The El Cheapo 2-30

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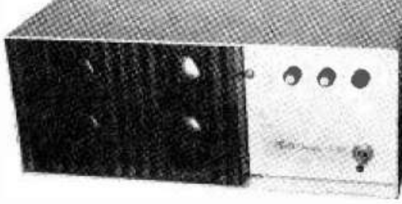


A versatile stereo power amplifier using silicon transistors. Changing the output configuration boosts the power output by 50 per cent.

A number of issues ago, Myers and Kahn presented an article in Audio describing a high-power, high performance audio power amplifier using silicon output transistors. The article presented an excellent design, and included was a warning to readers that duplicating this amplifier could be an expensive and troublesome job. Feeling that most Audio readers, myself included, are capable of building successful projects, I plunged into an amplifier building session that lasted several days, and left relatively few scars.

The Amplifier

The amplifier that Myers and Kahn described utilizes a circuit long familiar to perusers of The *General Electric Transistor Handbook.* The amp is direct-coupled (up to the speaker) and uses large amounts of negative feedback, both a.c. and d.c., and from Q_2 on, is an operational amplifier of the form shown in *Fig.* 1 where voltage gain equals R_f/R_{in}. The output stage is the now-familiar circuit described by Lin, which I can't seem to help calling a "push-push."

Using Myers' and Kahn's article as a guide, I plowed around in my spare parts, gathered transistors, 'scopes, oscillators, and regulated supplies, and set to work. The schematic of *Fig.* 2 is the result.

The choice of silicon output transistors is a natural from virtually every standpoint; better performance at high temperatures than germanium, along with less chance of "tunnelling through"; reasonable cost; and higher (in most cases) F_t than germanium. My breadboard amp, and for that matter, the amp from which the specifications come, uses 2N1488's, a less than ideal choice, due to a fairly high saturation resistance, and an almost $8 cost. Recently, the 2N3055 came along, with a very much lower R_{sat}, and lower cost, too. This transistor is rated at 115 watts, and is really pretty nifty.

The beauty of this amp, to me, is that several options are available to the home builder. The maximum power output may be chosen at will, to satisfy various needs, without affecting the performance in any negative way. The high-frequency response may be adjusted to taste; and, within limits, the input sensitivity may be adjusted to meet individual needs.

Output power: The factors affecting output power are power supply voltage and the current limitations of the output stage. Let's cover supply voltage when we discuss the power supply. The output-stage current limitation is defined by the transistors used. Assuming that the transistors are operating within their voltage ratings, the usual current limit is imposed by the increase of junction temperature. Here, however, we must also be concerned with the function of Beta *versus* collector current. The 2N3055's hold Beta quite well up to several amperes of I_c, insuring good transient response at high currents. However, at output powers above twenty watts, especially into 8-ohm or lower loads, parallel operation of the output stage is highly preferable, to keep Beta high, and junction temperature low. *Figure* 2 shows the changes; addition of a pair of transistors, and emitter resistors which provide enough degeneration to equalize the differences in members of pairs. Parallel operation is more expensive, but the cost is justified if high power is needed for long periods. If the amp is to be used for music reproduction, then even high supply voltages and high power output may be safely handled by a single pair of output transistors.

Risetime: If a 'scope and a pulse generator with a 10kc or thereabouts reprate are available, the rise time of the amp may be tweaked to most anything desired, in the range of two to six microseconds, by making C_f variable. An 8-50 pf trimmer in parallel with a 39-pf "dog-bone" will cover most of the range. More C may be needed to really slow the amp down. Some overshoot may be encountered if too little C is used in an attempt to speed the amp up. The test pulse should have a rise time of 200 nanoseconds or better, so as not to affect the display.

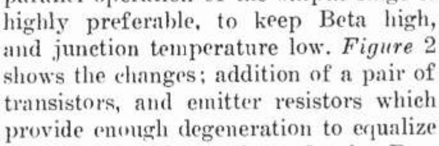


Fig. 1. Operational amplifier configuration.

Sensitivity: With the help of an AC-VTVM, or 'scope, and an audio signal generator, the input sensitivity may be adjusted. R_{in} and R_f may be pots, which will have values of 10k and 50k respectively, and can be whatever taper is handy. Linear taper is best if the pots are going to be built in. The idea is to select first the amount of feedback that is desired in the main loop, and then decide what sensitivity is needed, that is, how many volts in, for how many volts out; then, multiply the closed-loop gain (R_f/R_{in}) by the feedback factor to find the open-loop gain required. Set R_{in} to give the required gain with the loop open, then hook up the main loop, and tweak R_f to give the final gain. I had decided that 15 db of feedback in the main loop was a neat amount (although the amp will handle very large amounts), and I had decided that the amp should develop full power, 16v rms into 16 ohms, with a one-volt rms input. My closed-loop gain needed to be 16, and since I wanted to use 15 db of feedback, the open-loop gain needed to be $16(15\text{ db}) = 16(5.62) = 90$. I applied a 1kc, 50 mv signal, and adjusted R_{in} for an output of 4.5v. I conected the main loop, and using the same input signal, I adjusted R_f for an output of 800 mv. The values turned out to be 1k and 18k, to the nearest standard values. To obtain high output power, some input sensitivity must be sacrificed, or some feedback, whichever is the least objectionable.

If you have a transistor preamplifier with emitter-follower outputs, stage Q_1 can probably be eliminated, with attendent savings in parts and transistors. If, on the other hand, you have collector outputs, or a Fleming valve amp (perish the thought), Q_1 should be retained, as Q_2 needs a current drive with a large coupling cap. Without Q_1 the input impedance of the amp is quite low, equal to R_{in}, and the coupling caps in your preamp will seriously roll off the low-frequency response. If your preamp will tolerate the small value of load imped-

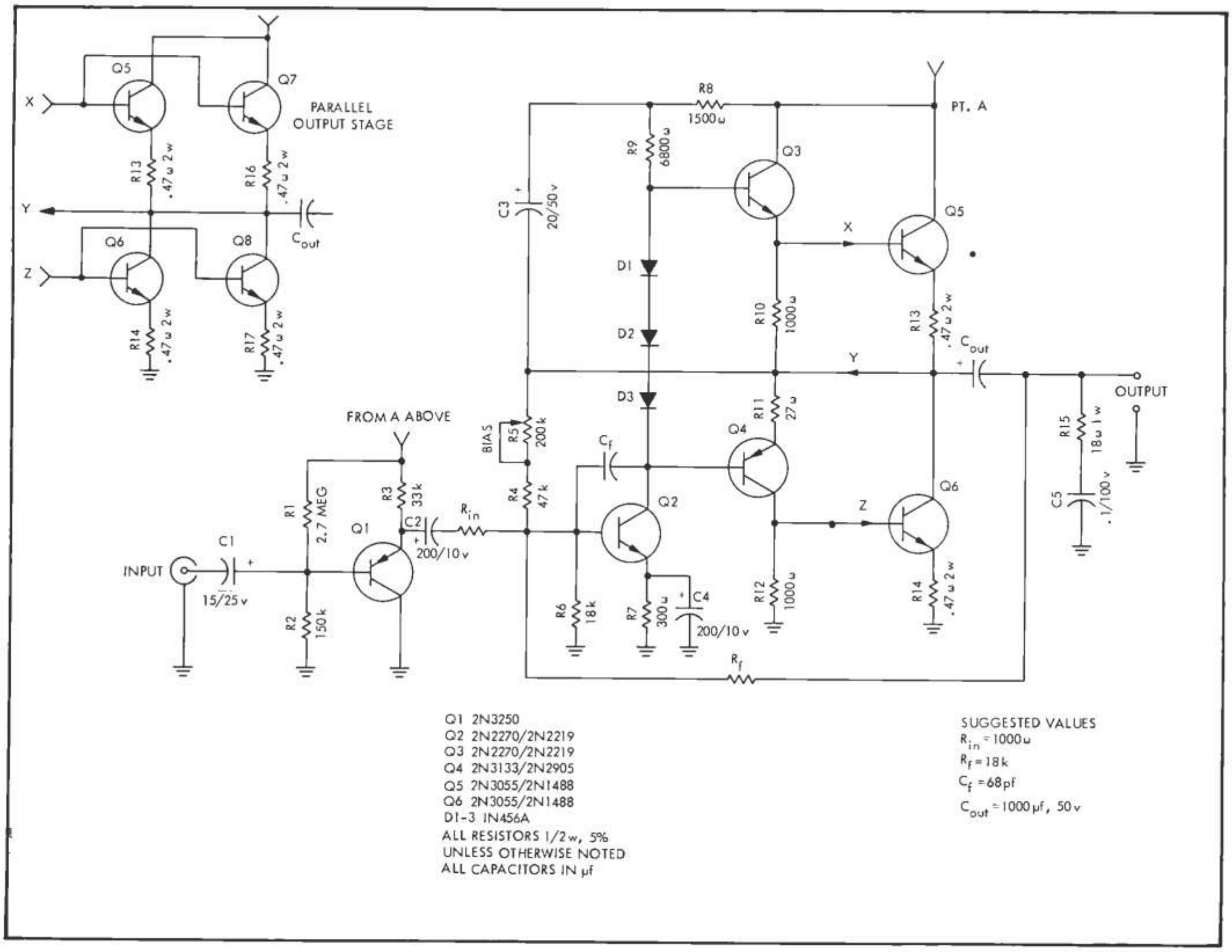
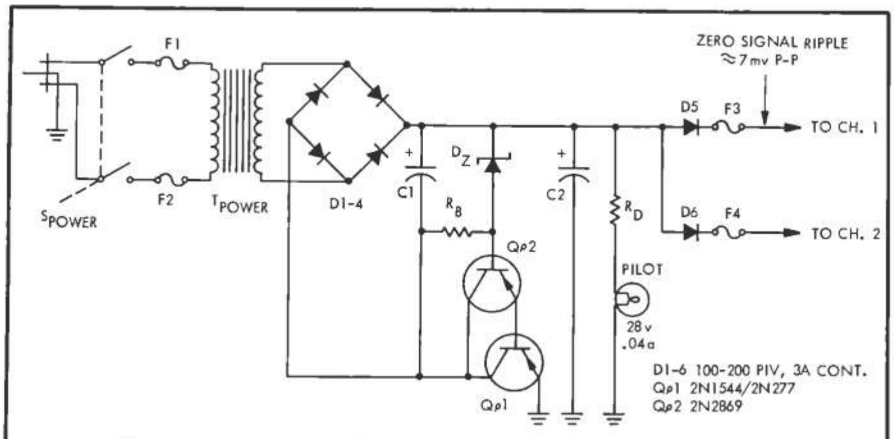


Fig. 2. Schematic diagram of power amplifier, plus changes necessary to achieve higher power.



	33 v	51 v	62 v
D_Z	33 v, 1 w, 5%	51 v, 1 w, 5%	62 v, 1 w, 5%
R_B	1000 ω, 1/2 w, 5%	2000 ω, 1/2 w, 5%	2700 ω, 1/2 w, 5%
C1	4000 µf, 50 v	3000 µf, 75 v	2000 µf, 100 v
C2	4000 µf, 50 v	3000 µf, 75 v	3000 µf, 75 v
R_D	120 ω, 1 w	560 ω, 2 w	820 ω, 2 w
F1, 2	1/2A, SLO	1A, SLO	2A, SLO
F3, 4	3/4A, FAST, AGC OR AGX	1A, FAST, AGC OR AGX	2A, FAST, AGC OR AGX
T	117:29, 2A STANCOR RT-202	117:46, 3A SIGNAL MV-2	117:56, 4A SIGNAL 56-4

Fig. 3. Power supply schematic.

ance, or if you desire the low-frequency roll off, you might be able to substitute larger caps for the ones present in your preamp. You might have to fiddle a little with the time constants.

The Power Supply

One of the first requirements in power supply design is that imposed because the amplifier designer usually assumes the availability of ideal sources of power, having zero impedance and perfect regulation. The downfall of many otherwise excellent commercial amplifiers, for my part, is the lack of regulated power supplies. Some manufacturers use very large power transformers to give some regulation, and the general use of low-impedance rectifiers has helped tremendously. But the best of these combinations can do nothing about changes in line voltage, and the worst can offer no regulation of any kind. The answer is, of course, regulated supplies, with the obvious rewards of lower hum, and greater stabilization of operating points. *Figure* 3 shows a regulated supply that powers two of the amps in *Fig.* 2. You'll notice that the regulator has to look through the rectifiers to see the load, which isn't the ideal way to have things. But this is the ideal place for germanium power transistors, for we can use their high Beta and high current capabilities here. Q_{p1} and Q_{p2} are in the familiar Darlington connection, and give very good regulation. Q_{p1} should have at least a 40-watt rating, and Q_{p2} should rate at least one watt. Both should have the highest Beta possible, at least 50, and over 100 preferably.

As mentioned earlier, output power is set by supply voltage, which is determined by the zener voltage of D_z. Supply voltage may be changed by changing the zener diode, and its dropping resistor R_B, which sets the zero signal current through the zener. Using the 62v supply, you can probably get 30 watts per channel into 8 ohms, possibly more. Likewise, output power may be reduced by lowering the supply voltage. If 10 watts per channel is enough, and I suspect that it is for most of us, a 33v supply will do the job. In any case, the no-load d.c. output from the rectifiers should be about 20 per cent higher than the regulated supply, to allow for line variations, and squashing of the transformer output under heavy load. The *Motorola Zener Diode and Rectifier Handbook* gives an excellent design procedure for this type of regulator in Chapter Three. *Fig.* 3-9.

Output power greater than 30 watts is easily obtainable from the amps, but as power goes up, so does the current that the regulator supplies, and it may be necessary to use a more elaborate regulator to maintain regulation for two channels. Finding a transformer might be a problem also. There are selenium rectifier transformers readily available, for use with the 33v and 62v supplies. For the 51v supply, or higher voltages, it will probably be necessary to series stack two transformers to obtain the required voltage.

The table in *Fig.* 3 lists the various values of parts for the different supplies. The values of the capacitors are minimum-but-adequate. The BV_{ceo} ratings of Q_{p1} and Q_{p2} need not be much higher than the zero signal drop across Q_{p1}, as the regulator follows the charging of C_1 easily. The pilot lamp, an incandescent unit, was chosen instead of a neon lamp, because it serves to bleed the supply very rapidly when the power is switched off.

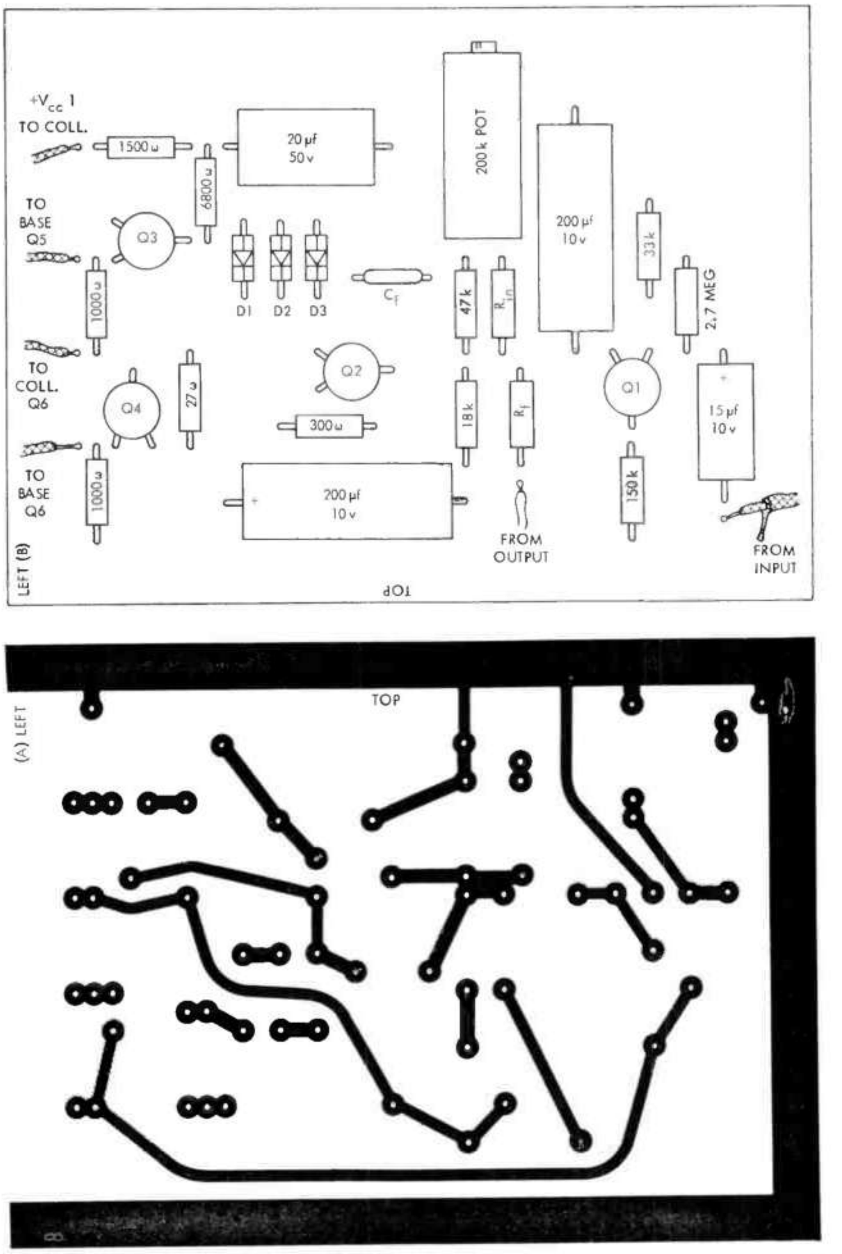


Fig. 4(A) Printed circuit board for one amplifier (foil side shown); (B) parts placement. Note location of top and left

Construction

The construction of this amp, while no job for the novice, isn't the least bit critical. Q_{p1} and the output transistors should be well heat sunk. The large variety of heat sinks on the market, most anodized and pre-punched, take the pain out of this. If you are building for high power, it might not be a bad idea to use heat sinks of some sort on Q_2, Q_3, and Q_4. D_1 through D_3 in the amplifier may be most any silicon diode with a rating of 100 mA or more, and with a reasonably small leakage. The amplifiers and power supply lay out very nicely on printed circuit board (see *Fig.* 4), either breadboard or photo etched. I grounded circuits where it was convenient, but due to the high currents involved, it may be necessary to fool around with ground runs to find the points of least noise. I would avoid using common ground busses of any sort. A good method is to ground at the point of least signal, and run each point to be grounded via a separate bus to this point. Unless the feedback components are made variable, the only adjustment in the amplifier is the setting of the 250k bias pot. This pot should be trimmed for symmetrical clipping of a sine wave at the output. If you don't have a 'scope, or one isn't available, the pot may be set so that one-half the supply voltage appears at the collector of Q_6. It is desirable to trim the pot at clipping, however, and it would be worthwhile to have it done, if you can't do it. Much reference has been made to test equipment in this article. If the parts list is followed, and the suggested values used, no test equipment is necessary to achieve excellent results, outside of a VOM.

Performance

The specifications, I feel, describe an excellent amplifier. If first grade components are used, I feel that the amp will

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