

# The Transistor Giant<sup>1</sup>

## A High-Power Transistor Transmitter from India

BY R. JAYARAMAN,\* VU2JN

**T**HIS compact, high-power transistorized transmitter runs with an input power of 75 watts on c.w. and 25 watts on a.m., in the 7-, 14-, and 21-MHz. amateur bands. It features a 28-volt regulated power supply, a stable FET v.f.o., and a 2N3950 power amplifier in the final feeding a T network.

The complete transmitter is built inside a 15 × 8 × 8-inch veneer cabinet with a 2½-inch high aluminum chassis and a ½-inch thick aluminum front panel. The front panel doubles as the heat sink for the audio power transistors.

In order to maintain a neat circuit configuration, n-p-n silicon transistors have been used throughout the r.f. section while p-n-p germanium transistors have been used throughout the audio section. The r.f. section works with the negative bus as common, while the audio section works with the positive bus as common. The schematic of the transmitter is shown in Fig. 1.

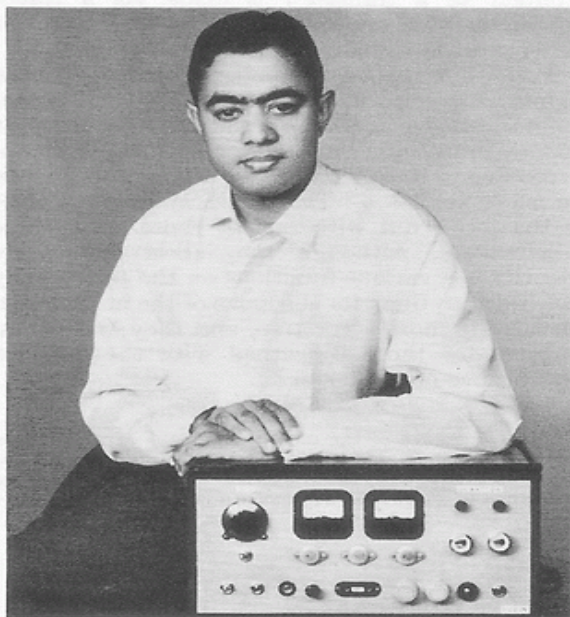
### Power Supply

The fully regulated power supply furnishes four d.c. voltages. A completely shielded power transformer supplies 30 volts r.m.s. to a molded bridge rectifier. The output is smoothed by a 3500-μf. 75-volt capacitor to provide about 42 volts at no load and about 33 volts at a load current of 3 amp. The output voltage is then regulated at 28 volts by a two-stage transistor regulator. Regulation is applied to the negative side of the supply voltage. The regulator is followed by another 3500-μf. capacitor.

The regulator, an improved version of the conventional series regulator, gives good regulation and enables the regulator power transistor to be bolted directly to the chassis. The regulator employs a 29-volt Zener (formed by a 16-volt and a 13-volt Zener in series), a 2N600 p-n-p high-gain germanium transistor as the reference amplifier, and a 2N3716 150-watt n-p-n silicon power transistor as the power regulator. The

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<sup>1</sup> Adapted from "A High-power Transistor Transmitter," by Jayaraman, Parts I to IV, *The Indian Radio Amateur*, June, August, October, and December, 1968.



VU2JN with the 75-watt transistor transmitter.

2N3716 is mounted on a small heat sink bolted to the chassis.

The power supply features good regulation, the output voltage beyond the ammeter being 28.8 volts at no load, 28.7 volts at 1 amp., 28.5 volts at 2 amp., and 28.0 volts at 3 amp. A scope test showed the ripple voltage to be 0.1 volt peak at a load current of 2 amp. Two 5-amp. fuses have been provided, one on the transformer secondary and another at the regulator, but in the event of a dead short the fuses do not offer much protection to the regulator transistor. The transistor can be protected against a short only by a transistor switch or limiter, which could not be incorporated since the d.c. input voltage under load is not high enough to accommodate the additional drop across a current sensor.

It is no pleasure operating a rig while being haunted by the fear of a short or a transistor burning out, especially when the d.c. voltage goes directly to the final tuning and loading capacitors. Spurred by an irrepressible urge to

*This article presents a fully transistorized transmitter capable of handling 75 watts input on c.w. In addition to complete construction data, the author presents problems encountered when using solid-state devices at this r.f. power level, and the solutions to these problems.*

dispose of an SCR which happened to be lying in the writer's "treasure box" for an unusually long time, the writer added an "emergency fuse-blower" circuit, incorporating a GE C20B SCR and a 16-volt 1-watt Zener diode. Under normal conditions the Zener blocks the positive gate signal and the SCR remains in the OFF state. When a short occurs in the output, the voltage across the 2N3716 transistor momentarily rises to more than 30 volts. Immediately, the Zener starts conducting and triggers the SCR into the ON state. The SCR plunges into heavy conduction, removes the dangerous voltage-current combination from the 2N3716 and maintains a short until the fuse blows. Since the C20B has a peak surge rating of 80 amp., it is hoped that the SCR will be able to bear the brunt of a short until the fuse blows. The writer did not want to lose a fuse (and possibly more!) by testing this protective circuit!

Subsidiary regulated voltages of 6.8 volts and 16 volts power the v.f.o. and frequency-multiplying stages, respectively. Another regulated supply of -7 volts with respect to the positive bus powers the speech-amplifier stages.

When used with a power supply operated from 230-volt mains, a solid-state v.f.o. is susceptible to hum pickup. To avoid this trouble, the writer has observed the following precautions, in addition to good power-supply filtering:

- The main power transformer is completely enclosed in a cadmium-plated steel box.
- The power transformer is provided with an electrostatic shield between the primary and the low-voltage winding.
- The power-line leads in the chassis are run throughout as twin-core shielded wire.
- The v.f.o. is built inside a  $3\frac{3}{4} \times 3 \times 3\frac{1}{4}$ -inch rigid cadmium-plated steel box. All these precautions may not be essential, but the writer did not want to take any chances when building transistorized equipment!

#### The V.F.O.

The v.f.o. employs a Motorola 2N4416 n-channel JFET as a 3.5-MHz. Colpitts oscillator, fol-

lowed by a two-stage untuned buffer amplifier utilizing a pair of 2N2369 n-p-n silicon transistors. The similarity of the oscillator circuit with that of a corresponding vacuum-tube version is striking. When the JFET oscillates, it automatically develops a negative gate bias. This is because of the gate current that flows through the high-value gate-leak resistor when the oscillating gate voltage swings positive with respect to the source.

To eliminate pulling of the oscillator, the output is taken from a low-impedance point (the source) and light resistive coupling is used to the next stage. The two-stage buffer amplifier is similar to the circuit that appeared in an earlier article in *QST*,<sup>2</sup> except for the difference in biasing. Because of the direct coupling and d.c. negative feedback employed in the circuit, the performance of the buffer amplifier is critically dependent on the bias level.

The 5- $\mu$ h. v.f.o. tank coil,  $L_1$ , is close-wound on a  $\frac{5}{8}$ -inch diameter ceramic form and is reinforced with four longitudinal strips of Araldite epoxy resin, a polystyrene-type material. The v.f.o. tuning capacitor,  $C_1$ , is a 50- $\mu$ f. double-ball-bearing type with short stiff plates. The 50-pf. bandspreading capacitor,  $C_2$ , is a Philips cylindrical air trimmer which, although quite small, is remarkably stable. This trimmer is mounted on a ceramic standoff and is so adjusted that the v.f.o. covers a frequency range of 3.500 to 3.575 MHz. The 150-pf. band-setting capacitor,  $C_3$ , is an APC trimmer which is mounted on the side wall of the box so that it can be adjusted from the outside. A small quantity of silicone grease is applied to the wiper contacts of the tuning capacitor and the APC trimmer.

The v.f.o. dial is a Japanese-made 2-inch planetary-drive dial having an 8 to 1 ratio. A flexible coupling is inserted between the dial drive and the tuning capacitor.

The v.f.o. is supplied with 6.8 volts from a Zener-regulated power supply, derived from the main 28-volt regulated supply of the trans-

<sup>2</sup> Hanchett, "The Field-Effect Transistor as a Stable V.F.O. Element," *QST*, December, 1966.

The Transistor Giant transmitter, housed in a 15 $\times$ 8 $\times$ 8-inch veneer cabinet. From left to right, the controls on the bottom are transmit/receive switch, c.w./a.m. switch, microphone socket, microphone gain, key socket, exciter bandswitch, exciter tuning, neon pilot light, and on/off switch. On the upper left are the v.f.o. tuning control and frequency-spotting switch, while on the right are the final tuning and loading controls and the two final bandswitches. Beneath the meters are the audio power transistors.



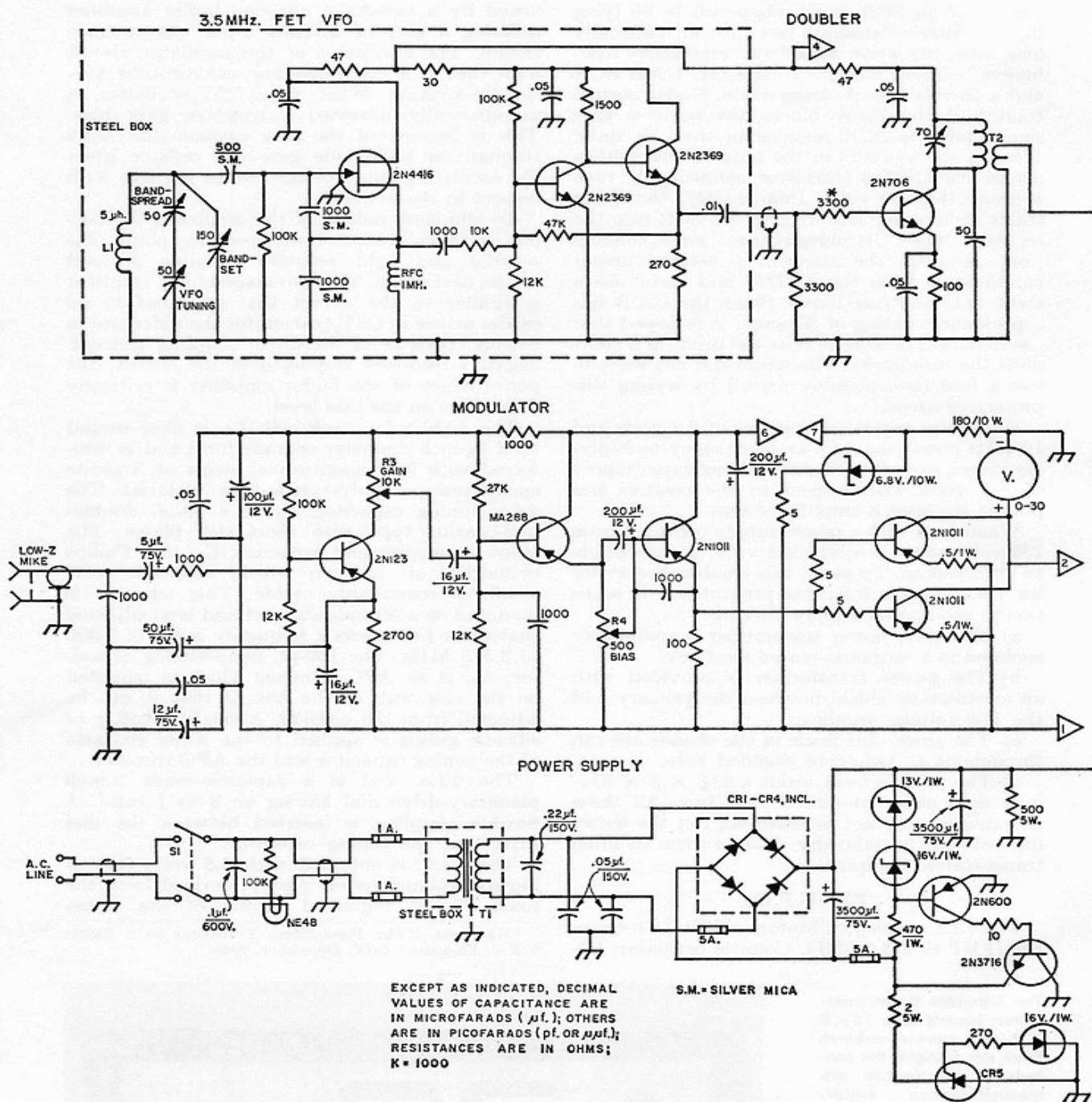


Fig. 1—Schematic of the high-power transistor transmitter. Unless otherwise indicated, resistors are  $\frac{1}{2}$ -watt, 10-percent tolerance. Capacitors with polarity indicated are electrolytic; S.M. indicates silver mica. The four resistors shown with an asterisk (\*) in the doubler, multiplier and driver stages may require slightly different values than shown for obtaining optimum drive to the p.a. on c.w. and a.m. The type of switch used by the author at  $S_2$ ,  $S_3$ , and  $S_7$  is not commonly available in the U.S.; readily available switches performing the same functions are shown in the schematic and in the parts list.

CR<sub>1</sub>–CR<sub>4</sub> incl. — Rectifier, molded bridge, 6 amp., p.r.v. per cell 200 volts (Motorola MDA952-3 or similar).

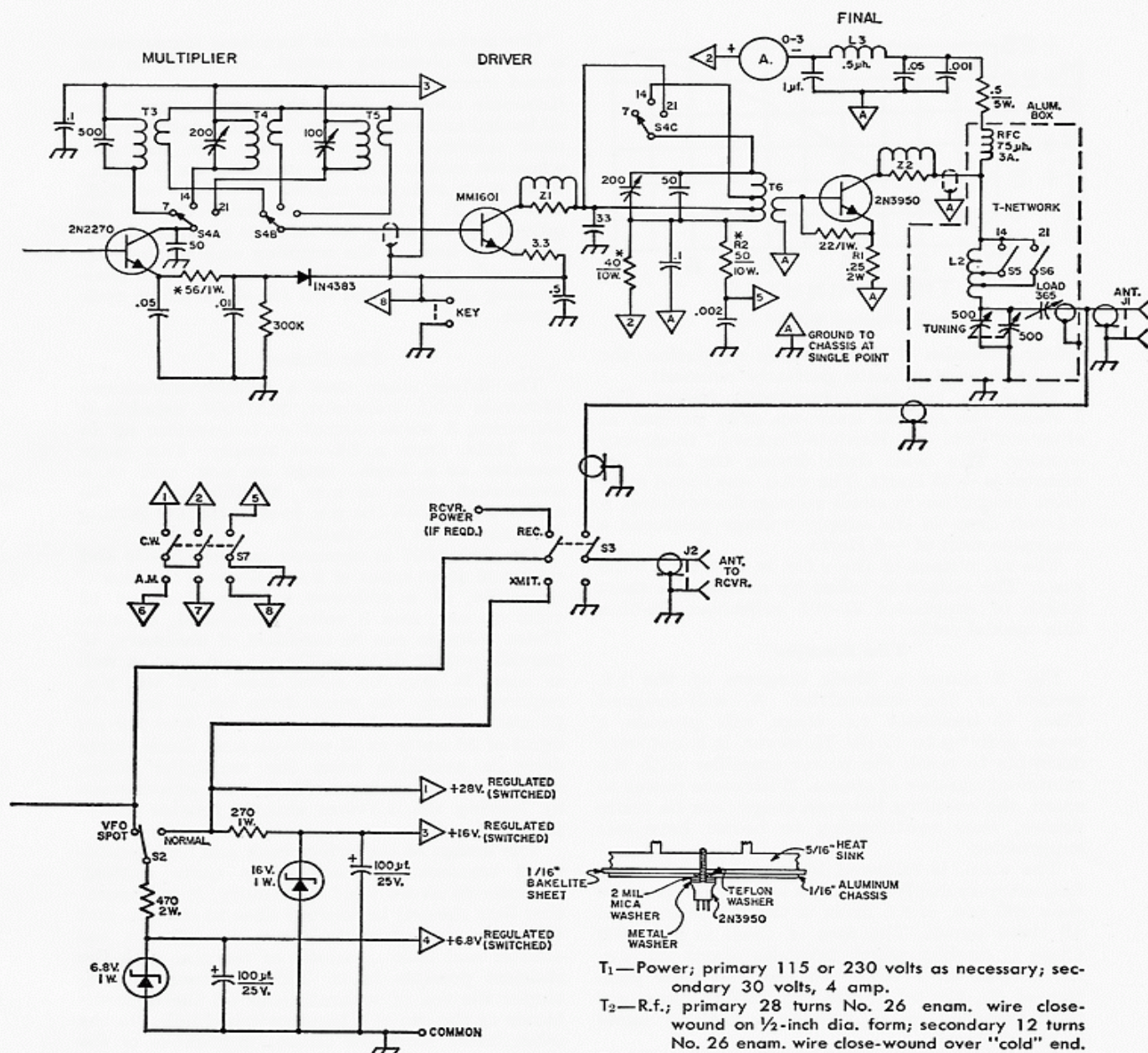
CR<sub>5</sub>—SCR, GE20B or equivalent.

J<sub>1</sub>, J<sub>2</sub>—BNC chassis connector.

L<sub>1</sub>—5  $\mu h$ ., 27 turns close-wound on No. 20 enam. wire,  $\frac{5}{8}$ -inch dia. ceramic form.

L<sub>2</sub>—1.2  $\mu h$ ., 11 turns No. 12 copper wire wound to a length of  $1\frac{1}{8}$  inches on  $\frac{7}{8}$ -inch dia. bakelite form. Tapped at 5th turn from collector end for 14-MHz. operation and 7th turn from collector end for 21-MHz. operation.

L<sub>3</sub>—0.5  $\mu h$ ., 6 turns No. 12 copper wire wound to a length of  $\frac{3}{4}$  inch on  $\frac{3}{4}$ -inch dia. ceramic form.



R<sub>1</sub>—0.25 ohm, 2 watts, low inductance; made by paralleling four 1-ohm 1/2-watt composition resistors.

R<sub>2</sub>—For text reference.

R<sub>3</sub>—10,000-ohm 2-watt control, audio taper.

R<sub>4</sub>—500-ohm 2-watt control, linear taper.

S<sub>1</sub>—D.p.s.t. toggle.

S<sub>2</sub>—S.p.d.t. toggle, minimum contact rating 4 amp. at 30 volts (Cutler-Hammer 7582K6 or similar).

S<sub>3</sub>—D.p.d.t. toggle, minimum contact rating 4 amp. at 30 volts (Cutler-Hammer 7592K6 or similar). One pole, as shown, is used for r.f. switching; the builder, instead, may wish to use this pole to control a coaxial antenna transfer relay.

S<sub>4</sub>—Miniature ceramic rotary, 1 section, 3 poles, 3 positions, non-shorting (Centralab PA-6007 or similar).

S<sub>5</sub>, S<sub>6</sub>—S.p.s.t. push-pull, heavy duty.

S<sub>7</sub>—3 p.d.t. toggle, minimum contact rating 4 amp. at 30 volts (Cutler-Hammer 7615K2 or similar).

T<sub>1</sub>—Power; primary 115 or 230 volts as necessary; secondary 30 volts, 4 amp.

T<sub>2</sub>—R.f.; primary 28 turns No. 26 enam. wire close-wound on 1/2-inch dia. form; secondary 12 turns No. 26 enam. wire close-wound over "cold" end.

T<sub>3</sub>—R.f.; primary 12 turns No. 22 enam. wire close-wound on 1/2-inch dia. form; secondary 4-turn link No. 20 enam. wire close-wound.

T<sub>4</sub>—R.f.; primary 6 turns No. 22 enam. wire close-wound on 1/2-inch dia. form; secondary 2-turn link No. 20 enam. wire close-wound.

T<sub>5</sub>—R.f.; primary 6 turns No. 20 enam. wire close-wound on 1/2-inch dia. form; secondary 2-turn link No. 20 enam. wire close-wound.

T<sub>6</sub>—R.f.; primary 20 turns No. 20 enam. wire close-wound on 5/8-inch dia. form, tapped 6 turns from the R<sub>2</sub> end for 21-MHz. operation and 10 turns from the R<sub>2</sub> end for 14-MHz. operation; secondary 2-turn link No. 20 enam. wire close-wound.

Z<sub>1</sub>—Parasitic suppressor; 6 turns No. 20 enam. wire close-wound over a 10-ohm 1-watt resistor.

Z<sub>2</sub>—Parasitic suppressor; 6 turns No. 18 enam. wire spaced to a length of 1/2 inch, wound over a 1-ohm 2-watt resistor.

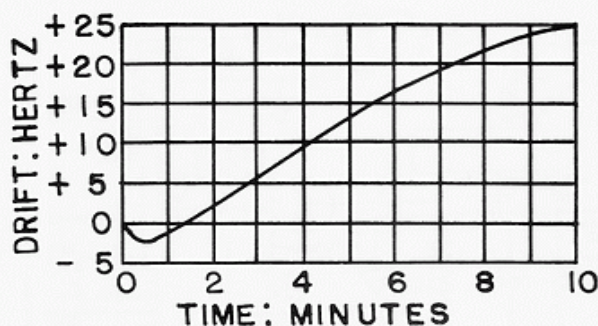


Fig. 2—Typical drift of v.f.o.

mitter. Because of this two-step regulation, the supply voltage remains perfectly constant.

The v.f.o. has been thoroughly tested. Fig. 2 shows the typical warm-up drift pattern as observed on a Hewlett-Packard frequency counter. The total drift during the first ten minutes is +25 Hertz. The v.f.o. was found to be quite insensitive to small voltage fluctuations. A 0.1-volt drop in the supply voltage produced a negligible drift of -6 Hertz.

The r.f. output of the v.f.o. is about 1.5 volts r.m.s. The output is taken by means of a short length of Amphenol 21-597 subminax 75-ohm thin coaxial cable.

#### The Exciter

Fig. 3 shows a block diagram of the r.f. section of the transmitter. A well-designed Class C transistor r.f. stage will provide a power gain up to 17 db. However, it is not very desirable to reach the power amplifier with the minimum number of stages. With some power to spare, the coupling between stages can be made lighter, thus contributing to better harmonic suppression.

The v.f.o. is followed by two high-efficiency frequency-multiplying stages which deliver more than 200 mw. of r.f. drive to the driver stage on all three bands. The first of these is a 2N706 Class C doubler which provides about 25 mw. r.f. output on 7 MHz. In the vfo spot position of  $S_2$ , the v.f.o. and the 2N706 stages are both switched on to provide a healthy signal in the receiver.

The 2N706 drives a 2N2270 Class C frequency-multiplier to an input of 400 mw. on 7, 14, or 21 MHz. Separate coils are band-switched on each band. Since the load impedance of the 2N2270 is around 200 ohms, while the input impedance of the driver is around 20 ohms, all the coils have a constant turns ratio of 3:1. The 7-MHz. coil is purposely detuned on the low-frequency side to equalize the output on all bands. The 14- and 21-MHz. coils are carefully peaked to provide the maximum output.

One serious problem in transistor transmitters is that of obtaining enough selectivity in the tuned circuits to give adequate rejection of the harmonic content. Since the tuned circuits are all loaded and work at very low impedance levels, their selectivity is rather poor. For example, when the exciter is delivering power on 14 MHz., there is an annoying amount of output on 10.5, 17.5 and 21 MHz. The selectivity can be improved by reducing the number of turns in the secondary links of the coupling coils to the bare minimum necessary. The writer is now experimenting on a toroidal coil for the doubler tank circuit.

#### The Driver

The driver stage uses a recently-introduced Motorola v.h.f. transistor, MM1601, capable of delivering 3 watts output at frequencies up to 175 MHz. from a 14-volt supply. This stage operates as a keyed stage on c.w. and as a modulated stage on a.m. Modulation of the driver along with the p.a. is essential for getting deep and clean modulation.

The MM1601 is mounted on the chassis and runs cool at an input of 2 to 2.5 watts in Class C operation, at a collector voltage of about 12 volts on c.w. and 8 volts, modulated, on a.m. These voltages can be modified, if necessary, to provide proper drive to the p.a. on c.w. as well as a.m. It may be noted here that the p.a. requires nearly the same drive for an input of 75 watts at 28 volts on c.w. as it does for an input of 25 watts at 13 volts on a.m. Since ample drive is available from the multiplier stage, negative feedback is provided in the driver stage by leaving the 3.3-ohm emitter resistor unby-passed.

The design of the driver tank coil for a multi-band transistor transmitter is quite critical. In order to avoid v.h.f. instability, it is imperative that the coil be located close to the p.a. and that the secondary link run straight to the emitter and base terminals of the p.a. with the shortest possible leads. This requirement precludes the use of separate coils on the different bands or the use of a band-switched link. On the other hand, since the output impedance of the driver is in the neighborhood of 50 ohms and the input impedance of the p.a. is about 5 ohms, a constant turns ratio of 3:1 should be maintained on all bands. The writer has reconciled these conflicting requirements in the coil design shown in Fig. 1. From the viewpoint of stability of the p.a., a high  $Q$  is not desirable for the driver tank circuit. The taps are so located that peak drive is obtained on all bands within the range of the tuning capacitor. It is desirable to provide a 50- to 100-pf. fixed mica capacitor in parallel

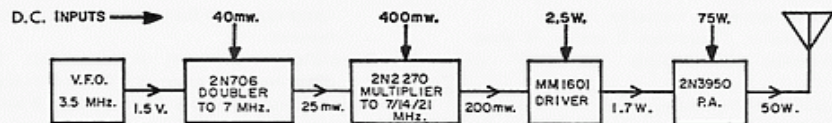
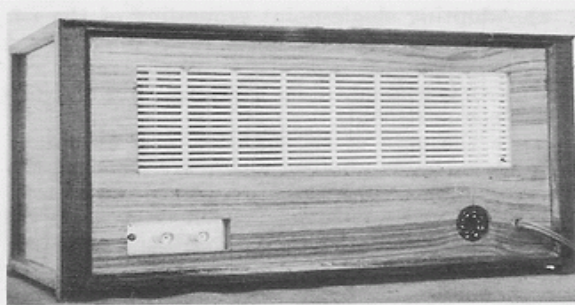


Fig. 3—Block diagram of the transmitter. R.f. levels are shown between blocks.



Rear view of the Transistor Giant, showing the author's method of ventilating the transmitter. The BNC jacks are used for connecting the antenna and the receiver's antenna input cables. The octal plug makes regulated d.c. voltage available for external use.

with the driver tuning capacitor, since reducing the tank capacitance to a low value may throw the p.a. into v.h.f. oscillation.

Although the drive to the p.a. can be controlled by detuning the driver tank circuit, this is not recommended since the harmonic suppression then suffers, especially on 14 and 21 MHz. The best procedure is to peak the driver tuning and adjust the secondary links on the collector coils of the 2N2270 multiplier stage so as to give a peak r.f. drive of 3 to 4 volts, measured at the base terminal of the p.a. The collector lead of the p.a. should be disconnected during the test. If necessary, the drive can be increased by cautiously lowering the value of the emitter resistor of the 2N2270 multiplier stage or the collector supply dropping resistor for the MM1601 driver.

### Keying

Because of the feedthrough capacitance of transistors, at least two stages must be keyed in order to get satisfactory keying. The writer has adopted emitter keying of both the multiplier and driver stages.

Emitter keying of two transistor stages is not as safe and simple as cathode keying of two vacuum-tube stages. If one of the two stages fails or starts oscillating in the key-up position,

there is the possibility of a positive voltage appearing at the emitter of the other stage, which could end up in destruction of the transistor. As a safety arrangement, therefore, the emitter of the multiplier stage is protected against any positive voltage leaking from the emitter of the driver by a silicon blocking diode.

Since the key-up voltage at the key is just about 3 volts, while the key-down current is 200 ma., the key contacts should be solid and clean for getting proper keying. It would have been better to adopt base-block keying (similar to grid-block keying), but unfortunately, there is no provision for a negative supply in the transmitter. The envelope shaping can be controlled by modifying the value of the 0.5- $\mu$ f. capacitor.

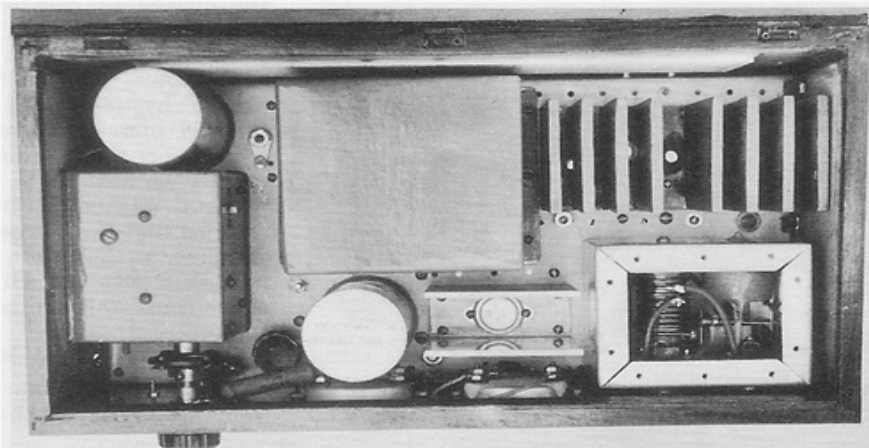
### The Final

The final employs a Motorola 2N3950 v.h.f. transistor capable of delivering an output of 50 watts at frequencies up to 50 MHz. from a 28-volt supply. The emitter of the transistor is internally connected to the TO-60 case so as to provide the very low-impedance emitter-to-ground path which is so vital for power gain. The collector voltage is 28 volts on c.w. and about 13 volts modulated on a.m. The drive power necessary to give the full input of 75 watts ranges from about 0.8 watt at 7 MHz. to 2.0 watts at 21 MHz.

The p.a. runs as a Class C stage without any quiescent bias. Although apparently a Class B stage, the p.a. actually runs as a Class C stage with a conduction angle of less than 180 degrees, since the base-emitter junction starts conducting only when the positive base voltage swings above 0.5 volt or so. When there is no drive, the p.a. collector current is zero.

When handling an input of 75 watts, the input impedance of the stage is as low as 5 ohms, and the output load impedance about 8 ohms. The input circuit is a two-turn link wound over the cold end of the driver tank coil, connected straight to the base and emitter terminals of the p.a. The output impedance is stepped up to 50 ohms by a T network, designed for a loaded Q of 6. The T network utilizes a sturdy 1.2- $\mu$ h. tank coil tapped for 14- and 21-MHz. operation.

Top view of the transmitter. The v.f.o. box is located at the left, while the shielded power transformer is near the center. The two round objects are the 3500- $\mu$ f. capacitors. The power-regulator transistor and its heat sink may be seen in front of the transformer, and on the right rear is the p.a. transistor and its heat sink. The final T-network compartment is shown with the cover removed.



**TABLE I**  
**T-NETWORK SPECIFICATIONS**

Input Impedance: 8 ohms.  
Output impedance: 50 ohms.  
Loaded Q: 6.

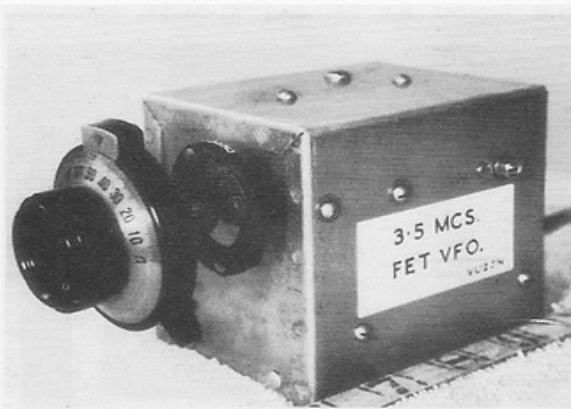
Freq., MHz.	Tank coil inductance, $\mu$ h.	Tuning ca- pacitance, pf.	Loading ca- pacitance, pf.
7	1.2	300	200
14	0.6	150	100
21	0.4	100	70

See Table I. Two heavy-duty push-pull switches are used for shorting part of the coil on 14 and 21 MHz. The tuning capacitor is a 2-gang 500-pf. receiving-type capacitor and the loading capacitor is a single-gang 365-pf. receiving-type capacitor. The loading capacitor has insulated mounting and is provided with a stop so that it cannot be turned open beyond a value of 50 pf. This precaution is necessary to prevent accidental decoupling of the antenna by inadvertent rotation of the tuning capacitor to the minimum position.

Two meters on the front panel monitor the performance of the p.a. A 0-30 voltmeter shows the voltage across the p.a., while a 0-3 ammeter shows the p.a. collector current.

Being a high-performance device, the 2N3950 is highly prone to v.h.f. and low-frequency self-oscillation, the latter being more difficult to tackle. V.h.f. parasitics have been suppressed by the following precautions:

- Providing negative feedback in the final stage by inserting a 0.25-ohm 2-watt emitter resistor.
- Loading the base with a 22-ohm 1-watt resistor.
- Inserting a parasitic suppressor choke directly at the collector pin.
- Providing an aluminum shield across the transistor and isolating the output network in an aluminum compartment.



The v.f.o. in its steel box. The box is rigidly bolted to the transmitter chassis during the final assembly stages.

e) Adopting single-point grounding of the r.f. returns of the final stage to a brass bolt affixed to the chassis.

RG-58/U coaxial cables carry r.f. into and out of the compartment.

Since the gain of r.f. transistors is frequency dependent, being greatest at low frequencies, the greatest danger to the final comes from low-frequency self-oscillation which can lead to voltage and current swings beyond the safe-area limits. The presence of low-frequency parasitics can often be noticed by carefully listening for any slight ringing or vibration of a series rheostat inserted in the collector-supply line during the initial tune-up of the transmitter. Low-frequency oscillation can be avoided with confidence only by eliminating the collector choke and feeding the collector voltage through an auxiliary tank coil forming part of the r.f. network. The writer did not adopt this arrangement since it leads to complications in band switching, but instead inserted a 0.5-ohm 5-watt wire-wound resistor in series with the r.f. choke so as to provide a certain amount of decoupling and to dampen oscillations due to resonance of the choke with the bypass capacitors.

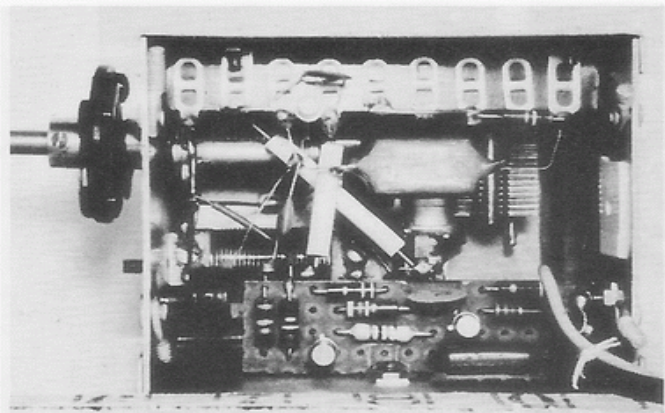
With all these precautions, the 2N3950 remains "quiet" and stable. The negative feedback in the stage does affect the stage gain. But without feedback, the final had wide-spectrum v.h.f. parasitics when run at the maximum collector voltage, possibly due to the final stage components not being located close enough to the p.a. It is no doubt preferable to compromise on the gain rather than risk losing the 2N3950!

The p.a. needs a high-capacity heat sink to take care of a collector dissipation up to 26 watts, assuming a minimum final-stage efficiency of 65 percent. For safe operation at ambient temperatures up to 45 degrees centigrade, the p.a. needs a heat sink with a thermal resistance of about 3 degrees centigrade per watt. To be on the safe side, a heavy (6-pound) integrally-cast copper heat sink is used. The heat sink was cast in a local foundry under the writer's supervision. The  $5 \times 2\frac{1}{2} \times \frac{5}{16}$ -inch base plate is machined on the bottom and tapped to receive the 2N3950. The heat sink is insulated from the chassis by a  $\frac{1}{16}$ -inch thick bakelite sheet, and is bolted to the chassis by means of four insulated bolts. Too thin an insulating layer should not be used, as this may result in excessive sink-to-chassis capacitance. The 2N3950 is insulated from the chassis by mica and Teflon washers, and is screwed onto the heat sink. See Fig. 1. Heat conduction takes place through the chassis as well as the heat sink.

Metal washers of different thicknesses should be tried and the correct one determined by trial and error so that when the 2N3950 is moderately tightened with a small spanner wrench, the pins of the transistor maintain the desired orientation.

#### The Modulator

The a.m. performance of a transistor p.a. is limited by the fact that, unlike a vacuum tube,



Inside view of the v.f.o. box. The FET is mounted on the tie-point strip appearing along the top edge of the compartment in this view.

the power transistor in a practical circuit is voltage- and current-limited, and not dissipation-limited. Full 100 percent modulation of the p.a. doubles the peak collector-emitter voltage and the peak collector current. It follows that on a.m. the collector supply voltage should be halved to prevent voltage breakdown, and the collector current should be limited to about two thirds of the c.w. value so as to avoid saturation effects. Thus, the maximum carrier input on a.m. is limited to about one third of the carrier input on c.w.

Two types of modulators are commonly used in transistor transmitters — the Class AB push-pull modulator and the Class A series modulator. The writer has adopted the series modulator in view of some of its attractive features, such as elimination of supply voltage switching for the p.a., elimination of all audio transformers, less distortion and better linearity of modulation. The chief drawback of the series modulator is the high collector dissipation of the modulator, and this is taken care of by a pair of Motorola 2N1011 90-watt p-n-p germanium power transistors in parallel.

The modulator consists of a four-stage audio amplifier capable of delivering an output of 12 watts. The audio stages work with the positive bus as the common return. The first three stages are fed from a supply of about -7 volts with reference to the positive bus, developed across a 6.8-volt Zener diode and a 5-ohm series resistor. The first stage uses a 2N123 medium-gain transistor, followed by an emitter-follower stage using a very high-gain transistor, Motorola MA288 ( $\beta = 320$ ). Hum is minimized by locating the speech amplifier close to the microphone socket and by placing the gain control after the first stage.

The second, third and fourth stages are cascaded direct-coupled stages. The d.c. bias level of the modulator is set by the 500-ohm potentiometer. The 2N1011 modulator transistors have matched 5-ohm base resistors to equalize the audio drive, and matched 0.5-ohm emitter resistors to provide a certain amount of negative feedback. The driver and modulator transistors

are mounted on the  $\frac{1}{8}$ -inch aluminum front panel with 0.002-inch thick mica insulating washers.

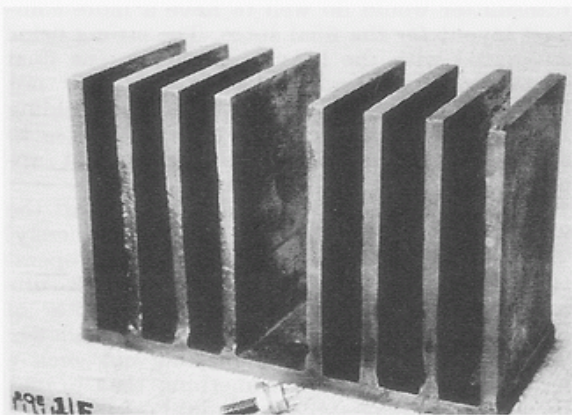
With a series modulator, it is very important to have proper division of the supply voltage between the p.a. and the modulator. A proper arrangement is to drop about 13 volts across the p.a. and 15 volts across the modulator. In the a.m. position, the bias potentiometer of the modulator is set so that the voltage across the p.a. is 13 volts when the p.a. collector current after tune-up is 1.8 amp.

### *Tune-Up of the Transmitter*

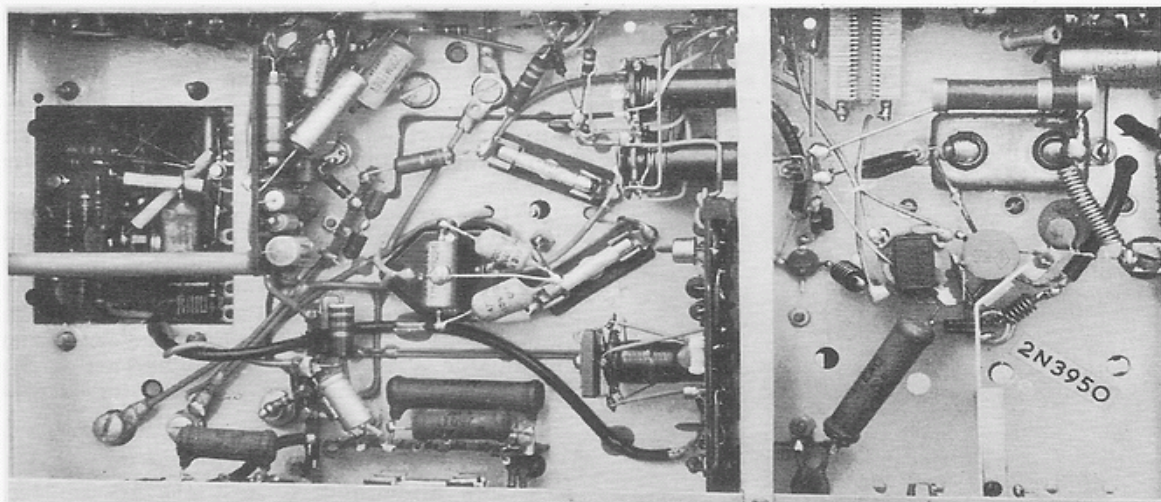
Before attempting to test the transmitter, it is worthwhile to feed the 28-volt regulated supply to an oscilloscope and make sure that the power supply voltage is free from a.c. components. The series regulator, in conjunction with the succeeding filter capacitor, may sometimes give rise to a low-frequency oscillation which will remain superposed on the d.c. supply voltage. Unless adequately suppressed, this parasitic component is almost certain to trigger disastrous low-frequency oscillation of the 2N3950.

The initial tune-up of the transmitter calls for extreme care and the observance of necessary precautions. A 50-ohm 3-amp. rheostat is inserted in the collector supply line to the p.a. A field-strength meter is a must for checking the output on the operating frequency as well as to check for the presence of any harmonic or spurious radiation.

Drive is applied and the T-network is tuned for maximum field-strength meter reading on the operating frequency. It is good practice to bring up the drive along with the loading. The collector voltage is then gradually increased to 28 volts in steps by turning the rheostat, retuning the T-network if necessary, and *making sure every*



The tiny 2N3950 p.a. transistor and the giant 6-pound heat sink.



Bottom view of the transmitter. The plate covering the bottom of the v.f.o. box has been removed at the left. The partially hidden diamond-shaped object near the center is the bridge rectifier. The frequency-multiplying stages are located on the left side of the shielding partition, with the driver and p.a. stages on the right. The upper partition divides the band-switch (hidden by the chassis lip), providing isolation between the multiplier and driver stages. The location of the 2N3950 p.a. transistor is marked in the photo. Note the shield, which just clears the transistor connecting pins. The shield isolates the input and output portions of the circuit for the final stage.

time that the collector current drops to zero in the key-up position. The p.a. can be loaded to a collector current up to 2.7 amp. on c.w. and 1.8 amp. on a.m.

After initial tune-up, the positions of the tuning and loading capacitors are marked on the front panel so that the T-network may be tuned approximately to the band of operation before applying power to the final. Also for operation, the tuning is always checked first in the a.m. position, in which the 2N3950 is comparatively safer.

Since the final is not provided with any sort of automatic bias control, operation with mismatched antennas is not contemplated. The transmitter is operated only with matched antennas of 50- to 75-ohm impedances.

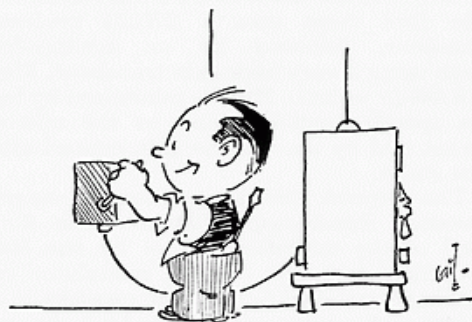
#### Conclusion

Any experimenter wishing to build a similar transmitter would do well to have a more compact layout for the final stage. The strong fields associated with the heavy currents in the final stage create unusual problems that may not be fully anticipated by the builder. Shielding and grounding assume a new perspective, so to say, in these low-impedance high-current applications.

It was discovered the hard way that the 2N3950 is too delicate to be handled carelessly! The writer is even inclined to believe that operation of the 2N3950 at the recommended 28 volts c.w. does not provide a comfortable factor of safety against base-collector voltage breakdown. The feeling one gets after burning out such a hard-to-get transistor is something that cannot be described adequately in words! Fortunately, a replacement was available to carry the project to completion.

The writer wishes to express his gratitude to Joe Mehafeey, K4IHP, but for whose spontaneous help and encouragement it would not have been possible to embark upon a project of this nature. Thanks are also due to Ed Bissell, W3MSK/VU2MSK, Marv Gonsior, W6VFR, and Bob Irish, K5ZOL, for their helpful cooperation, and to Paul Thorpe of Motorola Inc., U.S.A., for releasing transistor samples for the writer's experimental use. It is hoped that this article has highlighted the unique problems involved in the design and construction of high-power transistor transmitters for amateur-band applications.

Transistor transmitters are becoming increasingly popular in a variety of applications. As r.f. power transistors become more and more popular, their present high cost is bound to come down. The day may not be far off when a 100-watt r.f. transistor will be put in the market at a price well below that of a 6146B tube! **QST**



DO YOU KILL ALL TRANSMITTER CIRCUITS COMPLETELY BEFORE TOUCHING ANYTHING BEHIND THE PANEL?