Class 'A' Amplifier

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THIS type of amplifier which was designed whilst looking for a suitable unit to use in a theatre has been developed with two particular requirements in mind: reliability and short circuit protection of the output.

DESIGN CONSIDERATIONS

Class A was attractive for two reasons, which can be illustrated by reference to the conventional R.C. coupled stage shown in Fig. 1. The circuit is asymmetrical, there being only one transistor, which gives a low component count. Also the quiescent current through the stage is defined by the resistors and hence is not temperature sensitive. There is a bonus also from this type of circuit, as the output transistor is never turned off, there is no crossover distortion.

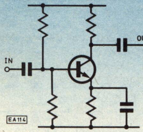


Fig. 1. Conventional R.C. coupled stage

There is, of course, one serious drawback with Class A, it's poor electrical efficiency. Sometimes referred to as conversion efficiency; the ratio between actual power into the load and power supplied from the d.c. supply. The best that can be achieved is about 17 per cent and that ignores the emitter resistor. Which would mean that a 50 watt amplifier consumed at least 294 watts and getting rid of 244 watts of heat (294-50) can be something of a problem.

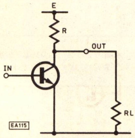


Fig. 2. Simple Class A circuit

If we look at a simplified Class A circuit without the complications of biassing and coupling as in Fig. 2 and consider the two *limiting conditions*. Firstly with TR1 just about cut off, i.e. the maximum positive excursion of the output. The current through the load R_L is $E/R + R_L$, but this current also flows through the collector resistor R; hence if W watts appears in the load, then WR/R_L watts appear in this resistor, which is wasted power. If R could be made very small this wasted power would also be small.

The other limiting condition appears when TR1 is just about saturated (ignoring the small collector-emitter voltage), the current through R_L is zero and hence the power is zero whilst the current through the collector resistor R is E/R and the power E^2/R, all the power is wasted. If R could be made large then this wasted power would be reduced.

This shows the two conditions have conflicting requirements. When the output is positive going R must be small, when the output is negative going R must be large.

An emitter follower, Fig. 3, has the property of impedance

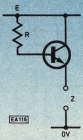
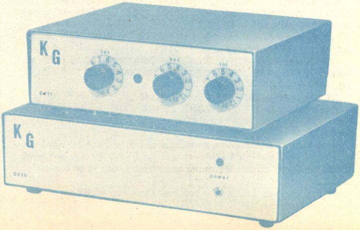


Fig. 3. Emitter follower circuit

reduction. The impedance Z measured between emitter and 0V (ground or signal earth) will be considerably less than the value of the base resistor R. Very roughly, it will be reduced in proportion to the current gain of the transistor, e.g. if the current gain is A then

$$Z = \frac{R}{A} \text{ approx.}$$

Returning to Fig. 2. If an arrangement having the characteristics of an emitter follower could be associated with R the collector resistor; and in addition, if this arrangement could be switched on whilst the output signal was positive going (made low resistance) and inhibited (high resistance) whilst the signal was negative going, then this would solve the conflicting requirements.



The requirement is to reduce the value of R whilst the output is positive going, i.e. supplying current (conventional flow) not during positive half cycles, the two are quite different. The same point must be made about the converse situation. The value of R must be increased whilst the output is negative going, i.e. demanding current, not the same thing as during negative half cycles.

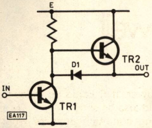


Fig. 4. Basic Class A stage with an emitter follower

Fig. 4 shows a basic combination of a Class A stage (Fig. 2) and emitter follower (Fig. 3). This combination is called Composite Collector Load Class A. The emitter follower being switched in or out of use by the diode D1.

Considering first the positive going situation where current is being supplied to the output. The collector potential of TR1 will rise in an attempt to supply current to the output or load. This situation will reverse bias diode D1 and forward bias the base emitter junction of TR2 which then behaves as an emitter follower supplying current to the load. The current through R will be only a small proportion of the load current, or looking at it another way the combined effect will be that of a collector resistor considerably smaller than R actually is.

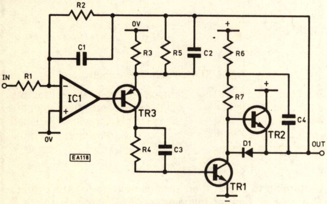


Fig. 5. Improved Class A circuit

Now consider the opposite situation when TR1 collector is negative going attempting to draw current from the output. The diode D1 will be forward biased and the base emitter junction of TR2 reverse biased. TR2 is thus out of action and the effective collector resistance is R only. TR1 thus absorbs the current from the load plus a small current via the resistor R.

CIRCUIT DESCRIPTION

The basic circuit shown in Fig. 4 *illustrates the* principle involved. To convert this to a practical design requires the addition of components to provide d.c. bias, the necessary a.c. drive to the base of TR1 and negative feedback to improve the performance. As shown in Fig. 5.

Resistors R1 and R2 establish the overall gain between input and output, which is equal to R2/R1. R2 also establishes the quiescent output voltage as equal to 0V as the other input of the op-amp IC1 is referenced to 0V.

Resistors R3 and R5 provide local negative feedback over the discrete components TR1, TR2 and TR3. This provides for a much more stable amplifier and *greatly* improves the distortion figures.

Resistor R4 serves two purposes. It reduces the power dissipated in TR3 enabling a TO5 assembly to be used and it also prevents any avalanche condition in the event of failure. For example, if TR2 failed in the short circuit mode the output would be driven fully positive. The negative feedback via R2 would cause TR3 to be turned hard on in an attempt to restore the output voltage and, of course, TR3 would break down. However, the presence of R4 will limit the current through TR3 to a safe value under these fault conditions.

The split collector resistor R6 and R7, together with C4, provides for bootstrapping to ensure that the base of TR2 never runs out of current, even as the output approaches the positive rail voltage. As the output voltage becomes more positive C4 causes the junction of R6 and R7 to also become more positive. This maintains a substantially constant current through R7 and hence the current handling capability of the output is reasonably constant also.

Capacitor C1 provides phase correction to the feedback loop. This may or may not be necessary and depends on component types used. The action of the switching diode D1 generates small transients and these are suppressed by C2 and C3.

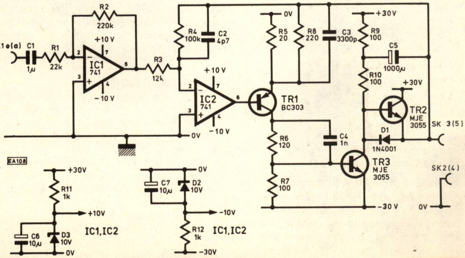


Fig. 6. Circuit diagram of one channel of the Class A amplfier. (Connections for R.H. channel shown in brackets.)

Having discussed the theory behind the Class A design we can now look at a practical implementation of the idea.

PRACTICAL AMPLIFIER

The construction of a practical amplifier, as opposed to the discussion of a theoretical one, inevitably involves compromise, and the most important compromise is between power output and readily available components.

The complete circuit diagram of the amplifier is shown in Fig. 6 (the left channel). This design is quite capable of delivering 30W into an 8 ohm load. Full drive (30 watts) is obtained with 350mV peak input. However, it was felt that it would be desirable to have a higher transient capability, hence the power supply design shown in Fig. 7 provides for ±30 volts as the quiescent supply voltages giving a transient capability approaching 60 watts. (The amplifier couldn't sustain this level for long as such a load rapidly reduces the supply voltages.)

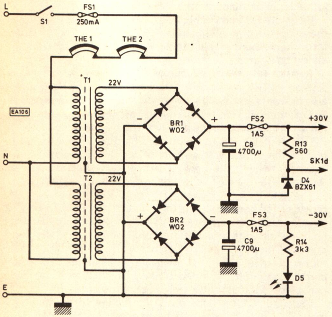
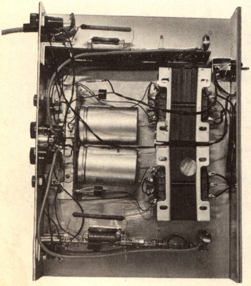


Fig. 7. Power supply circuit



Internal view of amplifier

COMPONENTS . . .

Resistors

*R1	22k
*R2	220k
*R3	12k
*R4	100k
*R5	20
*R6	120 1W
*R7	100
*R8	220 1W
*R9	100 7W
*R10	100 3W
*R11, R12	1k ½W (2 off)
R13	560
R14	3k3

All resistors ¼ or ⅓W except where otherwise stated

Capacitors

*C1	1μ polyester
*C2	4p7
*C3	3300p
*C4	1n
*C5	1000μ 25V
*C6, C7	10μ 25V (2 off)
C8, C9	4700μ 40V (2 off)

Semiconductors

*D1	1N4001
*D2, D3	10V Zener BZY88 (2 off)
D4	20V Zener BZX61
D5	LD57A
TR1	BC303
TR2, TR3	MJE 3055 (2 off)
BR1, BR2	Bridge rectifier WO2 (2 off)
IC1, IC2	741 (2 off)

Miscellaneous

THE1, THE2 thermal safety switch 70°C (RS 339-308) (2 off)
Fuse holders (3 off)
250mA fuse (slow blow)
1·5A fuse (2 off) (quick blow)
*P.c.b.
Banana sockets (4 off)
6-way DIN socket
Mains toggle switch
Suitable case
Veroboard
Transformer Douglas MT 79 FT (2 off)

* Two required for stereo design

CONSTRUCTION

The p.c.b. design for one channel of the amplifier is shown in Fig. 8 with the component layout in Fig. 9. All the components except TR2 and TR3 can be mounted on the board. The two resistors R9 and R10 should be set at least 10mm from the p.c.b.

The mounting details of the p.c.b.s, thermal switches and output transistors are shown in Fig. 10. The transistors TR2 and TR3 should be mounted onto the heatsink using mica washers.

The Veroboard layout for the power supply unit is shown in Fig. 11. The prototype was fitted into a case 250 × 180 × 60mm. The wiring diagram for the rear panel is shown in Fig. 12. The mains switch and the l.e.d. should be mounted onto the front panel.

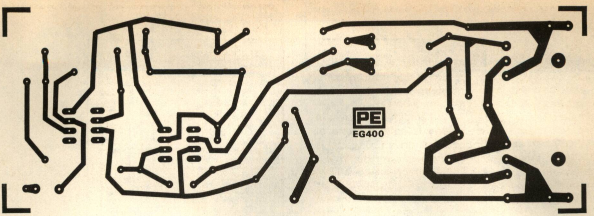


Fig. 8. P.c.b. design for one channel of the amplifier.

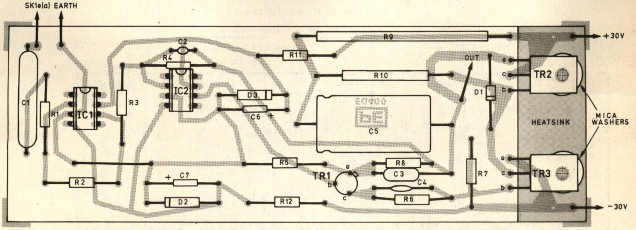


Fig. 9. Component layout

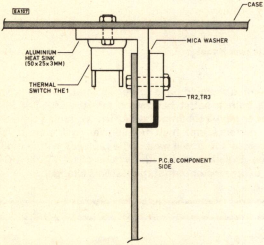


Fig. 10. Mounting details for the heatsink

TEST PROCEDURE

a. With the mains input fuse FS1 fitted and FS2 and FS3 removed, connect a 6k ohm 10 watt resistor in series with mains live and apply power. The power rails should run up to approximately their correct voltage (± 30V). Switch off and discharge the rails using a convenient resistor.

b. Fit FS2 and FS3 and with no speakers connected apply power again via the 6k resistor. A small voltage should appear at each rail, about half a volt or so.

c. If the two previous checks are good. Switch off, remove the 6k resistor and apply full power. Check across each pair of speaker sockets in turn that there is no more than a few millivolts of d.c. present.

d. If check c fails, check first the voltages supplying IC1 and IC2. ±10V.

e. Check there is no a.c. voltage at the speaker terminals.

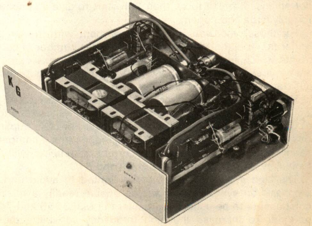
f. With speakers (8 ohm) connected but no input connection there should be a noticeable, but not loud, 100Hz buzz.

g. Check that this buzz disappears completely when the input pins are connected to 0V. Pins a and e connected to pin f on socket 1. Under these conditions there should be no sound from the speakers.

h. Check that there is +20V at pin d of socket 1.

OPERATION

The amplifier is now ready to accept a nominal input of 350mV peak output from a preamplifier. For inputs other than this the values of R1 and R2 should be changed, the



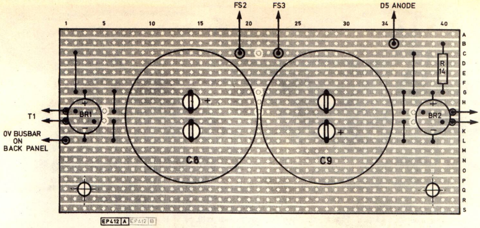


Fig. 11. Veroboard layout of the p.s u

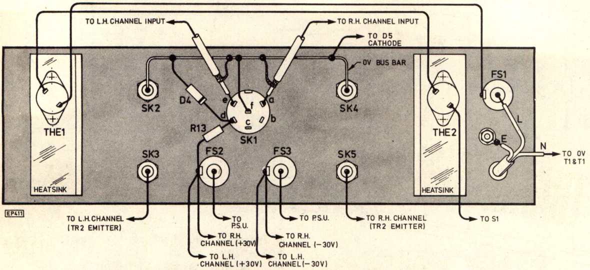


Fig. 12. Wiring diagram for the rear panel.

relationship being a direct one, i.e. for a peak input of 175mV the gain must be doubled which will be achieved by halving the value of R1. For a peak input of 700mV the gain must be halved, achieved by halving the value of R2. The limitations are that R2 should not be made larger than 220k. On the other hand, the 3dB point of C1, R1 is 18Hz, halving R1 without altering C1 will raise this to 36Hz by which point the loss of bass will be noticeable. Halving R1 and doubling C2 will maintain the status quo but values of C2 (which is not polarised) much more than 2µF start to give an uncomfortably large component.

For those who would like to experiment with the circuit rather than build a Hi-Fi system there are a number of comments which may be helpful. If higher continuous outputs are required the power supply must be uprated and the output stage fitted with cooling fins.

The circuit in Fig. 6 is deliberately bandwidth limited. It will be seen that the circuit is d.c. coupled with the exception of the input C1 and the bootstrapping C5. For d.c. coupling omit C1 and C5. The op-amp IC1 will require offset compensation and the output voltage/current capability will be limited by the current available in R9 and R10.

The high frequency capability is limited to avoid undue emphasis on system noise and to enable readily available components to be used, in particular the MJE3055 and 741 op-amp. To increase the high frequency capability these components would have to be replaced. The 741s with op-amps with a better bandwidth and the MJE3055s with a superior high frequency device. The switching time of D1 at high currents and high frequencies will start to become noticeable and it will have to be replaced with a high speed device. Experiment with the values of C2, C3 and C4 if the type of op-amp or output transistor is changed. ★

News Briefs

COMPUTING CLUB

A COMPUTING Club has been formed in the Falkirk area, to be known as the "Central Scotland Computing Club".

A Committee has been formed and it is planned to hold monthly meetings in Falkirk College of Technology, Grangemouth Road, Falkirk.

The Secretary is: James G. Lyon, 78 Slamannan Road, Falkirk, FK1 5NF, Tel: Falkirk 22430.