10 WATT TRANSISTOR TRANSMITTERS FOR 1·8 — 2·0 Mc/s

Designs suitable for Mobile, Portable or Fixed Station operation

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THE increasing availability of r.f. power transistors has made it possible to produce transmitters which are particularly suited to mobile and portable working by virtue of their remarkably high power output to total power input efficiency percentage. Gone are the days when a fair proportion of the input power was for the sole purpose of heating the valves. With transistors, nearly all the power is made to do useful work in terms of radiation.

In the designs to be detailed, the p.a. efficiency is even higher than that normally associated with transistorized designs, for the writers have employed a technique which, although not new in itself, is not commonly used in r.f. applications. The result is a substantial increase in overall efficiency almost to the point where, on the face of it, power losses are non-existent. Naturally, the writers do not claim to have achieved, in a radio sense, the alchemists dream—unfortunately.

Since the major improvements in efficiency occur in the p.a. stage of the transmitters, the design and operation of these are covered first.

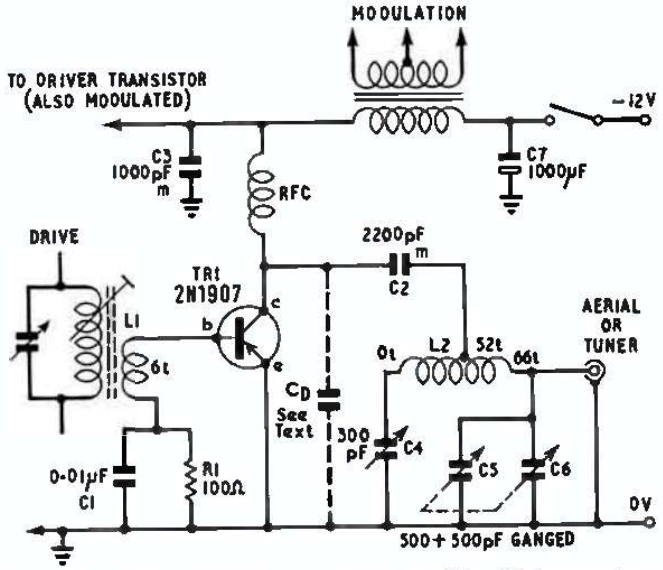

Fig. 1. The G2BCX transistor r.f. power amplifier. L2 is wound on a 1¼ in. diameter former.

The G2BCX R.F. Power Amplifier

The circuit of the improved r.f. amplifier is shown in Fig. 1, which, at first sight, may seem to be quite ordinary.

As will be seen, the r.f. drive is applied to the base of the transistor via the low impedance winding, L1, the earthy end of which is returned to the earth line through the CR network, C1, R1. Through the action of C1, R1, the negative half cycle of the drive switches the collector current of the transistor from "full on" to "fully off." *Thus in this case, the transistor has to be regarded as a switch which turns the d.c. on and off at a rate equal to the frequency of the drive.*

The output at the collector will appear as very large amplitude pulses as shown in Fig. 2a, but, due to the flywheel action of the tuned circuit, L2, C4, the "missing" portions of the waveform will be restored. In fact, and provided that L2, C4 are correctly proportioned, the output will be a sine wave with a fairly low harmonic content *at the actual aerial terminal.* Particularly note the words in italics.

The load value of the transistor is a function of the desired power output and can be found from $R_L = \frac{0{\cdot}5\ V_{cc}^2}{P_o}$ where R_L is the load resistance, V_{cc} the collector d.c. voltage, and P_o the r.f. power output. Consider an r.f. output of 10 watts at a collector potential of 12V, then substituting we have $\frac{0{\cdot}5 \times 12^2}{10} = 7{\cdot}2$ ohms. Such a low value of load resistance is not really a practical proposition when using a conventional parallel tuned circuit between the collector and the d.c. supply, and therefore an impedance transforming arrangement has to be employed.

The pi-network is ideally suited for the purpose since it will (a) effect the requisite load transformation for the collector, (b) with suitable constants resonate at the desired frequency, (c) provide matching to a low impedance aerial system, or aerial tuner and (d) act as a filter for harmonics generated by the pulsing action of the p.a. transistor.

Operation and Setting Up

The pulses developed at the collector should be of a duration of approximately a tenth of one cycle and have an

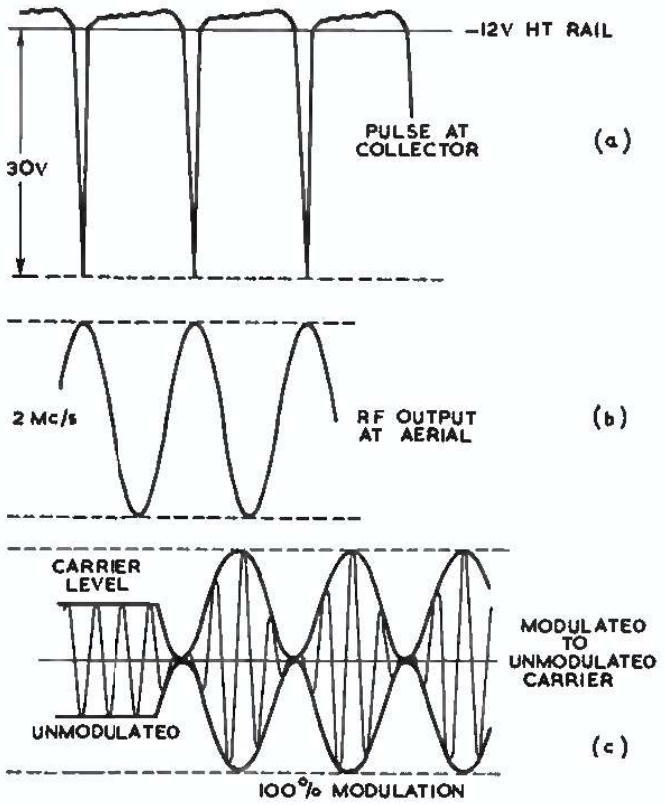

Fig. 2. Waveforms obtained from the transistor p.a. of Fig. 1.

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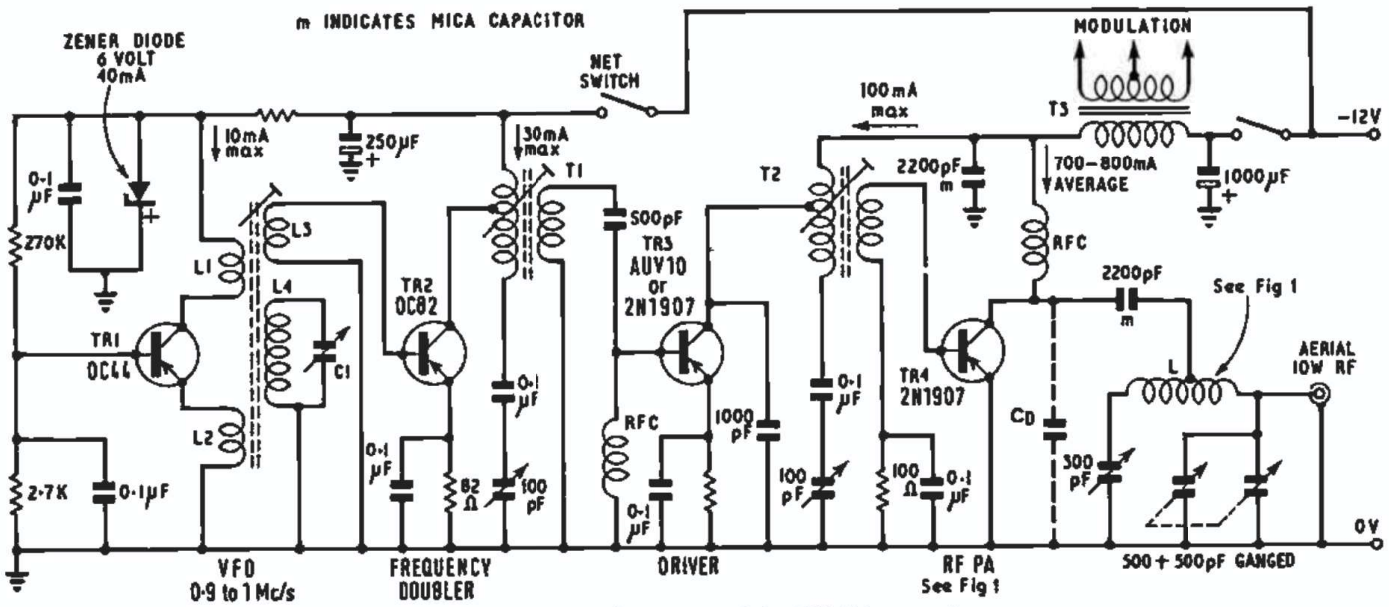

Fig. 3. The v.f.o. and driver stages of the G2BCX transmitter.

amplitude of 25 volts for an output of 9 to 10 watts with a 12V supply. It is most important that the pulse is generated with a clean waveform as any distortion, or insufficient amplitude due to damping—stray capacity, low Q in the tuned circuit, etc.—will reduce the r.f. output.

Under no circumstances should the p.a. tank circuit be tuned without the output being loaded.

Preliminary tests should be carried out with an oscilloscope. The Y amplifier on an average oscilloscope may not be capable of displaying the collector pulse in a satisfactory manner, for this amplifier must have a frequency response to at least four times the operating frequency. In this case, this requires that the Y amplifier extends to about 8 Mc/s without appreciable overshoot. Where difficulty is encountered, the pulses should be fed directly to the Y plates via an isolating capacitor of not less than 0·1µF.

It is essential to verify that the transistor is operating in the correct manner, for operation in any other mode can produce noise together with/or harmonics of considerable amplitude which could damage the transistor. It is also equally essential to include a large value capacitor (1,000µF) across the h.t. line immediately after any on-off switch to prevent large d.c. pulses being developed by inductive parts of the circuit such as the modulation transformer secondary, r.f. chokes, etc. Pulses of up to 500V could be produced by switching without the protection of such a condenser, and this might well result in the destruction of the p.a. and other transistors in the transmitter.

Efficiency

The usual method of measuring the d.c. power input to p.a. stage is to multiply the current taken by the voltage applied. For example, a class C valve p.a. may have an anode current of 40mA at an applied voltage of 250V, in which case the d.c. input would be 10 watts. Under these conditions, the same valve may deliver 6–7 watts of r.f. to the load indicating an efficiency of 60–70 per cent.

Due to the pulsed nature of the output from the transistor p.a. being described, similar calculations will not apply for an average meter will not respond to the *peak* current taken by the transistor. For example, while the p.a. may be found to be delivering 10 watts into a load, the measured current input from a 12V supply may be as low as 700mA on a meter indicator, and thus the measured input would be 8·4 watts. On the face of it, one appears to be getting something for nothing, but it is the indicated current which is in error. Indeed, if the indicated d.c. input is high, this could well mean a poor pulsing action by the p.a. transistor.

The actual efficiency of the p.a. can be expected to be impaired slightly by the resistance of the secondary winding of the modulation transformer, and that of the r.f. choke. Both of these items must have a low d.c. resistance, that of the r.f. choke not exceeding 6 ohms, but preferably less.

Notes on the G2BCX Transmitter

The circuit of the complete transmitter is shown in Fig. 3 to which the following notes relate.

(i) Approximately 6 watts of audio power are required to modulate the 2N1907 p.a., and this can be obtained from a transistorized modulator employing two OC25s in class A push-pull.[1]

(ii) The v.f.o. TR1 is of comparatively simple design, but, is nevertheless, sufficiently stable even under mobile conditions. The v.f.o. operates between 0·9 Mc/s and 1 Mc/s and therefore requires the following stage, TR2, to be a frequency doubler.

(iii) The driver stage is also modulated to ensure modulation up to 100 per cent.

(iv) If an AUY10 is used in place of the 2N1907 in the p.a., the capacitor shown dotted, C_D, may be required. Excessive off-tune noise can suppressed by means of this capacitor which should have a value of the order of 1,000pF (mica), but its use will reduce the r.f. output by about 10 per cent (use of the AUY10 in this circuit is not recommended).

(v) The pi-network p.a. tank coil, L, should be wound with at least 18 s.w.g. enamelled wire, or with a comparable diameter Litz wire, in order to maintain a high Q.

(vi) An r.f. thermocouple ammeter measuring up to 1 amp, and a 40 to 70 ohm carbon resistor capable of dissipating 10 watts without undue heating will be adequate for dummy load testing.

If the transmitter is functioning correctly, it should be possible to produce *an r.f. power of 10 watts* into the load, while a d.c. meter in the p.a. indicates between 700mA–750mA with a 12V supply.

(vii) To check for TVI, the transmitter has been operated at 10 watts output, fully modulated, into a vertical aerial some 20 ft. from a television receiver. No trace of patterning or sound breakthrough was detected on any TV channel.

THE G3FEW TRANSISTOR TRANSMITTER

This section deals with a completely transistorized transmitter devised by G3FEW and which employs a pulsed r.f. stage and covers 1·8 Mc/s–2 Mc/s. The unit is complete with its own modulator. A mains power pack, employing electronic stabilizing, is also described for when the unit is used under fixed station conditions.

The R.F. Section

The circuit of the G3FEW transmitter r.f. section is shown in Fig. 4.

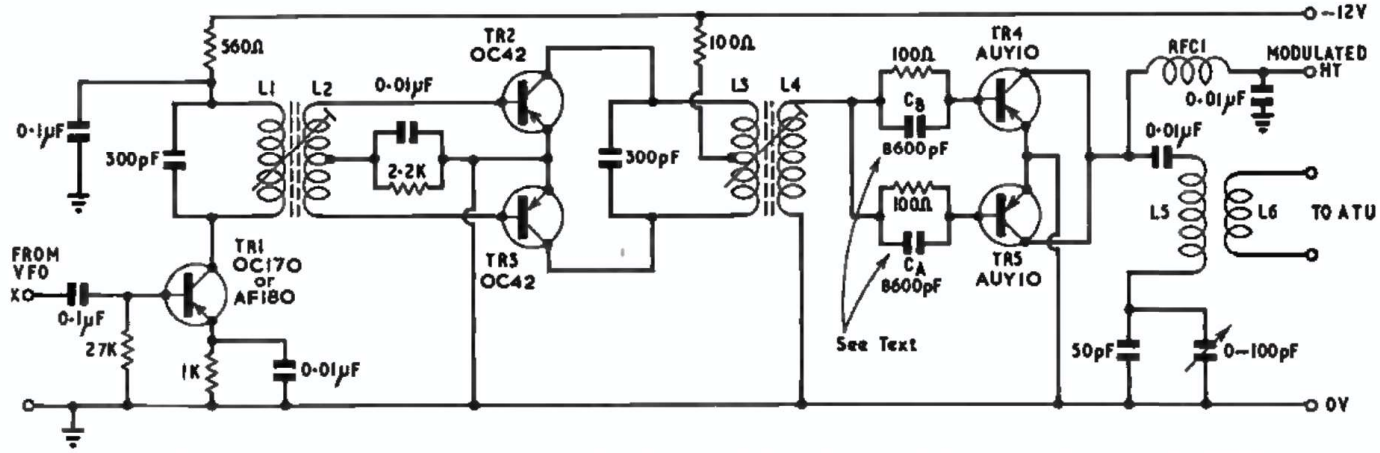

Fig. 4. The G3FEW transistor transmitter. L1, 30 turns; L2, 5 + 5 turns; L3, 15 + 15 turns, L4, 4 turns. L1-4 are wound with 28 s.w.g. enam. copper wire on ½ in. diameter slug-tuned formers. L5, 100 turns, 20 s.w.g. enam., ½ in. diameter with iron dust core; L6, 40 turns, 20 s.w.g. enam. and L7, 4 turns, 20 s.w.g. enam. on 1½ in. diameter ribbed former.

TR1, OC170, operates as a class B amplifier and requires an input of 3 volts from the v.f.o. The collector of this stage is connected across the whole of the winding of L1, and this has the effect of reducing the *Q* and providing a broadband transformer effect. The secondary winding, L2, is coupled to a pair of OC42s also operated in class B and connected in push-pull, the output of which is of the order of 150mW. As with TR1, the collectors of TR2 and TR3 are connected across the whole of the winding of L3, and for the same reason, namely to produce a broadband effect. The coupling winding, L4, feeds the base circuits of TR4 and TR5, which are a pair of AUY10s connected in parallel, and the bias for each of these transistors is developed across individual resistors in each base lead, one in parallel with C_A and the other in parallel with C_B. This bias should be approximately 0·7 volts positive.

As with the G2BCX p.a., due to the low saturation voltage obtained with the transistors in the p.a. stage, this can be regarded as a 2 Mc/s switch, the collector waveform of which will be as shown in Fig. 2. The pulses produced will have a peak current of about 1 amp at 12 volts depending on the amount of drive, and the duration of the pulse. Again it is stressed that a moving coil instrument will not indicate the correct peak input current, and that investigation of the operation of the p.a. should be in the manner previously described.

No particular difficulties should be encountered with the circuit of Fig. 4 when using the components specified, and a 12 volt supply. However, the greatest care should be taken if any attempt is made to increase the input power, and under such circumstances it is vital to measure the peak input power, for, to exceed the peak collector rating, even for the duration of one pulse, could be fatal to the p.a. transistors.

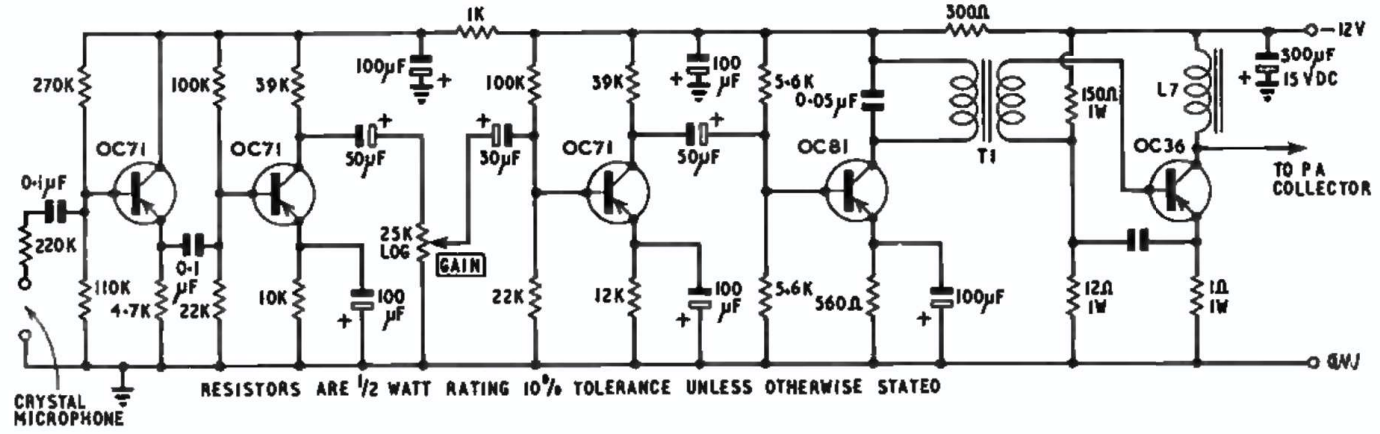

Fig. 6. A modulator for the G3FEW transmitter. T1 is a standard car radio driver transformer, and T2 is a similar output transformer.

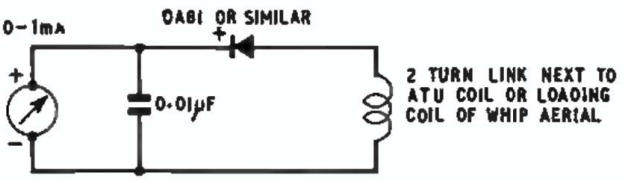

Fig. 5. Simple r.f. meter for tuning.

While the p.a. tank circuit may appear unconventional, this arrangement has been employed since it provides maximum power transfer from the p.a. to the aerial circuit. Furthermore, it is not critical in operation.

As with the G2BCX p.a., the p.a. of this transmitter should not be tuned without a load. The p.a. transistors only draw the correct operating current when the circuit is tuned to resonance and loaded, and without such a load, dangerously high currents can be passed by the collectors of the p.a. transistors, especially if the circuit should happen to be operated at greater than 10 watts input. The best method of tuning is to employ the simple r.f. indicator shown in Fig. 5, coupled either to the a.t.u. or the loading coil of the whip where such an aerial is used. Simply tune the transmitter for maximum r.f. output.

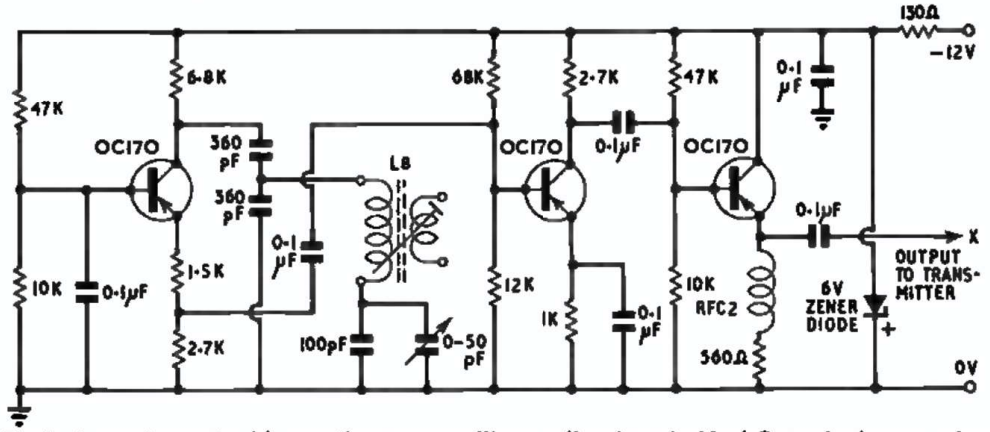

Fig. 7. A transistor v.f.o. L1, a medium wave oscillator coil such as the Maxi-Q standard range, colour coded red.

The transformers L1-L2 and L3-L4 should be tuned so as to provide constant drive over the whole band. Suggested frequencies are 1850 kc/s and 1950 kc/s which have been found satisfactory in practice. Once these are set, tuning the transmitter reduces to setting the v.f.o. to the correct frequency, and then tuning the p.a. for maximum output.

Modulator

Unlike the G2BCX design, in the G3FEW transmitter, modulation is only applied to the p.a. stage.

The audio modulator is a single OC36 which develops some 4 watts of audio which is quite sufficient to fully modulate the AUY10s up to an r.f. output of 8 watts.

The circuit of the speech amplifier stages and final modulator is shown in Fig. 6. The input of the amplifier is arranged for a crystal microphone, but a moving coil, or other low impedance microphone may be used simply by omitting the first OC71 stage. The driver transformer, T1, and the output choke, L1, are standard car radio driver and output transformers. The frequency response of the amplifier has been arranged so that there is a fairly sharp fall off below 300 c/s, and above 2500 c/s.

Variable Frequency Oscillator

The circuit of a transistorized v.f.o. suitable for driving this transmitter is shown in Fig. 7. In this an OC170 is used in a Clapp derived circuit followed by an untuned buffer amplifier and an emitter follower. No drift is detectable with a Zener diode stabilized supply which provides 6 volts for the oscillator. On "stand-by" the oscillator supply can be switched with the rest of the transmitter.

Mains Supply

The circuit of a suitable supply to allow the transmitter to be operated under fixed station conditions and from a.c. mains is shown in Fig. 8. This circuit features electronic stabilizing and smoothing which eliminates the need for large chokes and smoothing capacitors, while at the same time providing protection against overload and short circuits.

The output voltage is constant for currents up to 2 amps, after which the terminal voltage falls rapidly. Construction is relatively unimportant so long as the output transistor is mounted on a heat sink made from 16 s.w.g. material and has an area of not less than 49 sq. cm. Almost any power transistor may be employed so long as it has a current rating of at least 5 amps.

Conclusion

Both of the transmitters described have been in operation for over a year and have given highly satisfactory service under mobile, portable and fixed station operation.

The high efficiency of these units has a pronounced effect on signal strength reports, especially when comparisons are made between valve transmitters and these units operating into the same aerial system.

Development of pulsed p.a. stages is being continued, and it seems likely that push-pull stages for up to 50 watts or more at frequencies of at least 30 Mc/s should be possible. In relation to this, however, it should be mentioned that whilst transistors for such applications are still expensive, those employed in the transmitters described in this article are readily available at reasonable prices.

References

[1] *Survey of Transistors for Amateur Use*, by T. D. Towers. Available from Newmarket Transistors Ltd.

[2] "Transistor Transmitters for 8 Mc/s." *Mullard Technical Communications*, Vol. 7, No. 62, January 1963.

[3] "8 Mc/s and 30 Mc/s H.F. Amplifiers." Mullard New Products Information TP807, 1964.

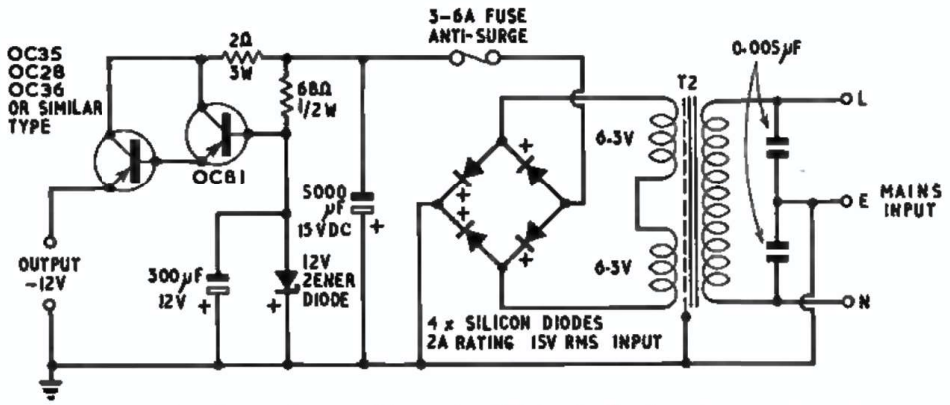

Fig. 8. Power supply with electronic smoothing and stabilizing for fixed station use. T1, mains transformer with 12 volt 2 amp or two 6·3 volt 2 amp winding in series.