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PUTTING THE 3-400Z TUBE TO WORK

Using A Zero Bias Tube in a Grounded Grid 1 Kilowatt Linear Amplifier

The "ideal" linear amplifier package would contain no more than a tube, a filament transformer, a plate supply and a tuned circuit. It would be simple to build and cost but a few pennies. Unfortunately, such a perfect device does not yet exist, and is not foreseeable in the near future. On the contrary, the relatively simple linear amplifier has "grown" to become an object of astounding complexity, requiring grid bias supplies, regulated screen supplies, power dissipating grid resistors and other awesome and complicated devices that add to the cost and weight of the linear, but do nothing to make the signal louder or clearer at the receiver. Indeed, some linear amplifier designs have been almost lost in the maze and complexity of expensive, regulated power supplies required to make the beast "tick".

A large quantity of auxiliary equipment can be swept aside and junked if a zero bias tube is employed in a simple grounded grid configuration, such as shown in Figure 2. Various types of transmitting tubes (originally designed for grid driven service) such as the 813, 811A and 4-400A have been used with success as "zero bias" grounded grid amplifiers, but no true zero bias triode of large power capability has been at hand for this class of service. The amplifier described in this article is designed around the Eimac 3-400Z, a member of a family of zero bias triode tubes now available to the amateur.

The 3-400Z Zero Bias Tube

The new 3-400Z tube is a high μ triode having a plate dissipation of 400 watts. It is rated to 1 kilowatt d c input for linear amplifier service (figure 2). Within the maximum plate voltage rating of 3000 volts, the 3-400Z has the very desirable characteristic of having no need for either a bias or a screen power supply. The Old Timers will remember with nostalgia the old '46 tube. (Remember the 160 meter pre-war transmitter using a flock of these bottles)? When excitation was removed from the '46 it would simply relax and stop working. The 3-400Z will do this trick, too.

The seated height of the 3-400Z is only 4½" to the top of the plate radiator cap, making it extremely attractive for the new, modern concept of linear amplifier design. Because of the small tube size, and because no one has yet been able to miniaturize a watt, it is necessary to cool the tube seals, envelope and plate lead with an auxiliary blower.

Elimination of the bias and screen supplies allows a large savings in cash normally spent for these items, and also saves the builder the labor (and skinned knuckles) required to drill the holes, mount the parts, and do the necessary wiring on these electronic nuisances. A large bonus in the forms of simplicity and low cost accrues to the user of a zero bias tube!

The Amplifier Circuit

The 3-400Z grounded amplifier circuit is shown in Figure 2. It is designed for an input of 1 kilowatt PEP sideband, or 1 kilowatt CW operation. In addition, it may be run as an AM linear amplifier at an input level of 600 watts. Bandswitching circuits are ganged, and cover the amateur bands between 3.5 and 29.7 MHz with generous overlaps. A high-C pi-network output circuit is used to enhance a high order of linearity. It is necessary to monitor the output level of any linear stage, and a simple semiconductor

voltmeter is incorporated in the output portion of the network. The voltmeter range is variable, as absolute readings are not necessary.

Proper operation of the amplifier may be established by maintaining a given ratio between grid and plate current. The grounded grid, therefore, is "ungrounded" sufficiently to permit insertion of a simple metering circuit. Done properly, the stability and operation of the grounded grid circuit remain unchanged. To achieve this, each grid pin of the 3-400Z socket is grounded by a low impedance resistor-capacitor combination. The resistors act as a shunt across the milliammeter, but have a value sufficiently high so as not to disturb the calibration of the meter to any great degree.

Plate current is measured in the negative lead of the power supply rather than in the filament return circuit, as the latter current is a combination of grid and plate current. The negative of the power supply is "above ground" by the voltage drop across R1 so it is necessary to "float" the power supply above the chassis as shown in Figure 2.

The driving impedance of the 3-400Z is a nominal 122 ohms. Since this figure varies widely over the operating cycle, a high-C tuned cathode circuit is employed to present a constant load impedance to the exciter. Filament voltage is applied to the tube via a bifilar coil, and excitation is applied to taps on the coil which are set for minimum standing wave ratio on the coaxial line from the exciter. The usual driving difficulties experienced with grounded grid amplifiers are entirely absent and no coupling problems are noted when switching from band to band. Increased power output, reduced intermodulation distortion, and ease of drive are gained when a tuned cathode circuit is used in preference to the old-fashioned untuned r f choke input circuit.

Construction of the Tuned Cathode Circuit

The tuned cathode circuit was built as a complete sub-assembly in a manner similar to a conventional grid-driven type coil turret. The unit consists of a bifilar coil, a suitable tuning capacitor, a bandswitch, and appropriate bypass capacitors. The photographs show various views of this sub-assembly.

The bifilar coil is wound from a 61" length of standard 3/16" diameter soft copper tubing, available at auto parts houses, refrigerator repair departments, and large hardware stores. Before the coil is wound, a length of #12 Formvar insulated copper wire is passed through the tubing, leaving about three inches protruding from each end. Be sure you sand the ends of the tubing to a smooth, rounded surface to prevent the insulation of the wire from being scraped or marred during this operation. Copper wire with enamel insulation should not be used as the enamel is too soft and may be easily damaged. Next, the coil is wound around a 1-5/8" diameter form (a section of water pipe may be used), and the turns are spread apart as required.

Soft 3/16" copper strap is used for the bandswitch leads, and the taps should now be soldered in position. The 50 ohm driving points are tapped with #18 enameled wire.

The completed coil is mounted on a piece of 1/4-inch bakelite or phenolic sheet measuring 4" x 1-5/8". The sheet is drilled and tapped to mount vertically on small ceramic standoff insulators bolted to the sub-assembly chassis. The chassis measures 6" x 4", with a 2-3/8" lip on the front end.

When mounting the bandswitch, keep in mind that the plate inductor and the cathode inductor will be switched simultaneously by means of a chain and sprocket drive. Therefore, the cathode turret must have the 80 meter setting fall in the full clockwise position corresponding to the tap sequence of the plate turret.

The capacitor in series with the exciter input (C23) carries the full excitation current and must be a transmitting-type mica unit. Filament capacitors C8 and C9 are paralleled ceramic units chosen to conserve space and yet provide sufficient capacity to insure that the secondary of transformer T1 is at r f ground potential. These capacitors are mounted directly at the "cold" terminals of the bifilar filament coil. The plate-cathode r f return circuit is via the cathode tuning capacitor, C12. The lead from the stator terminals of C12 to the filament circuit and the bifilar coil is made of ¼-inch copper strap.

The series input capacitor is wired directly to the arm of the bandswitch with copper strap. The center conductor of the coaxial line from the exciter input receptacle is soldered to the capacitor terminal and the shield is grounded directly to the frame of the cathode tuning capacitor. The impedance of this tuned circuit is extremely low, and care must be taken in the design and assembly to make sure that the impedance is in the tuned circuit, and not in the various interconnecting leads and switches.

Amplifier Construction

This little powerhouse measures only 8-¾" high, 14" wide, and 15" deep - small enough to sit on the desk beside your sideband exciter or receiver. Construction is unique in that no chassis is used. The cabinet serves as the chassis! The TVI-proof enclosure is fabricated from 0.063" aluminum sheet and ½ inch aluminum angle stock. The front panel is cut from 1/8-inch dural and measures 8-¾" high by 14" wide. The sub-panel and rear panel are cut of the thinner aluminum to the same dimensions. All three pieces are framed with the corner stock as shown in the illustrations. Spacing between the panel and the sub-panel is 2½".

The bottom of the enclosure is formed in the shape of a "U", wrapping around the sides of the unit. This piece measures 14" wide and 15" deep. The sides turn up 3-5/8". The front panel is set back ½ inch from the edge, and is held to the sub-panel by means of four corner posts cut from ½-inch square aluminum stock.

The top cover is also "U" shaped, and is made of perforated aluminum to allow the exhaust air to escape from the main compartment. The cover measures 14" wide, 15" deep and 5-1/8" high. Top and bottom pieces are attached to the frame by means of sheet metal screws.

The input circuit of the amplifier is contained within an "L" shaped box, as shown in the under-chassis photograph (figure 5). The compartment is approximately 12" deep (this depth is determined by the finish dimension between the sub-panel and the rear panel) and 3-¾" high. It has two ½-inch lips, one along the side and the other along the bottom. Together with the bottom cover and the panels, it makes an r f tight and air tight compartment for the cathode input circuit and blower.

The plate circuit components require no chassis. The two pi-network capacitors are mounted to the sub-panel by means of 6-32 machine screws and spacers. The plate coil is affixed in a similar fashion (figure 3).

Component Layout and Assembly

General component placement may be seen from the photographs. The panel meters are isolated from the r f circuits by virtue of the sub-panel. In the meter area is also located the chain drive for the cathode tank circuit (figure 6). The plate bandswitching inductor and the cathode circuit switch are ganged for ease of operation. A two-to-one drive ratio is needed as the plate inductor has 60-degree indexing and the cathode switch has 30-degree indexing.

The filament transformer is placed at the front of the chassis-box. Although slightly under rated, this unit has operated for hours with no evidence of overheating. The tube socket and chimney are centered on the chassis-box 5½" behind the sub-panel, and the remaining space is occupied by the centrifugal blower and motor (figure 3). A Johnson ceramic socket was used for the tube, but the new EIMAC SK-410 air socket and SK-416 chimney are recommended as an inexpensive substitute.

The bandswitching plate inductor is at the opposite side of the main compartment. The unit is rated at 500 watts input. However, it was disassembled, silver-plated, and modified for one kilowatt sideband and CW operation. A new 10 meter coil section was wound, and the turret taps altered to provide the proper L/C ratio for optimum amplifier linearity (see parts list).

Amplifier Wiring

Shielded wire is employed for all low voltage circuits and small "feedthrough" capacitors pass the leads from the amplifier compartment into the meter compartment. Coaxial capacitors are employed for the low voltage terminals on the rear apron of the chassis. Silver-plated, ½-inch wide copper strap is used for the output wiring of the pi-network circuit. The four stator sections of the output capacitor of the network are paralleled by a short length of strap. All wiring is short, and direct.

Testing the Amplifier

The amplifier is entirely free from unwanted regenerations or parasites, and operation is simple and straightforward. It is designed to operate with a 2500 volt, 400 milliamperere power supply of good regulation. Preliminary adjustments should be made at reduced plate voltage and a minimum value of excitation. Excitation should never be applied without plate voltage being on the stage. Once resonance is established, the tube should be loaded up to approximately 400 mA plate current. The grid current at this particular operating point should be about 140 mA. The ratio of about three plate milliamperes to one grid milliampere should be maintained for all operating conditions. If the grid current is excessive, it indicates that the plate circuit loading is too light. Low grid current indicates that plate loading is too heavy. As a final check, it should be observed that the power output of the stage (as observed on the output voltmeter) should increase in direct proportion to the excitation level. Finally, to achieve a condition of maximum linearity, the plate output circuit should be **overcoupled** (by decreasing the value of the pi-network output capacitor) until power output drops about 3%. With a two-tone test signal, the maximum signal plate current read on the meter will be 275 mA, and the grid current will be about 80 mA. With an average voice, plate current as read on the meter should kick to about 180 to 200 milliamperes, with grid current peaks of about 60 to 70 milliamperes. P E P input under these conditions will be one kilowatt, and all spurious distortion products will be reduced better than -35 decibels below peak signal level. Under proper operating conditions, signal-to-distortion ratios better than -42 decibels with a two-tone test signal have been achieved with this tube in this circuit. Distortion ratios of this order can only be obtained otherwise with conventional amateur tubes employed in feedback circuits.

The cost of all parts, including the tube, air socket, and chimney is under two hundred dollars. Amateurs owning a good junk box, or who are "surplus hounds" can cut this cost figure considerably. Considered both on a watts-per-dollar basis, and on a linearity basis, this little powerhouse is hard to beat for maximum performance!

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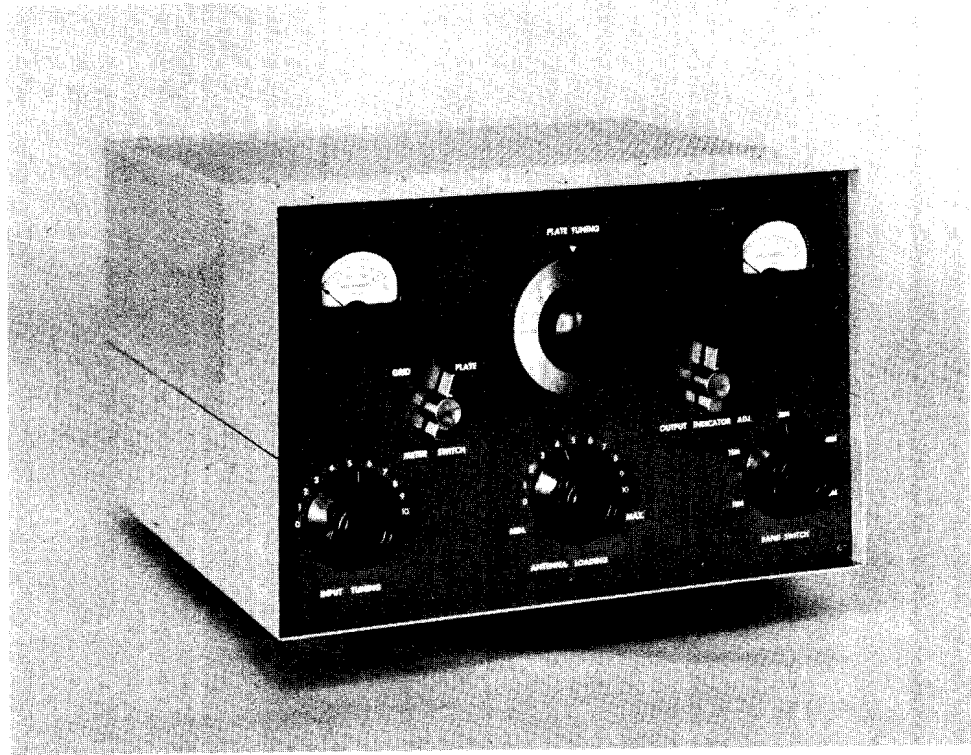


Figure 1. 3-400Z grounded grid amplifier runs 1 kw PEP input on all amateur bands between 10 and 80 meters, with a distortion figure better than -35 decibels below maximum output. Amplifier is enclosed in TVI-proof cabinet.

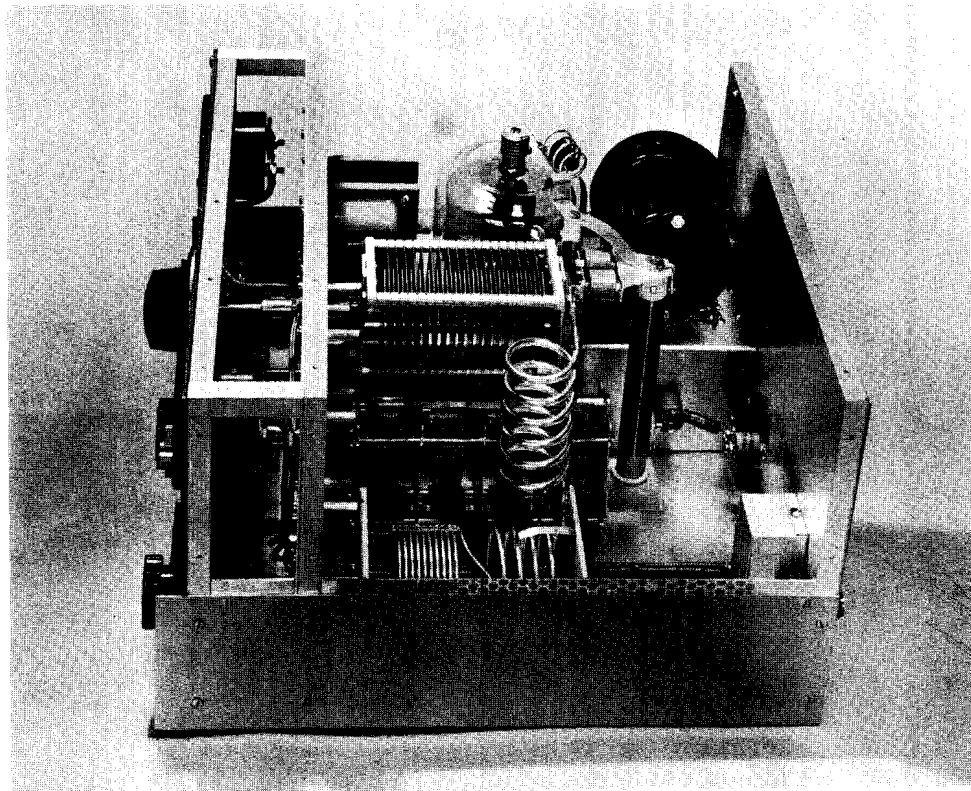


Figure 3. Plate tuning capacitor and loading capacitor are supported from sub-panel by three metal pillars, each 1-3/8" long. Loading capacitor sections paralleled by copper strap, and angle plate on rear of capacitor mounts plate choke. Ten meter inductor is placed in vertical position, in foreground.

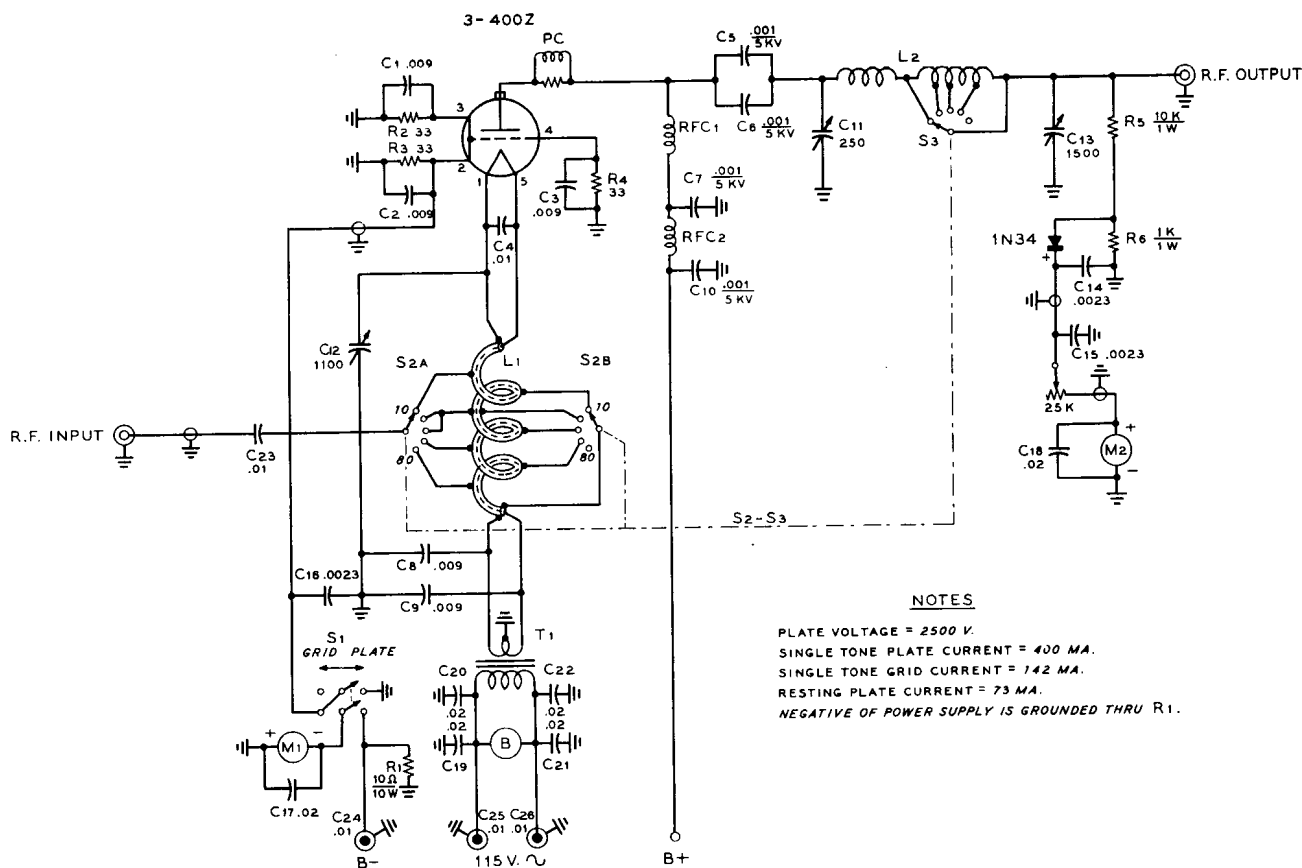


Figure 2

- C1-C3,C8,C9 -- Each: Two 4700 pF, 3 kV ceramic disc capacitors in parallel (10 req.)
 C4 -- .01 μ F, 1 kV ceramic disc capacitor
 C5,C6,C7,C10 -- .001 μ F, 5 kV. Centralab type 858S-1000
 C11 -- 250 pF, 3 kV. E.F. Johnson 250E30 (154-9)
 C13 -- 1500 pF. Four section b.c.-type capacitor. J.W. Miller #2104
 C12 -- 1100 pF. Three section b.c.-type capacitor. J.W. Miller #2113
 C14,C16 -- 2300 pF "feedthrough" capacitor. Centralab FT-2300
 C17,C22 -- .02 μ F, 600 V ceramic disc capacitor
 C23 -- .01 μ F, 1.2 kV mica capacitor. Aerovox #1446
 C24,C26 -- 0.1 μ F, 600 V. Sprague "Hypass" capacitor. Type 70P8
 M1 -- 0-500 d c milliammeter, 2" diam.
 M2 -- 0-1 d c milliammeter, 2" diam.
 PC -- Three 120 ohm, 2 watt composition resistors in parallel. Place inside of coil made of 4 turns #14, 5/8-inch diam., 1" long
 R1 -- 10 ohms, 10 watt wire wound resistor
 R2,R4 -- 33 ohm, 2 watt composition resistor
 R5 -- 10,000 ohm, 1 watt
 R6 -- 1,000 ohm, 1 watt
 R7 -- 25,000 ohm, 1 watt potentiometer
 S1 -- 2 pole 5 position rotary switch

S2A,B -- Make up of two Centralab "RR" decks (2 pole, 5 position, 30 degree index) and Centralab P-122 Index Assembly

S3 -- Part of L2 assembly

T1 -- 5 V @ 13 A Triad F-9A

Blower -- Fasco Industries #50745-IN, 115 V

Coil data:

L1 -- Wound of 3/16-inch copper tubing. 10½ turns, 1-5/8-inch diam. Spread turns apart 1/16-inch. Top two turns (tube end) are spread apart 5/16-inch. S2A taps coil (from "cold" end) as follows: 10 meters, 9½ turns; 15 meters, 9 turns; 20 meters, 9 turns; 40 meters, 7½ turns; 80 meters, 6 turns. S2B taps coil (from "cold" end) as follows: 10 meters, 9 turns; 15 meters, 8 turns; 20 meters, 7 turns; 40 meters, 4 turns; 80 meters, tap at "cold" end.

L2 -- Barker & Williamson #851, modified as follows:

- A- Remove turns from main coil from "cold" end until 11½ turns remain.
- B- Tap as follows: 80 meters, entire coil; 40 meters, tap 7½ turns from "cold" end; 20 meters, tap at junction of #12 wire and 1/8" wire coil; 15 meters, tap 1-3/4 turns toward "hot" end of coil from junction.
- C- 10 meter coil consists of 6 turns, 3/16-inch copper tubing, 1-3/8-inch inside diam., 4" long.

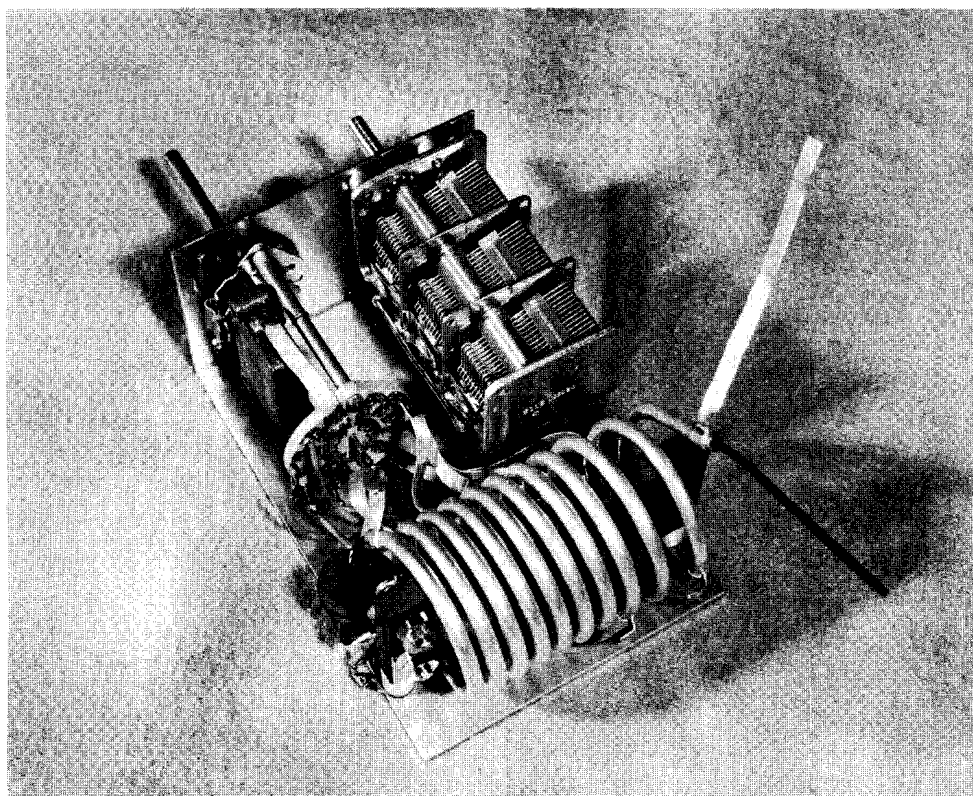


Figure 4. High-C cathode tank employs bifilar-wound coil to carry filament voltage to 3-400Z. Switch leads are made of copper strap, and coil is supported on phenolic strip, mounted to the support plate by two ½-inch ceramic insulators.

Figure 7

General characteristics, 3-400Z tube

Filament: 5.0 volts at 14.5 amperes

Interelectrode capacitances:

Grid-filament: 7.4 pF

Grid-plate: 4.1 pF

Plate-filament: 0.07 pF

Typical operation, 2500 volts plate potential, grounded grid circuitry.

Zero signal plate current:	75 mA *
Single tone d c plate current:	400 mA
Single tone d c grid current:	140 mA
Two tone d c plate current:	275 mA
Two tone d c grid current:	82 mA
P E P input:	1000 watts
P E P output	560 watts **
Resonant load impedance:	3450 ohms
Intermodulation products:	-35 db or more below P E P signal level
Driving power (approx.):	32 watts, P E P

* Approximate value

** Includes circuit losses

The new EIMAC 3-400Z is a zero bias triode specifically designed for grounded grid r f linear amplifier service. It is rated to one kilowatt PEP input for linear or CW service, and is also rated for modulator and class C operation. Only 4½-inches high, this little “powerhouse” delivers a big signal in a small package! The big brother of this tube is the 3-1000Z, rated to 2-kilowatt PEP input in sideband or CW. service.

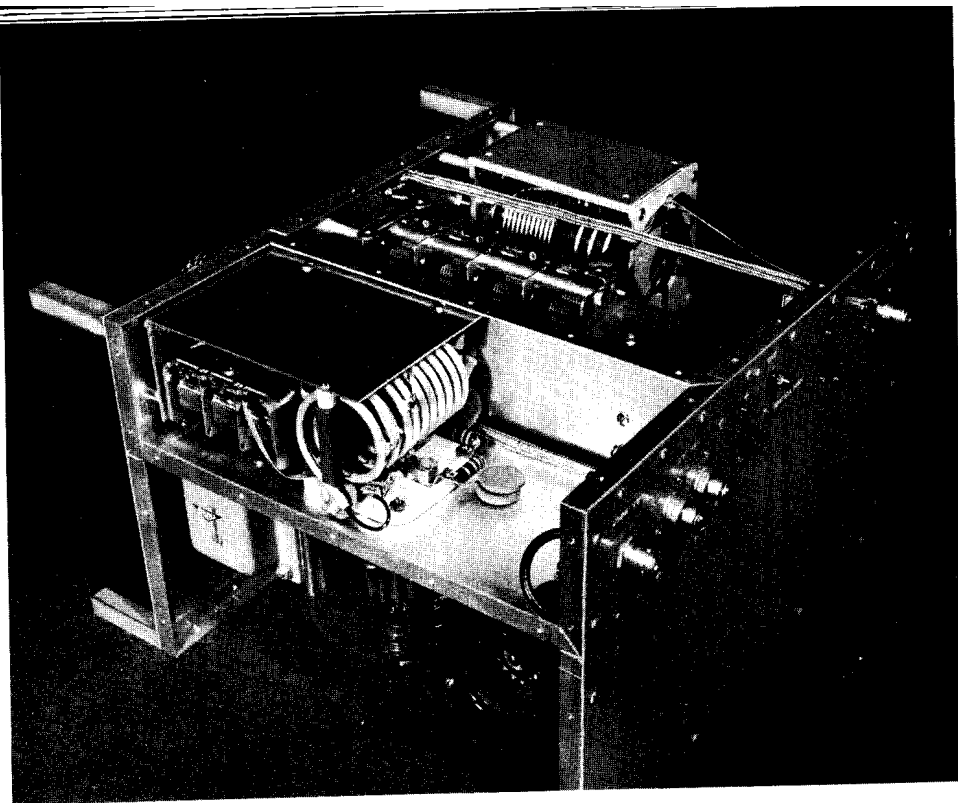


Figure 5. Under-view of chassis showing input compartment with tuned cathode circuit in place. Filament pins of socket face side of chassis. Each grid pin is grounded by R-C termination. All power leads run in shielded braid.

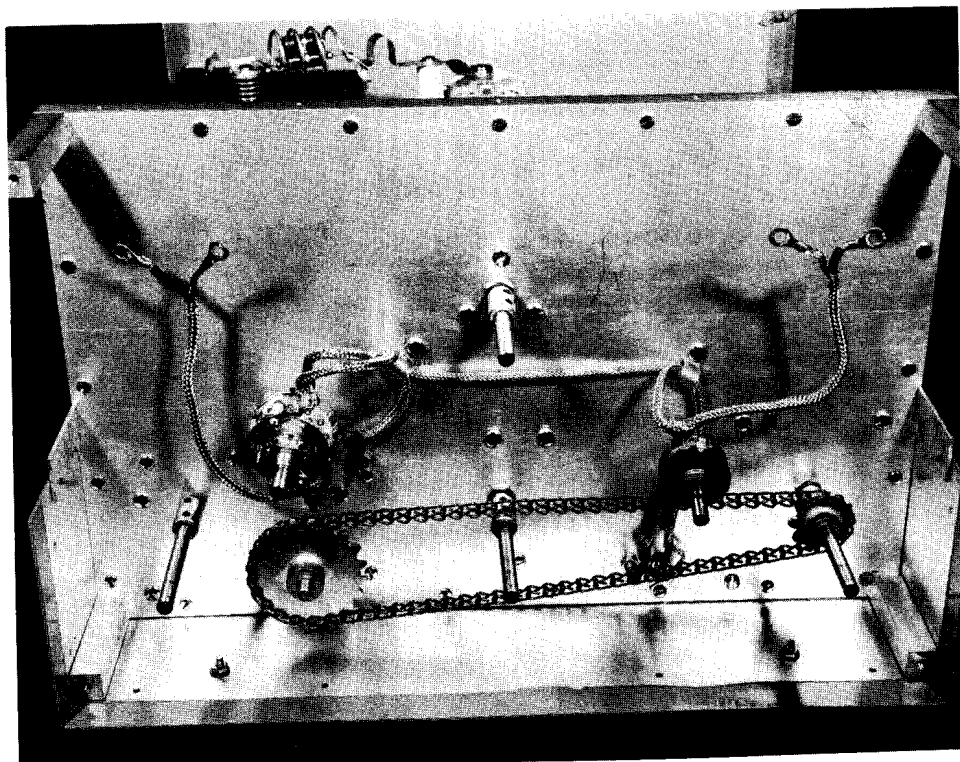


Figure 6. Meter wiring and chain drive behind panel. Cathode tank (left) and plate turret (right) are ganged, using American Stock Gear #C-10 sprocket (10 teeth, 1.125" diam.) left, and American Stock Gear #C-20 sprocket (20 teeth, 2.030" diam.) right. "Ladder" chain drive is American Stock Gear #18/42.