of depth provided by the SeeZak units is necessary to accommodate C_2 which has a length of 13$\frac{1}{16}$ inches. Machining of the front and rear chassis walls and the top deck is greatly simplified by using these handy rails and panels. No more trying to get big fingers and tools into small corners. You can do all of the drilling and cutting on flat plates, and then assemble your chassis.

[2] Barker & Williamson, Bristol, Penna. Mention 850A type number when ordering.

[3] SeeZak products are available from Radio Shack Corp., 730 Commonwealth Ave., Boston 17, Mass., Terminal Hudson Electronics, 236 West 17th St., New York, N. Y., and California Electronics Supply, Los Angeles, among others.

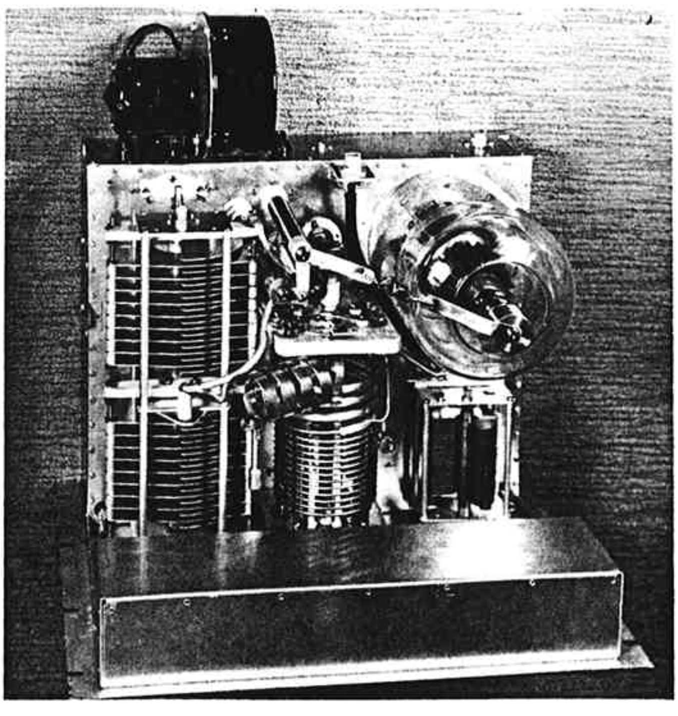


Fig. 5—Plan view of the 4-1000A grounded-grid amplifier. This view shows how the position of the 10-meter section of L_2 is changed.

Cathode Coupler

Place S_1, L_1, and C_1 close to the tube socket, as shown in Fig. 6. In this amplifier, Millen type 39005 universal-joint couplings were used between the shaft of C_1 and the front panel to allow the control to be placed symmetrically in respect to others on the panel. Even though the shaft and rotor of C_1 are at ground potential, use an insulated shaft coupling to couple the indicator dial to avoid the possibility of setting up a spurious tuned circuit. If you don't gang the input and output band switches, as described presently, use an extension shaft on the input switch so that the switch can be placed close to the tube socket.

Ganging the Switches

It is not difficult to gang S_{1A-B} and S_{1C} to provide single control. This can be accomplished by means of a National type RAD geared right-angle shaft coupler. A Johnson rigid ceramic shaft coupler (type 104–252) is attached to the tail shaft of the B & W coil unit. A short length of ¼-inch brass rod couples the gear end of the right-angle drive to the ceramic coupler. S_{1A-B} is mounted below deck with its shaft extending through a clearance hole in the chassis so that the shaft can be lined up with the shaft of the right-angle drive. The two shafts are coupled together by means of a ceramic semiflexible coupler (Johnson 104–262). Since the switch on the B & W coil unit has 60-degree indexing, S_{1A-B} must have the same indexing, rather than the more common 30-degree indexing. The 60-degree switch is, however, a standard item in the manufacturer's catalog. A 30-degree switch may be used, of course, if ganging is dispensed with.

Wiring

As the photographs indicate, very little actual wiring is required. The positive high-voltage lead enters the rear of the chassis through a Millen high-voltage connector where it immediately connects to the first 500-pf. bypass capacitor. RFC_3 is mounted between this capacitor and a feedthrough insulator which is connected to one side of the voltmeter multiplying resistor. The feedthrough carries the high voltage through to the top of the chassis where it connects to the second 500-pf. capacitor mounted on the chassis, and to the bottom end of RFC_2. A tapped ceramic pillar insulator threads onto the top terminal of this capacitor. The two blocking capacitors are suspended from a short copper strap fastened across the top end of the insulator, and a second strap connects them to the top of the r.f. choke. The parasitic suppressor Z_1 is inserted at the center of a copper strap connecting the top of RFC_2 to the plate cap of the tube.

Since the high-C input circuit carries considerable current, the r.f. wiring should be done with reasonably heavy wire (I used No. 10). This includes the short between the 80-meter contacts of S_{1A}.

A lead attached to the stator of C_3 passes down through the chassis via a second feed-through insulator to the box below containing the r.f. output-indicator components. A short section of RB-8/U connects the stator of C_3 to J_2. Be sure to ground both ends of the outer conductor.

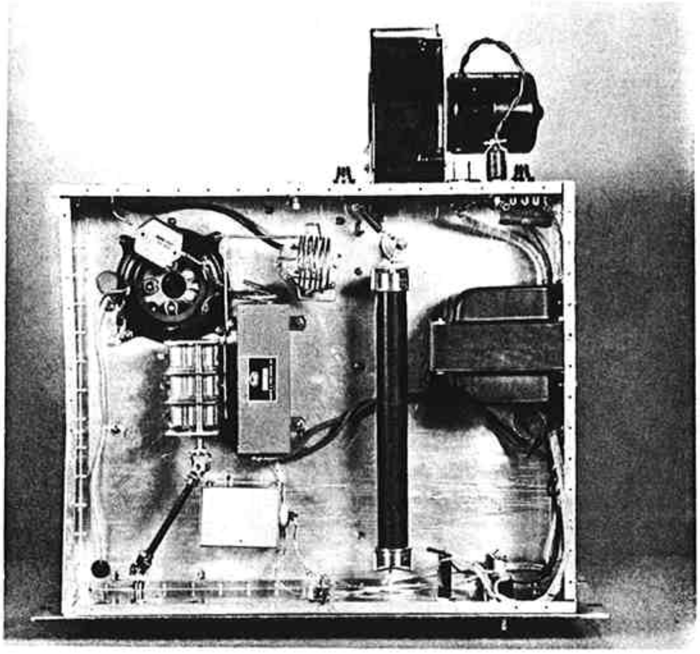


Fig. 6—Bottom view of the 4-1000A amplifier. The filament transformer and voltmeter multiplier resistor are to the right. The input coil, L_1, is at top center, supported on S_{1AB} by its leads. Input capacitor C_1 is operated through a pair of universal-joint shaft couplers so that the capacitor may be placed close to the tube socket without upsetting panel-layout symmetry. The small shielding box (2¾ × 2⅛ × 1⅝-inch Minibox), below the bifilar filament choke, houses the r.f. output-indicator diode and associated components.

Blower Mounting

Don't compromise on the blower. The 4-1000A requires 60 c.f.m. at 0.6 inch of static pressure. Some so-called 60-c.f.m. blowers aren't worth their salt when you try to pressurize the chassis. The blower suggested does an excellent job in this respect, and is priced quite reasonably.

Be sure to place the blower well away from the tube socket. If it is placed too close, it will create a pressure wall across the bottom of the socket which will tend to restrict the flow of air through the base and chimney.

An a.c. receptacle is set in the rear apron of the chassis and a short cord from the blower motor plugs into it.

The Panel

The panel is a standard 15¾ × 19 × ⅛-inch unit of aluminum. The four meters are in line across the top. A 4 × 17 × 3-inch aluminum chassis fits over the back of the line of meters to shield them from r.f. fields. It is held in place by eight No. 6 sheet-metal screws inserted from the front. Shielded meter leads (Belden 8882 wire) are brought up from below chassis through rubber grommets in the chassis and in notches filed in the bottom front corners of the meter enclosure.

The panel is fitted with chrome handles (Bud type H9113) for lifting the amplifier in and out of the rack mounting. They also serve to protect the controls if it becomes necessary to place the unit face down on your workbench for service.

The lettering was done with Tekni-Cals, and the engraved plates are obtainable from Central Engravers[4] at 5 cents per letter.

The Shielding Enclosure

The two ends and the back of the shielding enclosure are made of 0.51-inch solid sheet aluminum, while the top is made of perforated sheet of the same weight. One of the SeeZak P1417 panels is used for the bottom cover. Aluminum angle stock, ½ inch by ½ inch, is used to join the pieces with the help of ¼-inch No. 6 sheet-metal screws spaced every two inches. All of the above pieces, including the angle stock, may be obtained cut to size if desired.[5]

Adjustment

After checking out the filament circuit and grounding the center tap of T_1, reduce the sensitivity control of the r.f. voltmeter to near minimum. Select the proper band with S_1 and apply excitation. Adjust C_1 for a grid current of approximately 150 ma. Apply plate voltage and load, and resonate the output circuit with C_2. With a plate voltage of 3000 and grid current of 160 to 170 ma., alternately adjust C_3 and C_2 to increase the plate current to 300 ma. or slightly over. In observing the r.f. voltmeter, you will note that maximum output does not always occur at the point of resonance as indicated by the dip in the plate current.

The amplifier may be checked for linearity as described in the *Radio Amateur's Handbook*.

I am very grateful for the technical advice and suggestions of Bill Orr, W6SAI, and George Stinson, W9KDK. Their analysis of the problems encountered, as well as their suggestions for changes during construction, made this a much better amplifier, and a pleasure to build. Operating at an input of 1 kw. or less, this amplifier actually "coasts" and will give you years of trouble-free service. QST

[4] 529 South State, Belvidere, Illinois.
[5] From Dick's, 62 Cherry Ave., Tiffin, Ohio.

Reprinted from July 1963 QST

"PULSE TUBES" IN AMATEUR SERVICE

Certain vacuum tubes designed for high voltage pulse service are now available to the radio amateur through "surplus" channels. Some of these tubes (such as the 6C21, which is a variation of an earlier transmitting tube) are suitable for amateur service. The 6C21 is roughly equivalent to the Eimac 1000T triode and the data sheet for the latter may be used to arrive at the proper operating parameters for the 6C21. Other pulse tubes, such as the 4PR60A, 715A-C, 4PR250C, X643A-F, X556D and Y-158 have no earlier r.f. prototype, as the tubes were developed solely with pulse service in mind. This family is designed to be used in high voltage service (up to 50 kilovolts) and the internal geometry is such that the tubes do not perform efficiently at plate potentials normally encountered in amateur operation. In particular, the 4PR60A type can be damaged by excessive screen dissipation when lower than normal plate voltages are used. These tubes, therefore, must be considered impractical for amateur service.

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PLANAR TRIODE TUBES FOR UHF AMATEUR SERVICE

Planar triodes (or lighthouse tubes) are well suited for amateur use in the UHF spectrum. Various surplus versions, such as the 2C40, 446B and 2C39 have been used at frequencies up to 1300 Mc. A new planar triode, the 3CX100A5 is now available for improved service in this frequency region.

The 3CX100A5 is relatively unknown to the amateur fraternity, but its older relative, the 2C39A, has been long a favorite UHF tube of the "surplus hounds". The 3CX100A5 is an improved, modern version of this old World War II tube, dressed up in a brand-new ceramic and metal envelope. This tube, and its twin, the 7289 fit into the amateur picture very nicely as a straight-through amplifier, a doubler, or as a tripler in the frequency range of 1000 to 3000 Mc. In addition, it is not expensive, and various glass versions of the older 2C39/2C39A/2C39WA can often be obtained at give-away prices on the surplus market.

The following data covers grounded grid operation of the 3CX100A5 as a UHF power amplifier and multiplier. Because of the high power gain of the tube, grounded grid circuitry is desirable, since intercoupling between the input and output circuits is reduced to a minimum, and neutralization is not required. This data can be used to estimate the performance of the 2C39 glass family of tubes by noting that the useful power output of this style tube will be somewhat less (depending upon the frequency) by an amount up to 25-percent at 2.5 kMc as shown on the graphs.

Various 3CX100A5 tubes were run in a coaxial cavity capable of tuning from 1000 mc (1 kMc) to 3000 mc (3 kMc). A series of measurements was made using a representative sample of standard production tubes, with the tube under test operating as an amplifier, doubler and tripler. Drive and output power were carefully measured for each test, and appropriate filters were used to eliminate feedthrough and harmonic power. In the case of the amplifier configuration, the feedthrough power was useful output and therefore was measured as such. When the tube is operated as a doubler or tripler, the feedthrough power is at the driving frequency and is undesired. In actual use, it is necessary to eliminate this power from the output circuit of any grounded grid frequency multiplier. High-Q tuned circuits or wave filters will do the job.

The 3CX100A5 as a Grounded Grid Amplifier

A graph of average tube performance is shown in figure 2 of the UHF grounded grid amplifier circuit. Grid drive, grid bias, and plate loading were adjusted to provide maximum power output while maintaining the plate current at 100 ma. Average potentials for tubes tested are indicated on the graph. At 1300 mc, for example, the 3CX100A5 is capable of a power output of about 47 watts at an efficiency of 47%. The power gain of the tube is 8 decibels, indicating a required drive level of about 7.5 watts as measured at the input of the coaxial fitting to the cavity. Power output gradually decreases as the frequency of operation is raised. At 2400 Mc, power output (at 100 watts input) drops to 25 watts, and grid driving power increases to 10 watts. Power gain at this frequency is 2.5. The comparative curve for the 2C39A tube over the same frequency range is shown by a dotted line on the graph.

The 3CX100A5 as a Grounded Grid Doubler

The same sample of tubes used in previous tests was used in performing the gain and power output measurements for the doubler configuration. Excitation was applied at half-frequency and the same precautions were followed as in the case of the amplifier. Test conditions were adjusted for maximum power output at a plate current of 100 ma. At 1300 Mc, power output is about 27 watts, with a circuit efficiency of 27%. Power gain is 5.4 decibels. Accordingly, a drive power of about 8 watts is required. At 2400 Mc, power output is 13 watts, with a drive power of about 9 watts. Power gain drops to unity at a frequency of about 2700 Mc. The tube is still useful as a frequency doubler to this frequency, however, as a power output of 10 watts can be obtained. 2C39A curve is shown as dotted line on the graph (figure 3).

The 3CX100A5 as a Grounded Grid Frequency Tripler

The same tubes and general test techniques were used to determine the operating parameters of this tube as a frequency tripler. Drive power was applied at one-third output frequency, and the circuit was adjusted for maximum power output. At 1300 Mc, 17 watts of power were obtained with about 10 watts driving power. At 2400 Mc, power output was about 8 watts, with about 12 watts drive power (figure 4).

Socket and Collets for the Planar Tubes

A complete socket for the 3CX100A5/2C39 type tube is a rare bird indeed: most equipments have the tube sockets built directly into r.f. cavities. Collet rings for the tube, however, may be bought from Instrument Specialties Co., Little Falls, N.J. The catalog numbers are: Plate collet, #97-70; grid collet, #97-72; cathode collet, #97-76; filament collet, #97-280. The Braun Tool & Instrument Co., 140 5th Avenue, Hawthorne, N.J. can supply the following: Plate collet, #134-53; grid collet, #134-51; cathode collet, #165; filament collet (none). A complete socket assembly may be purchased from Jettron Products, Inc., 56 Route 10, Hanover, N.J.

Conclusions

The planar triode tubes of the 3CX100A5 family perform well in the frequency range encompassing the 1215 Mc and 2400 Mc amateur bands. Efficiency is good, considering the frequency of operation. "Radio Engineering" by F.E. Terman indicates that a doubler will provide about 65% of the power output of a straight-through amplifier, and a frequency tripler will provide about 40% of the power output of the amplifier. These figures agree closely with the data shown herein. A pair of 3CX100A5's should make quite a dent in the 1215 Mc band! See you on the high end!

Robert I. Sutherland, W6UOV

Type	Manufacturer	Comment
2C39A	Eimac, Machlett	Glass or ceramic construction
2C39WA	"	"
6897	General Electric	Not interchangeable electrically in most high frequency sockets with 3CX100A5 or 7289
2C41	Machlett	Not interchangeable physically with 3CX100A5 or 7289
381	Eimac, Machlett	3CX100A5 type, rated for pulse service (Eimac-glass or ceramic)
3CX100A5	Eimac, Machlett General Electric	All ceramic construction
7289	Eimac, Machlett, General Electric	Identical to 3CX100A5
3CX100F5	Eimac	Identical to 3CX100A5 except heater voltage is 26.5 volts

Figure 1. Planar Triode Tubes

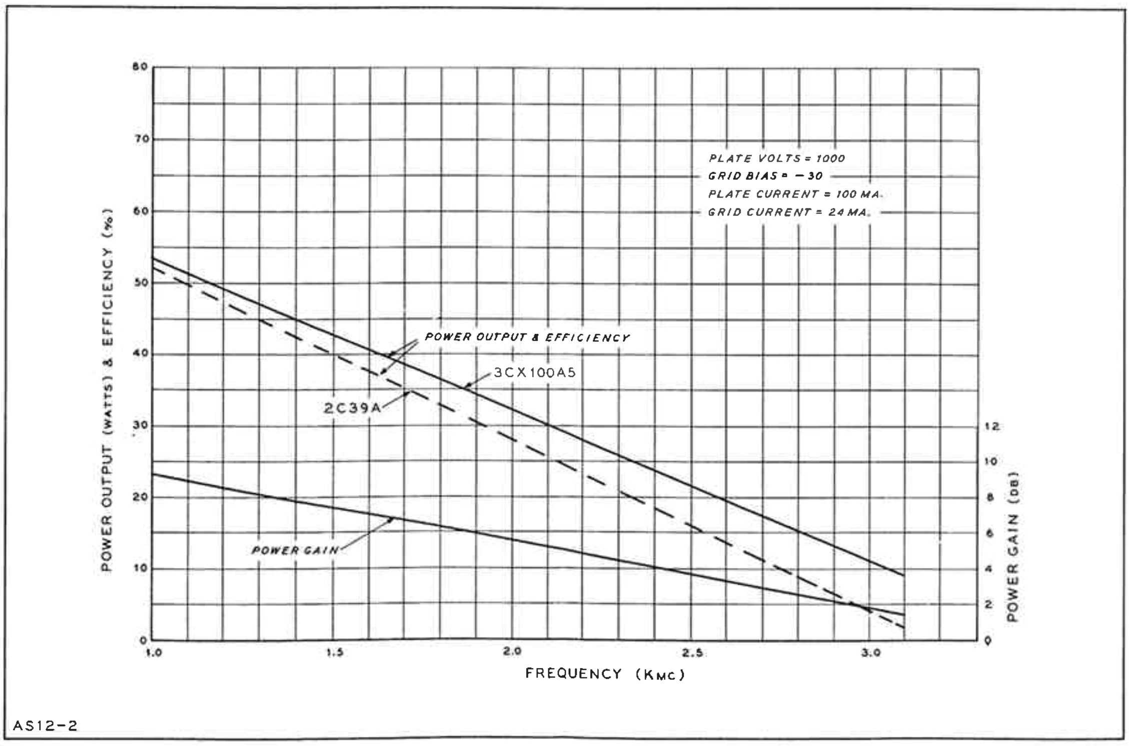

Figure 2. 3CX100A5 grounded grid amplifier; typical power output, gain and efficiency. Glass 2C39A power output shown by dashed line.

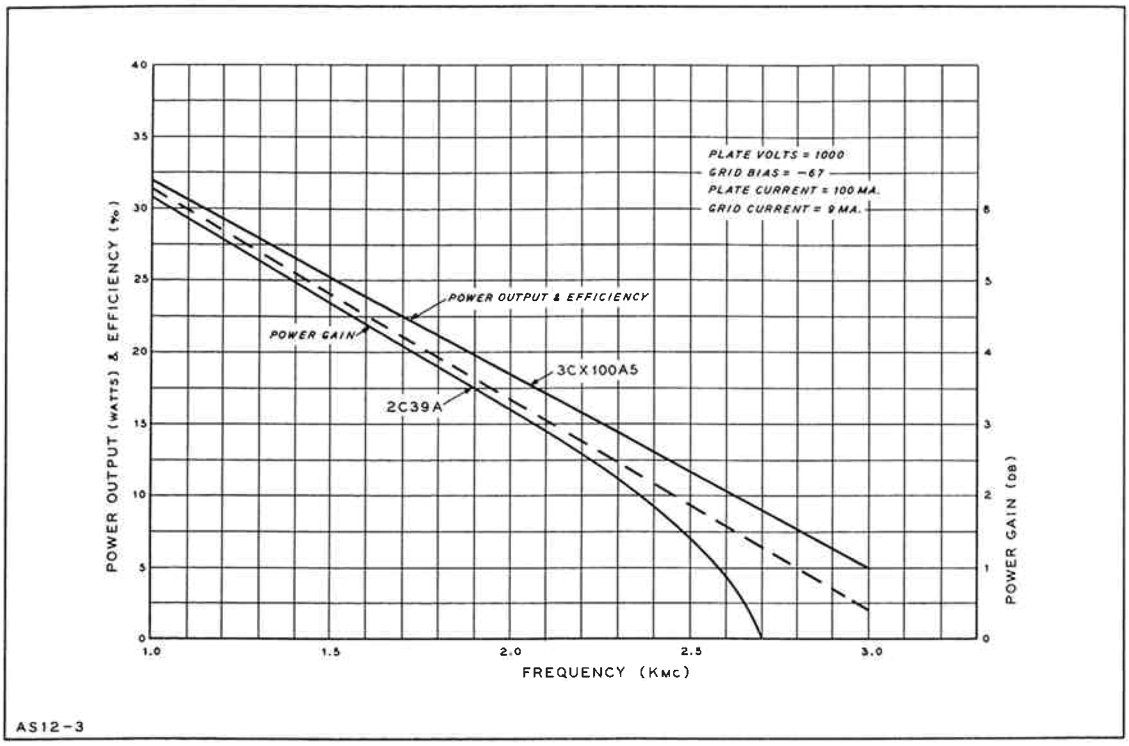

Figure 3. 3CX100A5 grounded grid doubler; typical power output, gain and efficiency. Glass 2C39A power output shown by dashed line.

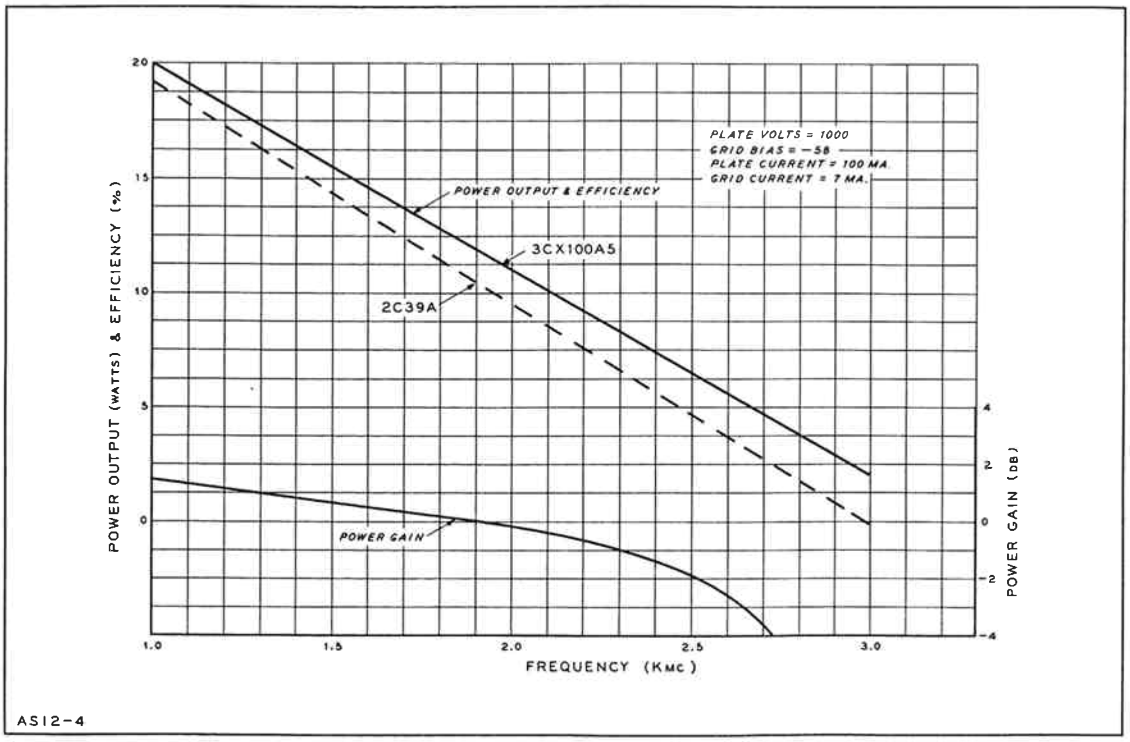

Figure 4. 3CX100A5 grounded grid tripler; typical power output, gain and efficiency. Glass 2C39A power output shown by dashed line.

amateur service newsletter
W6SAI

UNDERSTANDING TETRODE SCREEN CURRENT

Significance in R.F. Amplifier Adjustment and Operation

by David D. Meachum, W6EMD

This article discusses the behavior of screen current in a tetrode r.f. power amplifier using fixed screen voltage, and explains why a screen-current meter is a better indicator of operating conditions than a plate-current meter. Particular reference is made to the adjustment of AB_1 linear amplifiers.

Perplexing screen-current behavior has probably disturbed many amateurs, particularly single-sideband operators. The need for a thorough discussion of the subject has prompted this article. Class AB_1 operation has been chosen for discussion because of its current popularity as a means of achieving good linearity and TVI-free operation. The information given herein assumes grid-driven conditions, but it applies equally well to cathode-driven tetrodes operated Class AB_1 with normal d.c. voltages on the grid and screen, provided that grounded-grid characteristic curves are used for computations.

Screen Characteristics

Fig. 1 shows a set of constant-current characteristics for a typical 4CX300A. The term "constant current" is used because the lines plotted are lines of constant plate, screen, or grid current. The grid-voltage scale appears on the left axis and plate voltage is shown horizontally. These curves depict instantaneous values of plate and screen current for any given grid- and plate-voltage conditions. In this reproduction, the grid-current lines are omitted because grid current is not drawn in Class AB_1 operation. The curves are valid only for fixed screen voltage (350 volts in this case).

Inspection of Fig. 1 will reveal that the lines of constant plate current are nearly horizontal, whereas the constant-screen-current lines are tilted upward from left to right and are concentrated in the left-hand region of the plot. This is generally true for all tetrodes and accounts for the fact that the screen-current meter is the most sensitive indicator of resonance. This important fact will be explained subsequently.

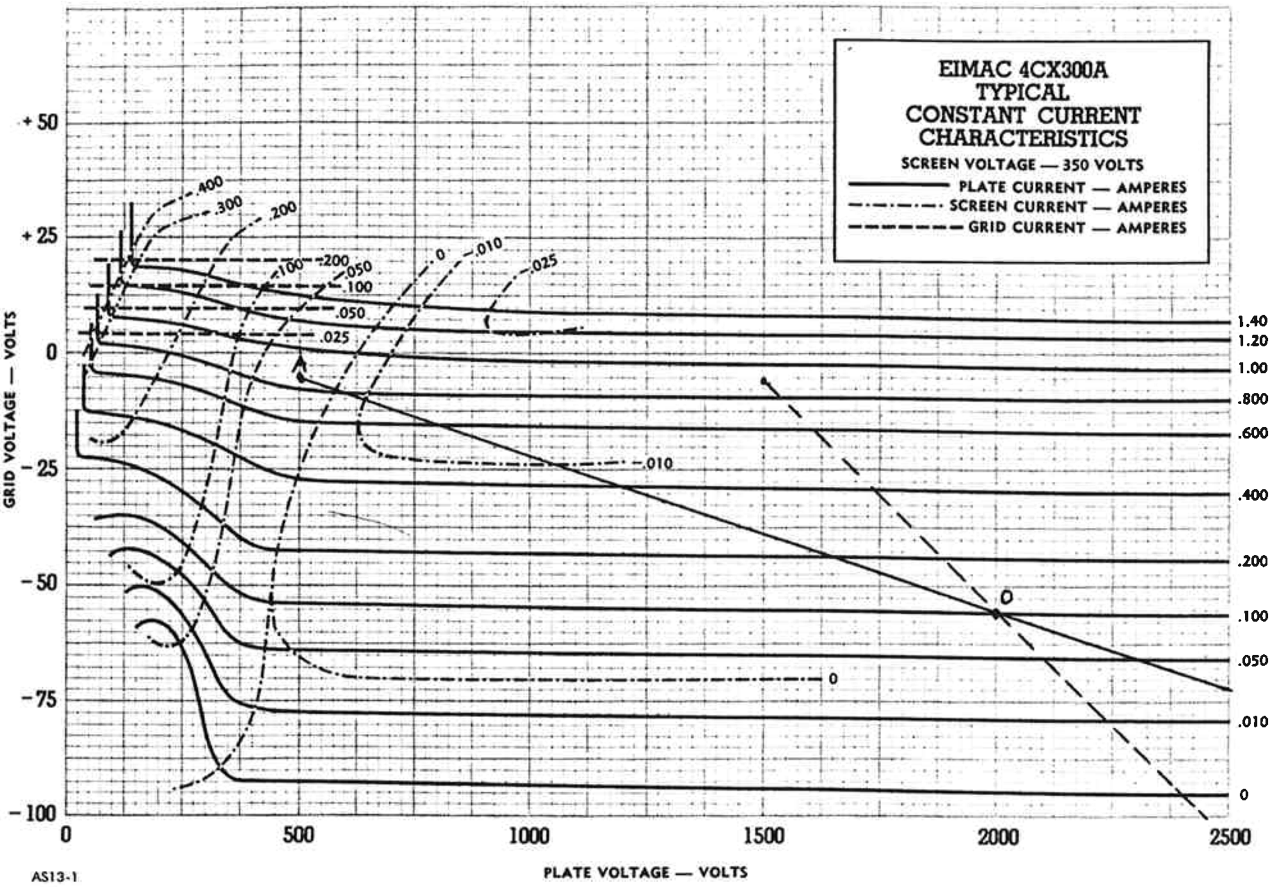

Fig. 1 - Typical constant-current characteristics for the EIMAC 4CX300A tetrode

1 This is different from the usual load line associated with audio calculations using plate characteristic curves.

2 OA is actually only half the operating line length. The other half continues from O out beyond the right-hand edge of the chart for an equal distance and represents the effect of the negative half-cycle of grid driving voltage as it swings down to -105 volts and back to point O again. This half of the operating line is not important since the tube does not "work" during the negative half cycle.

Let us plot a typical operating line[1] on our set of curves, as in Fig. 1. Point O (at -55 volts on the grid in this case) is the operating point at which the tube rests with zero r.f. grid drive. Straight line OA represents a tuned r.f. circuit load (a pure resistance at the operating frequency)[2]. As 100 volts peak-to-peak grid drive is applied, the first positive half cycle can be represented by a point moving along the operating line from O to A and back to O again. During this half cycle, the grid-voltage swing from -55 volts has caused the plate current to swing from the value at point O (100 ma.) up to the value at point A (850 ma.) and back to 100 ma. again. At the same time, the plate voltage swings from 2000 volts down to 500 volts. The a.c. plate current is made up of all the instantaneous values intercepted by the point traveling along the operating line. The same is true of screen current. During the other 180 degrees of the driving cycle, our point merely travels from O down the slope through cutoff to a point opposite -105 volts on the grid-voltage scale and back to point O again along the operating line. Thus, the negative-going grid voltage swings the plate current down to cutoff (for a small portion of the cycle). Plate voltage continues on up to 3500 volts and back down again due to the fly-wheel action of the plate tank circuit.

Drive and Tuning

Now that we can predict exactly what the screen and plate current will be for any instantaneous point during the grid-voltage cycle, let us ask some more probing questions. What happens when we cut our grid-driving voltage in half? The answer is simple. The length of our operating line is merely cut in half! The grid voltage swings to only one half the original peak-to-peak amplitude and the operating point O is still the center of the new operating line length. Now what happens if we detune the plate tank circuit? Detuning the plate circuit actually changes the plate load impedance. How does this appear on our set of curves? It tilts or rotates the operating line about the operating point O. As the load impedance is lowered (detuning from resonance), the operating line[3] assumes a steeper angle (a zero-impedance load would be represented by a vertical operating line).

As "seen" by the tube, the act of tuning to resonance amounts to increasing the load impedance to a maximum value consistent with the degree of antenna loading selected. Thus, the operating line will have minimum slope at resonance. Notice the angle at which our typical operating line in Fig. 1 cuts the constant-plate-current lines. It's a small angle. As the plate tank circuit is tuned to a point out of resonance, the operating line might assume the position indicated by the dashed line[3] (lower impedance). Note that the angle between the dashed line and the plate-current lines has not changed radically, and that our moving point will still intercept essentially the same plate-current values. This is precisely the reason that plate current in a tetrode is not a good indicator of resonance (very little dip). Look at the screen current. It consists of zero or even negative values in the out-of-resonance position. At resonance, though, it is positive. Thus, a peak in screen current indicates resonance.

[3] The tank-circuit impedance would no longer appear resistive at the operating frequency, but would contain a reactive component. Under these conditions, the operating line becomes an ellipse whose center is point O and whose major axis is represented by a dashed line.

During the rotation of the operating line while tuning, its length actually changes, since it is confined vertically only by the constant peak-to-peak amplitude of the grid-driving voltage (two imaginary horizontal lines, one at -5 volts and one at -105 volts). The length increases as resonance is approached and reaches a maximum at resonance. As the length increases, point A penetrates the heavy-screen-current region and the d.c. screen current reaches a sharp peak at resonance.

Loading

What happens if we change the antenna loading? This merely changes the plate-load impedance (still resistive). Again, the effect is to tilt the operating line about the operating point. As the load impedance is lowered (more coupling), the operating line assumes a steeper angle (such as the dashed line). It is easy to see that as loading increases, screen current decreases. Thus, screen current is also an indicator of loading. Screen current varies somewhat from tube-to-tube of a given type, but if each tube is loaded to the same value of screen current at resonance (with the same drive) power output differences will be small, and loading and linearity will be essentially the same.

D.C. Meter Readings

During the r.f. cycle, our point traverses the operating line and intercepts many different instantaneous values of screen current and plate current. The average of all these values is what the d.c. meter in the circuit reads. The fundamental frequency component of plate current is utilized in the plate circuit to produce output (except in a multiplier where use is made of a harmonic component of plate current). For a given operating line, both of these values can be calculated[4]. Suffice it to say that for Class AB_1 operation, the d.c. meter reading is approximately one third the peak value of current at the top of the operating line, and the fundamental component of plate current is approximately one half the peak value.

Tune-Up Procedure

Contrary to somewhat popular opinion, a linear amplifier should never be loaded for maximum power output. Loading should be set to obtain a pre-determined value of screen current under single-tone or inserted-carrier driving conditions. Ideally, loading should be set for minimum distortion - a rather difficult feat to practice. It is recommended that the amateur try to duplicate as nearly as possible a given set of data-sheet conditions as presented by the tube manufacturer. These typical operating conditions are usually given for peak-envelope operation (single-tone or inserted-carrier) and represent the maximum input on c.w. or the peak-envelope-power input (not meter peaks) on single sideband. After adjusting drive, tuning, and loading to duplicate a given set of conditions, the single tone (or carrier) is removed and the single-sideband audio gain is adjusted so that grid current is never drawn and the condition adjusted for above is never exceeded on peaks. The peak-to-average ratio of d.c. plate current (as read on a fluctuating meter) varies, with the individual voice, from about 2:1 to over 3:1. Thus it is normal on voice peaks for the plate-current meter to read no more than half the value of current obtained in the maximum static single.tone condition.

4 By the use of the EIMAC Tube Performance Computor, Applications Bulletin No. 5, which is based on the method presented by Chaffee in the "Review of Scientific Instruments," October, 1936.

A straightforward tune-up procedure consists of the following steps:

1. Ensure that the tetrode amplifier is neutralized and free of parasitics.

2. With recommended heater, plate, and screen voltages applied, adjust the d.c. grid bias to obtain the recommended zero-signal value of plate current. This value affects linearity and plate dissipation.

3. Connect a suitable dummy load and set the loading control for rather heavy loading.

4. With a single-tone source, gradually increase the drive from zero to a value that produces a significant though small change in screen current.

5. Resonate the plate tank circuit by tuning for a peak (in the positive direction) in screen current.

6. Resonate the grid tank circuit (if any) by watching for a peak in plate current.

7. Now increase the drive until either the desired value of single-tone screen or plate current is reached (whichever is reached first).

8. Without drawing grid current, adjust loading, plate-tank tuning, and drive level to duplicate as nearly as possible a given set of data-sheet peak-Envelope conditions. Remember that plate current increases with drive, whereas screen current peaks at resonance and decreases with heavier loading.

After matching a set of data-sheet conditions, the amplifier is ready to connect to an antenna. With a suitable antenna connected, it should be easy to repeat the operation obtained in Step 8 above by merely adjusting plate-tank tuning and loading with the same drive level as before. Now set up for voice single-sideband drive and adjust the audio gain for the highest level possible without drawing grid current on voice peaks or flat-topping (check this with a scope).

Reverse Screen Current

Most transmitting tetrodes employing oxide-coated cathodes exhibit negative screen current under certain conditions of operation. This is nothing to get alarmed about - it merely means that on the average, more electrons are leaving the screen than are being intercepted by the screen. This results because of secondary electron emission at the screen grid. Small values of negative screen current are not detrimental to tube operation and are quite normal for some tetrodes. Such values usually appear under heavily-loaded conditions or during the idling condition.

Large values of negative screen current are abnormal and should be avoided. Excessive secondary emission usually results in higher values of intermodulation distortion. This condition also prevents an accurate determination of screen dissipation.

Protection

Screen protection can take many forms. Before using a given circuit, it should be analyzed to ensure that it satisfies the two basic criteria for screen protection. First, the circuit connected to the screen must be capable of maintaining the proper screen voltage in the presence of moderate negative d.c. screen current, or normal positive values of current. Second, the protective circuitry must not allow a condition of excessive screen current (positive or negative) to persist, since this causes excessive screen dissipation and resultant tube failure.

The first of these two criteria can be easily satisfied by the use of a bleeder resistance connected directly from the screen to ground, in combination with a suitable well-regulated power supply. The bleeder resistance should be made equal to the screen voltage divided by the largest negative d.c. screen current to be expected for the particular tube used. This eliminates any power supply problems (soaring voltage) when "supplying" negative screen current.

Complete screen protection satisfying both criteria can be obtained by adding a screen-current overload relay to a bleeder and regulated-power-supply combination. The overload relay will protect the screen against excessive currents, either positive or negative, and the regulated power supply will maintain the screen voltage at the proper value as the d.c. screen current varies. The bleeder resistance from screen to ground will not allow the screen voltage, in the presence of negative screen current, to rise above the proper value. This bleeder is good insurance, since even some regulated power supplies react in an undesirable manner when subjected to a negative-current load.

When using a screen-current overload relay one can easily provide for manual resetting in the event of an overload. This feature allows time to consider why the overload occurred and prevents repeated successive overloads. Using an s.p.d.t. relay, merely connect the armature to the positive supply through the coil (with the usual pull-in-adjusting potentiometer shunting the coil). Connect the normally-closed contact to the screen through the screen-current meter and the normally-open contact through a resistor to ground[5]. Adjust this resistor so that the current through it will hold the relay closed, once it has been tripped. First, of course, the pull-in shunt should be adjusted for pull-in at the value of screen-bleeder current, plus screen current, that produces maximum rated screen dissipation. Now, with this circuit it will be necessary to shut off the screen supply (or push a circuit-breaking series reset button) to reset the overload relay after an overload has occurred.

In contrast to the protective scheme outlined above, voltage-regulator tubes offer a simple and nearly foolproof method of screen-current protection. Their use will completely satisfy the first criterion and also the second criterion insofar as positive current overloads are concerned. Since excessive negative current is uncommon, one may elect to disregard protection against its occurrence. VR tubes then become an inexpensive and practical solution for the amateur.

The VR tube solution consists of an appropriate combination of VR tubes (to add up to the desired screen voltage) connected in series to ground and fed from a high-voltage source through an adjustable dropping resistance. The screen bypass capacitor from screen to ground and a screen-current meter from screen to the top of the VR-tubes string complete the circuit. Adjust the dropping resistance so that the VR string extinguishes at or slightly lower than the value of screen current that produces maximum rated screen dissipation. R.F. screen-current peaks will be supplied by the screen bypass capacitance and the VR tubes will "see" only the d.c. component. Now, excessive positive screen current will extinguish the VR tubes, lowering the screen voltage, The VR tubes will supply normal positive current values while maintaining screen voltage at the desired value. Negative currents will not change the voltage, but will merely increase the current flowing through the VR tubes.

[5] See Evans, "Screen Protection and More," QST, October, 1961.

In conclusion, it should be obvious to the amateur that a screen-current meter is a vital necessity in modern transmitters employing tetrodes. By proper interpretation of screen-current readings, one can easily tune to resonance and properly load the tetrode amplifier. The plate-current meter is useful only as an indicator of drive level and average plate-input power (knowing the plate voltage). One more meter - for grid current - is useful but not absolutely necessary. A one-milliampere meter in the grid circuit will warn the operator by a slight kick when grid current is being drawn on voice peaks.

amateur service newsletter
W6SAI

Triode Tubes as Linear R.F. Amplifiers

Many of the common triode transmitting tubes will perform well as linear r.f. amplifiers for single sideband operation. Unfortunately, little operating data for this class of service is available for these tubes, and the radio amateur does not always have the operating curves or other data available to derive proper circuit potentials necessary to achieve low distortion linear operation. The amateur owning a high dissipation transmitting triode, therefore, is often at a loss as to the proper operating parameters for linear service, or he might not know if the tube is really suited for this class of operation. Then, too, good transmitting equipment exists, designed before the advent of SSB, that may be easily converted to single sideband linear service, provided the correct operating potentials can be determined. The purpose of this article is to provide rough guidelines whereby any triode tube may be easily and quickly evaluated as to its useability as a linear r.f. amplifier.

Important Tube Characteristics for Linear Service

Triode tubes[1] may be operated either in grid- or cathode driven service, and may be run in Class-AB-1, Class AB-2, or Class B Mode. The problem, then is to determine **which** triode tubes are most suitable for linear service and in **what** circuit configuration they work best, and finally, to establish the operating potentials which will provide satisfactory results for the user.

Plate dissipation and **amplification factor** are two triode tube characteristics which, in general provide the information to establish the work of the tube as a linear amplifier and which may also suggest the proper circuitry. Other tube characteristics, of course, enter the picture, but by merely examining these two main features, a triode tube may be easily evaluated for linear amplifier service.

Plate dissipation is important because it determines the maximum power limit that the tube may achieve under a given degree of operating efficiency. Linear amplifier efficiency commonly runs between 50- and 65- percent with the remainder of the power being lost as plate dissipation. As a rule of thumb, therefore, 50- to 35- percent of the maximum permissible power input to the tube represents the rated value of maximum plate dissipation. Twisting this idea around, it can be seen that a triode tube having, for example, 450 watts of plate dissipation is probably good for a power input of 900 to 1250 watts, depending upon operating efficiency. Class AB-1 operating efficiency runs close to 50-percent. Class AB-2 efficiency is about the same as Class B; in the vicinity of 65-percent. Thus, knowing the plate dissipation of the tube, we can easily determine approximate maximum power input and power output by first establishing in which class of service the tube is to be operated. It is wise to use "steady state" or single tone condition when making this rough determination of power levels. It is tempting to think that

1 - This discussion deals solely with triode tubes. Similar conclusions may be drawn about tetrode and pentode tubes, but these are not within the scope of this article.

the peak envelope power (P.E.P.) rating may be greater than this level (and it may--!) but this reserve power capability varies between tube types, and can only be determined by experiment at a later stage of the game.

Small transmitting tubes having low values of plate dissipation (3C24, 35T) afford little worth in linear amplifier service as the power capability of these small "bottles" is quite low. The picture changes rapidly as the power capability of the transmitting tube increases, however, and large triode transmitting tubes having high values of plate dissipation are often quite reasonable in cost and are likely candidates for linear service.

Amplification Factor of a triode tube expresses the ratio of change of plate voltage to a given change in grid voltage at some fixed value of plate current. It is determined primarily by the density of the grid structure and the grid-plate spacing of the tube. Amplification factors are expressed in terms of **mu** (u), and values of u between 8 and 300 are common for triode transmitting tubes. **High-u** tubes are those having an amplification factor of 30 or more, **medium-u** tubes have amplification factors in the range of 10 to 30, and **low-u** tubes fall in the range of 3 to 10.

Amplification factor for many commonly used transmitting triodes is given in most tube manuals and in the transmitting tube section of **The Radio Amateur's Handbook**. This characteristic may be determined experimentally by operating the tube in a quiescent state at normal plate voltage. A small change in the resting bias is made, thus slightly changing the plate current. The plate current is then returned to the original value by making an appropriate change in plate voltage. An amplification factor of 20, for example, means that if the grid potential is changed by one volt, it will take a plate voltage change of about 20 volts to restore the plate current to the original value.

Armed with a knowledge of plate dissipation and amplification factor, an intelligent choice of circuitry may now be made.

Class AB-1, Class AB-2, or Class B Grid Driven Service

These classes of operation are defined by the operating potentials applied to the tube. In general, **any** triode tube in **any** conventional linear amplifier circuit can probably work in **any** of these three modes. Results, however, depend upon circuit design considerations which may be extremely stringent in order to provide a satisfactory degree of linearity for a specific tube in a given circuit. Thus, in order to relax circuit considerations while reaching a desired degree of performance, certain tubes and circuits have been chosen which are widely used in SSB equipments while other tubes and circuits have been cast aside as being economically undesirable.

The Class AB-1 Amplifier is defined as one wherein grid current does not flow over any portion of the operating cycle. That is, grid excitation is held below that value at which the applied **peak** signal level is less than the value of grid bias on the tube. Plate current flows for more than 180 degrees of the r.f. cycle but less than 360 degrees. Once the bias value is exceeded by the driving signal, grid current will flow when the grid is driven positive with respect to the cathode, and the amplifier passes into the **Class AB-2** operating mode. As the peak driving signal level is increased and the bias reduced to substantially cutoff, grid current flows over half the operating cycle, and the amplifier is now operating in the **Class B** mode. As the grid driving signal increases, passing the amplifier stage through the successive operating modes, the instantaneous plate voltage swing increases, and electrode voltages applied to the tube must be varied to allow optimum circuit efficiency and low distortion in each mode of operation. Good and valid reasons exist for each mode of operation, and while it is tempting to jump to the conclusion that all tubes should be operated Class B mode for highest efficiency and output, such is not the case! Other factors affect the choice of operating mode and in doing so, also affect the circuitry and potentials to be used with a particular tube.

In general, a **low-u** triode tube is a preferable choice for a Class AB-1 grid driven linear amplifier. It is easier to obtain maximum plate current swing with this type of triode tube because it is impossible to drive the grid into the positive region of operation (Figure 1). A high-u tube of equal plate dissipation must be driven into the positive grid mode of operation to obtain output comparable to that of a low-u tube driven just to the point of grid current. Of the many triode tubes, the 304TL and the 211 (VT-4C) are common low-u types that perform well in Class AB-1 service. Other low-u triodes that are satisfactory for grid driven linear service are the 75TL, 100TL, 250TL, 806, 450TL and 750TL. Even though large values of driving voltage are required for these tubes, little driving power is required, as the grid never draws current and only circuit losses require that the driving stage supply power to the linear amplifier in question. High-u triode tubes are not recommended for class AB-1 service because the grid must be driven into the positive (grid current) region before appreciable power output can be obtained.

The Class AB-2 amplifier is defined as one wherein the grid current is drawn over a portion of the operating cycle, yet the plate current flows for more than 180°. Grid current flows because the exciting signal has a peak value greater than the fixed operating bias of the tube, and the grid assumes a positive potential when the peak signal exceeds the fixed bias level. Electrons intercepted from the cathode to plate current flow by the positive grid create the grid current, and the power required to create the necessary positive grid swing is derived from the exciting signal that drives the linear amplifier. The impedance the grid presents to the input circuit under conditions of grid current is a function of the ratio of instantaneous grid voltage to current which varies in a nonlinear manner. Thus, unless the r.f. power source (the exciter) has extremely good output voltage regulation, and unless the linear amplifier is properly designed to present a fairly constant load to the exciter, waveform distortion will invariably result whenever this class of amplifier loads the exciter during those intervals of the operating cycle when the grid of the tube is driven positive with respect to the cathode. (**The Class B** linear amplifier represents an extension of the Class AB-2 mode, wherein grid driving power requirement is greater and the demand placed on the driving source is even more stringent).

Class AB-2 grid driven operation of triode tubes should be approached with caution because of this problem, as most radio amateurs do not have the test equipment to properly evaluate and adjust their linear amplifier for this mode of operation. It is possible to swamp a portion of the driving signal by means of low value noninductive resistors placed across the grid circuit of the linear amplifier, and by the use of a high-C grid tank circuit achieve the best possible drive-signal regulation. Both of these methods have been used with good results when properly applied.

In most instances, the increase in output power gained from shifting from Class AB-1 to Class AB-2 operation may not be justified, and more power output may be gained in an easier fashion by operating two tubes in parallel in the Class AB-1 mode. Driving requirements and bias supply regulation problems are thus simplified. These remarks apply equally well to Class B grid driven linear amplifiers, and their use should also be tempered with caution.

Class AB-2 and Class B Cathode Driven Service

High-u triode tubes may be used to advantage in cathode driven (so-called grounded grid) linear amplifier circuits (Figure 2). In this mode of operation, the grid is bypassed to ground and normal Class AB-2 or Class B bias is applied to the stage. No bias is necessary, of course, in the case of zero bias tubes, such as the 811A, 3-400Z and 3-1000Z, and the grid of the tube may be grounded directly. A high-u triode tube should be employed for this style of amplifier, and the inherent feedback of the grounded grid stage combined with the use of a tuned cathode input circuit insure a minimum of driver waveform distortion. Use of a high-u tube is suggested for two reasons: First, the inherent cathode-plate shielding of a high-u tube is better than that of a comparable low-u tube; and second, a high-u tube provides better gain per stage and requires less drive because of less feedthrough power. Tubes such as the 811A, 805, 75TH, 250TH, 450TH and 6C21 work well in this circuit. Resistive loading of the driving circuit is not required as long as there is sufficient "Q" in the cathode tank because of the constant "feed through" power load on the exciter. For most triode tubes, a tuned input circuit having a resonating capacitance C-1 of about 15 mmfd per meter of wavelength is sufficient.

Low-u tubes, on the other hand, require extremely large driving signals in the cathode driven mode, and stage gain is extremely small. Thus, the use of these tubes in this particular circuit configuration is not recommended.

In summary, then, triode tubes to be used for linear amplifier service should have a large plate dissipation, and the power output to be expected from the tube will run from approximately once to twice times the rated plate dissipation. Moreover, high-u triode tubes perform better in cathode driven, class B circuits. Medium-u tubes, falling in the shadowy region (u = 10 to 20) usually are easier to get working in cathode driven circuits, as a general rule.

Bias Supplies

Bias supplies for linear amplifier stages that draw grid current must be capable of good regulation so that the fixed bias does not vary as grid current increases. Shown in Figure 3 is a simple bias supply that will provide a regulated bias variable over the range of -20 to -80 volts. Regulation is 0.001 volt per milliampere of grid current. Between -30 and -80 volts the supply will regulate grid current up to 200 milliamperes. Between -20 and -30 volts, maximum grid current is restricted to 100 milliamperes. The adjustable resistor R-1 is set to produce about 20 milliamperes current through the first regulator tube.

A regulated supply for the -100 to -600 volt range is shown in Figure 4. The tap switch of this supply permits rough bias adjustment over the range, while the potentiometer permits a fine adjustment to be made. Maximum permissible grid current runs from about 100 milliamperes in the vicinity of -100 volts to about 25 milliamperes in the -600 volt region.

Operating Potentials for Linear Service

Once the circuit and class of service have been determined for the particular tube at hand, the proper operating potentials for the tube must be determined. Luckily, much of this data is at hand, although in a disguised form. Most data sheets provide Class AB-1 or AB-2 audio data, usually for push-pull operation. As the tube doesn't know if it is being driven by an audio signal or an r.f. signal, this data applies to a significant degree to r.f. linear amplifier service. For a single tube, it is only necessary to divide the indicated currents by two, as the currents are for two tubes. (Actually, only one tube in the push-pull audio service is "working" at one time, but the current meters register currents that are averaged for the two tubes). For example, Figure 5 provides operating data for a 304TL, grid driven, Class AB-1 r.f. linear amplifier, used in the circuit of Figure 1. A plate circuit Q of 15 should be used, and the grid current of the amplifier should be high-C (Q of 15 or better) in order to take care of accidental grid current peaks. Normal grid current is zero. In order to properly load the exciter, it is necessary to swamp the exciter output with a non-inductive load so that the exciter develops nearly full rated output when grid current just starts to flow in the linear stage. The load may be placed across the coaxial line between the exciter and amplifier and consist of a number of 2 watt composition resistors arranged in series-parallel to present a near-52 ohm load. Total wattage rating of the resistor bank should be equal to about one-half the P.E.P. output of the exciter.

Figure 6 provides operating data for a 304TH, cathode driven, Class AB-2 r.f. linear amplifier used in the circuit of Figure 2. At 3000 volts plate potential the 304TH is good for a P.E.P. input close to one kilowatt, and two tubes in parallel can provide the "so-called" two kilowatts P.E.P. Figure 7 provides data for the 450TH in cathode driven, Class AB-2 r.f. linear amplifier service.

It should be noted that steady state conditions are given, and P.E.P. operation should be held to these limits, unless the oscilloscope tells the operator that the tube may be "pushed" a bit before peak flattening or distortion occurs. Use of the oscilloscope should be tempered with caution, however, as it is nearly impossible to read distortion or peak flattening on the "scope" until the degree of intermodulation distortion approaches a level near -20 decibels below one tone of a two tone test signal. By this time, the operator will probably receive a brick through the shack window! To be on the safe side, then, meter readings of grid and plate currents should be one-half or less of those indicated in the tables for voice peaks.

FIGURE 5

304TL, GRID-DRIVEN, CLASS AB1 LINEAR AMPLIFIER

D.C. Plate Voltage	1500	2000	2500	3000	volts
D.C. Grid Voltage*	-118	-170	-230	-290	volts
Zero Signal D.C. Plate Current	135	100	80	65	ma
Single Tone Max. D.C. Plate Current	280	275	245	225	ma
Max. D.C. Input	420	550	615	675	watts
Max. Drive Power	0	0	0	0	watts
Plate Load Impedance	1270	2650	4250	6000	ohms
Max. Output	128	245	305	365	watts

FIGURE 6

304TH, CATHODE-DRIVEN, CLASS AB2 LINEAR AMPLIFIER

D.C. Plate Voltage	1500	2000	3000	volts
D.C. Grid Voltage*	-65	-90	-145	volts
Zero Signal D.C. Plate Current	130	100	75	ma
Single Tone Max. D.C. Plate Current	480	380	320	ma
Max. D.C. Input	720	760	960	watts
Max. Drive Power	70	55	60	watts
Cathode Input Impedance**	195	260	385	ohms
Plate Load Impedance	1850	3000	5500	ohms
Max. Output	510	530	715	watts

FIGURE 7

450TH, CATHODE-DRIVEN, CLASS AB2 LINEAR AMPLIFIER

D.C. Plate Voltage	1500	3000	4000	volts
D.C. Grid Voltage*	0	-50	-85	volts
Zero Signal D.C. Plate Current	50	200	150	ma
Single Tone Max. D.C. Plate Current	400	450	335	ma
Max. D.C. Input	600	1350	1340	watts
Max. Drive Power	70	105	70	watts
Cathode Input Impedance**	262	322	350	ohms
Plate Load Impedance	2200	4100	6400	ohms
Max. Output	416	992	1000	watts

NOTE: 1500 volt operation is zero bias service

*Adjust to give stated zero-signal plate current.

**Fundamental frequency component. High-C, tuned cathode tank should be employed to obtain lowest intermodulation distortion.

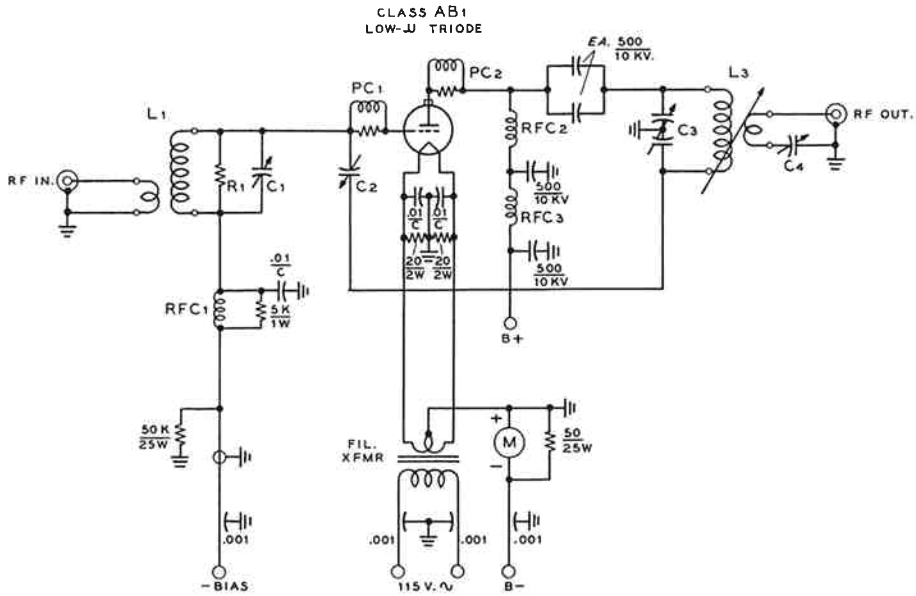

FIGURE 1

TYPICAL GRID DRIVEN, CLASS AB-1 TRIODE LINEAR AMPLIFIER CIRCUIT

C-1, L-1:	Grid input circuit (Q = 15). Ratio of L to C chosen so as to match impedance presented by R-1, the loading resistor.
C-2:	Neutralizing capacitor. Capacitance approximately twice the grid-plate capacitance of the triode tube. Breakdown voltage equal to three times the d.c. plate voltage.
C-3, L-3:	Plate output circuit (Q = 15). Ratio of L to C chosen to match r.f. load resistance of amplifier tube. Handbook charts for Class C Service may be used, provided single tone plate current is used in formulas.
C-4:	Series tuning capacitor for link circuit. Approximately 6 uufd per meter of wavelength (See Chapter 6, A.R.R.L. Handbook, or "Radio Handbook").
PC-1, PC-2:	Parasitic suppressors. Try two 100 ohm, 2 watt composition resistors in parallel, wound with 5 turns, ½-inch diameter #16 wire, spacewound.
RFC-1:	2-½ mH (National R-100). RFC-2: High voltage choke. B & W #800 or equivalent RFC-3: VHF choke. Ohmite Z-50 or equivalent.
Note:	20 ohm, 2 watt composition resistors placed across filament capacitors to "de-Q" bypass resonances.

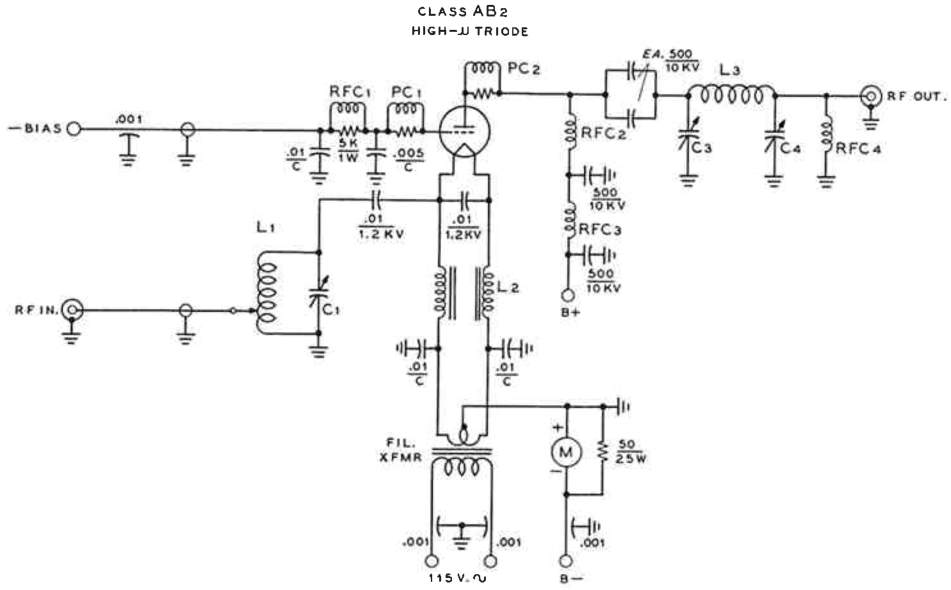

FIGURE 2

TYPICAL CATHODE DRIVEN, CLASS AB-2 TRIODE LINEAR AMPLIFIER CIRCUIT

C-1, L-1: Cathode input circuit (Q greater than 2). Resonates to operating frequency with approximately 20 uuf per meter of wavelength.

C-3, L-4, C-4: Pi-network output circuit (Q = 15). Ratio of L to C chosen to match r.f. load resistance of amplifier tube. For appropriate charts, see A.R.R.L. Handbook and "Radio Handbook". Use single tone plate current in formulas.

L-2: Filament choke. B & W or equivalent.

PC-1, PC-2: Same as Figure 1. RFC-1, RFC-2, RFC-3: Same as Figure 1.

RFC-4: 2½ mH (National R-100).

Notes: Adjust drive tap on L-1 for minimum SWR on coaxial line to exciter. Positive terminal of bias supply is grounded. Grid of tube may be grounded for Class B, zero bias operation with triodes having u of 200 or better.

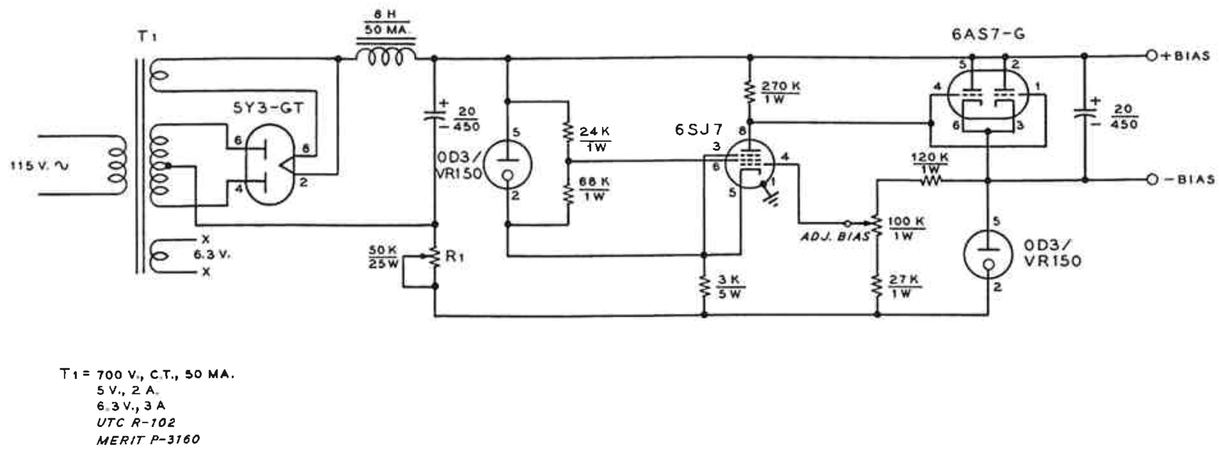

FIGURE 3

LOW VOLTAGE REGULATED BIAS SUPPLY

This simple supply provides a regulated bias voltage variable over the range of -20 to -80 volts. Regulation is 0.001 volt per milliampere. Between -30 and -80 volts, the supply will regulate grid current up to 200 ma. Below -30 volts, maximum grid current is restricted to 100 ma.

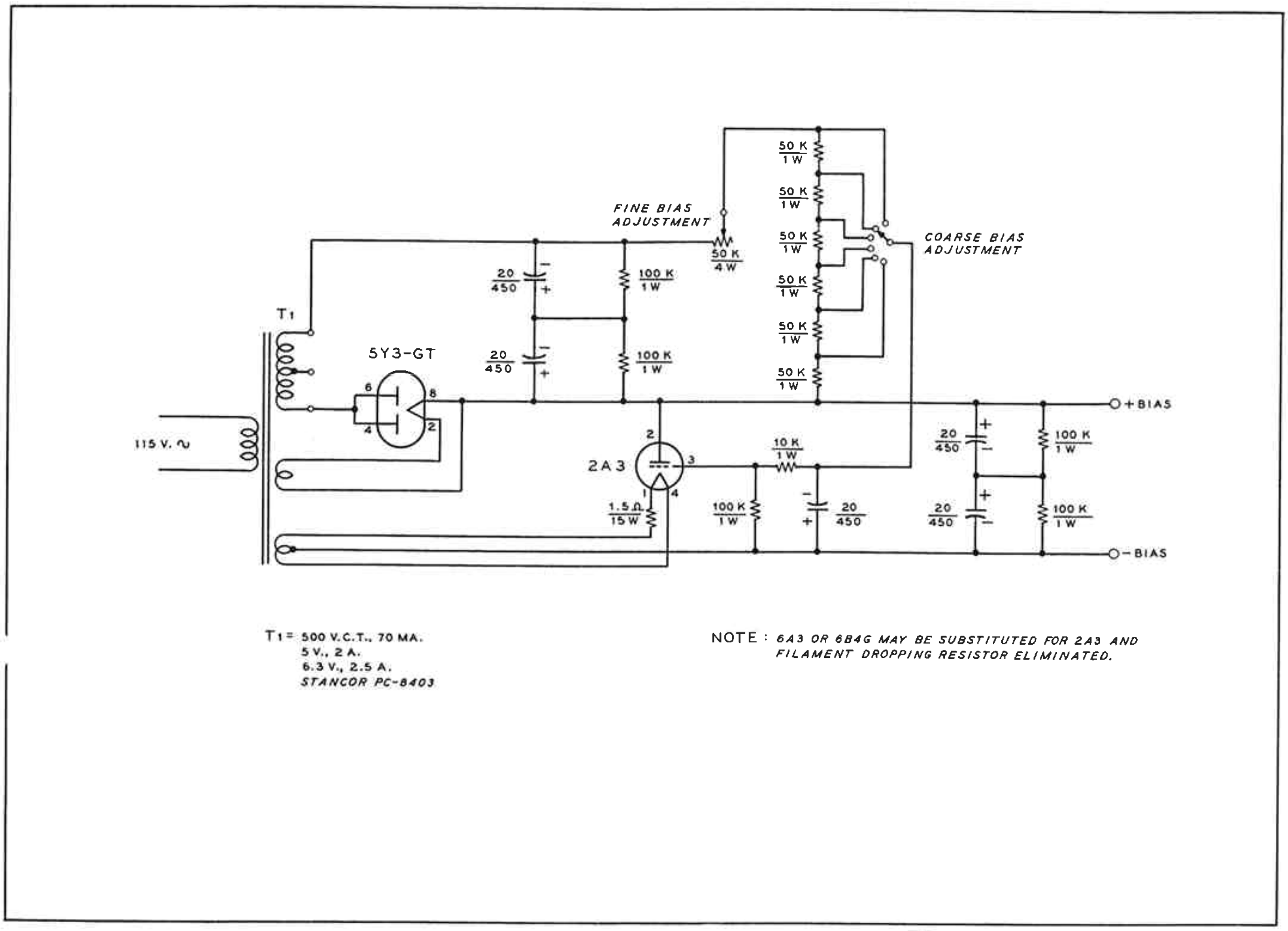

FIGURE 4

MEDIUM VOLTAGE REGULATED BIAS SUPPLY

This series regulated supply acts as a variable bleeder resistor which automatically adjusts its resistance to a value such that grid current flowing through it will develop a constant voltage across the supply terminals. The tap switch permits rough bias adjustment over the range of about -100 to -600 volts, while the potentiometer permits a fine adjustment to be made. Maximum permissible grid current is about 100 ma in the vicinity of -100 volts, dropping to about -25 ma. in the -600 volt region.