The G2DAF Linear Amplifier

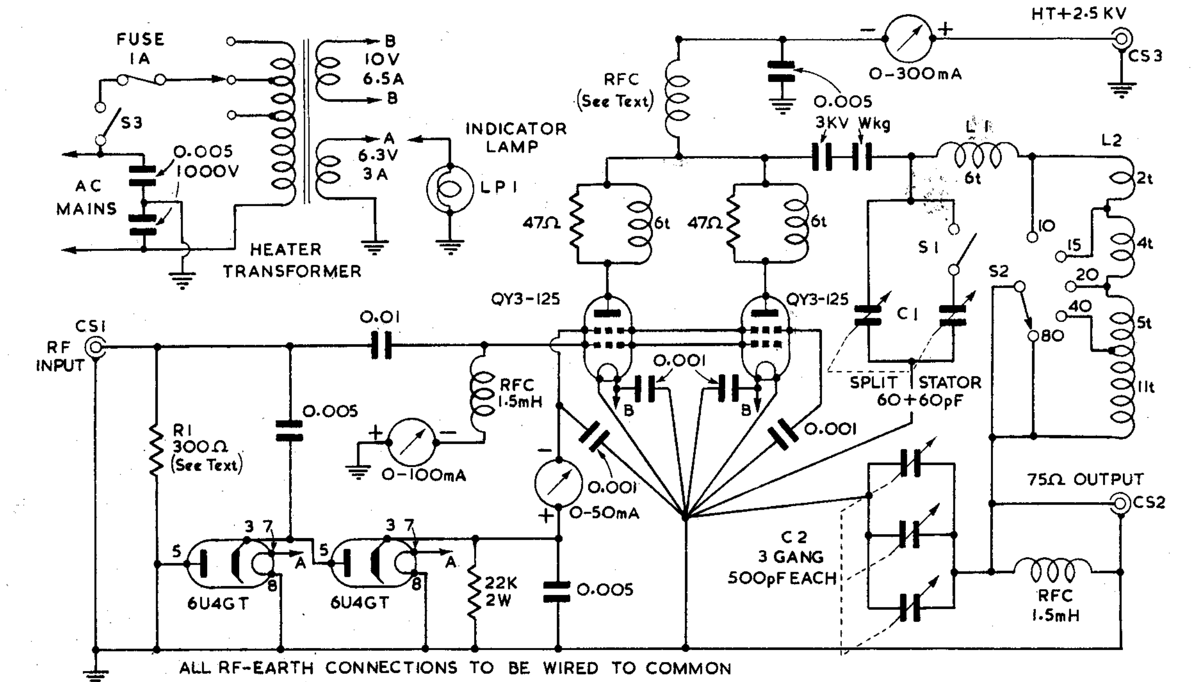
IN the G2DAF linear amplifier the valves are operated under zero bias conditions and without the complication of screen dropper resistors, stabilizer or clamper valves. The screen voltages are derived by rectifying a small portion of the input signal. The amplifier may be driven by the G2DAF s.s.b. transmitter Mk. 2 without modification.

The complete circuit diagram is shown in Fig. 19. The diode rectifiers may be either semi-conductors of the point contact type suitable for r.f. use, or alternatively thermionic valves. Suitable rectifier valves are already available at low initial cost and were used in the original amplifier. The main requirement is a good heater-cathode insulation and a heater rating suitable for the additional 6 volt winding generally provided on standard p.a. heater transformers. Suitable valves are the Brimar 6U4G or the Mullard EY81. The Brimar valve is preferred because the anode connection is brought out to a base pin and, as this is underneath the chassis, it is screened from the p.a. output circuits.

* Condensed from an article in the April 1963 issue of the RSGB BULLETIN.

The pi tank coil is wound on an Eddystone 2½ in. diameter ceramic former grooved eight turns per inch, and this is attached to the switch (from a TU5B unit) before it is fitted to the panel. A gap of one groove is left between the 15 and 20, and 20 and 40m sections. The total winding length of 16 s.w.g. tinned copper wire is 3¼ in. For the 10m band the coil of six turns of 12 s.w.g. wire is spaced to approximately 2 in. long and is self-supporting—with the axis at right angles —between the tuning capacitor and the end of the main tank coil.

The pi tank values depend on the required value of anode load (R_L) and as with any amplifier it is important that the valves are operating into the correct load. If they are not, both the power handling capability and the efficiency will suffer. Assuming that V_a is the h.t. supply voltage; $V_{a(min)}$ the instantaneous anode voltage at its lowest point; $I_{a(dc)}$ the maximum signal anode current meter reading; then $I_{a(peak)} = I_{a(dc)} \times K$ (where K is a constant dependent on the angle of current flow—in this case approximately 3) and $R_L = 2(V_a - V_{a\ min})/I_{a\ peak}$. For the amplifier under consideration $R_L = 2(2500 - 250)/0{\cdot}3 \times 3 = 5000$ ohms.



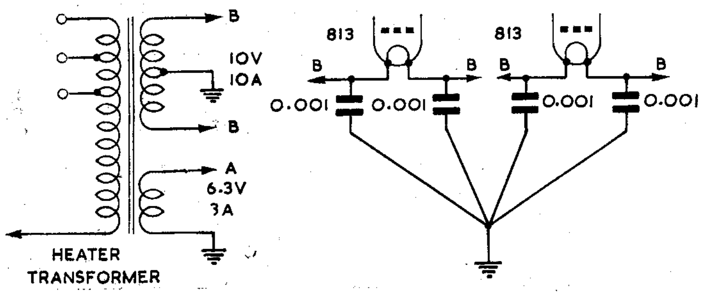


Fig. 19. Circuit diagram of the G2DAF linear amplifier. S1 should be open for 10, 15 and 20m., closed for 40 and 80m. Details of L1 and L2 are given in the text. All fixed capacitors mica, except the 0.005μF 3 kV anode blocking capacitor and h.t. bypass which are disc ceramic. For CS3 (high voltage input) Belling-Lee chassis sockets and co-axial plugs are available coloured red. S1 and S2 are ceramic switches. Connections to the panel meters are made via coaxial cable. Suitable screen rectifiers are the 6U4GT, EY81 and 6X4 with the anodes strapped together. The circuit is equally suitable for use with a pair of 813s which have 10V 5A filaments. The revised arrangement of the r.f. bypass capacitors and heater winding is shown at the left.

The pi constants are then R_L = 5000 ohms; $R_{L(out)}$ = 75 ohms. The ratio $R_L/R_{L(out)}$ = 5000/75 = 66. The square root of 66 is approximately 8 and this is the reactance ratio (XC1 : XC2). For a Q of 12:

$$XC1 = RL/Q = 5000/12 = 416 \text{ ohms}$$
$$CX2 = XC1/8 = 416/8 = 52 \text{ ohms}$$
$$XL = XC1 + XC2 = 416 + 52 = 468 \text{ ohms}$$

These values are a simple approximation but are quite near enough for amateur purposes. From a reactance chart the values for 80m are C1 = 116 pF; L = 20 μH; C2 = 900 pF. Values for other bands scale down in the same ratio as the band wavelength as follows:

Band	*C1*	*L*	*C2*
80m	116	20	900
40m	58	10	450
20m	29	5	225
15m	20	3·5	160
10m	15	2·5	113

The type of transmitter tuning capacitor suitable for C1 generally has semi-circular rotor plates and therefore a large minimum capacity value—usually about 15 to 20 pF. This, together with circuit and valve anode capacity, will make up a total that is greater than required for the 10 and 15m bands. It is possible to overcome this in two ways, (i) redesigning the tank circuit for a higher Q value of, say, 15 or 20; (ii) reducing the minimum capacity of C1. A high value of Q in the tank coil will increase the circulating r.f. currents and therefore the losses. Accordingly the second expedient has been adopted and the tank capacitor was, in fact, made into a two-gang unit of 60 pF each section by sawing through the bars holding the stator plates. One section only is connected to the 10m coil and the anode r.f. blocking capacitor and this tunes the three higher frequency bands. The other section is switched in parallel for the 40 and 80m bands. In addition to reducing the minimum capacity value, this method also doubles the dial bandspread and makes tuning less critical on the 10, 15 and 20m bands.

The required air gap for C1 is approximately one-tenth of an inch. A standard three gang broadcast tuning capacitor of 500 pF each section is suitable for C2 and provided the amplifier is working into a load (as it should be) the plate spacing is ample to prevent flashover.

The r.f. choke comprises 300 turns of 32 s.w.g. enamelled wire wound in unequal sections—165, 65, 35, 20 and 15—on a ceramic former 1 in. in diameter and 5½ in. long with a ⅛ in. spacing between each section. Standard multi-section pie wound r.f. chokes are unsuitable for pi-tank circuits and should not be used. A standard 1·5 mH r.f. choke rated for at least 300 mA is connected across the output co-axial socket as a safety precaution that should never be omitted when high voltages are in use. Should there be failure of the r.f. blocking capacitor the h.t. current through the choke will blow the main h.t. fuse and prevent h.t. voltage reaching the aerial circuits.

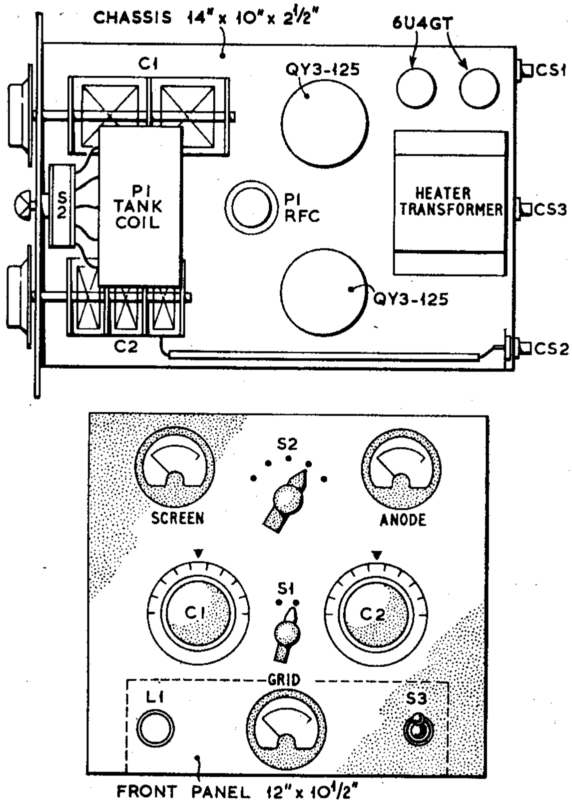


Fig. 20. Chassis and panel layout for the G2DAF Linear Amplifier.

TABLE 5

Amateur Band operating conditions (400 watts p.e.p. output) for two QY3-125 valves.

V_a = 2·5 kV	*Single-tone*	*Two-tone*
Anode current	250 mA	175 mA
Power input (d.c.)	650 watts	440 watts
P.E.P. input	650 watts	660 watts
I_{g2}	38 mA	22 mA
I_{g1}	70 mA	45 mA
V_{g2}	105 volts	75 volts
V_{g1} (r.m.s.)	65 volts	64 volts
Driver Load (p.e.p. out)	30 watts	35 watts
Anode Dissipation	250 watts	240 watts
Power Output (mean)	400 watts	200 watts
P.E.P. Output	400 watts	400 watts
Anode Efficiency	61·5 per cent	46 per cent

Typical operation with 300 ohm grid swamping resistor.

With an anode supply of 3 kV the efficiency figures will show an improvement on those quoted. It is estimated that they will be as follows:

Single-tone efficiency = 72 per cent. Two-tone efficiency = 58 per cent.

Operation

Tuning and loading is exactly the same as a conventional class AB amplifier. Initially the drive level is increased until the anode current meter reads 150 or 200 mA. With the loading capacitor fully meshed, the anode tuning is adjusted for a dip in anode current. With the tank circuit at resonance, the screen current will be a high value. As the loading is increased by reducing the capacity of C2, the anode current will rise and the screen current will fall in the usual manner. The drive can now be increased until the grid, screen and anode currents are the required values.

Should the amplifier have been built using some other type of valve, the manufacturers' figures for class AB1 or AB2 working can be used initially. If an oscilloscope is available the amplifier should be driven with a two-tone input and the modulation envelope monitored on the c.r.t. It is then a simple matter to adjust excitation, tuning and loading for maximum r.f. output consistent with adequate loading to prevent flat topping or other distortion of the modulation envelope. The grid, screen and anode currents are then noted and in all subsequent operation the amplifier is adjusted to obtain these values. If an oscilloscope is not available, the loading should be adjusted so that the dip in anode current is not more than about 20 per cent of the off-resonance value, i.e. 250 mA off-resonance—load to 200 mA at resonance. A golden rule to observe is, "If in doubt, load heavily!" Under speech conditions adjust the exciter audio gain or r.f. drive so that the anode meter does not swing beyond half the steady signal value. Remember that the meter movement cannot follow at syllabic rate—if it swings up to 150 mA, the true maximum signal current is at least twice this value.

The question of harmonic generation and TVI as a result of the method of operation is of importance to all amateurs. Tnis can only be answered by stating that careful measurement of harmonic output using the identical amplifier under (i) conventional class AB2 conditions, and (ii) the G2DAF method of operation, indicate clearly that there is not in fact any appreciable difference between the two methods.

The 813 in the G2DAF Linear Amplifier

In many ways the 813 is a quite remarkable valve—in fact its performance in the G2DAF amplifier is quite outstanding. With 2·5 kV anode potential it is possible to run *one* valve to the full maximum licence rating of 400 watts p.e.p. output. This is possible without degradation of linearity, and in fact " on the air " reports indicate that the intermodulation distortion products are at a level 45db down in relation to the wanted voice sideband signal. This is about 5db better than the writer's amplifier using a pair of 4-125A valves.

Running amplifier valves beyond the rated maximum-signal anode dissipation is a method of operation that has been used by a number of single sideband operators in the past. Because the valve only exceeds the rating on voice " peaks " and has resting periods in the " troughs " the average dissipation over a period of time embracing a number of words is less than half of the peak-signal value. Due to this fact it is possible to grossly overdrive a valve and get away with it!

The 813 running to a p.e.p. output of 400 watts is being operated at a level where the two-tone input power is 500 watts d.c. and the anode dissipation is 300 watts. This is greatly in excess of the manufacturers' rating of 125 watts, and while it is permissible to do this under voice input conditions where the valve is only being driven to its peak input at syllabic rate, it would be dangerous under continuous single-tone or two-tone input conditions. This means that the amplifier—at maximum input—cannot be correctly loaded or monitored on the oscilloscope, other than for a very short period of time. For this reason it is recommended that a single 813 is not driven to a power output of more than 200 watts p.e.p. If the requirement is the full licensed maximum, the amplifier should be built using two 813 valves in parallel.

At 2·5 kV anode potential the zero signal anode current (one valve) is 45 mA and the anode dissipation 112·5 watts. This is just nicely inside the rated dissipation of 125 watts and therefore limits the maximum h.t. supply voltage to 2·5/2·75 kV. For those operators who do not like high voltage power supplies, the valve will operate just as satisfactorily in regard to low distortion product level with 1·2/1·5 kV, but obviously the output power and the efficiency will be less.

The 813 is a high voltage-low current valve and therefore requires a high value of anode load (R_L). For one valve at 2·5 kV anode voltage the recommended value of R_L is 10,000 ohms, and for two valves in parallel 5,000 ohms. Table 6 gives the maximum signal operating conditions for both single-tone and two-tone inputs. The efficiency figures are lower than for the more modern valves such as the QY3-125 and 4X150A, as would be expected, but in fairness to the 813 it should be noted that measurements were made with one valve in the standard station amplifier (normally using two 4-125A valves) with a tank circuit designed for an anode load of 5,000 ohms. Under the correct operating conditions—R_L = 10,000 ohms—the efficiency figures would be improved. Reference to the Mullard manual *Valves for Single Sideband Suppressed Carrier Service* will show, however, that at 2·5 kV anode potential the usual figure for two-tone efficiency for the modern tetrodes is nearer to 40 per cent and in practice any amplifier giving an efficiency figure for two-tone input of between 40 and 50 per cent is doing very well and can be considered to be operating in a satisfactory manner. Fortunately the s.s.b. operator is rated by the GPO on output power so the lower efficiency of the sideband linear amplifier is not of any particular importance. What is of particular importance is the amplifier linearity—the better the linearity the lower the distortion product level. It is far better to operate at a lower level and sacrifice some of the efficiency and it is sincerely hoped that all prospective operators of the G2DAF amplifier will bear this in mind. After all, another 100 watts obtainable by " pushing " the amplifier means about one more decibel on the signal strength—is it worth it? To any sensible amateur who takes a pride in his signal the answer is " No!"

TABLE 6

One 813 Valve (V_a = 2·5 kV)	*Single-tone*	*Two-tone*
Anode Current	260 mA	200 mA
Power in (d.c.)	650 watts	500 watts
P.E.P. input	650 watts	650 watts
Screen current	17 mA	8 mA
Grid current	25 mA	12 mA
Screen voltage	210 volts	170 volts
Grid Drive (r.f.)	110 volts r.m.s.	105 volts r.m.s.
P.E.P. output	400 watts	400 watts
Power output (mean)	400 watts	200 watts
Anode efficiency	61·5 per cent	40 per cent

Construction

Prospective constructors of any high power linear amplifier should realize that higher power may bring increased TVI problems. All reasonable precautions should therefore be observed. These include thorough screening, with v.h.f. r.f. chokes and non-inductive bypass capacitors on all outgoing supply cables, a single earthing point for all return paths for C1, C2. the screen bypass capacitors and the heaters of the p.a. valves. All connections carrying r.f. should be made with copper strap at least ½ in. wide and 10 thou. thick and not more than 3 in. long—every endeavour should be made to keep these connections as short as possible and in fact the amplifier should be built as if operation is intended on 60 Mc/s. If the amplifier is using one valve with the heater winding floating and the transformer centre tap earthed, both heater pins of the valveholder must be effectively bypassed for r.f. with mica or ceramic capacitors taken to the common earthing point. On the higher frequency bands the transmitter output should be fed into the aerial via an efficient low-pass filter giving at least 60db suppression at television frequencies in Band 1. Finally, TVI can be caused by sheer weight of r.f. at the *fundamental* operating frequency. An increase in power of four or five times may be sufficient to cause overload or cross-modulation in nearby TV receivers that were previously unaffected.