SIMPLE POWER AMPLIFIER

Complementary Hexfet devices offer improved performance over the equivalent bipolar output stage and allow simplified drive circuitry. This design delivers 60 watts into a four-ohm load, 32 watts into an eight-ohm load, from a simple ±30V supply.

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The split power supply rails of this design give good rejection of supply voltage ripple allowing both a simple supply circuit to be used and the load to be directly coupled. The output devices operate in the source follower mode, which offers a twofold advantage: the possibility of oscillation in the output stage is reduced as voltage gain is less than unity, and signal feedback through the heatsink is eliminated as the drain terminal, which is electrically connected to the tab on the TO-220 package, is at a direct voltage.

Symmetrical output is achieved by providing a "boot-strapped" drive to the gate of the n-channel device from the output. The use of the bootstrap circuit, C_4, R_8,R_9, also allows the driver transistor to operate at near constant current, which improves the linearity of the driver stage. The diode clamps the bootstrap circuit, restricting the positive voltage at the gate of Tr_5 to $+V_{DD}$ to maintain symmetry under overload conditions.

Transistor Tr_3 and resistors 11, 12 & 13 provide gate-source offset voltage for the output device with R_{12} variable to adjust quiescent current for variation in threshold voltage. A degree of temperature compensation is built into the circuit as both the emitter-base voltage of Tr_3 and the combined threshold voltages of the f.e.ts have a temperature coefficient of −0.3%/deg C.

The class A driver transistor operating at a nominal bias current of 5mA set by R_8, R_9 is driven by the p-n-p differential input pair biased at 2mA by R_3. Components R_7, C_2 set the closed-loop gain of the amplifier R_6/R_7 and provide low-frequency gain boosting. Additional components R_{15}, C_7 connected between the output and ground suppress the high-frequency response of the output stage, allowing the h.f. performance of the amplifier to be determined by the input circuit. Component R_1, R_2, C_1 at the input of the amplifier define the input impedance and suppress noise.

To achieve 60 watts into a four-ohm load, the current in the load is 3.9A r.m.s. or 5.5A peak. To sustain this source current, the n-channel Hexfet, IRF533, requires a gate-source voltage of 5V.

As peak load voltage is 22V, gate bias voltage to achieve peak power in the positive sense is $V_{pk} + V_{gs} = 27V$. A similar calculation for the negative peak, using the p-channel device IRF9533, shows that a negative gate bias supply of − 28V is required. Consequently, a ± 30V supply is adequate for a 60 watt output, provided that the supply voltage does not fall below ± 28V when loaded: a source impedance of one ohm or better. When the supply voltage impedance is high, use a higher voltage supply together with complementary Hexfets of a higher voltage rating − IRF532/IRF9532.

When an eight-ohm load is used, 32 watts output power can be achieved from a ± 30V supply with source impedance better than two ohms.

The curves drawn in Fig 1 show the power consumption of the amplifier, output power and power dissipated in the f.e.ts as a function of r.m.s. output current with ± 30V supplies and four and eight-ohm loads. It can be deduced that the maximum power dissipated in the devices is 56 watts and 28 watts with four and eight ohm loads respectively. Limiting the case temperature to 90°C and making an allowance for the thermal impedance of insulating washers, heatsink requirements are 0.5°C/watt with a four ohm load and 1.67°C/W with eight ohm load. Smaller heatsinks may be tolerated if the amplifier is not operated continuously at rated output power.

Open-loop gain measured with gate and source connections to the f.e.ts broken is 30 dB, − 3dB points occuring at 15Hz and 60kHz, Fig. 2. Closed-loop curves are shown for amplifier gains of 100 (R_7 470Ω) and 20 (R_7 2.2k). In both cases the curves remain flat to within ± 1dB between 15Hz and 100 kHz with an eight ohm load. The slew rate of the amplifier, measured with a 2V pk-pk square wave input is 13V/μs positive-going and 16V/μs negative-going. The discrepancy could be balanced out by addition of a series gate resistor for Tr_6.

Reduction of the closed-loop gain from 100 to 20 produces a significant improvement in distortion figure, Fig 3. Considering the simplicity, performance is quite acceptable. The output stage quiescent current was adjusted to 100mA and can influence the distortion measurement significantly if allowed to fall below 50mA.

The dependence of the quiescent current in the output stage and of the output offset voltage on power supply voltage are illustrated in the Table. Current is set by first adjusting the potentiometer R_{12} for minimum offset voltage − turned fully anticlockwise if the p.c.b. layout shown is used − and apply the power supply voltage, the positive supply passing through an ammeter with 1A f.s.d. It is then adjusted until the meter reading is 100mA with a ± 30V supply. Remove the meter from the circuit before applying an input signal to the amplifier.

When assembling the printed circuit board, mount the passive components first, ensuring the correct polarity of electrolytic capacitors. Then solder in bipolar transistors, checking for correct pin identification. Finally mount the f.e.ts, avoiding static discharge by shorting the pins together to ground and using a grounded soldering iron. Check the assembled board for correct component place-