A 1-kw. Final Power Amplifier

By **HERBERT S. BRIER**
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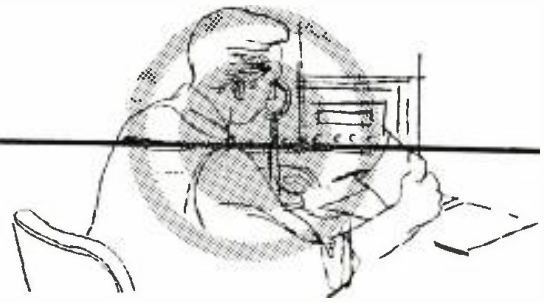


This 10 to 80 meter r.f. amplifier will boost the output of a low-power ham rig to the legal limit.

LOW-POWER transmitters usually get out well when conditions are ideal but a bit more power is always helpful when conditions are unfavorable or when trying to raise those rare DX stations that always seem to answer the other fellow.

The r.f. amplifier described in this article will boost the output of a low-power transmitter to 1000 watts or any desired fraction of that amount. For inputs up to 1000 watts, two 813's in parallel are required while for inputs up to 500 watts, a single tube will do the trick. The 813's were selected because they perform well and are reasonably priced.

The Circuit

As the schematic diagram shows, the amplifier is of the bandswitching type and covers the amateur bands between 3.5 and 29.7 mc. It performs equally well as a class C amplifier for c.w. and plate-modulated phone work and as a class AB_1 amplifier for boosting SSB and other low-level modulated signals.

Radio-frequency excitation is fed into the grids of the tubes *via* the bandswitched grid circuit. Table 1 gives specifications for grid-circuit coils.

A *Barker & Williamson* 850A inductor, with a built-in bandchange switch, is employed in the plate tank circuit. It is tuned with a 150-$\mu\mu$fd., 7000-volt variable capacitor and the output loading is controlled with a 1500-$\mu\mu$fd. variable capacitor, C_3 on the schematic.

The 7000-volt rating of input capacitor C_2 is sufficient for any mode of operation with up to 2500 volts on the plates of the 813's. A 4500-volt capacitor will be sufficient for c.w. and linear-amplifier operation; however, it will flash over in plate-modulated service at a plate voltage of 1500 volts.

The single 1500-$\mu\mu$fd. "loading" capacitor was found by test to be easier to adjust and more tolerant of mismatched loads than a smaller capacitor used in conjunction with additional fixed capacitors cut in and out of the circuit with a multi-contact switch. This capacitor is made by *The Allen D. Cardwell Co.* and may be ordered through most parts distributors.

The 813's are neutralized for stability in a capacitance bridge. To permit the screen voltage of the 813's to be self-modulated in plate-modulated operation, the voltage is fed to the screens through a 10.5-henry choke.

A built-in supply furnishes fixed bias for the 813's. This is the operating bias for AB_1 operation, but additional operating bias for class C operation is developed by the flow of the grid current through an additional resistor R_3. The filament transformer is also included on the chassis.

A switch, S_3, shorts out the screen choke and added grid resistor for class AB_1 operation.

Three milliammeters measure control grid, screen grid, and plate currents to the 813's. For safety, the plate meter is placed in the cathode circuit; consequently, it measures total cathode current. However, it is a simple matter to subtract the control grid and screen currents from the total to determine the actual plate current.

Precautions against television interference include complete shielding, making all d.c. and 60-cycle connections with shielded wire, and the generous use of bypass capacitors. In addition, all external connections are filtered before leaving the enclosure.

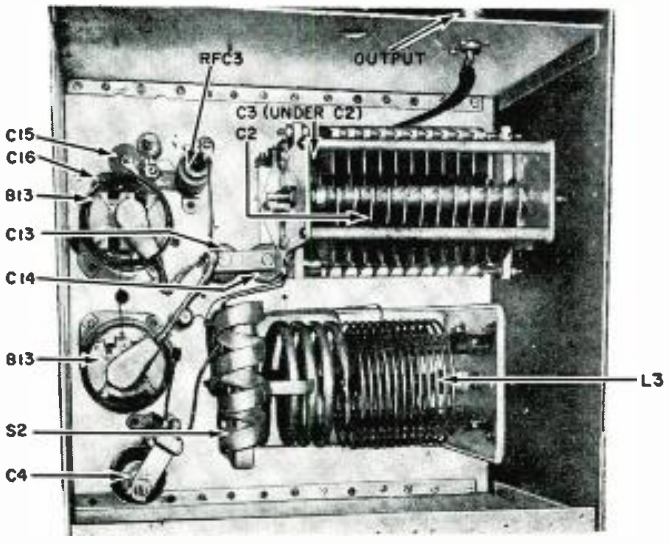
Construction

The amplifier is constructed on a 14" x 13" x 4" aluminum chassis and a 19" x 12¼" x ⅛" aluminum panel. The chassis is formed by cutting three inches off one end of a standard 17" x 13" x 4" chassis and putting the open end against the panel. Actually, another inch could be shaved off the width and depth of the chassis without overcrowding the amplifier components.

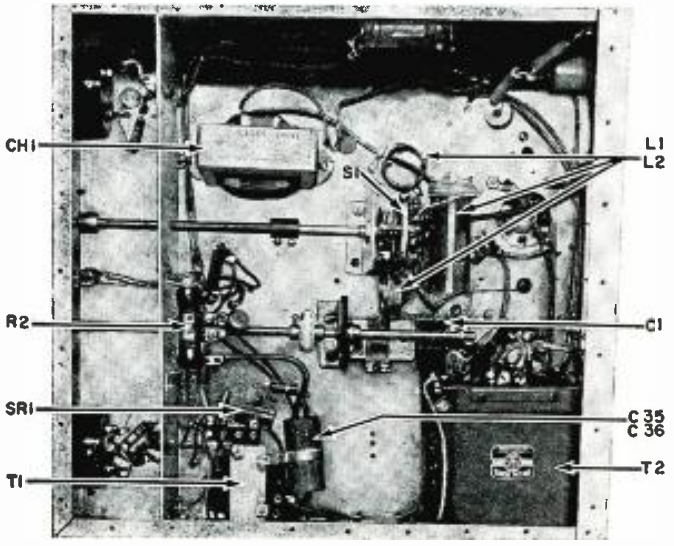
The chassis is fastened to the panel with aluminum angle stock, 1" from the left edge of the panel and 1/16" from the bottom of the panel. When the bottom plate is in place, it is flush with the bottom of the panel.

The top of the chassis is enclosed in 1/16" aluminum. The two side pieces are 14" x 8" x 1/16" and the back is 13" x 8" x 1/16". They can be separate pieces or

Top view of high-power final r.f. amplifier built by author.



Bottom view shows wiring and layout of the smaller components.



a single "U" bent from a single piece of sheet aluminum. The top and bottom plates are 14" x 13" x 1/16". One-half inch flanges can be bent along the edges of the pieces of shielding to join them together or they may be joined with aluminum angle. The author used a combination of both methods.

Both the sheet aluminum and the 3/4" x 3/4" x 1/8" or 1/2" x 1/2" x 1/8" aluminum angle stock are available from the "do-it-yourself" racks of hobby shops and department or hardware stores.

The 6-32 x 1/4" machine screws were used in preference to sheet-metal screws for joining the various pieces of metal together. They are spaced approximately 1 1/2" apart, with the angle stock and flanges drilled and tapped to accept the screws. The holes in the top and bottom plates are countersunk so that flat-head screws may be used with five or thirty 3/16" holes drilled above each tube.

The photographs show the positions of most of the amplifier components. However, a few measurements will be helpful. The plate inductor is mounted on the left of the chassis, 1 1/2" behind the panel with its shaft 3 3/4" from the left edge.

C_3 is mounted directly on the chassis about 2 1/2" behind the panel with its shaft 3 3/4" from the right edge. C_2, in turn, is mounted directly over C_3 on brackets 3 1/2" above the chassis. The rear bracket is fastened to the rear of C_2, utilizing a pair of tapped holes already there, to provide a direct, low-resistance connection between the two capacitors, as well as supporting C_2.

The tube sockets are mounted on 1/2" pillars above the chassis. Their centers are 4 3/4" in from each side of the chassis and 2" from the bottom of the panel, while the screen meter is mounted with its center 2" from the right edge of the chassis and 3" from the top. S_3 is positioned between the grid control, 3 1/2" from the bottom of the panel. The dial scales and other panel markings are from *Tekni-cal* decal sets.

Wiring the Amplifier

As stated earlier, all connections carrying d.c. and 60-cycle a.c. are made with shielded wire. The conductors are bypassed (by .001-μfd. disc ceramic capacitors) to the shielding where they enter and leave the chassis. The leads are strung along the chassis with the shielding grounded, wherever convenient, at soldering lugs under the various mounting screws.

The tube sockets are wired before being mounted. Insert 1" round-head screws through the socket mounting holes and place a 1/2" bushing and a flat soldering lug on each screw, holding them in place with a nut on the screws. Solder terminal #5 of each socket to the nearest lug. Next, solder flexible shielded leads (about a foot long) to the filament and screen terminals (#1, #7, and #3), grounding the shield to the nearest solder lugs. Also, bypass these terminals with .001-μfd., 2000-volt disc ceramic capacitors to the same solder lugs.

Turn the sockets so that the grid terminals (#4) face each other and determine how far apart they will be when the sockets are mounted, then connect them together with a length of heavy wire. Remove the nuts temporarily placed on the mounting screws and mount the sockets, threading the leads soldered to their terminals through the holes drilled in the chassis. Cut the leads to length and connect them to the appropriate points in the circuit.

Connect a #14 wire from the center of the wire joining terminal #4 of the sockets to the stator terminal of C_1 and to the rotor terminal of S_{1A}. Next, connect a length of 52-ohm coaxial cable between the rotor terminal of S_{1B} and the r.f. input connector. Ground its shield at the switch end to a solder lug bolted to the switch assembly screw near the top of the chassis. Mount an insulated tie-point to this same screw.

Prepare the grid coils as indicated in Table 1 and connect them as shown in the diagram, positioning them as shown in the photograph of the bottom

BAND	L_1	L_2
80 m.	46 t.	6 t.
40 m.	22 t.	3 t.
20 m.	8 t.	2 t.
10-15 m.	3 1/4 t.	1 t.

All L_1 coils are air wound of #18 tinned wire, 1" dia., 16 t. per inch (B & W "Miniductor" #3015). Two required.

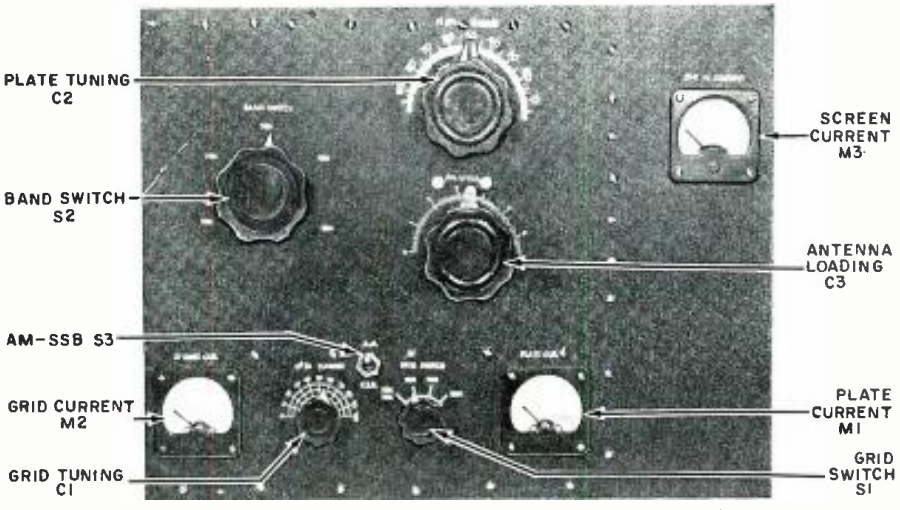
L_2 coils are wound of #20 plastic-insulated hookup wire, wound over L_1 coils at bypassed end and held in place with Duco cement. All coils supported by their leads.

Table 1. Coil data for the amplifier.

	C.W.	PLATE-MOD. PHONE	LINEAR (Class AB_1)
Plate Voltage	2250	2000	2500
Screen Voltage	400	350	750
Plate Current (ma.)	225	200	150 (peak)*
Grid Current (ma.)	16	16	0
Screen Current (ma.)	40	40	28 (peak)

*Adjust grid bias for 25 ma. zero-signal plate current.

Table 2. Voltage and currents obtained for three modes of operation.



Front panel view of the 1-kilowatt power amplifier, with parts identified.

them. The paint is removed from the panel at the points where the chassis and shielding touch it.

An aluminum partition inside the chassis, two inches from the front, separates the plate and grid meters and their r.f. filters from the rest of the amplifier components.

A surplus squirrel-cage blower, mounted on the side of the transmitter cabinet, cools the amplifier. It blows air into the chassis *via* a 3" diameter hole cut in the left side of the chassis. The hole is covered with metal screening to preserve the shielding.

The air flows up through 2" holes under each tube socket and 3/8" holes drilled around the sockets, then around the tubes and out the top of the enclosure through a cluster of twenty-sis and 1 1/2" in from the back. Besides the 2" holes under the sockets and the 3/8" ones around it, drill 3/16" holes under the filament and screen terminals to accommodate the leads to them.

Under the chassis, S_1 and C_1 are mounted approximately eight inches behind the panel with their shafts five inches in from each side of the chassis and two inches from its top, S_1 is mounted on a metal bracket and C_1 is mounted on a piece of Bakelite for insulation.

One-quarter inch metal shafts extend the various controls to the front panel. All shaft couplings, except the one on C_1, are metal.

On the front panel, the grid and plate meters are mounted with their centers 1 1/2" in from the sides of the

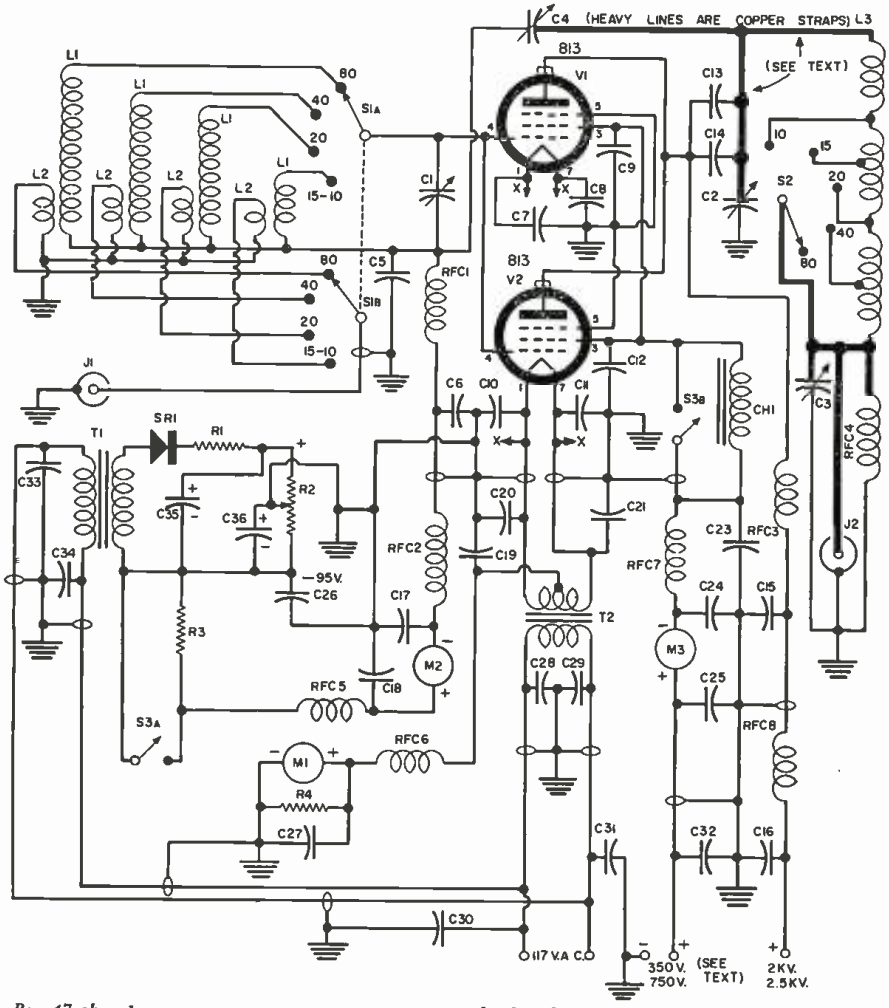
view. The bypassed ends of the four L_1 coils are terminated at the tie-point and the inner end of each link winding is grounded to the soldering lug. Connect the other ends of each winding to the appropriate terminals on S_1.

The tie-point and the bottom terminal of C_4 are connected to the rotor terminal of C_1. This terminal is bypassed by a 500-$\mu\mu$fd. mica capacitor, C_5, and the negative grid bias for the 813's is fed into this point *via* RFC_1.

Other connections below the chassis can be determined from the circuit diagram. Use insulated tie-points where necessary to support small components.

The connections in the plate circuit, indicated in heavy lines on the schematic, are made with ¾" wide copper straps cut from "flashing copper" obtainable at any sheet metal shop. A short length of copper strap connects C_{13} and C_{14} together and to the stator terminal of C_2. Short lengths of silvered copper braid, stripped from a length of RG-9/U coaxial cable, connect the other side of these capacitors to the 813 plate caps. As the tops of the tubes come fairly close to the metal top of the box, insulated plate connectors should be used.

Fig. 1. Schematic of amplifier. A single 813 is used for input up to 500 watts.



R_1—47 ohm, 1 w. res.
R_2—2500 ohm, 25 w. res. with slider
R_3—3000 ohm, 10 w. wirewound res.
R_4—100 ohm, 2 w. res.
C_1—150 $\mu\mu$fd. midget var. capacitor (Bud CE-2006)
C_2—150 $\mu\mu$fd., 7000 v. var. capacitor (E. F. Johnson 150D70)
C_3—1500 $\mu\mu$fd., 1000 v. var. capacitor (Cardwell #PL-8013)
C_4—12.5 $\mu\mu$fd., 12.5 kv. neutralizing capacitor (E. F. Johnson N250)
C_5—500 $\mu\mu$fd., 1250 v. mica capacitor
C_6, C_{17}, C_{18}, C_{19}, C_{20}, C_{21}, C_{26}, C_{27}, C_{28}, C_{29}, C_{33}, C_{34}—.001 μfd., 1000 v. disc ceramic capacitor
C_7, C_8, C_9, C_{10}, C_{11}, C_{12}, C_{22}, C_{23}, C_{24}, C_{25}, C_{32}—.001 μfd., 2000 v. disc ceramic capacitor
C_{13}, C_{14}, C_{15}, C_{16}—500 $\mu\mu$fd., 20 kv. "TV" ceramic capacitor
C_{30}, C_{31}—.1 μfd., 600 v. a.c. capacitor (Sprague 80P3 "Hypass")
C_{35}, C_{36}—16 μfd., 250 v. elec. capacitor
CH_1—10.5 hy., 110 ma. filter choke (Stancor C-1001)
L_1, L_2—See Table 1
L_3, S_2—Part of pi-network inductor (B & W 850A)
RFC_1—2.5 mhy., 125 ma. r.f. choke (National R125)
RFC_2, RFC_3, RFC_4, RFC_7, RFC_8—7 μhy. r.f. choke (Ohmite Z-50)
RFC_5—225 μhy., 800 ma. r.f. choke (National R-175A)
RFC_6—1 mhy., 300 ma. r.f. choke (National R300)
S_1—D.p. 4-pos. rotary switch ceramic insulation (Centralab #2505)
S_2—Part of plate-tank inductor
S_3—D.p.s.t. toggle switch
SR_1—65 ma. selenium rectifier
J_1, J_2—R. f. coax jack
T_1—125-volt, 50 ma. trans., 117-volt a.c. primary (Stancor PA8421)
T_2—10-volt, 10-amp. trans., 117-volt a.c. primary (UTC S-62)
M_1—500 ma. d.c. meter (2" size)
M_2—50 ma. d.c. meter (2" size)
M_3—100 ma. d.c. meter (2" size)
V_1, V_2—813 tube (see text)

Adjustment and Operation

After the amplifier is wired, apply 117-volts a.c. and set the slider on R_2 for −95 volts. Leave the "B+" and screen voltage leads disconnected. Turn the bandswitches to the 20-meter position and S_3 to the AM/CW position. Feed 20-meter energy into the input connector. Tune C_1 for maximum grid current, adjusting the exciter for about 20 ma. current.

Couple a sensitive r.f. indicator to the plate tank circuit and, with C_3 set to maximum capacitance, tune C_2 for maximum r.f. output. Using an insulated tool, adjust C_4 for minimum output, repeaking C_1 and C_2 from time to time to insure that they remain resonated. If an r.f. indicator is not available, after C_1 is tuned for maximum grid current, adjust C_4 for minimum flicker of grid current as C_2 is tuned through resonance.

When the amplifier is neutralized, connect a load to the amplifier output terminal and tune the amplifier on the various bands with reduced plate and screen voltages applied.

Because of the relatively high output capacitance of two 813's in parallel, it is necessary to decrease the inductance of the 10-meter section of the plate tank inductor before it will resonate on 10 meters. To do this, remove the 4-turn coil from the circuit and twist it in your hands until it has five turns of reduced diameter. Straighten out the fifth turn and bend it to fit the original mounting screws. Drill a ¼" hole to mount it, cut off the excess material and remount the coil.

After pruning the coil and tuning the amplifier on 10 meters, still at reduced voltages, touch up the neutralization by carefully adjusting C_4 until detuning C_2 slightly to either side of resonance causes the grid current to decrease and plate current to increase. If neutralization is not exact, detuning C_2 to the high-frequency side of resonance causes grid current to increase, indicating regenerative feedback.

After the amplifier has been tested at reduced voltages, they may be increased to normal values. Table 2 gives the maximum ratings for the 813 for different modes of operation.

The amplifier has been driven by a variety of low-power commercial and home-built exciters. Among them have been a modified *Heathkit* AT-1, a DX-20, and a *Johnson* "Adventurer." The power output of the exciters is controlled by varying the amplifier-tube screen voltage. At present, it is driven by a *Johnson* "Navigator" for c.w. and AM phone work and a *Central Electronics* "10A" for SSB work.

Used with a TVI-free exciter and with a good low-pass filter at the output connector, this amplifier causes no TVI to a television receiver sitting on top of the transmitter cabinet on any of the author's locally available channels (2, 5, 7, 9, and 11). -30-