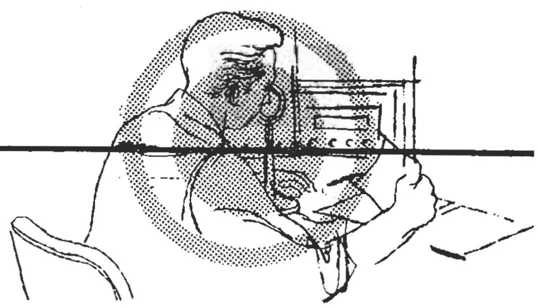
A 1-kw. Final Power Amplifier

By HERBERT S. BRIER
W9EGQ



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 band-switched 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-μμfd., 7000-volt variable capacitor and the output loading is controlled with a 1500-μμfd. 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-μμfd. "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.

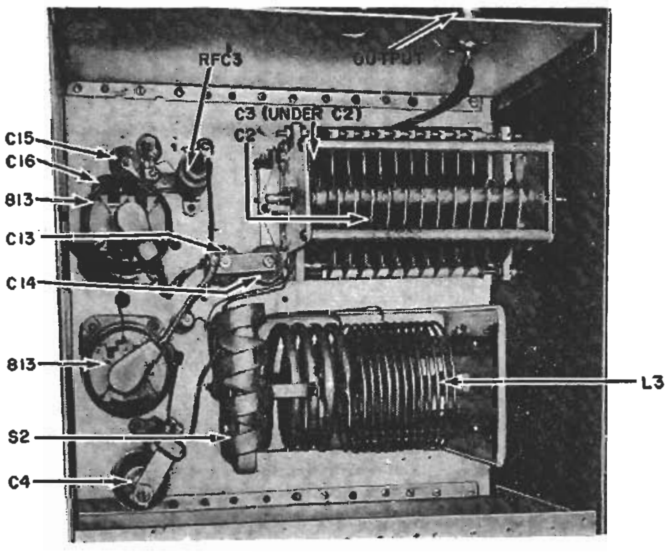
Construction

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.

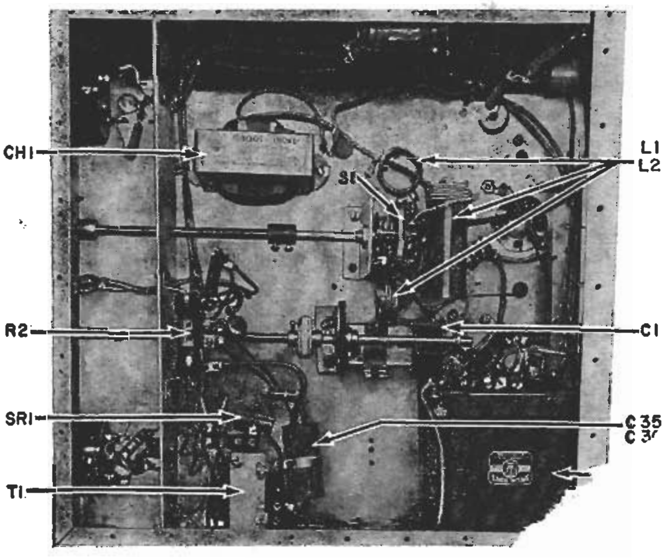
The chassis is fastened to the panel with aluminum angle stock, 1" from the left edge of the panel and 1/16" from the bottom of the panel. When the bottom plate is in place, it is flush with the bottom of the panel.

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 1½" 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, 1½" behind the panel with its shaft 3¾" from the left edge.

C_3 is mounted directly on the chassis about 2½" behind the panel with its shaft 3¾" from the right edge. C_2, in turn, is mounted directly over C_3 on brackets 3½" 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 ½" pillars above the chassis. Their centers are 4¾" 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, 3½" 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 ½" 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.	3¼ t.	1 t.

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

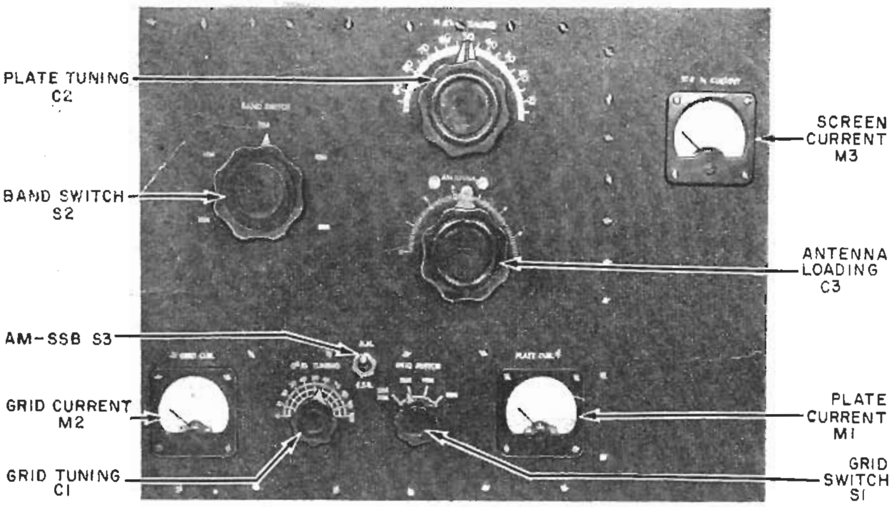
L_2 coils are wound of #20 plastic-insulated hookup wire, wound over L_1 coils at by-passed end and held in place with Duco cement. All coils supported by their leads.

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 1½" 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.

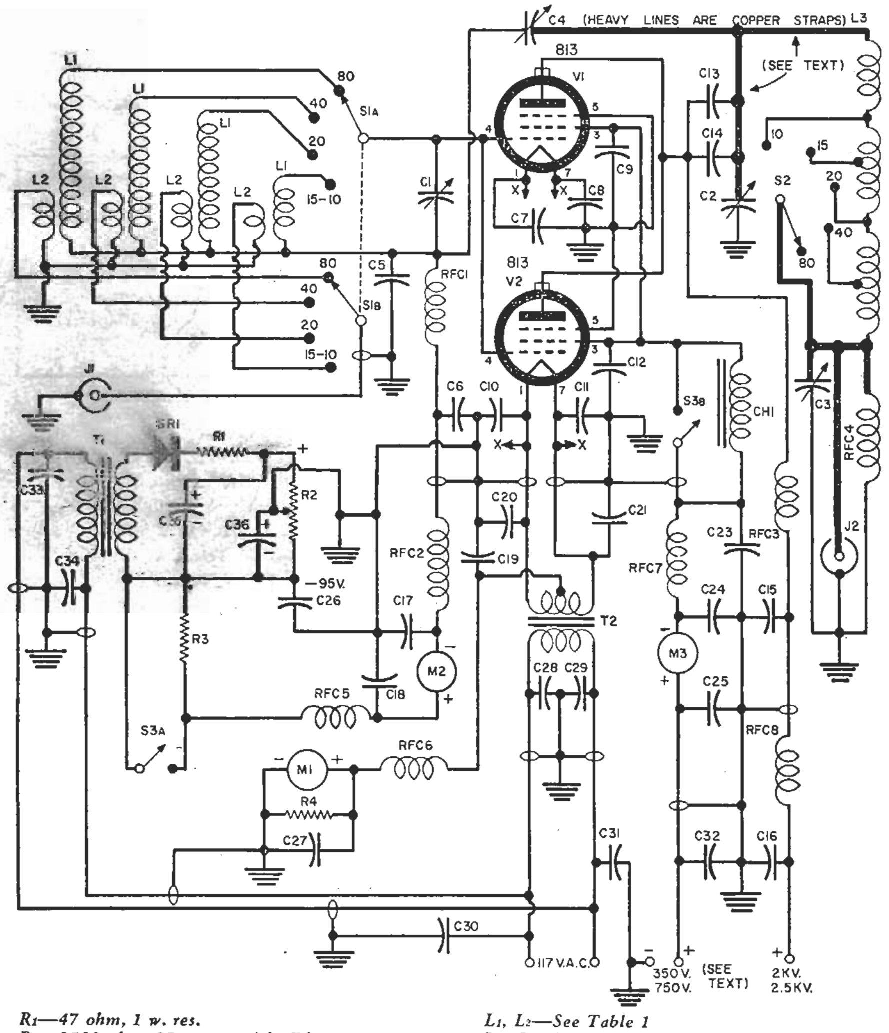
On the front panel, the grid and plate meters are mounted with their centers 1½" in from the sides of the view. The bypassed ends of the four L_1 coils are terminated at the tie-point and the inner end of each link winding is grounded to the soldering lug. Connect the other ends of each winding to the 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_5, RFC_6, RFC_7, RFC_8—7 μhy. r.f. choke (Ohmite Z-50)
RFC_3—225 μhy., 800 ma. r.f. choke (National R-175A)
RFC_4—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-

RADIO PILL . . .

transmits from inside you . . .

By ERIC LESLIE

A "RADIO PILL," an encapsulated FM transmitter that can be swallowed and is used to "telemeter" information from the digestive tract, was demonstrated April 8 at the Rockefeller Institute in New York City. Its action was explained by Dr. Vladimir K. Zworykin, affiliate in biophysics in the Medical Electronics Center of the Rockefeller Institute and honorary vice president of RCA, who had been active in the early stages of its design.

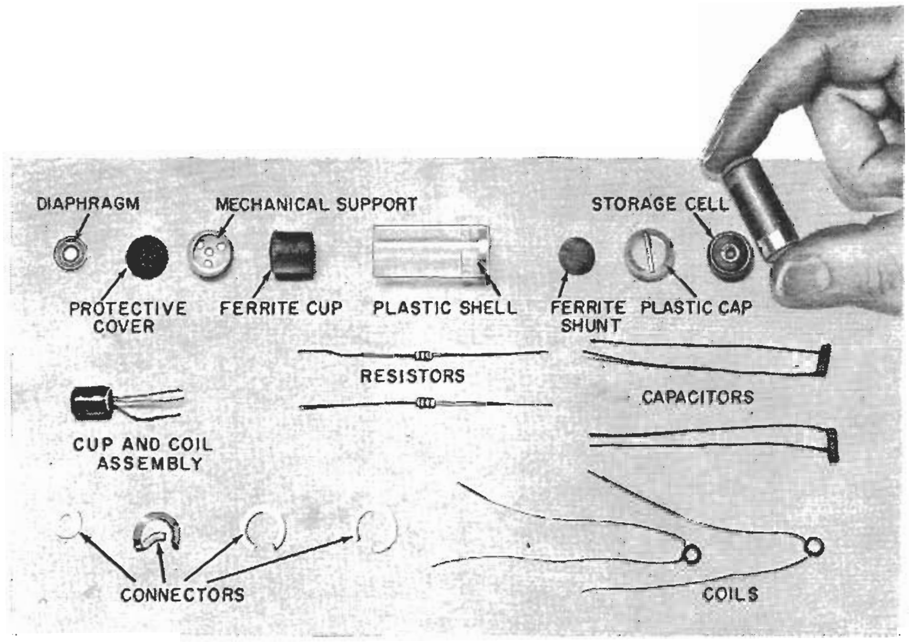
A "radio pill" offers the medical man many possibilities since it causes no discomfort to the patient and thus can make measurements under more normal conditions than older tools. It can easily penetrate such areas as the right side of the colon, hitherto almost inaccessible to study. Present models (only three were in existence at the time of the demonstration) have been used to measure pressure. Temperature measurements are also possible, and it is expected that means will be devised to measure acidity in the gastro-intestinal tract.

The transmitter consists of a ferrite cup core, two coils, two resistors, two capacitors, a transistor and a small rechargeable 1.5-volt cell in a plastic capsule 1⅛ inches long and 0.4 inch in diameter. Operation is at approximately 1 mc, and the signal is receivable for a foot or two outside the body. The unit is frequency-modulated by a disc-shaped magnetic shunt, which changes the inductance of the core as it moves closer and farther away. Since frequency modulation is used, changes in amplitude caused by the unit moving nearer to or away from the body's surface create no reception problems.

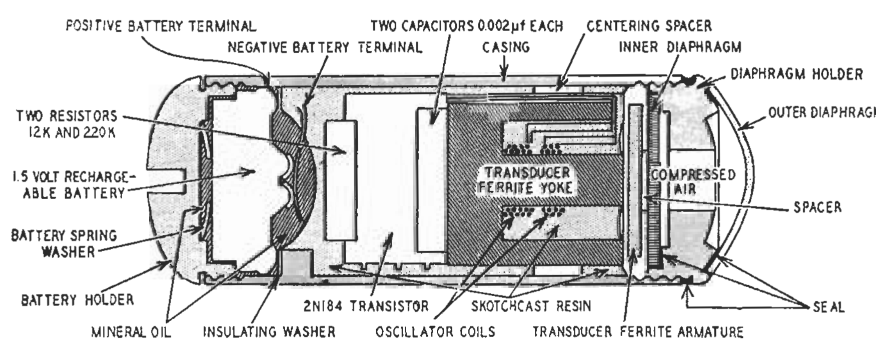
The pressure transducer consists of a rubber diaphragm (a metal diaphragm was used in the first model, shown in exploded form in the photograph) to which the magnetic shunt is attached. As pressure is increased, the diaphragm is bent inward, forcing the shunt nearer to the core and lowering the transmitter's frequency. A second diaphragm is provided at the end of the tube, for mechanical protection. The space between the two is filled with air, under enough pressure to make the whole space act as a piston, transmitting the pressure from one diaphragm to the other without significant loss.

The idea of such a pill was conceived by John T. Farrar of the Rockefeller Institute and its design worked out by Dr. Zworykin. The development work was done by a team of engineers of RCA's Commercial Electronics Products Division in Camden, N. J.

A remarkable feature of the apparatus is that it was constructed from available miniature components. Even the battery was found on the market.



These components all go together to make up the 0.4-inch-diameter, 1⅛-inch-long "Radio Pill" (upper right) that "telemeters" information from the digestive tract.

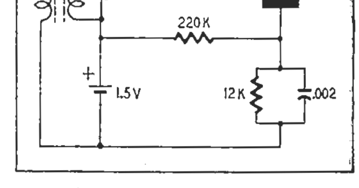


Cross-section diagram of the capsule containing the FM transmitter.

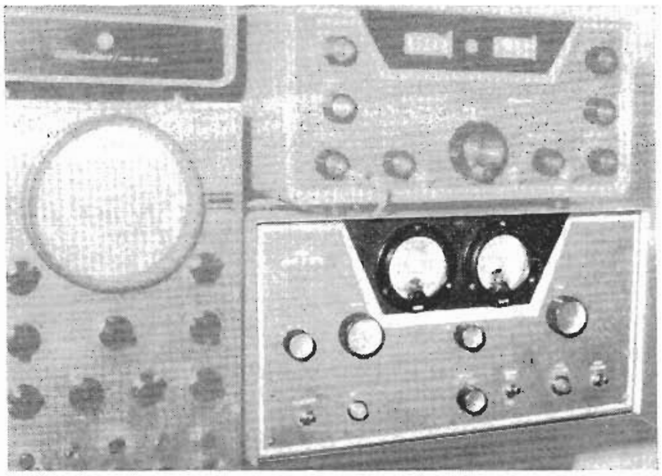
The constructors did not have time to get special components made for the job and had to rely on standard parts. With specially made components, an even smaller capsule could be built.

In its present stage of development, the radio pill must be considered an experimental technique but one which holds important implications for future medical research. The pill's practical uses will be evaluated following laboratory tests and experiments which will be conducted jointly by RCA, the Rockefeller Institute and the Veterans Administration.

Studies involving use of the radio pill, for the time being at least, are being carried out in the New York Veterans Hospital with the patient under continuous observation. Preliminary testing has taken place during the last year. END



Circuit of the tiny transmitter.



The completed linear amplifier on the operating desk at VE1KK. Design matches the Hallicrafters SR-150 used as an exciter, and the oscilloscope beside it keeps constant watch on linearity. Controls from left to right are: Top row-coarse loading, fine loading, bandswitch, and plate tuning. Bottom row-filament switch, filament pilot light, Linear In-Out, plate voltage High-Low, plate voltage pilot light and plate voltage switch.

A Homebrew Linear Amplifier

by George Cousins, VE1TG

During recent years, commercial SSB transceivers and transmitters have almost succeeded in pushing home construction into the dim mists of time. The complexities of building and aligning an all-band SSB unit do indeed present some problems, but it's a somewhat different story when one considers the boost to high power which sooner or later becomes the desire of most operators. Whether justified or not, most of us would like to have that little extra punch which a good linear amplifier will provide.

So what course is open? We can buy one of many manufactured units, or we can choose one in kit form and capture at least a fragment of the enjoyment of actually building a piece of equipment. Or we can study circuitry, heed the advice of those who know, look at the work of others, and then sit down and create our own. At the same time we'll have immeasurable satisfaction from doing a good job.

Doing a good job requires some careful forethought and even more careful construction, and the unit I'm going to describe has been given large doses of both. It was designed and built by Wilbur "Bill" Hills, VE1KK, of Moncton, N.B., and the care which went into it is apparent in both appearance and performance. The linear uses standard parts readily available anywhere in the country, and can be built for a price directly proportional to one's junk box and horse-trading ability.

Design

The circuit is a grounded-grid amplifier using two old reliable 813 tetrodes in parallel. Any of the usual 100-200 watt transceivers or transmitters on the market will drive it to full output. A rather unusual screen circuit is used, plus a self-contained solid state power supply with provision for low or high power operation. The complete unit fits into a cabinet for table-top use beside the exciter and receiver.

Construction

Most of the construction details will be obvious from the photographs and schematics. The chassis is a standard 17″ x 14″ x 3″ (Hammond 1440-38), which allows plenty of room for both RF and power supply sections. The two 813s are mounted horizontally, with their sockets sub-mounted ½ inch into a small 8″ x 4″ x 2″ chassis (Hammond 1440-10) with its bottom panel (1430-10) providing easy access to the sockets and their associated wiring. The filament, grid and screen by-pass capacitors are wired with the shortest possible leads directly to the socket pins. This, plus heavy bus wiring and the shielded enclosure, ensures good isolation between grid and plate circuits as well as aiding in TVI prevention.

The plate choke and bypass are also mounted horizontally and placed carefully to ensure short leads. The choke may be the familiar National R-175A used here, or may be home-made as described in the parts list. The plate tuning capacitor shown has been cut down by removing about half the plates. This was done deliberately to get a better L/C ratio in the plate tank, but does not allow enough tuning capacitance for 80 and 40 meters. Therefore, an additional 100 pf. capacitor is switched in parallel with the tuning capacitor when these bands are selected. This is done by one deck of the bandswitch, the second deck being used to select the correct tap on the pi-network output coil. This is a combination of commercial coil stock and home-wound inductance and mounts on small standoffs parallel to the front panel.

Output tuning of the pi-network is a combination of fixed capacitors, selected by a front panel switch, and a three-section broadcast type variable unit. This allows matching to a very wide range of line impedances. Finally, the output RF lead is fed to a Linear In-Out switch on the front panel. This allows instant selection of either the exciter alone or the combination of exciter-plus-linear for immediate power increase or decrease. The Linear In-Out switch is a heavy duty ceramic affair with two poles and two positions.

The bandswitch is made from two separate wafers of different characteristics. The section which selects the coil taps is a 5-position continuously shorting type, while the other section is a 5-position non-shorting type. This was made up from wafers of two switches which were dis-assembled and re-assembled on one set of shafts and spacers. This was necessary because of switching in the extra capacitor on 80 and 40 meters, but might not be required if a different final tank design were used.

The two meters are enclosed by a home-made sheet metal box (a small chassis would be suitable), which is well grounded along its perimeter and effectively shields the meters from the strong RF field around the plate coils. Finally, a small cooling fan is mounted in the centre of the chassis on a small metal plate, with the airflow directed at the tube envelopes. Originally mounted firmly on the chassis, the fan caused some noise so the plate was remounted on rubber grommets. The fan used is a small Japanese unit distributed by Temco.

The only part of the RF section which is somewhat unusual is the screen circuit. Note that there is no DC screen supply, as such. Instead two 6X5 rectifiers are connected between the screen grids and ground, with the screens being held at zero potential for both DC and RF. As soon as an SSB signal is applied to the input connector, a portion of it is fed to the 6X5s, which rectify the signal voltage and apply it as a DC potential to the screens. Of course, the stronger the input signal, the higher the screen voltage, so that the screens are controlled in exact phase with the input signal. On AM or CW, the same thing happens, except that the screen voltage becomes steady due to the constant amplitude of the carrier.

The remainder of the amplifier is straightforward. The output pi-network tank may be any of the commercial types now available or may be home-made. However, some instability may occur on 10 and 15 meters if the tank circuit is not designed and positioned carefully, and neutralization of the tubes may be necessary.

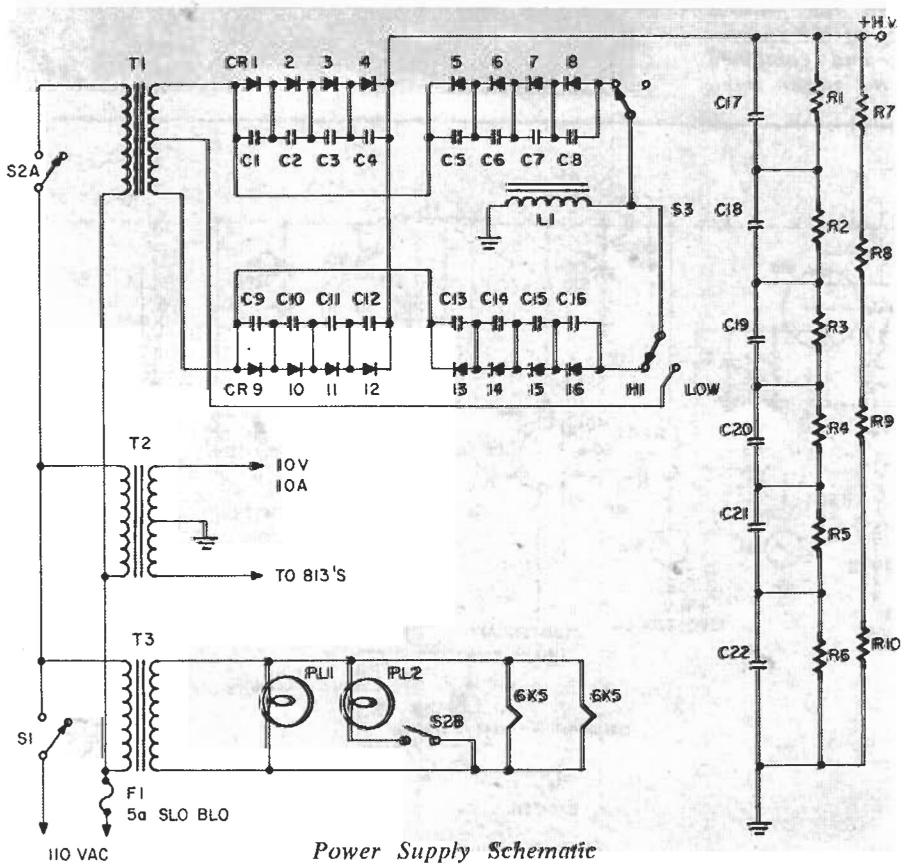
Power Supply

The power supply components above the chassis are the high voltage transformer (anywhere from 600 to 1200 volts each side of center tap), the high voltage choke, and the 813 filament transformer. Solid state circuitry eliminates bulky rectifier tubes and their associated filament transformers, though of course if these are available and cost is a vital factor they could be used. Space limitations would probably necessitate a separate power supply chassis, however.

Now let's look underneath, referring to the photo as we go along. In the lower left corner are the two 6X5 tubes mounted horizontally on a small plate. The long black cylinder is the 813 filament choke, home-made by double-winding #14 wire on a ferrite rod. Plexiglass mounting brackets hold the choke securely in place. The RF output connector is mounted under the choke on the rear wall of the chassis. Along the far wall, a bakelite terminal board holds the 16 silicon diodes on the side visible in the photo. On the underside of the board are the 16 associated disc ceramics used for balancing and spike elimination. The entire board can be quickly removed by unsoldering five wires and removing two screws in the standoff insulators.

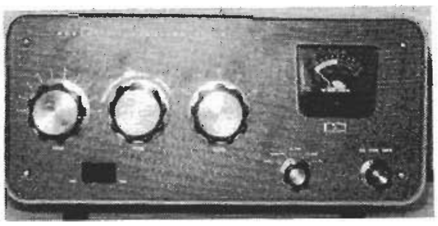
Adjacent to the diode board is the small 6.3 volt filament transformer for the 6X5 tubes, and the filament wiring to the 6X5s is shielded and well bypassed. Along the front wall are the various filament and plate switches, pilot lights, and the Linear In-Out switch. There is also a High-Low power switch but more about this in a moment. Finally, in the foreground is the 80-40 meter extra plate padding capacitor mentioned earlier. Though a variable was used in this linear, a fixed capacitor would be equally suitable and would take less space.

Two more plexiglass boards occupy the middle of the chassis and hold the



Power Supply Schematic

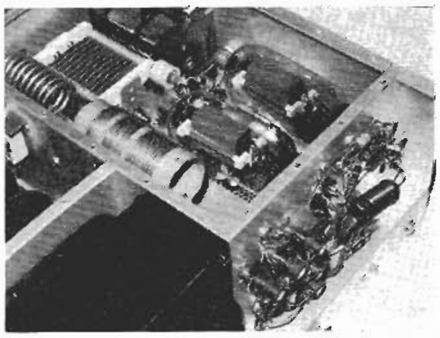
Linear Amplifier Kit



The kit referred to in the accompanying article is the Heath SB-200. A self-contained desk-top unit weighing 35 pounds, it is capable of the legal limit on cw and 1200 watts pep on ssb.

The size and simplicity of the SB-200 centres round the two carbon anode triodes (572-B/T-160L). Two of these in parallel provide 320 watts of plate dissipation with only a moderate amount of envelope cooling.

A standard grounded grid arrangement is used with a fixed tuned cathode circuit for each band. Any 100 watt class exciter will provide sufficient drive. The RF enclosure is shown below.

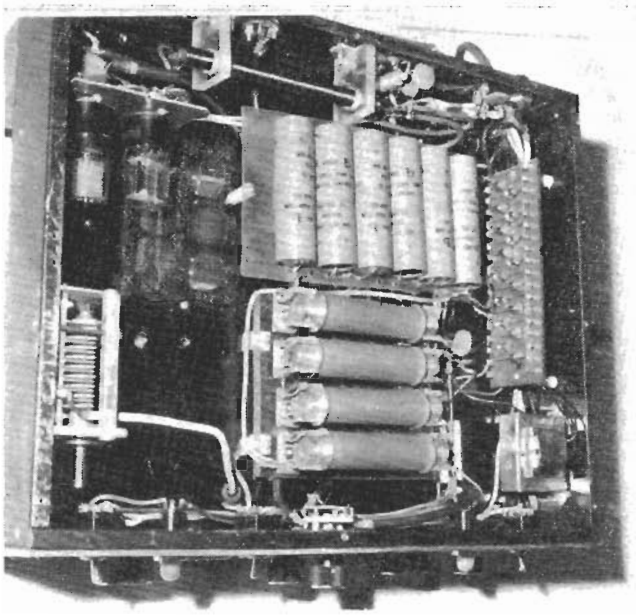


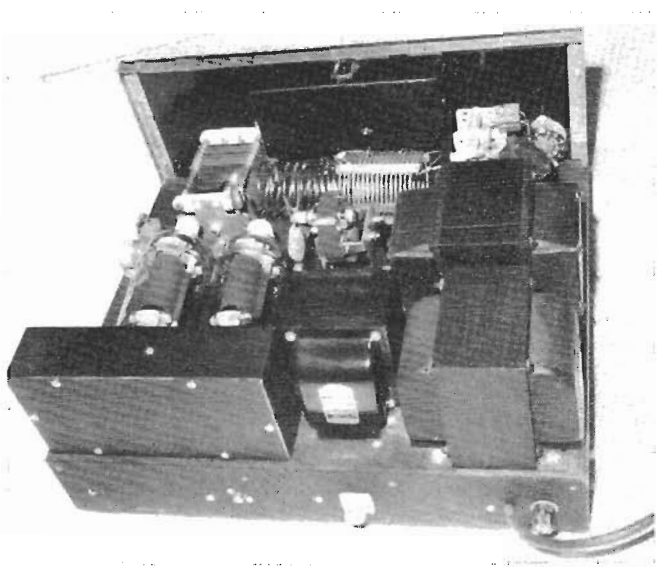
Front panel controls are, left to right, plate loading, plate tuning, band selection. Meter switching selects grid, plate, forward power, reverse power, and high voltage. The on-off switch puts the linear into instant operation as the tubes have directly heated filaments and a transfer relay takes care of the input/output switching.

Either 110 or 240 vac line input can be used by changing taps on the power transformer and circuit breakers are installed in the primary. Plate voltage of about 2400 is supplied by a silicon diode voltage doubler. Most of the power supply components are assembled on a printed circuit board. The RF compartment is fairly well shielded although not as tightly as some situations might require.

It is not a difficult kit and assembly takes only a few evenings. When complete there are no adjustments to make although an oscilloscope is desirable to check the waveform for various conditions of load and drive.

The SB-200 matches the other components in the Heath line. It is priced at $335 direct from Heathkit, 1480 Dundas Highway East, Cooksville, Ontario. *(E. W.)*

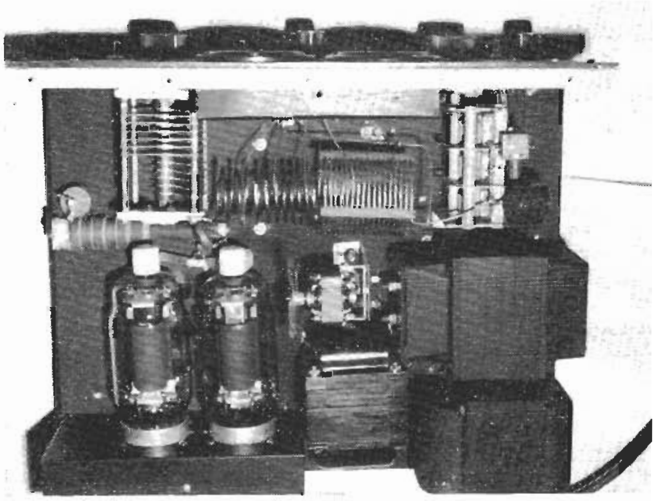


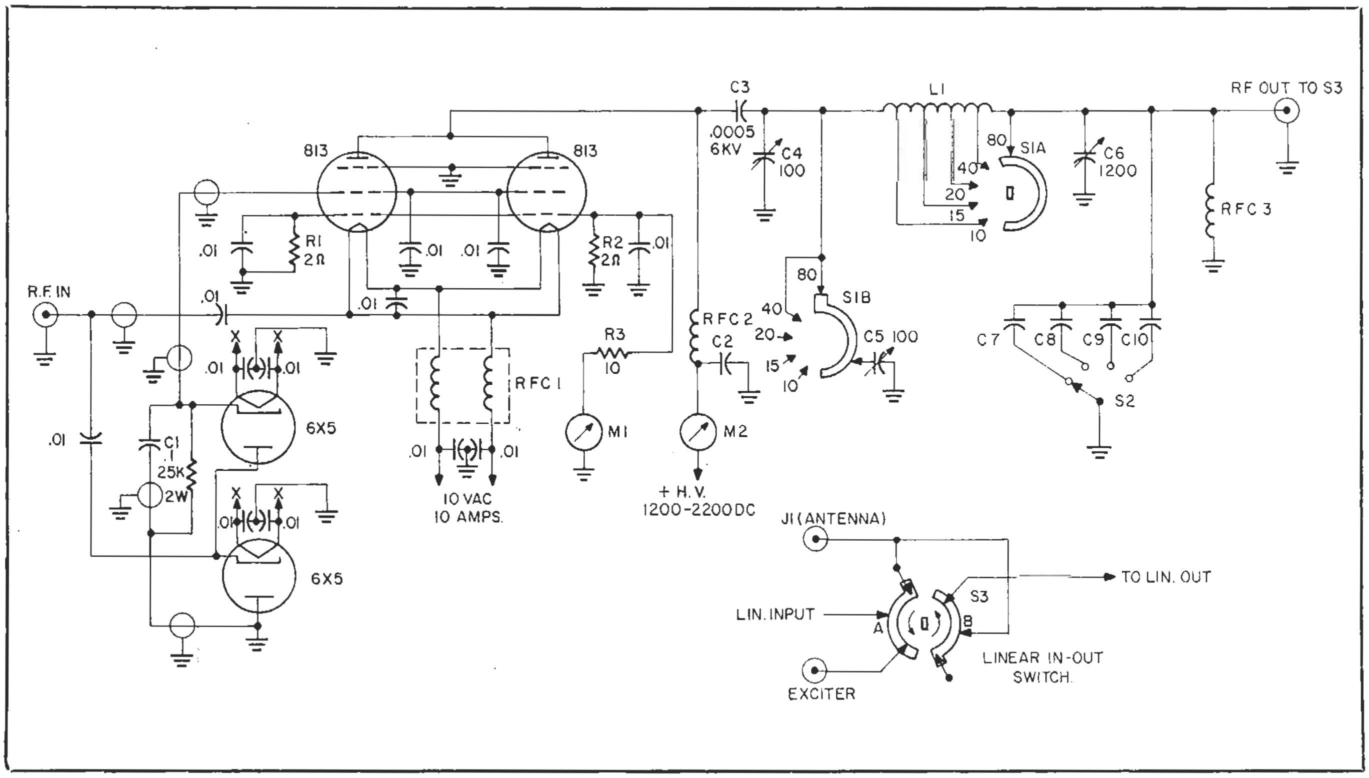


Underneath the chassis (above). In foreground, the 80/40 meter capacitor and 6X5 tubes. Filter capacitors and bleeders occupy the centre space, with the silicon diodes at the right. The Linear In-Out switch is on the front panel adjacent to the bleeders.

In the top right view the cabinet mounting strips can be seen around the front panel, as well as the input and output connectors on the rear of the chassis. The 813 input enclosure has its cover in place.

Top view of the amplifier (right) shows power supply components in the lower right hand corner. The 813s plug into the small chassis at the left, and the various RF tank components occupy the remainder of the chassis. Note the cooling fan, meter enclosure, and combined fixed and variable loading capacitors at the upper right.





filter capacitors and the bleeder resistors. Here again, some variation in components would do no harm but might not fit in the available space, whereas by using the diodes in combination with the six low-voltage high-capacitance capacitors a very compact power supply can be built.

The power supply circuit uses a full-wave OR a bridge configuration, selected by the High-Low switch, with either full or half voltage output depending upon the switch position. Notice that the switch and the filter choke are both placed in the ground return line; therefore low voltage (and low cost) components can be used. This voltage selection also permits the use of a smaller plate transformer and permits low power operation of the 813s during initial tune-up.

The filter capacitors are all in series and with 100 mfd, units there is a total effective capacitance of about 16 mfd, across the high voltage output. The balancing resistors across each filter are physically mounted under the filter board. A single 100,000 ohm 50 watt bleeder resistor could be used in place of the four smaller units shown here.

The primaries of the filament and plate transformers are controlled by S1 and S2A, which are arranged to prevent high voltage application until the filaments are lit. A second section of S2 is used to operate a pilot light for high voltage indication, obtaining power from the 6.3 volt filament transformer.

Tune-Up

SSB tune-up is quite simple. Select the band of operation, then advance the RF level of the exciter until 15 ma. of grid current is shown on the 813 grid meter. The loading should be set to minimum and the final dipped to resonance with the High-Low switch set to Low to make initial familiarization less hazardous to the tubes. The exciter level, plate tuning and loading must all be adjusted simultaneously to obtain a plate current of 200 ma. approximately with a grid current of about 12 to 14 ma. If the plate current exceeds 200 ma., reduce the loading until this figure is attained. On 80 meters, it may be necessary to switch in one or two of the fixed loading capacitors. Voice peaks will drive the plate current to about 400 ma. For AM operation the loading should be set to 150 ma. plate current and 12 ma. grid current. These values are for the best linearity with plate voltages of about 1200 to 1500 DC. However, higher plate voltages and heavier loading may be used if some linearity is sacrificed. This is especially the case when the amplifier is used for cw.

Finish

The cabinet was made from sheet metal in a metal working shop, then primed and sprayed with metal lacquer. The front panel was designed to match the Hallicrafters SR-150 used as an exciter, with gray and white lacquer for the panel and trim, and black lacquer around the meters.

In addition to being a professional appearing unit, the linear has operated in VE1KK's station for several years without maintenance of any kind. The enjoyment of building a similar unit can be yours, and wouldn't you like to point it out to friends and say, "The linear? Well, ah, I built it myself".

PARTS LIST

Power Supply

C1 to C16	.001 disc ceramic 1 kv.
C7 to C10	100 mmfd mica 2.5 kv
C17 to C22	100 mfd. 450 vdc. filter capacitor.
R1 to R6	40,000 ohm 10 watts.
R7 to R10	25,000 ohm 50 watts.
T1	Plate transformer, from 600-0-600 to 1200-0-1200 vac.
T2	Filament transformer, 10 V. 10 amp. Hammond 1144X60 or similar.
T3	Filament transformer, 6.3V. 2 amp., Hammond 167D or similar.
L1	Filter choke, 30 henries, 300 ma. Hammond 30-300X or similar.
PL1, PL2	¼ amp. dial light, 6.3 volts.
S1	SPST toggle switch 115 vac 10 amp.
S2, S3	DPDT toggle switch 115 vac 6 amp.
CR1 to CR16	silicon diodes, 800 p.i.v., 1 amp.

Linear Amplifier

S3	2 Pole 2 Position Ceramic. Switch shown in linear OUT position. Output from exciter switched direct to antenna by wafer A
S1A	5 position continuous shorting.
S1B	5 position non-shorting.
C1	.1 mfd. 400 V. moulded
C2	500 mmfd. doorknob 10 kv.
C3	500 mmfd. disc ceramic 6 kv.
	All other capacitors are 1 kv. discs.
R1, R2	2 ohm 1 watt.
R3	10 ohm carbon or suitable value to measure voltage drop across R1 and R2. M1 should read full scale with 150 ma. through R3 to ground.
RFC1	15 amp. filament choke, or 32 turns #14 double wound on ½" x 7" ferrite rod.
RFC2	National R175A or 220 turns #24 formex close wound on ⅝" x 4" ceramic form.
RFC3	2.5 mH — National R100 or equivalent
M1	0-150 ma. with internal shunt removed.
M2	0-500 ma.

Note: filament and signal leads to 6x5 tubes are shielded and filament leads also bypassed.

He Won A Trip Around the World

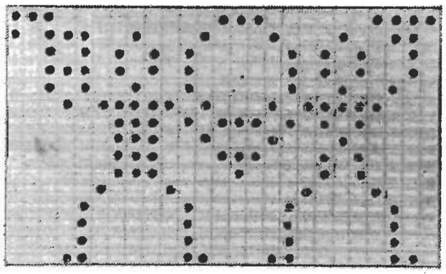
The happy Ham pictured above is the winner of the "Tam-Tam" contest organized by the Canadian Broadcasting Corporation, in collaboration with Radio Amateur du Quebec Inc. (RAQI), and the Youth Pavilion at Expo 67, (*electron,* July 67, p. 31). His name — C.E. Aimar, K4ZVQ, of Darlington, South Carolina; his prize — a trip around the world, lasting 30 days, with all expenses paid (the contest prize remitted to R.A.Q.I. by Lufthansa with CBC covering the travel expenses).

The contest's radio message consisted

EEETT TTTTT TTEEE TTTTT TEEEE ETEEE TTETT TETTT ETTTE TTEET TTETE
TETET ETTTT TETET ETTET TTEEE TETET ETTTT TETET ETTET TTETE TTETT
ETTTT TETTE TTETT TTTET EEEEE TETTT ETEEE EETTT TTTTT TEEET ETEEE
TETET ETTTT TTTTT TEEET TETTT ETTTE TTTTT TTTTT TEEET TTEEE TTTET
ETTTT TTTTT TEEET TTTET TTTET ETTTT TTTTT ETTTE TTTTT TTETT TETTT
TTTTE TTTTT ETTTT TETTT TTETT TTTTE TTTTT ETTTT TETTT TTETT TTTTE
TTTTT ETTTT TETTT TTETT TTTEE TTTTT EETTT EETTT TTEET

of 375 bits of information (in morse, either letter E or T) and was transmitted from the Youth Pavilion for the duration of Expo-67. The contestants were required to decipher the message and submit a graphic symbol deduced from the message. Mr. Aimar's interpretation was selected as the most accurate and logical of the more than 30 correct answers submitted from many parts of the world.

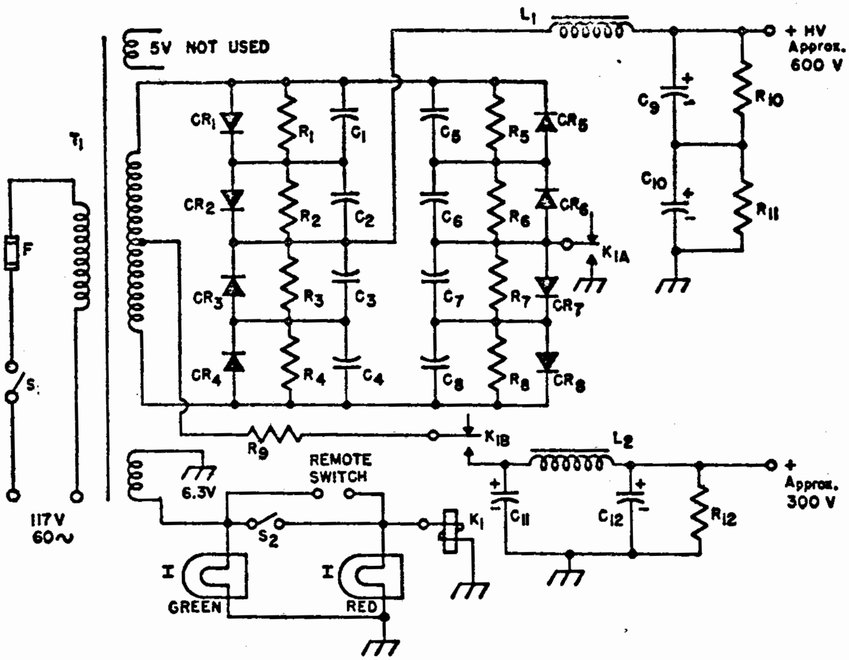
Marking the message on a chart. Mr. Aimar divided the 375 individual signs into 15 lines of 25 characters each using the E as a dot and the T as a space and he came up with the following picture :



Mr. Aimar's interesting interpretation was based on the picture's suggesting that the "Inhabitants of the (outer space) world are bisexual man-like creatures. Probably mammalian. They walk upright . . . have prehensile hands.

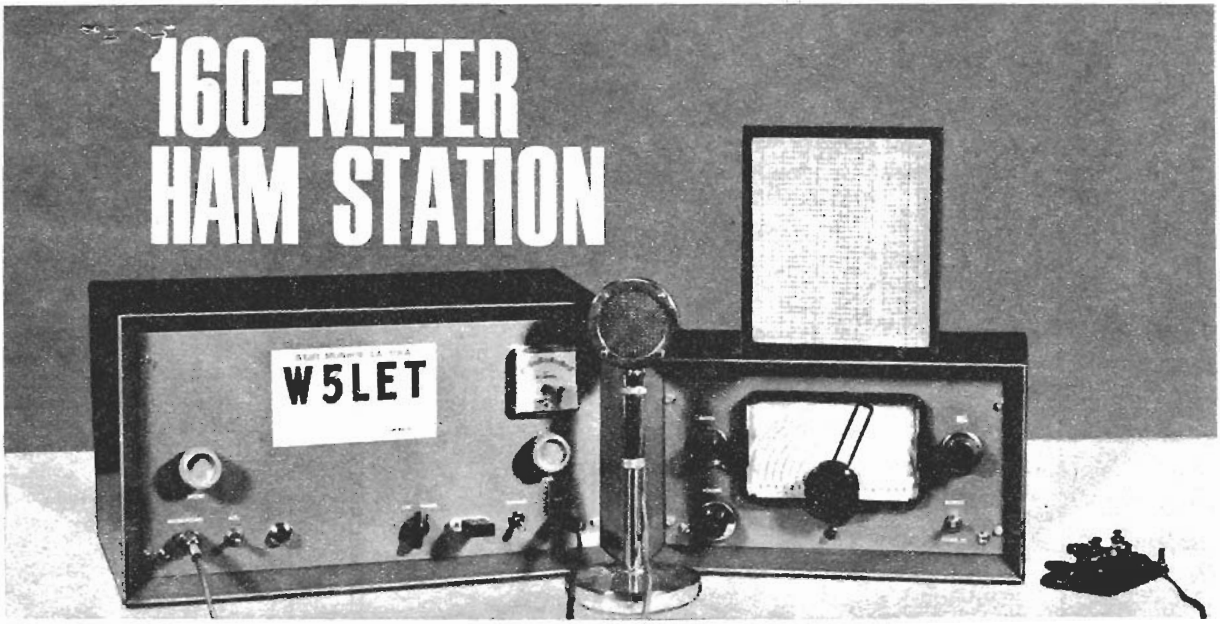
10-4 POWER SUPPLY FOR AMATEUR TRANSMITTER

600 Volts; 300 Volts; Total Current 330 Milliamperes (Intermittent Duty)



C_1 C_2 C_3 C_4 C_5 C_6 C_7 C_8 = 0.001 μf, ceramic disc, 1000 v.
C_9 C_{10} C_{11} C_{12} = 40 μf, electrolytic, 450 v.
CR_1 CR_2 CR_3 CR_4 CR_5 CR_6 CR_7 CR_8 = RCA-1N2864
I = indicator lamp
K_1 = relay; Potter and Brumfield KA11AY or equiv.
L_1 = 2.8 henries, 300 ma; Stancor C-2334 or equiv.
L_2 = 4 henries, 175 ma; Stancor C-1410 or equiv.
R_1 R_2 R_3 R_4 R_5 R_6 R_7 R_8 = 100000 ohms, 0.5 watt
R_9 = 47 ohms, 1 watt
R_{10} R_{11} = 15000 ohms, 10 watts
R_{12} = 47000 ohms, 2 watts
S_1 S_2 = toggle switch, single-pole single-throw
T = power transformer; Stancor P-8166 or equiv.

160-METER HAM STATION



This issue... THE TRANSMITTER

By JIM WHITE, W5LET

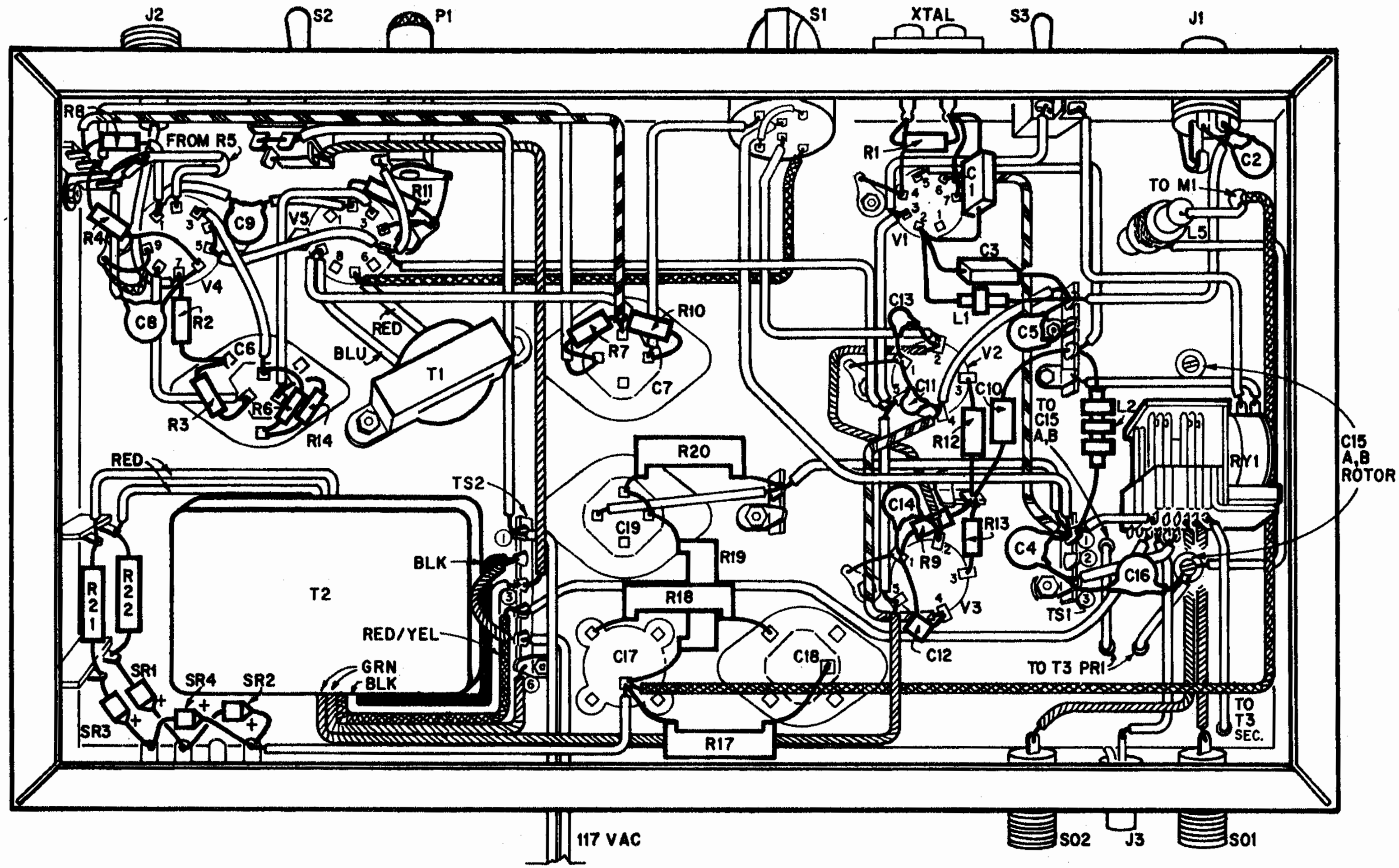
FOR challenging operating on the almost forgotten 160-meter ham band we started plans for a complete station in our July, 1967 issue. We presented plans for only the receiver in that article. By now you should have done some listening and may be ready to start the transmitter. And you may also be convinced there is a better chance of QSOs on this band than there is on 80 or 40. Okay, so there was some Loran interference, but there were still some quiet spots.

We now present plans for the transmitter portion of the station. Just in case you've forgotten, the transmitter runs 100 watts input on AM phone or CW. In the RF section of the transmitter, there are three tubes. A 6AQ5A is a crystal oscillator and the final stage is a pair of reliable old 807s. By the way, you should be able to pick up 807s on the surplus market for very little. If you can't, you'll find them in the special-purpose tube section of electronics parts distributors' catalogs. New, they run about $3.50 each.

The audio section of the transmitter consists of a 12AX7A mike preamp followed by a 6BQ5 modulator. The power supply is solid state.

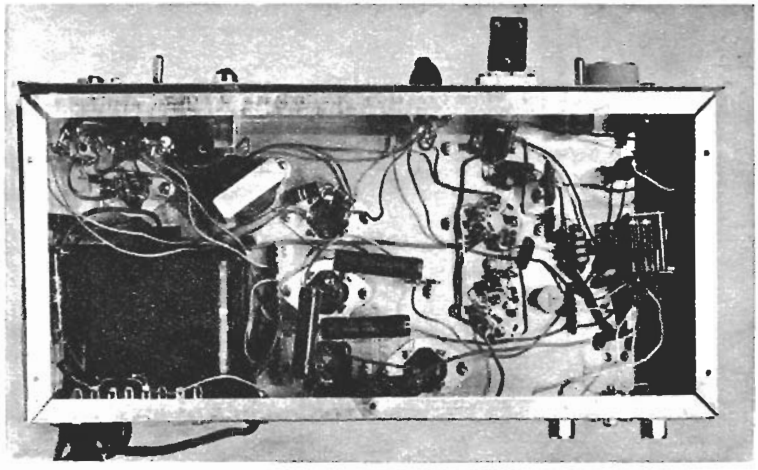
The transformer in our power supply was taken out of an old scrapped TV set. If you can get one from an old TV, too, you'll save yourself almost $18. The voltage ratings are in our Parts List.

Construction. The transmitter should be built on a 3 x 7 x 15-in. aluminum chassis. Begin by attaching the front panel to the 3 x 15-in. side of the chassis with two screws. It is a good idea to raise the panel ½ in. above the chassis bottom. By doing this and placing the chassis controls slightly higher than normal, the front flange of the shadow



J2
S2
P1
S1
XTAL
S3
J1
R8
FROM R5
R4
V4
C9
V5
R11
C8
R2
C6
R3
R6
R14
RED
BLU
T1
R7
R10
C7
R1
C1
V1
C3
L1
C13
C2
TO M1
L5
C5
V2
C11
C10
R12
TO C15 A,B
L2
RY1
C15 A,B ROTOR
R20
TS2
C19
R19
R18
C14
R9
R13
C4
C16
V3
TS1
C12
TO T3 PRI
TO T3 SEC.
R21
R22
T2
BLK
RED/YEL
GRN
BLK
SR1
SR4
SR2
SR3
C17
C18
R17
117 VAC
SO2
J3
SO1

Fig. 1—Note in pictorial of underside of chassis (left) where relay RY1 is mounted. Refer to Fig. 2 below for connections to RY1's lugs. Although not critical, try to duplicate our layout. Cut off the enameled-wire secondary leads of T1 as they are not used. Knob in upper right corner in photo, right, is on C15. Color coding of leads of T2 is for a standard transformer. Color of leads of TV transformer may differ.



THE TRANSMITTER

cabinet will not interfere with anything. This also results in a neater looking job.

After the panel is in place locate the position of each control, mark the location and drill a hole large enough for each control's bushing. Locate and cut the meter hole along with its four mounting-screw holes. The location of these holes can be determined by examining closely the photographs above and Fig. 5. Some variation from the original layout will not affect performance adversely.

Next, examine the pictorial in Fig. 1 and the photo of the underside of the chassis to see the location of the major parts. Layout the chassis and punch and drill the necessary holes. After these holes are made, mount the parts. Be sure that you use the fiber insulating plate that comes with C17 when you mount this capacitor. The can must not touch the chassis. And put an insulating sleeve on this capacitor's can to keep it from being a shock hazard. The negative side (can) of C18 *is* grounded to the chassis so no such precautions are necessary.

When wiring the transmitter, most of the small parts, such as resistors and capacitors, should be mounted close to the tube sockets. Orient the tube sockets as shown in Fig. 1 so that the leads to the socket will be direct and short. Be sure to use shielded wire to audio gain control R5 as well as from mike jack J2 to pin 7 of V4.

The plate-tuning capacitor (C15A and

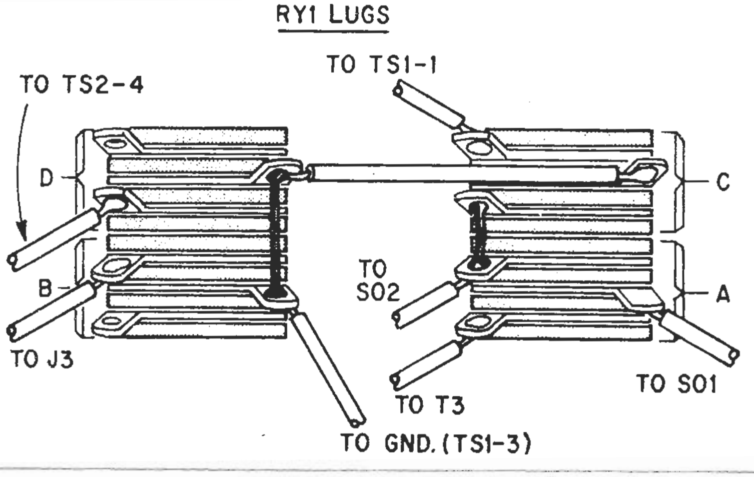


Fig. 2—The relay specified in the Parts List comes in two parts: the coil and the contacts. After assembling them connect hook-up wire to lugs shown here. Force spaghetti on leads and lugs to prevent shorts. Mount relay where shown in pictorial at the left.

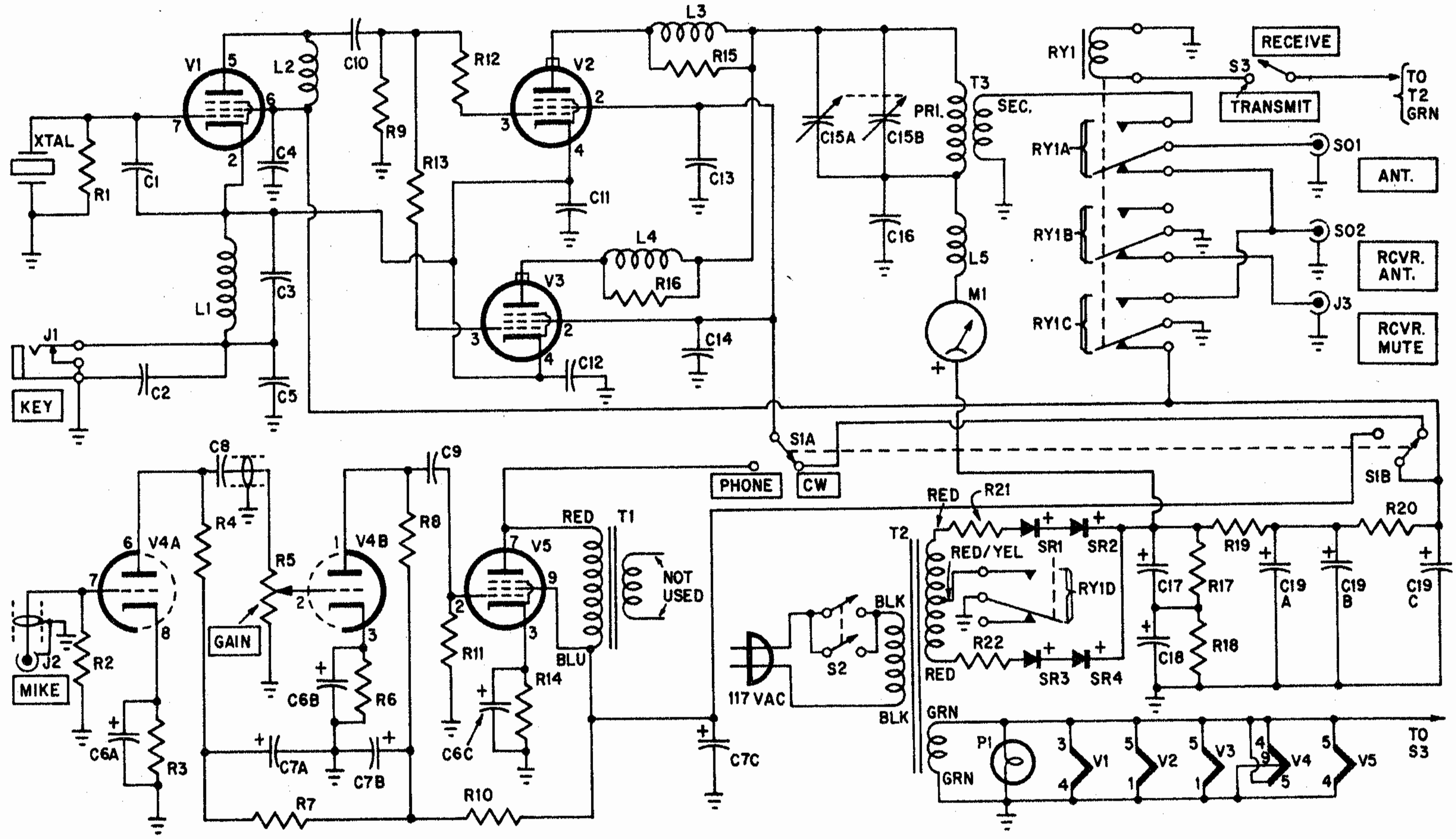


Fig. 3—RF portion of transmitter consists of crystal-oscillator V1, which drives parallel-connected finals—a pair of 807s. V4 is speech amplifier; V5 is modulator. When S1 is in phone position, modulation is applied to screens of 807s via S1A. S1B applies B+ to V4 and V5. When S1 is in CW position B+ is removed from V4 and V5 by S1B and is applied by S1A to screens of V2 and V3. RY1 is shown in receive mode. In transmit, RY1's wipers move up. Note RY1D near T2.

C15B) frame *must be* insulated from the chassis and panel. To insulate if from the chassis use three flat fiber washers along with fiber shoulder washers. Use an insulated coupling along with a shaft extension to insulate the shaft from the panel.

It is a good idea to connect and solder the leads to RY1's lugs before you mount it. Follow the diagram in Fig. 2 for the connections. Some of these leads are so close to each other that it will be necessary to slip spaghetti over them where they connect to the lugs.

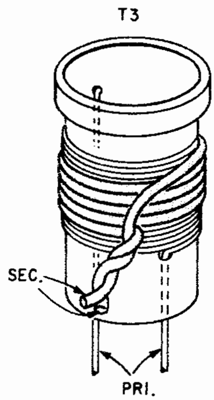


Fig. 4—T3 in detail. After removing prongs, wind primary which consists of 25 close-wound turns of No. 18 enameled wire. Then wind secondary, consisting of 7 turns of No. 20 solid hookup wire, directly over primary. Primary leads go out through prong holes.

PARTS LIST

Capacitors:
C1—75 μμf, 500 V silvered mica
C2,C4,C8,C9—.01 μf, 1,000 V ceramic disc
C3,C10—150 μμf, 500 V silvered mica
C5—.05 μf, 1,000 V ceramic disc
C6A,C6B,C6C—40/40/40 μf, 150 V electrolytic (Sprague TVL-3440 or equiv.)
C7A,C7B,C7C—20/20/20 μf, 450 V electrolytic (Sprague TVL-3780 or equiv.)
C11,C12—.001 μf, 1,000 V ceramic disc
C13,C14—470 μμf, 1,000 V ceramic disc
C15A,C15B—15.5-467.8 μμf, two-gang variable capacitor (Allied 43 A 3528 or equiv.)
C16—5,000 μμf, 3,000 V ceramic disc (Lafayette 33 C 2407 or equiv.)
C17,C18—150 μf, 350 V can-type electrolytic
C19A,C19B—40 μf, 450 V can-type electrolytic
J1—Closed-circuit phone jack
J2—Chassis-type microphone connector (Amphenol 75-PC1M. Allied 47 A 1965 or equiv.)
J3—Phono jack
L1—180 μh peaking coil (J. W. Miller 6180. Lafayette 34 C 8863 or equiv.)
L2—2.5 mh RF choke (National R-50. Allied 54 A 1161 or equiv.)
L3,L4—Choke: 7 turns No. 20 enameled wire wound on resistors R15,R16
L5—2.5 mh RF choke, vertical mount (National R-300U. Allied 54 A 1511 or equiv.)
M1—0-500 ma DC milliammeter (Emico Model RF-2¼C. Lafayette 38 C 3136 or equiv.)
P1—6.3 V pilot light and assembly (Dialco 502-8136. Allied 60 A 7969 or equiv.)

Resistors: ½ watt, 10% unless otherwise indicated
R1—47,000 ohms
R2—1.5 megohms
R3,R6—1,500 ohms
R4—150,000 ohms
R5—500,000 ohm audio-taper potentiometer
R7—15,000 ohms, 1 watt
R8—220,000 ohms
R9—6,800 ohms
R10—4,700 ohms, 1 watt
R11—470,000 ohms
R12,R13—47 ohms
R14—150 ohms, 1 watt
R15,R16—47 ohms, 1 watt
R17,R18—50,000 ohms, 20-watt wirewound
R19,R20—1,000 ohms, 20-watt wirewound
R21,R22—10 ohms, 10-watt wirewound
RY1—4-pole, double-throw relay, 6-VAC coil (Potter and Brumfield type GPA coil; Lafayette 30 C 8715. Contacts: Potter and Brumfield GP17-4PDT. Lafayette 30 C 8727)
S1A,S1B—2-pole, 2-position non-shorting rotary switch (Mallory 3222J)
S2—DPDT toggle switch
S3—SPST toggle switch
SO1,SO2—SO-239 coax connector
SR1,SR2,SR3,SR4—Silicon rectifier; minimum ratings: 750 ma, 750 PIV
T1—Output transformer; primary: 10,000 ohms, secondary: 4 ohms
T2—Power transformer; secondaries: 620 V center tapped @ 240 ma, 6.3 V @ 6 A. (Stancor P-8331. Allied 54 A 4413 or equiv.)
T3—Antenna transformer wound on Amphenol 1¼-in. dia. coil form No. 24-6P. (Allied 47 A 6697) Primary: 25 turns No. 18 enameled wire. Secondary: 7 turns No. 20 solid hookup wire.
V1—6AQ5A tube
V2,V3—807 tube
V4—12AX7A tube
V5—6BQ5 tube
XTAL—160-meter crystal

Misc.
Crystal socket (National CS-6)
Plate caps for 807 tubes (Millen 36002)
3 x 15 x 7-in. aluminum chassis
9½ x 17 x 11-in. cabinet (Bud SB-2142)
Insulated shaft coupling (Allied 47 A 2405)
Panel bushing (Lafayette 32 C 6407)
6-in. shaft extension (Lafayette 32 C 6408)
Flat and shoulder fiber washers
Grommets
Terminal strips
7-pin miniature tube socket with shield base (Amphenol 147-914)
9-pin tube sockets (Amphenol 59-407)
5-prong ceramic tube sockets (Amphenol 49-RSS5)

THE TRANSMITTER

There is only one coil to wind—T3. Both the primary and secondary are wound on a 1¼-in. dia. standard polystyrene form. The form specified in the Parts List has six prongs. Clip these off and drill out the remaining stumps. This will leave six holes in the closed end of the form. Two of these are used for mounting the form to the chassis. The leads from T3 to tuning capacitor C15 pass through two other holes. These leads must be covered with spaghetti.

The primary winding consists of 25 close-wound turns of No. 18 enameled wire. The secondary consists of 7 turns of No. 20 solid hookup wire wound over the primary as shown in Fig. 4. Twist the ends of this winding together to hold it securely. These two leads terminate in a terminal strip on top of the chassis. This terminal strip is in front of the coil in Fig. 3.

Be sure to use rubber grommets where the 117 VAC lead goes through the chassis and also where the meter leads pass through the chassis. The lugs of power switch S2 are wired in parallel to increase S2's current-carrying capacity.

Relay RY1 has a 6-VAC coil and is controlled from the front panel by S3. One thing that might seem strange in the wiring of the relay is the connection from SO2 to a contact on the relay (RY1C) which grounds the receiver antenna when the transmitter is transmitting. This prevents RF from getting into the receiver.

The power transformer we specify in our Parts List is a TV replacement type. You may have an old TV set around which has just such a transformer. Be sure that the current and voltage ratings do not fall to much below those shown, or you will not able to run 100 watts. If the color coding is not the same as ours, measure the secondary voltages with a VOM.

Tune Up. The transmitter is simple to get going. With the tubes, crystal and AC power plug in, *phone/cw* switch S1 in the *cw* position and S3 set to receive, connect a good antenna cut for the 160-meter band (or via antenna tuner if it's not the correct length) to SO1. Now flip S3 to the transmit position and quickly dip the final with C15. If things are okay, the final should load up to about 210 ma. If it doesn't you may have to play with the secondary of T3 or even add a turn or two. *Be sure power is off before you do this.*

We strongly recommend a good antenna tuner which will greatly facilitate loading. Unless you are extremely lucky you probably do not have enough room for a full-size 160-meter half-wave antenna.

To operate the transmitter on phone it is only necessary to flip S1 to phone and turn up audio gain control R5. When you speak into the mike the needle in plate-current meter M1 should just move a little.

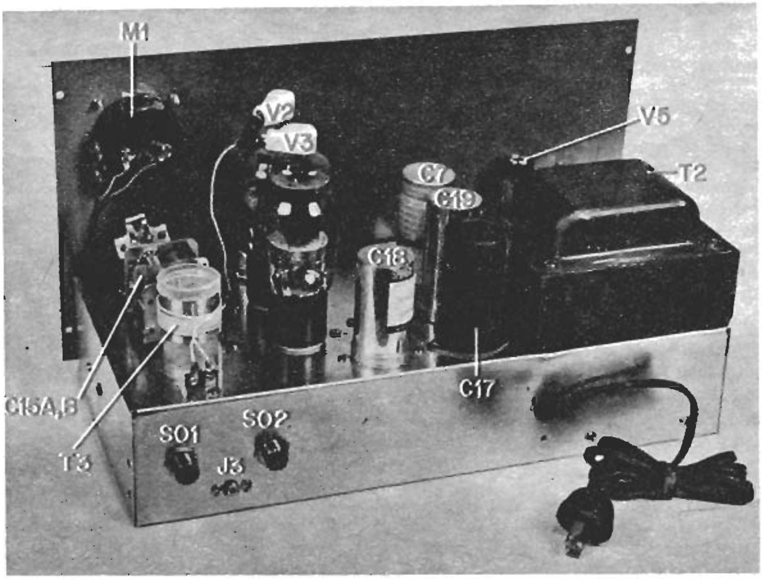


Fig. 5—View of rear of transmitter. Note where T3 is mounted and how secondary winding is connected to terminal strip. Because metal case of C17 is above ground potential and is a shock hazard, it is covered with cardboard tube. L3, L4 and resistors on which they are wound, are installed at tube plate caps.

Solid-State Ham Transmitter for 40 and 80

Two transistors for 18 watts of input power and a clean CW signal.

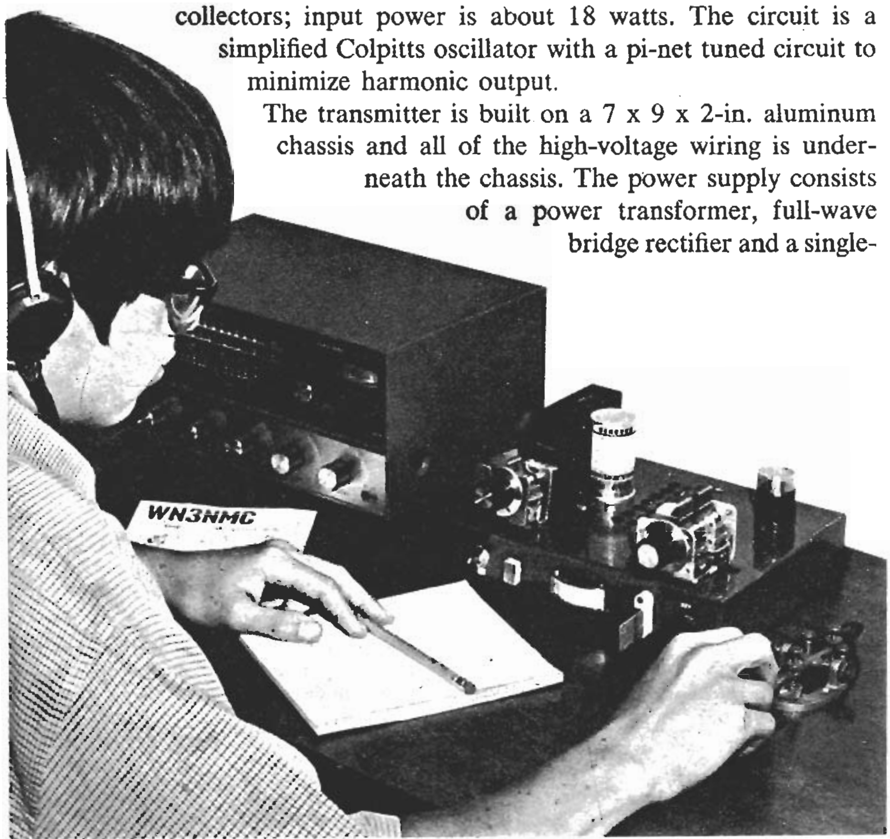
By CHARLES GREEN, W6FFQ

TRANSISTORS may have swept vacuum tubes off the radio, TV, CB and hi-fi scene, but as yet they haven't come on very strong in ham transmitters. The reasons for this are the high cost of high-power RF transistors and output-stage impedance-matching problems.

A way to get around this is to use high-voltage transistors originally designed for the output stage of 117-V line-operated audio amplifiers. High-voltage transistors allow high-impedance matching to the input of a pi-net antenna tuner, instead of complicated taps and special tuned circuits required by low-voltage, low-impedance transistors.

Our solid-state CW transmitter is crystal controlled and uses plug-in coils for the 80- and 40-meter ham bands. Two high-voltage transistors are connected in parallel. There's approximately 175 V on their collectors; input power is about 18 watts. The circuit is a simplified Colpitts oscillator with a pi-net tuned circuit to minimize harmonic output.

The transmitter is built on a 7 x 9 x 2-in. aluminum chassis and all of the high-voltage wiring is underneath the chassis. The power supply consists of a power transformer, full-wave bridge rectifier and a single-



Solid-State Ham Transmitter for 40 and 80

section filter that includes a choke.

How It Works

Transistors Q1 and Q2 are connected in parallel in a Colpitts oscillator circuit (note the similarity to an equivalent vacuum-tube Colpitts oscillator). The emitters of Q1 and Q2 are kept above RF ground by L1. The RF voltage across the crystal is divided across the internal capacitance of the emitter-base junctions of Q1, Q2 and C1.

When the key (plugged in J1) is pressed, the RF generated by Q1 and Q2 is coupled via C8 to the pi-net tuned circuit consisting of C7, C9A/B and plug-in coil L4 (or L5). Coil L4 (or L5) couples the high-impedance output of Q1 and Q2 to the low impedance of the antenna.

Meter M1, connected in the Q1, Q2 collector circuit indicates proper tuning of the pi-net circuit. The necessary DC power is supplied by T1 and BR1 and is filtered by L3 and C12A, C12B.

Construction

The transmitter is built on a 7 x 9 x 2-in. aluminum chassis. Most of the parts are mounted on a 2 x 4-in. piece of perforated board. For best performance, follow our component and wiring layout.

Start construction by cutting ventilation holes in the rear and top of the chassis, as shown in Fig. 5. Also drill holes in the chassis bottom plate and on the rear apron to

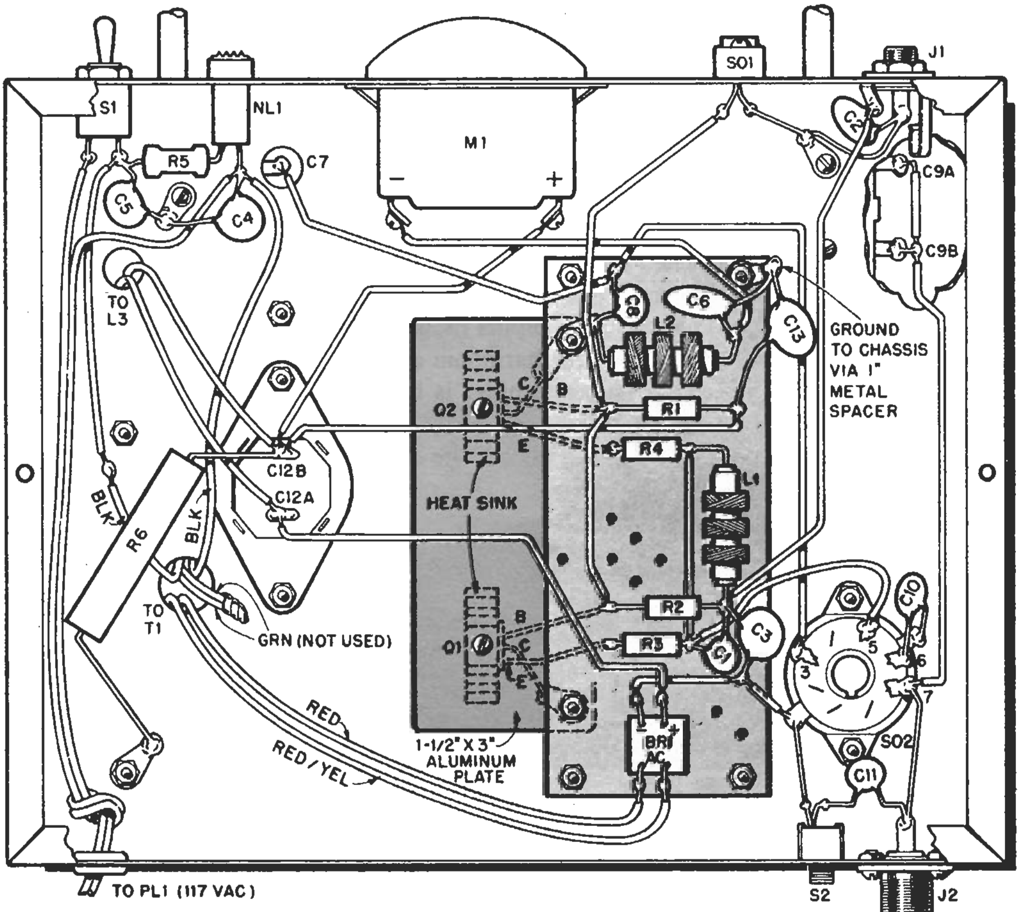


Fig. 1—Area shown in color is 1½ x 3-in. piece of aluminum—a heat sink on which Q1 and Q2 are mounted. Gray area is perforated circuit board. Parts are grounded to the chassis by a 1-in. spacer at upper right corner of the board.

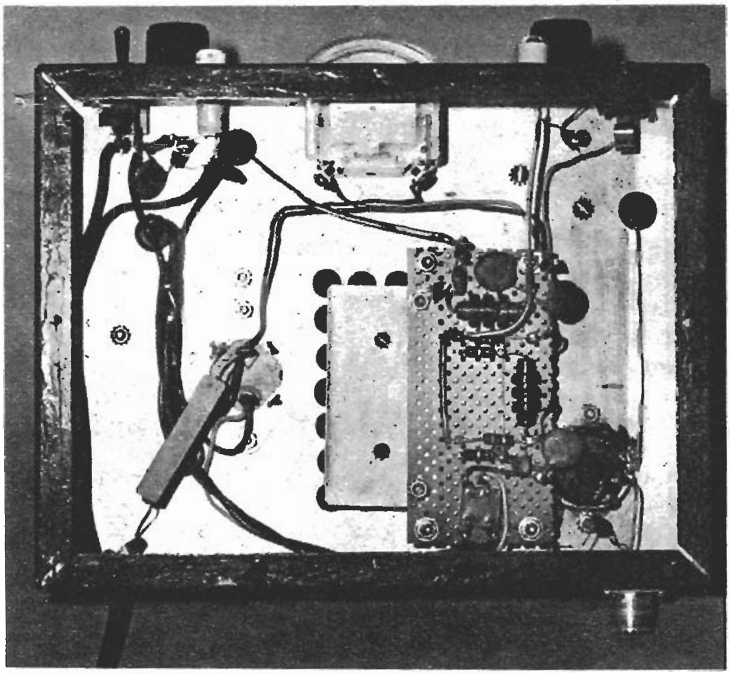


Fig. 3—Underside of chassis. Note open layout of our model. Duplicate parts placement to assure proper operation. There are 21 ⅜-in.-dia. ventilation holes over the aluminum plate on which the transistors, Q1 and Q2, are mounted.

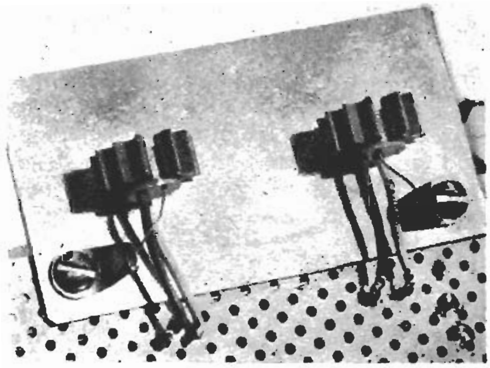


Fig. 2—Photo shows how Q1 and Q2 are mounted on aluminum plate. Finned heat sinks are Motorola HEP-158. Collectors are connected to solder lugs.

allow maximum air flow through the chassis and around the Q1 and Q2 sheet-aluminum heat sink. The size of the holes is not critical (we drilled ⅜-in. dia. holes) as long as the top of the chassis and bottom plate holes cover an area of about 1½ x 3¼-in.

Mount variable capacitors C7 and C9 at the front of the chassis near the corners, and then mount the remaining chassis componets where shown. Keep them spaced out in the same positions as in our model. We used an edgewise meter for M1 to save space.

Mount the remaining components on the front and rear of the chassis, as shown in Figs. 3 and 5. Mount S1 and S2 so that their up position is *on*. Install rubber grommets in the chassis holes through which wires pass. Use lock washers on all mounting screws to prevent them from loosening.

Cut a 2 x 4 in. piece of perforated board and cut a 1½ x 3-in. piece of aluminum. Fit Q1 and Q2 in their heat sinks and mount the heat sinks (with their centers 1½-in. apart) on the piece of aluminum as shown in Fig. 2. Mount the piece of aluminum on the edge of the perforated board as shown in Figs. 1 and 3 so that the heat sinks are between the board and the underside of the chassis. Connect the collector leads of Q1 and Q2 to solder lugs installed on the board (Fig. 1) at the aluminum panel's mounting screws. Connect their emitter and base leads to push-in terminals on the perforated board. Mount the perforated board on to the bottom of the chassis with 1-in. metal spacers at each corner so that the aluminum panel is directly under the chassis ventilation holes.

Mount and wire the board components as shown in Fig. 1. Four separate dilicon diodes (Motorola HEP-158, 600 PIV, 1 A; or equiv.) can be used in place of the full-wave bridge assembly (BR1). Wire the remaining chassis components keeping all of the wir-

Solid-State Ham Transmitter for 40 and 80

ing (except the RF leads) close to the chassis. We used No. 18 bus wire covered with plastic sleeving for the RF leads in our model. Keep the RF leads away from the components and do not have any sharp bends in them.

The two plug-in coils (L4 and L5) are made from Barker & Williamson No. 3016 Miniductor coil stock as shown in Fig. 4. Coil L4, the 80-meter coil is 32 turns. Coil L5, the 40-meter coil is 16 turns. The coils are mounted in the bases of discarded octal tubes. We cemented 14-dram plastic pill bottles over the coils to protect them, but plastic tubing can also be used. Install a jumper wire in the 80-meter coil (L4) between pins 5 and 6.

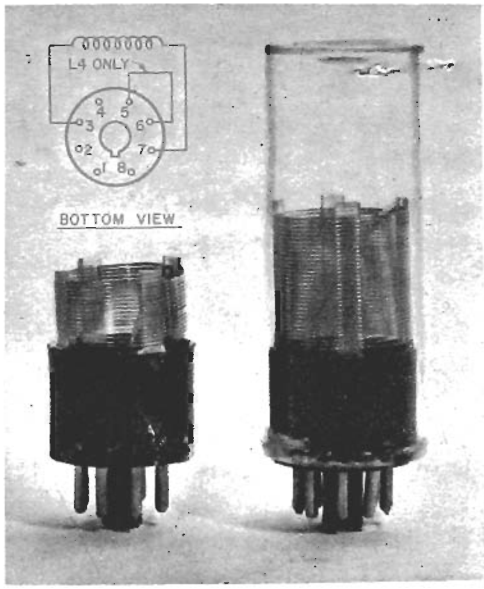


Fig. 4—Coils. 40-meter coil (L5) is shown at left; 80-meter (L4) is at right. Both are made from Barker & Williamson No. 3016 Miniductor coil stock. L5 is 16 turns and L4 is 32 turns.

Tune-Up and Operation

Connect a 7-watt lamp (using short leads or coax) to J2, and set S2 to *off* (C1 out of circuit). Plug the 80-meter coil (L4) in SO2 and plug an 80-meter crystal in SO1.

Set C7 and C9 to maximum capacitance, plug a key in J1 and plug in the line cord. Set S1 to *on*, momentarily press the key and quickly tune C7 for minimum indication (sharp dip) on M1. Press the key again and tune C9 for about a 100-ma indication on M1. Retune C7 for minimum indication.

Repeat the adjustments of C7 and C9 until M1 indicates 100 ma after final adjustment of C7. Do not press the key for too long while tuning up the transmitter. After tune-up is completed, allow the transistors to cool

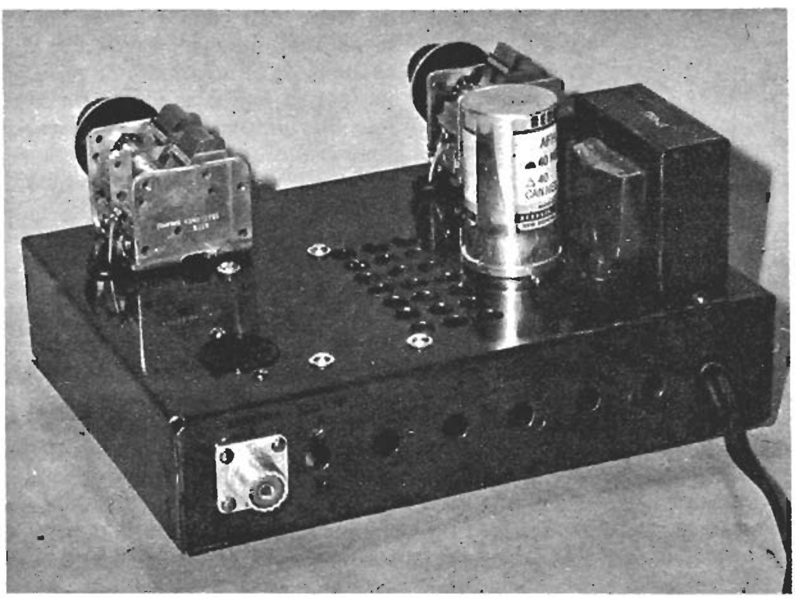


Fig. 5—Rear of transmitter. Note ventilation holes on top and on rear apron. Output connector J2 is at left of rear apron. Switch S2 is to right of it. Coil goes in socket above SO2.

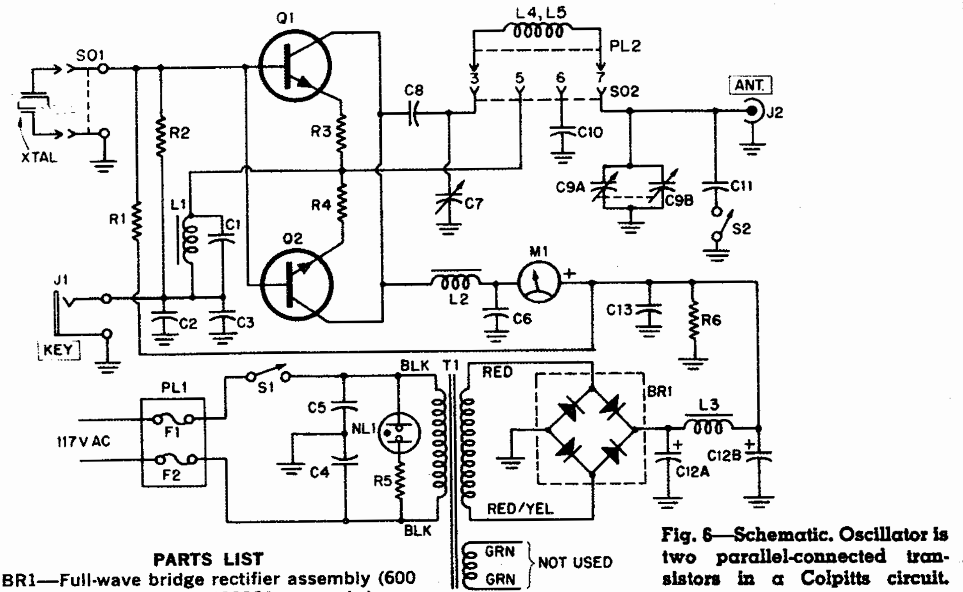


Fig. 6—Schematic. Oscillator is two parallel-connected transistors in a Colpitts circuit.

PARTS LIST

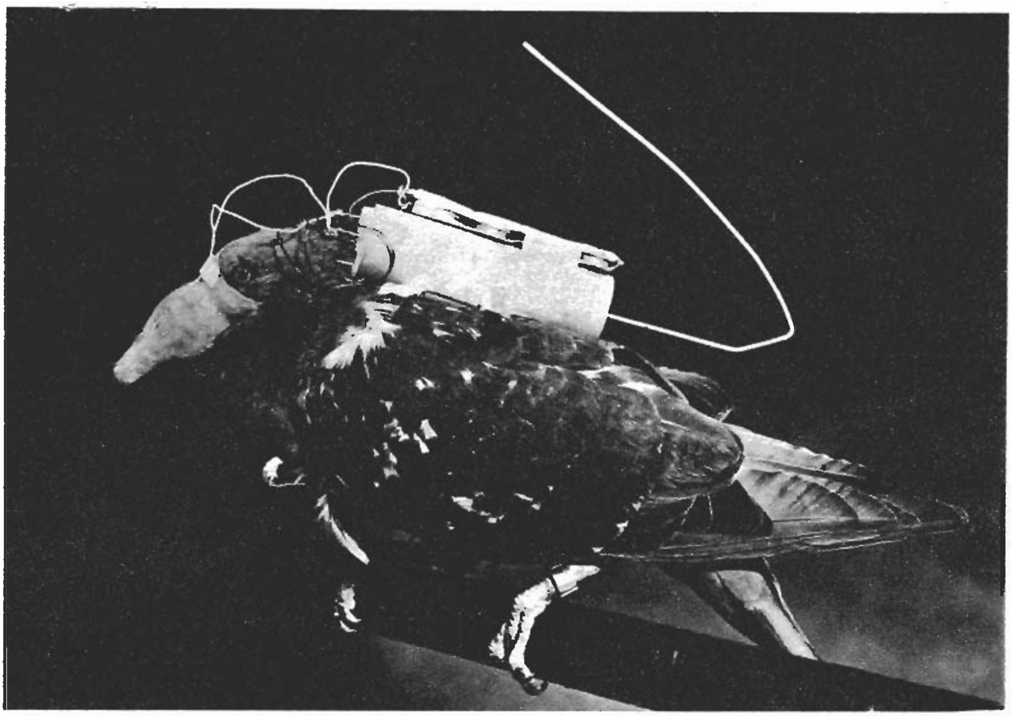
BR1—Full-wave bridge rectifier assembly (600 PIV, 1.5 A, Erie FWB3006A or equiv.)
Capacitors: 1,000-V disc unless otherwise indicated
C1—100 μμf
C2—.01 μf
C3,C4,C5,C6,C13—5,000 μμf
C7—10-365 μμf variable capacitor (Calectro A1-227)
C8—1,000 μμf, 3,000 V
C9A,C9B—Dual 10-365 μμf variable capacitor (Calectro A1-228)
C10—200 μμf
C11—500 μμf
C12A,C12B—40/40 μf, 450-V electrolytic
F1,F2—1-A fuse
J1—Open-circuit phone jack
J2—SO-239 coax connector
L1—1 mh RF choke (J. W. Miller 4662)
L2—2.4 mh RF choke (J. W. Miller 4666)
L3—Filter choke: 1 hy, 240 ma, 50 ohms (Triad C-24X or equiv.)
L4,L5—Coils made from Barker & Williamson No. 3016 Miniductor (Lafayette 40 F 16259. See text)
M1—200 ma DC milliammeter (Emico Model 13, Lafayette 38 F 31450)
NL1—Neon pilot lamp assembly (Radio Shack 272-338. Includes R5)
PL1—Fused AC plug (Radio Shack 270-1249)
PL2—Octal tube base
Q1,Q2—40321 transistor (RCA)
Resistors: ½ watt, 10% unless otherwise indicated
R1—100,000 ohms
R2—2,700 ohms
R3,R4—33 ohms
R5—100,000 ohms (part of NL1)
R6—20,000 ohm, 10-watt wirewound resistor
S1,S2—SPST slide switch
SO1—Crystal socket
SO2—Octal tube socket
T1—Power transformer; secondaries: 135 V @ 50 ma, 6.3 V @ 1.5 A (Triad R-30X. 6.3-V winding not used)
Misc.—7 x 9 x 2-in. aluminum chassis and bottom plate, perforated board, push-in terminals, TO-5 heat sinks for transistors Q1,Q2 (Motorola HEP-502), 1-in. metal spacers

down for a few minutes, then recheck the final tune-up and readjust if necessary for a 100 ma minimum indication of M1. Observe that the 7-watt lamp lights indicating RF power is being delivered to the lamp.

If a 72-ohm or 50-ohm dummy load is available, connect it in place of the lamp and tune the transmitter for a 100 ma minimum indication. A dummy load should have a 10-watt rating. It can be made up of paralleled resistors connected to a coax plug. It may be necessary to set S2 to *on*, placing C1 in the antenna circuit, for proper tune-up on the 80-meter band when using a dummy load. Repeat the tune-up procedure with the 40-meter coil (L5) and a 40-meter crystal.

After you are satisfied that the transmitter is operating properly, remove the dummy load and connect either an 80-meter or 40-meter antenna whose impedance is 52 to 72 ohms (depending upon the coil and crystal in the transmitter) to J2. Check for proper tune-up with the transmitter feeding the antenna. The transmitter (as is the case with most pi-net output circuits) works best with an antenna cut to the transmitting frequency.

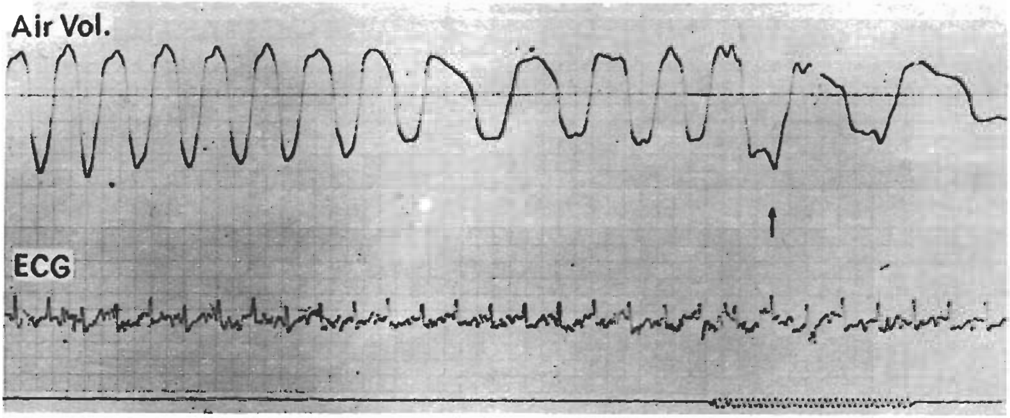
Set S2 to *on* (as necessary) for best loading into the antenna. The value of C11 may have to be changed to fit your particular 80-meter antenna. The final tuning of C7 should result in a collector current of about 100 ma (minimum indication).

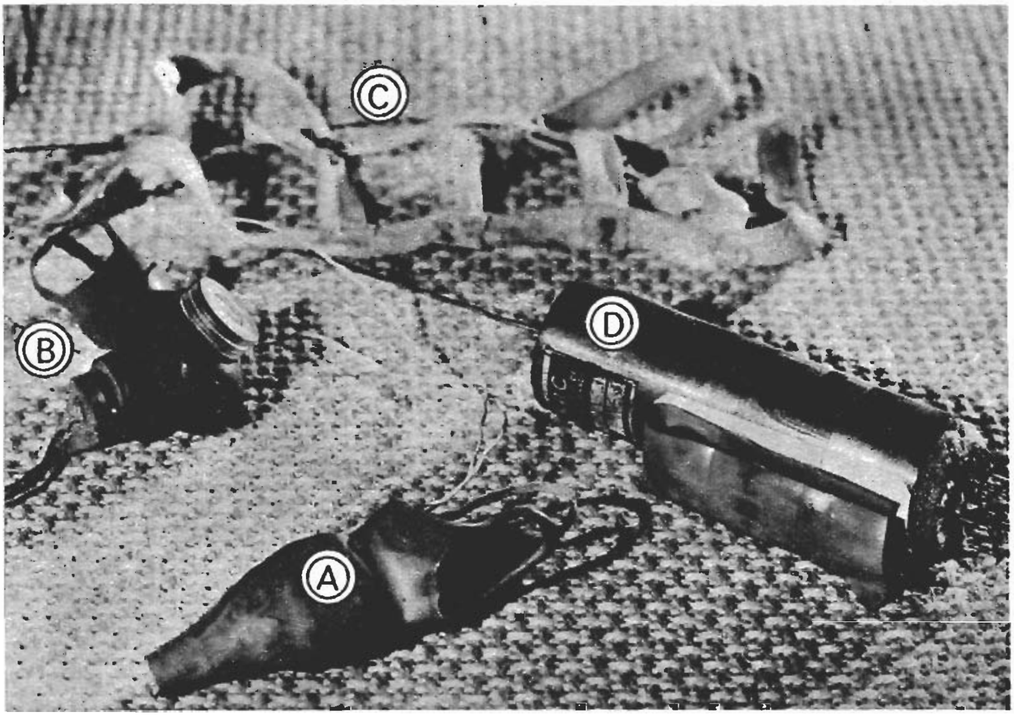


THE CASE OF THE BUGGED PIGEON

NO, the pigeon in our picture (above) is not from outer space, although it's carrying almost as much telemetry equipment as an astronaut. It's taking part in a bionics project directed by O.Z. Roy, Radio and Electrical Engineering Division, National Canadian Research Council of Canada. Preliminary results of the project include such interesting data as the fact that on take-off the pigeon's heart-beat rate jumps from 166 to 540 per min. (more than three times as fast). Flying is hard work, it seems.

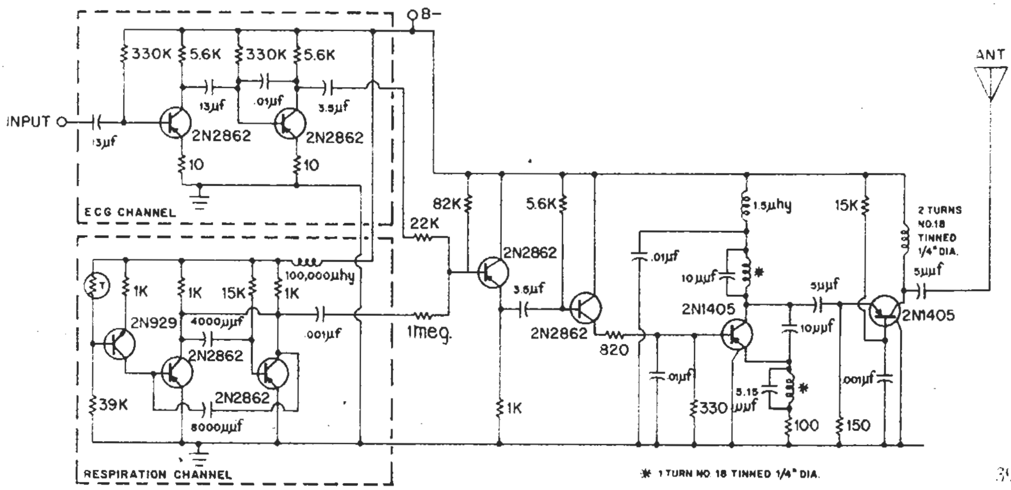
Telemetry provides information on body temperature (in two places), breath rate, breath volume, wing-beat frequency and heart rate—via an electrocardiogram (ECG). In the chart (below) recording breath volume and ECG, the arrow toward





the right indicates the moment of landing. Only two factors are recorded at a time to keep pigeon's pack light. This information is transmitted from the pigeon simultaneously by a circuit like that below. Input for the ECG channel is from electrodes painlessly implanted in the pigeon's chest cavity. The thermistor (circled resistor with *T* next to it) in the respiration channel senses temperature changes in a face mask as air is inhaled and exhaled, recording breathing rate (rather than air volume). This measurement was later abandoned when it was discovered that the pressure-sensitive transducer used to record air volume was reliable and provided more information (including breath rate).

The gear spread out in the picture above includes (A) mask with breathing-rate gauge, (B) mask with gauge for measuring the volume of air breathed, (C) harness, (D) transmitter. Antenna is a ground-plane (quarter-wave) using the transmitter's metal case as a ground. It transmits an FM signal at 230 mc.—*Thomas W. Hill*



25-watt Transistor Transmitter for 20 metres

by S. A. Money, G3FZX

The circuit, forming a basic transmitter, contains three stages operating respectively as crystal controlled oscillator, frequency doubler and power amplifier, and is designed primarily for c.w. transmission.

For many amateurs a major interest of the hobby is that of working stations in distant countries. This can be more readily achieved by using the h.f. bands such as 14 or 21MHz. In order to make one's signal heard above the general din on the bands in their present crowded state, it is highly desirable that the transmitter used should have a power input to the final r.f. amplifier of at least some 20–30W. With an efficient aerial system such a transmitter can provide contacts with stations in all parts of the world.

Choice of p.a. transistor

R.f. power transistors capable of operating at powers of up to 100W have become available in the past few years. These devices are expensive, at prices varying from £30 to £60 each, and are primarily intended for use in military and commercial equipment. Transistors of this type are not readily available to the amateur so the design of this transmitter was based on the use of cheaper and more easily obtainable types.

Many power transistors have a maximum collector voltage rating V_{ceo} of 60 to 80V. When class B or C operation is used, the collector voltage can rise to twice the supply voltage due to the flywheel action of the collector tuned circuit. To allow an adequate margin of safety the supply rail should not be more than 24 to 28V.

If we assume a power input of 25W, the mean d.c. collector current will need to be about 1A with a 25V supply. In class B, the peak collector current will be roughly three times the mean d.c. value. For class C, the peak current may be as high as four times the mean value. Under these conditions therefore the p.a. transistor used must be capable of handling peak values of collector current up to 3 or 4A.

Assuming that the efficiency of the p.a. stage will be about 60%, the transistor must be capable of dissipating about 10W. This requirement rules out transistors in TO5 cans and implies the use of TO3, TO66 or other high power dissipation types.

In order to have reasonable power gain and to maintain stable operation, the transition frequency (f_T) should be at least five times the frequency at which the amplifier operates. For 14MHz operation this requires an f_T of at least 70MHz.

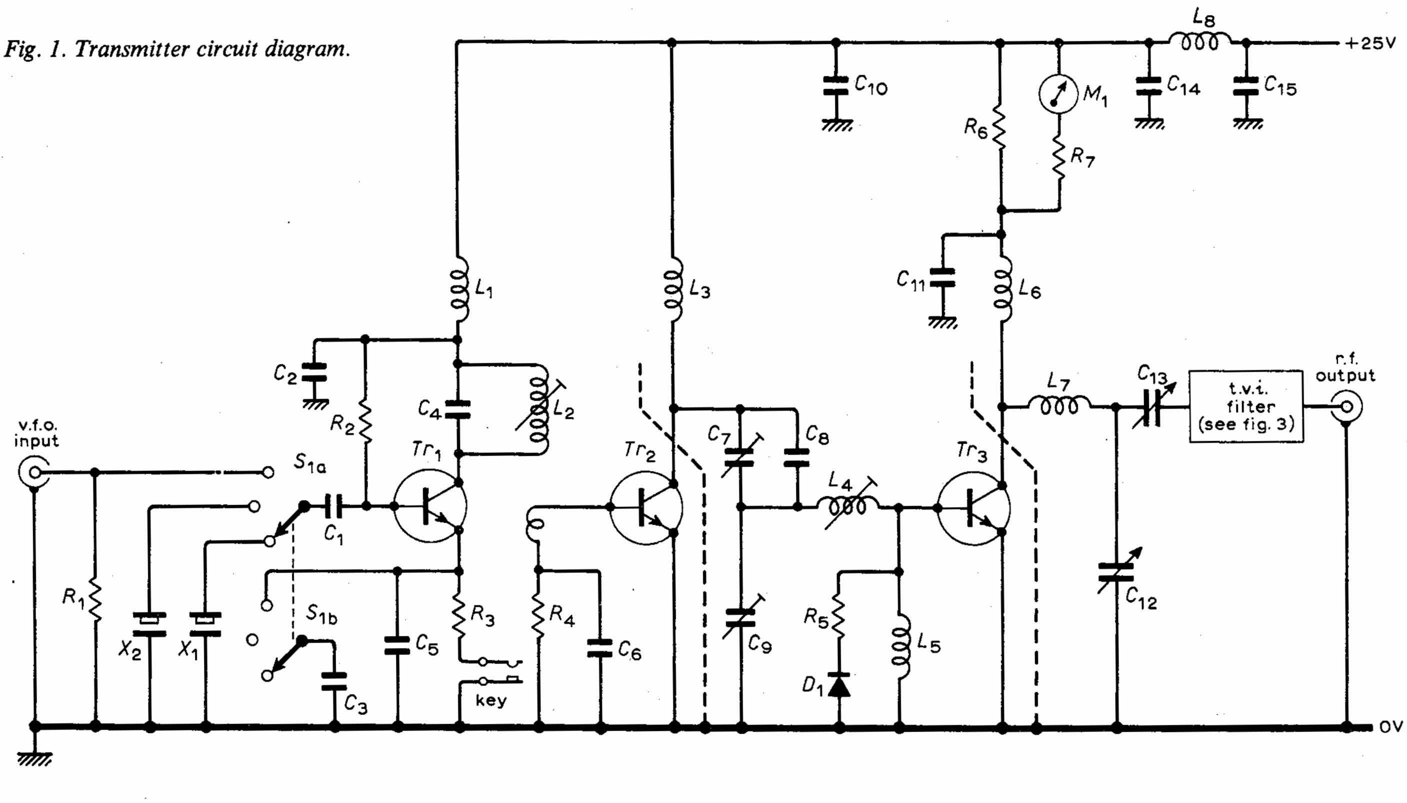
The transistor chosen for this stage of the transmitter was the Mullard type BD123, which has a V_{ceo} of 80V. Its maximum peak collector current is 5A and the f_T is 85MHz. The BD123 is mounted in a TO3 can and will dissipate up to 35W safely if it is mounted on a sufficiently large heat sink.

Power amplifier design

The final stage of the transmitter Tr_3, Fig. 1, runs at 25W input with a BD123 transistor operating in the class B mode. Class B operation was chosen because, although it is less efficient, it produces lower harmonic output and needs less drive power than an equivalent class C stage.

To obtain optimum power transfer, this

Fig. 1. Transmitter circuit diagram.



stage must be correctly matched to the load. The output impedance of this transistor is made up of a resistive component R_p in parallel with a capacitive component X_p representing the collector capacitance and circuit strays.

The value of R_p can be calculated from the formula,

$$R_p = \frac{V_s^2}{2P_o}$$

where V_s is the d.c. supply voltage and P_o is the power output from the stage. The value for the power output is assumed to be about 60% of the power input since this is a reasonable value for the efficiency of a class B stage. With V_s at 25V and P_o at 15W this gives a value of roughly 20Ω for R_p. The capacitance of the transistor and circuit strays is about 100pF which, at a frequency of 14MHz, represents a reactance of approximately 125Ω.

The matching network used to couple this amplifier stage to the load must not only match the two impedances but also provide sufficient selectivity to reduce the output of harmonics to an acceptable level. A good compromise can be obtained between power transfer and harmonic output by designing the matching circuit to have a loaded Q value somewhere between 10 and 15. In this transmitter it was decided to aim for a Q value of 12.

In many transmitters using valves for the output stage, the matching to the load is achieved by using a low-pass Pi section network. Unfortunately this type of network is only effective if the ratio between the source and load impedances is fairly high. If the two impedances to be matched are similar in value it becomes impracticable to design a Pi network which will have the required value of working Q. In the output stage of this transmitter, the impedance ratio is only about 3:1 if we assume that the load is a normal 70Ω aerial feeder cable properly terminated.

It would be possible to match this ratio of impedances by using two Pi networks in cascade with one network having a very low Q value. However, a more attractive solution is to use the T type network shown in Fig. 2. This particular type of circuit is most suitable for transistor transmitters because it easily matches two similar impedances.

The equivalent circuit of the transistor is shown as an impedance represented by series resistance R_s and capacitive reactance X_s. As a first step in the design of the network the parallel impedance values R_p and X_p must be converted into their equivalent series form by using the two equations

$$R_s = \frac{R_p}{1+(R_p/X_p)^2}$$

and

$$X_s = \frac{R_s R_p}{X_p}$$

For the BD123 stage the value for R_s will be about 20Ω and the value for X_s will be around 4Ω. At this point the value of the series inductance L_1 can be calculated from:

$$XL_1 = QR_s + X_s$$

If we are designing for a Q of 12 then XL_1

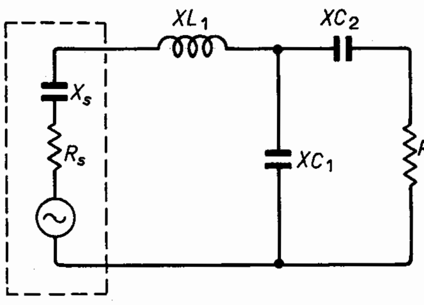


Fig. 2. A "T" matching network.

will be 240Ω which at 14MHz represents an inductance of 2.7μH. A coil to give this inductance consists of 16 turns of 16 s.w.g. enamelled wire close wound with a diameter of ¾in. The coil length will be about 1¼in and the coil should be completely self supporting.

In order to find the values for the tuning and loading capacitors C_1 and C_2 two constants A and B must be calculated from

$$A = R_s(1+Q^2)$$

and

$$B = \sqrt{(A/R_L)-1}$$

where R_L is the load impedance which is assumed to be a pure resistance. If R_L is taken as 70Ω then the value of A will be 2900 and B will be 6.4.

At this point the reactance values for the tuning and loading capacitors can be found from:

$$XC_1 = \frac{A}{Q-B}$$

and

$$XC_2 = BR_L$$

which give values of $XC_1 = 480\Omega$ and $XC_2 = 448\Omega$. The corresponding capacitors will have values of 24pF and 25pF respectively at a frequency of 14MHz. In the actual transmitter these capacitors C_{12} and C_{13} are 50pF air-spaced variable types. In the prototype transmitter 100pF variable capacitors were used with 100pF fixed capacitors in series to reduce the maximum value and to make the tuning adjustment easier. It should be noted that both the stator and the rotor of capacitor C_{13} are live and this capacitor must therefore be insulated from the panel which is grounded. These two capacitors may be of the preset type since the tuning adjustment will remain correct over most of the 14MHz band.

Since the output is taken off in parallel from the collector of the power amplifier stage an r.f. choke L_6 is required to feed the d.c. supply voltage to the collector. This choke has an inductance of about 15μH and consists of 100 turns of 28 s.w.g. enamelled wire close wound in one layer on a 2in length of ⅜in diameter s.r.b.p. rod. A similar choke L_5 is used from base to ground but in this case the winding consists of 120 turns of 30 s.w.g. wire wound in one layer on a ¼in diameter rod.

Diode D_1 and resistor R_5 are included in the base circuit of the transistor to protect it during the half cycle when the base is reverse biased. For a BD123 the reverse base to emitter breakdown voltage is only 5V whereas the unloaded base drive signal may exceed 10V peak unless a diode limiter circuit is used. It was found that the addition of a diode limiter actually tended to increase the base drive current to the p.a.

It is essential that the inductance of the emitter to ground lead from the p.a. transistor should be kept as low as possible to prevent instability. The actual wire should be as short as practicable and of heavy gauge. All other earth returns for this stage should be connected to the chassis at the same point as the lead from the emitter.

Frequency doubler and oscillator

For the frequency doubler stage Tr_2 a second BD123 transistor is used. This stage is operated in class C to obtain maximum harmonic output.

The p.a. stage has an effective power gain at 14MHz of about 10dB. This means that it requires an input drive signal of some 1.5W from the doubler stage. Since the efficiency of the doubler stage is not likely to be better than 25%, its d.c. collector input power will need to be 6 to 8W in order to produce the required drive power. The mean d.c. collector current drawn by this transistor is between 250 and 300mA.

Matching between Tr_2 and Tr_3 is via a T network similar to that used at the p.a. collector. The inductance of L_4 needs to be 3μH which is obtained by winding 20 turns of 26 s.w.g. wire in a single layer on a ⅜in diameter former. This former is of the type used for television i.f. coils and is tuned by a 6mm dust core. This dust core is adjusted in conjunction with variation of C_7 and C_9 to give correct tuning and matching. The r.f. choke L_3 is made in the same way as L_6 in the p.a. stage.

The 7MHz drive signal from the oscillator stage Tr_1 is link coupled to the base of Tr_2. Resistor R_4 and capacitor C_6 give the reverse bias needed for class C operation.

In the interests of simplicity a crystal controlled oscillator is used for frequency control. The value of the emitter bypass capacitor C_5 is chosen so that a large phase shift is produced in the emitter circuit. Positive feedback then occurs, the quartz crystal ensuring stable oscillation.

A switch S_1 has been included to enable one of two alternative crystals to be selected, allowing transmitter frequency to be easily changed. Since the average amateur tends to have a collection of crystals in different types of holders, it is convenient to make sockets available for two different types.

Unless a wide selection of crystal frequencies is available, operation of the transmitter would normally be limited to one or two frequencies. To allow greater flexibility of operation, therefore, provision has been made to drive the transmitter from an external v.f.o. With S_1 set in its third position, the v.f.o. input is applied to Tr_1 which acts as a straightforward amplifier.

To ensure stable operation of Tr_1 as an amplifier, the base circuit is shunted by a low resistance R_1 and the emitter bypass capacitor is increased to 0.047μF.

Keying of the transmitter is carried out by simply breaking the d.c. feed to the emitter of Tr_1. When the stage is operating as a crystal oscillator, keying is quite clean with no "chirp" or key clicks. When the oscillator is keyed-off, no drive signal is applied to the doubler and p.a. stages so that they both remain cut-off.

Harmonic filter

In common with other amateur band transmitters this unit can cause quite severe harmonic interference on nearby television receivers unless some form of low pass filter is included in the output circuit. Details of a t.v.i. filter used in this transmitter are given in Fig. 3 which is a five section filter with constant *k* middle sections and *m* derived half sections at the ends to give better impedance matching. Nominal roll-off frequency of this filter is 20MHz and its characteristic impedance is 70Ω.

Without a filter the transmitter harmonic radiation caused complete wipe out of Band 1 signals on a television receiver 15ft from the aerial. With the filter in the circuit, interference was reduced to a slight pattern.

Construction

Layout of the transmitter does not seem to be very critical, provided that normal r.f. construction techniques are used such as keeping leads short and making use of single point earth returns for each stage.

The transistors used in the p.a. and doubler stages are required to dissipate a few watts of power when the transmitter is radiating, and to avoid overheating they must be mounted on some form of heat sink.

To avoid unwanted feedback and possible instability, it is a good idea to mount a screen between the base and collector circuits of each of the stages. It is convenient to make these screens perform a dual function as both screen and heat sink for the transistors. Mica washers are used to insulate the transistors from the screen whilst allowing conduction of heat.

To obtain good heat conduction the screens must be made of aluminium at least $\frac{1}{16}$in thick. In the prototype transmitter the screens used were 4×2 inches of 16 s.w.g. aluminium and were solidly connected to the chassis and case of the transmitter to improve heat transfer. Under normal keyed operation, the p.a. transistor heat sink will run slightly warm after a long period of transmission.

If it is desired to run the transmitter with continuous carrier output, such as for n.b.f.m. working, the heat sink used for the p.a. stage must be made larger. A standard finned type heat sink giving about 4° C/W should however be large enough for use under these conditions.

The t.v.i. filter must be mounted in the same case as the transmitter. Individual sections of the filter must be screened from one another to prevent direct coupling of harmonics. This is indicated in Fig. 3. To avoid mutual coupling coils in adjacent sections of the filter are mounted at right angles to one another.

Power supply

An external 24 to 28V power supply is used for the transmitter. This supply must be either stabilized or regulated to handle the large variations in current drawn by the transmitter. With the key down the current drawn from the supply will be about 1.5A,

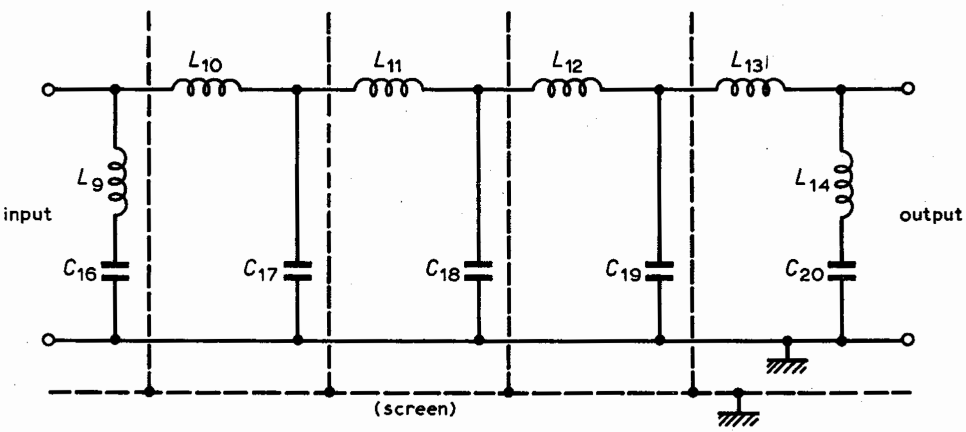


Fig. 3. Harmonic suppression filter to prevent television interference.

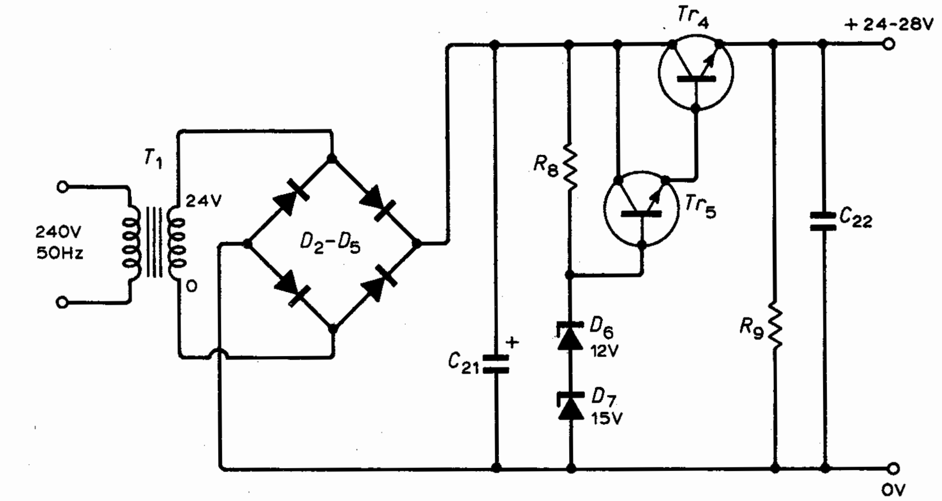


Fig. 4. Power supply circuit diagram.

whereas with the key up the current will be virtually zero.

An r.f. filter comprising L_8, C_{14} and C_{15} (Fig. 1) is included at the point where the power supply lead enters the case of the transmitter. This filter is intended to prevent leakage of r.f. signals into the power supply leads which could cause unwanted radiation.

A circuit of a suitable power supply for use with the transmitter is given in Fig. 4. A 2N3055 transistor Tr_4 is used as a series regulator. The output voltage is set by the two zener diodes D_6 and D_7 which drive the base of the series transistor via the emitter follower Tr_5. The 2N3055 transistor will need to be mounted on a heat sink since it will have to dissipate about 4 to 6W when the transmitter is radiating.

While carrying out initial tests with the transmitter it is useful to be able to supply only 12V, which reduces the possibility of destruction of transistors due to mistuning or overloading. By tapping the base of Tr_5 at the junction of the two zener diodes, an output of about 12 to 15V is obtained.

Testing and tuning

Monitoring of the collector current to the p.a. stage is provided by measuring the voltage drop across the 1Ω resistor R_6 using a 1mA meter in series with a 1kΩ resistor R_7.

A 70Ω dummy load will be needed when setting up. This can easily be made up from four 68Ω carbon, or other non-inductive type, resistors which are wired in series/parallel to give a total value of 68Ω. Each of these resistors must be rated at 2 or 3W.

To give a visible indication of the power output a 2.5V, 0.3A torch bulb is connected in series with the dummy load. At full power output from the transmitter the current in the dummy load will be about 0.5A. Since this level of current will overload and possibly burn out the lamp it is advisable to connect a low value resistor across the lamp during the later stages of testing.

Before starting any tests the transmitter wiring should be checked for any possible errors. Capacitors C_7, C_9, C_{12} and C_{13} should all be set at roughly half their maximum value. At this point the supply, set to 12V, may be applied. With the key circuit open no current should flow.

To check the oscillator stage connect a voltmeter across R_4 with the positive lead connected to ground. A 7MHz band crystal is now plugged in the circuit and the key closed. Adjust L_2 until a voltage is obtained across R_4 which indicates that the oscillator is running and drive is being applied to the doubler stage.

There should at this point be some current flowing in the output stage. Adjust L_4 to produce the maximum current on the meter M_1. The capacitors C_{12} and C_{13} may now be adjusted to obtain maximum current into the dummy load.

With power being delivered to the load

and the p.a. and doubler stages roughly tuned to resonance, the full supply voltage can be applied. The network L_4, C_7 and C_9 are adjusted together to produce maximum p.a. collector current which should be about 0.9 to 1.0A. Adjust C_{12} and C_{13} again to produce maximum brilliance on the dummy load indicator lamp. These adjustments will be found to be interdependent, but as a rough guide C_{13} adjusts the load coupling and C_{12} is used to tune the circuit to resonance. It will be found that if C_{13} is made too large or too small there will be a fall off in the maximum achievable output. The capacitors should be adjusted to give an optimum between these states. The settings will be fairly broad and, once set up, they should hold over a large part of the 14MHz band.

Performance

Over the past two years two versions of this solid state transmitter have been used on the 14MHz band. One transmitter was only run at 12W input whilst the later unit was run at the full 25W. In both cases the aerial used was a rather inefficient indoor dipole running NE to SW.

Contacts with all parts of Europe were found to be easily made and consistent reports of signal strengths from S-7 to S-9 were obtained. Working stations in Asia, Africa and North America is naturally a little harder but reports averaging S-5 to S-8 are regularly received during contacts with the U.S.A. and Canada. So far it has not been possible to contact Australia but this is probably due to the orientation of the aerial which does not favour Australia and the Pacific area.

Components list

Resistors

R_1	100Ω	R_6	1Ω 3W
R_2	33kΩ	R_7	1kΩ
R_3	100Ω	R_8	330Ω
R_4	330Ω	R_9	4.7kΩ
R_5	10Ω		

All resistors ½W unless otherwise stated

Capacitors

C_1	0.002μF	paper
C_2	4700pF	ceramic
C_3	0.047μF	polyester or paper
C_4	330pF	mica
C_5	330pF	mica
C_6	1000pF	ceramic
C_7	3–40pF	tubular trimmer
C_8	22pF	mica
C_9	3–40pF	tubular trimmer
C_{10}	0.047μF	polyester or paper
C_{11}	0.047μF	polyester or paper
C_{12}	50pF	air spaced variable
C_{13}	50pF	air spaced variable
C_{14}	0.047μF	polyester or paper
C_{15}	0.047μF	polyester or paper
C_{16}	68pF	mica
C_{17}	220pF	mica
C_{18}	220pF	mica
C_{19}	220pF	mica
C_{20}	68pF	mica
C_{21}	10,000μF	36V
C_{22}	0.47μF	polyester or paper

Semiconductors

Tr_1	BFY51	D_1	1N4001
Tr_2	BD123	D_2–D_5	3A, 100–1000 p.i.v. silicon diodes
Tr_3	BD123		
Tr_4	2N3055	D_6	12V, 400mW zener diode
Tr_5	2N2219		
		D_7	15V, 400mW zener diode

Inductors

L_1	2.5 mH r.f. choke
L_2	Primary—14 turns 26 s.w.g. enamelled Secondary—4 turns 26 s.w.g. enamelled, wound at d.c. supply end of primary Former—Neosid 8mm diameter with dust core
L_3	100 turns 26 s.w.g. enamelled, close wound on ⅜in diameter s.r.b.p. rod
L_4	20 turns 26 s.w.g. enamelled Former—Neosid 8mm diameter with dust core
L_5	120 turns 30 s.w.g. enamelled, close wound Former—¼in diameter s.r.b.p. rod
L_6	Same as L_3
L_7	16 turns 16 s.w.g. enamelled, close wound ¾in diameter, self supporting 1¼in long
L_8	20 turns 18 s.w.g. enamelled, close wound ¼in diameter self supporting
L_9	12 turns 18 s.w.g. enamelled, close wound ¼in diameter self supporting
L_{10}	18 turns 18 s.w.g. enamelled, close wound ¼in diameter self supporting
L_{11}	Same as L_{10}
L_{12}	Same as L_{10}
L_{13}	Same as L_{10}
L_{14}	Same as L_9
T_1	50Hz mains isolation transformer with secondary winding of 0–24V, 2–3A

Microwaves at the Physics Exhibition

Impatt diode applications

The Impatt diode is challenging the travelling-wave-tube in many respects. An amplifier shown by S.T.L. provides an output of 1W c.w. at 8GHz, and requires 120V d.c. supply, a great advantage over currently available t.w.ts. The amplifier comprises four cascaded stages, circulator coupled, and each stage is provided with its own constant-current and transient protection circuits allowing the simplest of external d.c. supplies to be used. A novel design for each amplifier circuit is used so that each of the four stages can use the same type of matching circuit to provide the optimum gain and bandwidth characteristics with reduced manufacturing problems. Overall, it provides a bandwidth of 250MHz at 8GHz — prototype centre frequency — with 40dB of gain but this can be increased to 400MHz by overdriving to a reduced gain of 30dB. Silicon Impatt diodes used in the prototype yield better than 70% operating efficiency but work is now going on to replace these with the more efficient gallium arsenide devices, around 15%. (Overdriven Impatt diode amplifiers are necessarily non-linear and obviously not suitable for a.m. systems.)

Phase switching, usually performed by p-i-n diodes at a loss in microwave phase modulation systems, can be achieved with Impatt diodes with the advantage of power gain, as demonstrated by the Services Electronics Research laboratory. An Impatt diode, forming the termination of a transmission line, reflects signals that are incident with magnitude and phase depending on the values of the real and imaginary parts of the diode terminal admittance. Under conditions of reverse bias, where avalanche current is flowing, the diode conductance can appear negative over a wide range of frequencies and therefore can provide signal gain where the reflected wave is greater than that of the incident wave. The magnitude of the reflected wave basically depends on the real or conductive components of the diode equivalent circuit whereas the phase is associated with the imaginary or shunt reactance part of the model.

A situation can arise where at or near the avalanche transit-time frequency, the conductance component can be equal at two different levels of diode current, but because the series inductance element is a function of this current the phase delay at these two currents is different. In the demonstration, the diode current was switched alternatively between two values, chosen to give the same amplifier gain, providing phase switching of up to 180° with small-signal gains of about 10dB with very little amplitude modulation. For further details, see *Electronics Letters*, vol.8 no. 19.

Q-band communications

A lightweight Q-band communications link capable of handling data rates of up to 1Mbit/sec has been developed by Decca Radar Ltd. Designed for short-distance communications of up to 5km, the link can be tuned to any frequency in the 26.5 to 40GHz band. The demonstration link was operated with a Gunn device transmission source providing a c.w. power output of around 7 to 10mW at approximately 34GHz, pulse modulated at 1MHz with a p-i-n diode circuit. The Gunn devices are apparently operating in the $n\ \lambda/2$ mode in full-height waveguide and it is claimed that little trouble has been found with moding or hysteresis. Aerial gain is greater than 30dB with parabolic reflectors of around 25-cm diameter and the hardware is mounted in the case space behind the box-shaped aerial mounting.

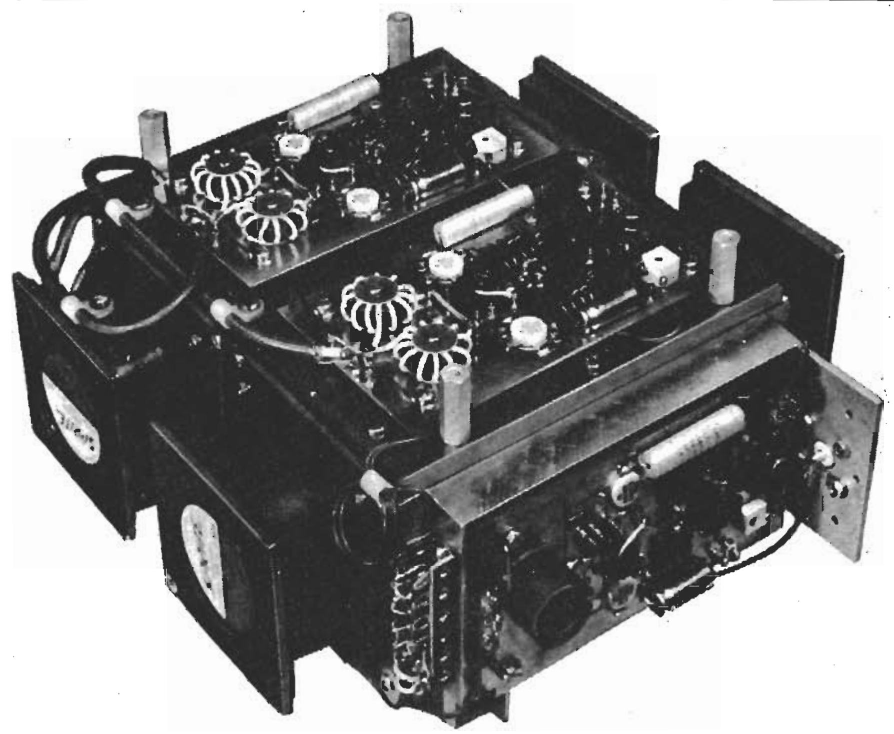
The receiver uses a similar Gunn oscillator, suitably attenuated, to drive the Q-band mixer which, it is said, maintains its sensitivity figure over at least a 6dB variation in local oscillator power — very useful for long-term gain stability. The overall noise factor, with 50MHz i.f. bandwidth, of < 12.5dB allows good link range, easy tuning and a minimal drift problem.

Two-stage h.f. linear amplifier

by Helge O. Granberg

Motorola Semiconductor Products, Phoenix, Arizona

This article discusses the design of 50W and 300W linear amplifiers for the 1.6 to 30MHz frequency band, both of which employ push-pull design for low, even-harmonic distortion. This harmonic distortion and the 50Vd.c. supply voltage make the output impedance matching easier for 50Ω interface, and permit the use of efficient 1:1 and 4:1 broadband transformers. The four 300W modules are combined to provide a 1 to 1.2kW p.e.p. or c.w. output capability. The driver amplifier increases the total power gain of the system to approximately 34dB.



Prototype 1kW linear amplifier showing input power divider in foreground, with preamplifier to the right. Two of the four 300W modules can be seen on the upper side of the structure.

Bias voltage

The bias voltage source shown in Fig.1 is employed with each of the 300W modules and the preamplifier. Its basic components are the integrated-circuit voltage regulator MC1723C, the current boost transistor Tr_3, the temperature sensing diode D_1 and the voltage adjustment element R_{10}. advantages of this type of bias source are:

- line voltage regulation, which is important if the amplifier is to be operated from various supply voltages,
- adjustable current limit,
- very low stand-by current drain.

The supply voltage is reduced by D_2 and R_{12} to a level below 40V, which is the maximum input voltage of the regulator. The base-emitter junction of a 2N5190, in a Case 77 plastic package, forms the diode D_1 of which the temperature compensation has a slight negative coefficient. Current limiting resistor R_5 sets the limit to approximately 0.65A, which is sufficient for devices with a minimum h_{FE} of 17, ($I_B = I_C/h_{FE}$) when the maximum average I_C is 10.9A. Typically, the MRF428 h_{FE} is 30-40.

Measured output voltage variations of the bias source (0 — 600mA) are ± 5 to 7mV, which implies a source impedance of approximately 20 milliohms.

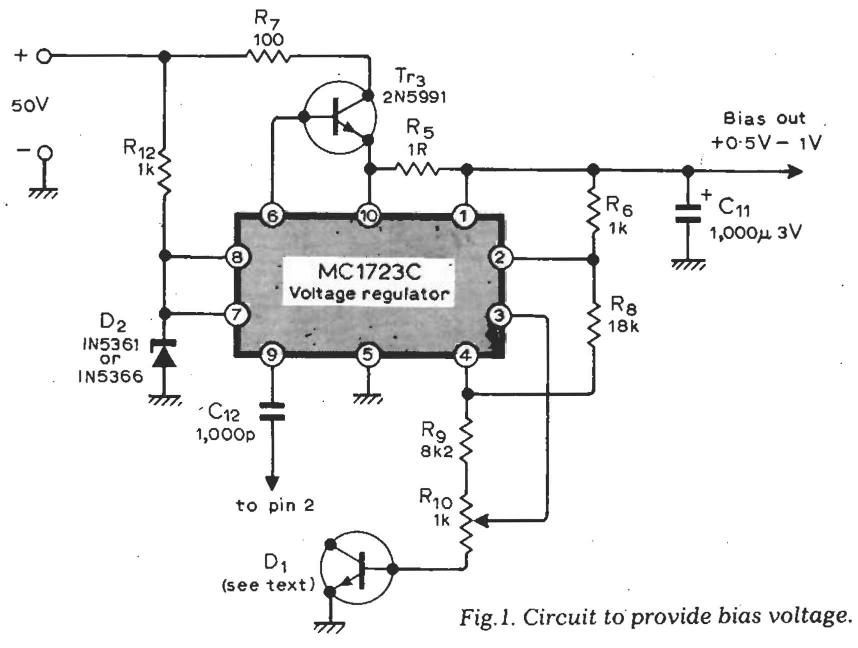


Fig. 1. Circuit to provide bias voltage.

300W amplifier

Due to the large emitter periphery of the MRF428, the series base impedance is as low as 0.88 — j0.80Ω at 30 MHz. In a push-pull circuit a 16:1 input transformer would provide the best impedance match from a 50Ω source but would result in a high v.s.w.r. at 2 MHz, and would make it difficult to implement the gain-correction network design. For this reason a 9:1 transformer, which is more ideal at the lower frequencies, was chosen. This represents a 5.55Ω base-to-base source impedance.

A centre tap, common in push-pull circuits, is not necessary in the input transformer secondary, if the transistors are balanced. (C_{ib}, h_{FE}, V_{BEf}.) The base current return path of the momentarily amplifying transistor is through the base-emitter junction of the momentarily non-amplifying transistor, which acts as a clamping diode, and the power gain is somewhat dependent upon the bias current. The equivalent input circuit of Fig. 2 represents one half of the push-pull circuit, and for calculations R_S equals the total source impedance (R_S') divided by two.

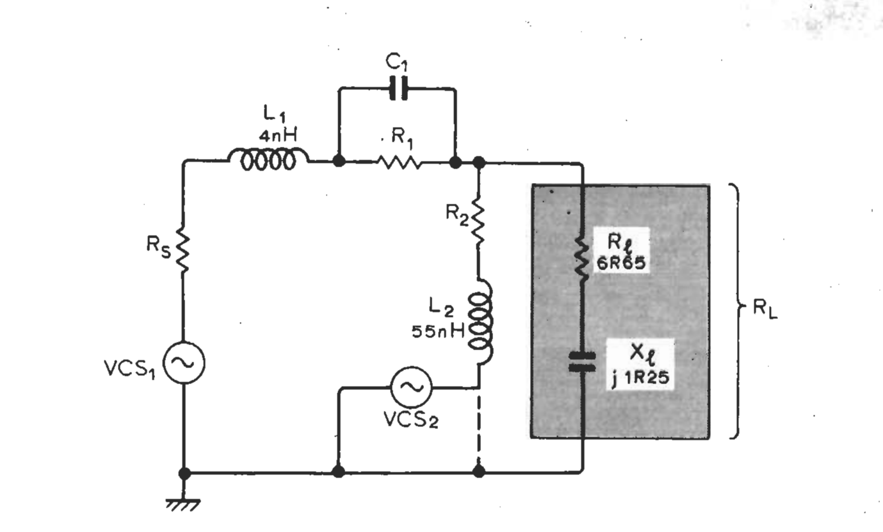


Fig.2. Equivalent base input circuit for Tr_1.

Since a junction transistor is a current amplifier, it should ideally be driven from a current source which, in r.f. applications, would result in excessive loss of power gain. However, input networks can be designed with frequency slopes having some of the current source characteristics at low frequencies, where excess gain is available.

The complex base input characteristics of a transistor would require a very complicated input compensation network for optimum overall performance. The design goal here was to maintain an input v.s.w.r. of 2:1 or less and a maximum gain variation of ±1.5dB from 2 to 30MHz. Initial calculations indicated that these requirements could be met with a simple RC network in conjunction with negative collector-to-base feedback. Fig. 2 shows this network for one device, where L_1 and L_2 represent lead lengths, their values being fixed. The feedback is provided through R_2 and L_2. Because the calculations were done without the feedback, this branch is grounded to simulate the operating conditions.

Calculated values of R_1 and R_2 along with other known values and the device input data at four frequencies were used to simulate the network in a computer programme.An estimated arbitrary value of 4000 pF for C_1 was chosen, and V_{CS2} represents the negative-feedback voltage (Fig. 2). The optimization was done in two separate programmes for R_1, R_2, C_1 and V_{CS2} and in several steps. The goals were (a) V_{CS} and R_2 for a transducer loss of 13 dB at 2 MHz and a minimum loss at 30 MHz. b) R_1 and C_1 for input v.s.w.r. of <1.1:1 and <2:1 respectively. The optimized values obtained were C_1 – 5850 pF, R_2 – 1.3Ω, R_1 – 2.1Ω and V_{CS2} – 15V. The minimum obtainable transducer loss at 30MHz was 2.3dB, which is partly caused by the highest reflected power at this frequency, and can be reduced by "over-compensation" of the input transformer. This indicates that at the higher frequencies, the source impedance (R_S) is effectively decreased, which leaves the input v.s.w.r. highest at 15 MHz.

In the practical circuit the value of C_1 (and C_2) was rounded to the nearest standard, or 5600 pF. For each half cycle of operation R_2 and R_4 are in series and the value of each should be 1.3Ω/2 for a V_{CS2} of 1.5V. Since the voltage across ac

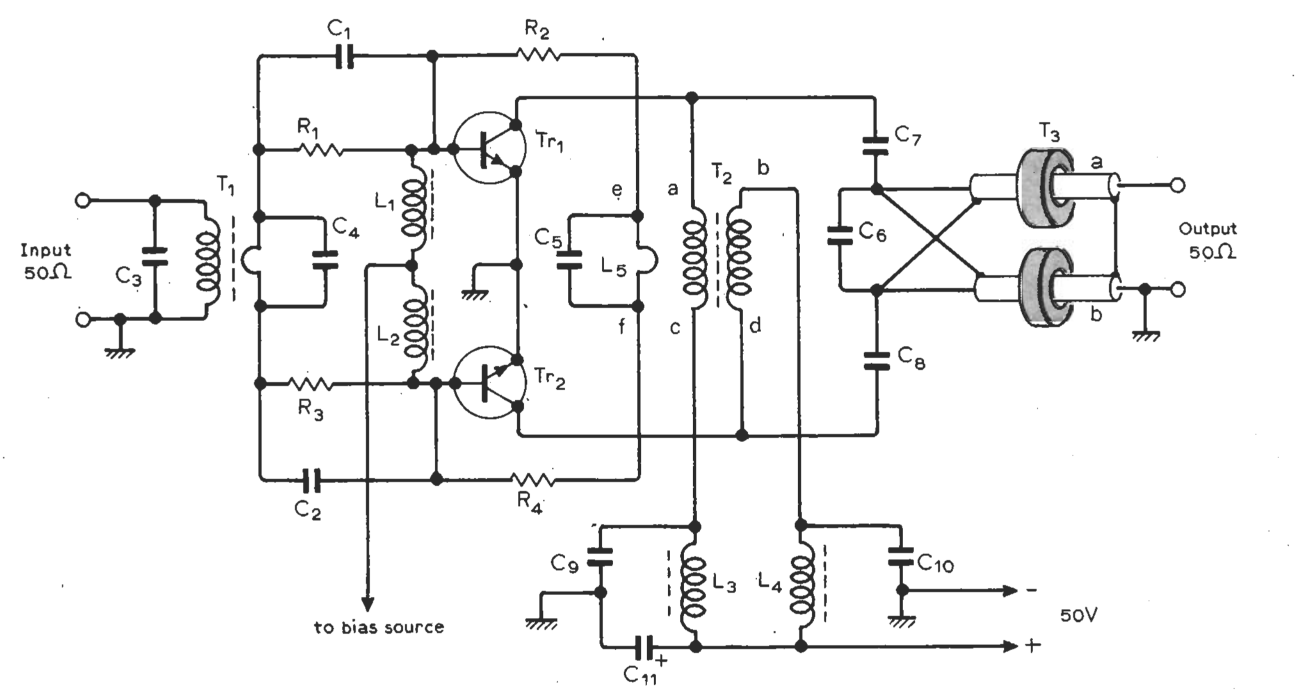


Fig.3. Practical circuit of 300W amplifier.

and bd = V_{CE}, a turns ratio of 32:1 would be required. It appears that if the feedback voltage on the bases remains unchanged, the ratio of the voltage across L_5 (V_{CS2}) and R_2R_4 can be varied with only a small effect to the overall input v.s.w.r. To minimize the resistive losses in the bifilar winding of T_2 in Fig. 3, the highest practical turns ratio should not be much higher than that required for the minimum inductance, which is

$$\frac{4R}{2\pi}=\frac{50}{12.5}=4.0\mu H,$$

where R is the collector-to-collector impedance of 12.5 Ω and f=2MHz. The inductance of ac or bd will then be 1.0 μH, which amounts to 5 turns. A margin of 25% over this represents a 7:1 ratio, setting V_{CS2} to 6.9V.

The currents for each half cycle are in opposite phase in ac and bd and, depending on the coupling factor between the windings, the even harmonic components will see a much lower impedance than the fundamental. The optimum line impedance for ac, bd would equal the collector-to-collector impedance, but experiments have shown that increasing this number by a factor of 2 to 3 affects the second and fourth harmonic amplitudes by only 1 to 2 dB.

Since the minimum gain loss obtainable at 30 MHz with the network in Fig. 2, and the modified V_{CS2} source was about −3.8 dB at 30 MHz, C_5 was added to form, with L_5, a parallel resonant circuit with a Q of approximately 1.5. Its purpose is to increase the shunting impedance across the bases, and to disturb the 180° phase difference between the input signal and the feedback voltage at the higher frequencies. This reduces the gain loss of 3.8 dB, of which 1.4 dB is caused by the feedback at 30 MHz. The amount depends upon the resonant frequency of C_5L_5, which should be above the highest operating frequency to avoid possible instabilities.

The input transformer is a 9:1 type, and uses a television aerial balun type ferrite core, made of high permeability material. The low-impedance winding consists of one turn of 1/8in copper braid. The sections which pass through the openings in the ferrite core are rounded to resemble two pieces of tubing electrically. The primary consists of 23 s.w.g. p.t.f.e insulated wire, threaded through the rounded sections of braid, with the primary and secondary leads in opposite ends of the core [1,2]. The saturation flux density is about 60 gauss, which is well below the limits for this type of core.

Several types of output transformer configuration were considered. The 12.5Ω collector-to-collector impedance estimated earlier requires a 4:1 transformer for a 50Ω output. A coaxial cable version was adapted for this design, since the transmission line type transformers are theoretically ideal for r.f.

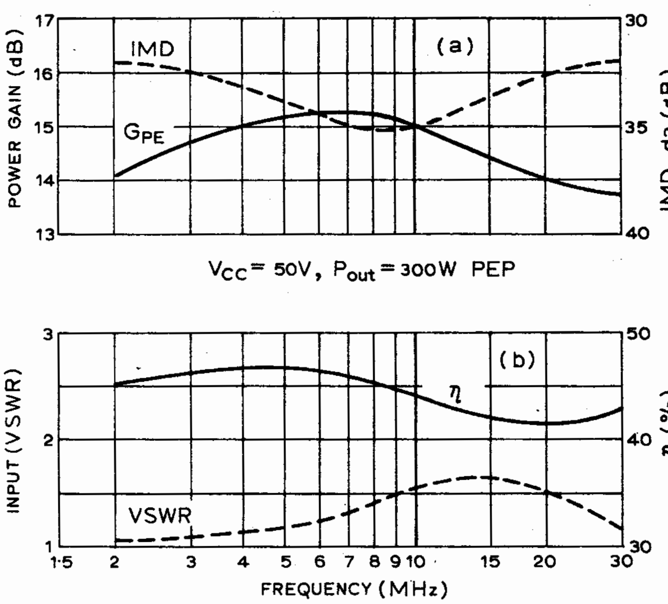


Fig. 4. Intermodulation distortion (3rd) and power gain are shown at (a), while (b) gives input voltage standing-wave ratio and efficiency (η) against frequency.

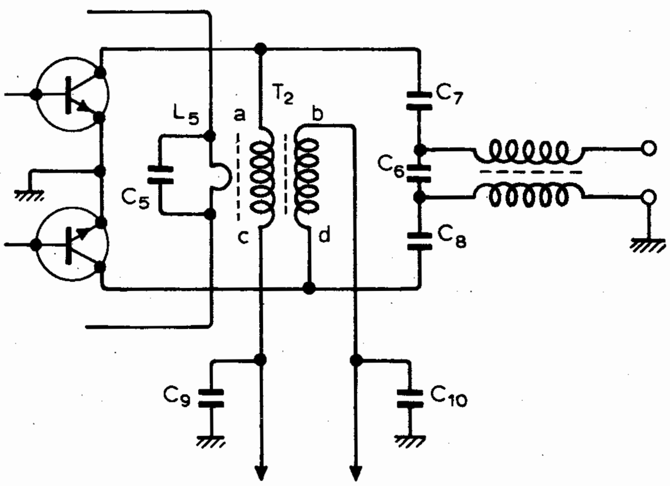


Fig. 5. Driver amplifier for 50W output.

applications, especially in the 1:4 impedance ratio. A balanced-to-unbalanced function would normally require three separate transmission lines including a balun,[2,3] but the third line can be omitted, if lines a and b in Fig. 3 are wound on separate magnetic cores, and the physical length of the lines is sufficient to provide the necessary isolation between the collectors and the load. Measurements showed the core losses to be negligible compared to the line losses at 2 MHz and 30MHz. However, the losses increase as the square of B_{max} at low frequencies.

With the amount of h.f. compensation dependent upon circuit layout and the exact transformer construction, no calculations were made on this aspect for the input (or output) transformers. The values of C_3, C_4, and C_6 were selected by employing adjustable capacitors on a prototype whose values were then measured. The performance data of the 300W module is shown in Fig. 4.

Driver amplifier

The driver shown in Fig. 5, uses a pair of MRF 427 devices, and the same circuit board layout as the power amplifier, with the exception of the type of the output transformer.

The input transformer is similar to that used with the power amplifier, but has a 4:1 impedance ratio. The required minimum inductance (4μH) in the one turn secondary (Fig. 3) being considerably higher in this case, the A_L product of the core is barely sufficient. The measured inductances between a number of cores range 3.8 – 4.1μH.

This formula also applies to the output transformer, which is a 1:1 balun. The required minimum inductance at 2MHz is 16μH, amounting to 11

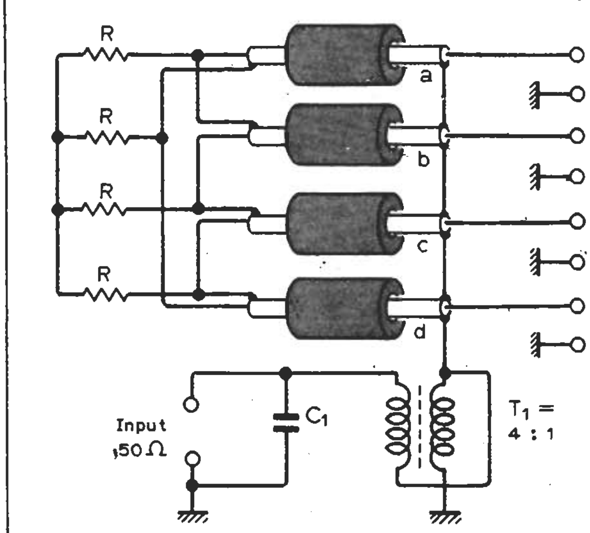


Fig. 6. Four-port input power divider.

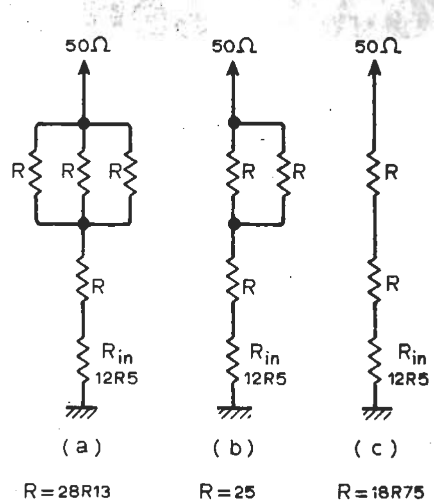


Fig. 7. Balancing resistors R in Fig. 6 when one or more loads open-circuit.

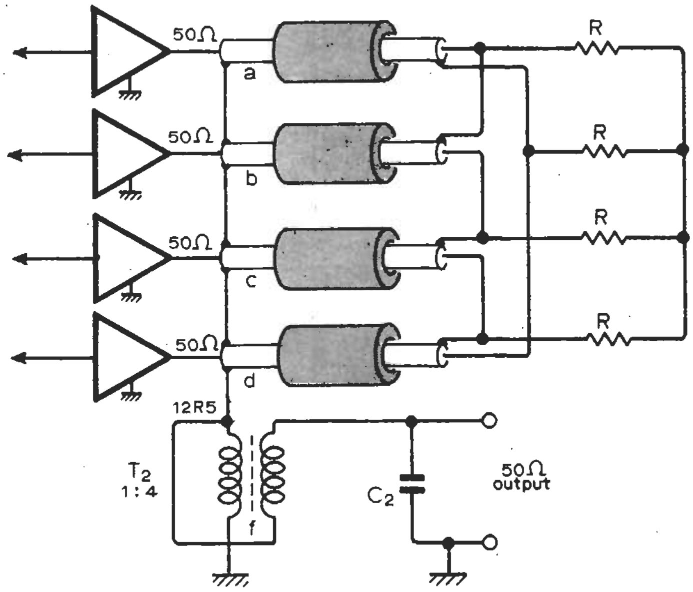


Fig. 8. Circuit of four-port power combiner – the reverse of circuit of Fig. 6.

turns on a Ferroxcube 2616P-A100-4C4 pot core.

Input power divider

The purpose of the power divider is to divide the input power into four equal sources, providing an amount of isolation between each. The outputs are designed for 50Ω impedance, which sets the common input at 12.5Ω. This requires an additional 4:1 step down transformer to provide a 50Ω load for the driver amplifier. Another requirement is a 0° phase shift between the input and the 50Ω outputs, which can be accomplished with 1:1 balun transformers (a,b,c and d in Fig. 6). For improved low frequency isolation characteristics the line impedance must be increased for the parallel currents. This can be done, without affecting the physical length of the line, by loading the line with magnetic material. In this type of transformer, the currents cancel, making it possible to employ high-permeability ferrite and a relatively short physical length for the transmission lines.

The purpose of the balancing resistors R is to dissipate any excess power if the v.s.w.r. increases. Their optimum values, which are equal, are determined by the number of 50Ω sources assumed unbalanced at one time, and the resistor values are calculated accordingly.

Examining the currents with one load open, it can be seen that the excess power is dissipated in one resistor in series with three parallel resistors, whose total value is 50–12.5 = 37.5Ω. Similarly, if two loads are open, the current flows through one resistor in series with two parallel resistors, totalling 37.5Ω again. This situation is illustrated in Fig. 7.

Output combiner

The operation of the output combiner shown in Fig. 8, is the reverse of that of the input power divider. In this application we have four 50Ω inputs and one 12.5Ω output, which is transformed to 50Ω by a 1:4 impedance transformer.

An arrangement similar to the input power divider is employed in the combiner. The baluns consist of straight pieces of coaxial cable loaded by a sleeve of magnetic material (ferrite). The line length is determined by the physical dimensions of the ferrite sleeves. Straight-line baluns such as these have the advantage over multi-turn toroidal types in introducing a smaller possibility for phase errors, due to the smaller length of the line. The largest possible phase errors occur in the input and output connnecting cables, whose lengths are 18in and 10in respectively. All four input and output cables must be of equal length within approximately ¼in, and the excess in some, caused by the asymmetrical system layout, can be coiled or formed into loops.

The output connecting cables between the power amplifier outputs and the combiner are made of low loss RG-142B/U coaxial cable, that can adequately handle the 300W power with the average current of 2.45A.

The purpose of the step-up transformer T_2 is to transform the 12.5Ω impedance from the combiner up to 50Ω. It is a standard 1:4 unbalanced-to-unbalanced transmission line type transformer 3,4,5 in which the line is made of two RG-188 coaxial cables connected in parallel. As in the input transformer, the h.f. compensation (C2) was not required.

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15 Communications Rebroadcaster

☐ One way to keep an ear on the Amateur or Citizens band while working around the house or searing steaks out on the patio, is to install a lot of remote speakers. An easier way is to feed the audio signal from your CB or amateur receiver into a broadcast band Rebroadcaster and radiate the signals throughout the house and yard. A small transistor pocket radio tuned to the rebroadcaster frequency will alert you in-

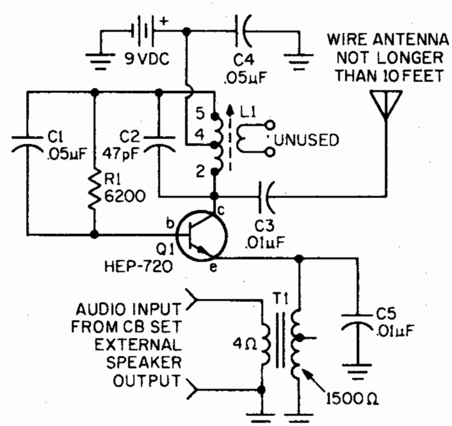
stantly if a call is received on your communications gear. Best of all, since the radio travels with you, you're never away from your receiver.

Build the rebroadcaster in a metal cabinet. The power supply can be a transistor radio type 9-volt battery, though a line supply is preferred for more dependable continuous operation. The unit draws about 10 mA. Power input and antenna length are limited by FCC regulations. If the input current exceeds 10 mA, increase the value of R1 in 20% increments until the current is below 10 mA. The antenna wire cannot exceed 10 feet. Adjust slug L1 so the rebroadcaster operates on an unused BC frequency. The audio input connects to the speaker or headphone output of your communications equipment. Adjust the volume on the receiver for a high, undistorted transmission by the rebroadcaster.

UPDATED

PARTS LIST FOR COMMUNICATIONS REBROADCASTER

- **C1, C4**—0.05-uF disc capacitor, 50 VDC or better
- **C2**—47-pF silver mica capacitor, 100 VDC or better, Allied Electronics 782-0860
- **C3, C5**—0.01-uF disc capacitor, 50 VDC or better
- **L1**—Oscillator coil, Miller 2022 (Do not substitute)
- **Q1**—NPN transistor, HEP-720
- **R1**—6200-ohm, ½-watt resistor, see text
- **T1**—Output transformer, 4 ohms to 1000 or 2500 ohms



55 Radio Pager

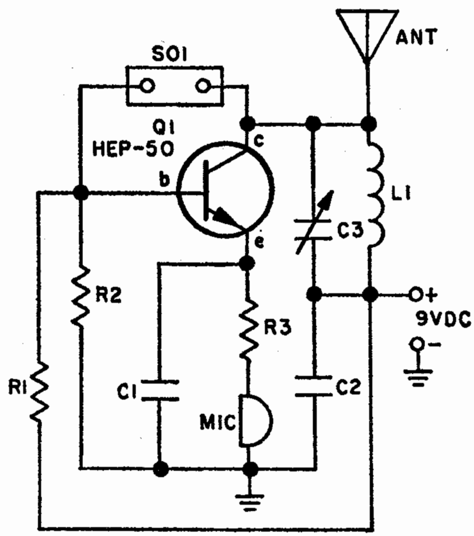
Small enough to fit into a cigarette pack, this pocket pager produces a low-output signal on the Citizen's Band (27 MHz) suitable for paging inside a building. The signal is strong enough to be heard on a standard transceiver, but not enough to cause receiver overload.

If only one crystal frequency is needed, socket SO1 can be eliminated and an overtone type crystal soldered directly into the

circuit. Salvage crystals from junked units. The whip antenna is a standard walkie-talkie three-section replacement type. The carbon microphone can be a telephone transmitter. You may want to use the portable CB antenna described in circuit 22 on page 26 or Extended CB Antenna in circuit 31 on page 31.

To tune; receive the signal on an S-meter-equipped receiver and adjust trimmer C3 for maximum output. Key the transmitter a few times to check crystal activity. If starting is intermittent, slightly alter C3's adjustment until operation is consistent.

The power supply can be a standard 9V (2U6 type) battery.



PARTS LIST FOR RADIO PAGER

- **C1, C2—0.001-uF, 100-VDC disc capacitor**
- **C3—50-pF trimmer capacitor**
- **L1—10 turns #16 enameled wire wound on 3/8-in. form, spaced 1 in. end to end**
- **MIC—Carbon microphone element**
- **Q1—Motorola HEP-50 npn transistor**
- **R1—47,000-ohm, 1/2-watt resistor**
- **R2—10,000-ohm, 1/2-watt resistor**
- **R3—330-ohm, 1/2-watt resistor**
- **SO1—Crystal socket**