NOW WITH OUTPUT STAGE PROTECTION . . .

THE 10-PLUS-10 STEREO AMPLIFIER

By LEO SIMPSON

In the few months since November, 1968, when we first presented this amplifier, it has become a popular project. We were, however, conscious of the desirability of protecting the output transistors against destructive overloads and, since then, we have been able to develop suitable circuitry which will add little to the cost of the amplifier. Because we feel that most readers will in the future prefer to assemble the amplifier with protection circuitry incorporated, we are presenting a complete article, so that details of the amended design will be available in the one issue.

Many systems have been suggested for protecting the output stages in an amplifier, some of which were described in the "Audio Topics" article in the December, 1968, issue of "Electronics Australia." For the most part, however, the ideas were not very appropriate for use with an economy stereo amplifier. Since then we have developed a protection circuit which is incorporated into the power supply: It is effective, easily reset after overload — and economical.

lished in "Miniwatt Digest" for June-July, 1967. Four transistors are used in each power amplifier, one silicon type for initial amplification, and three germanium types as the driver stage and output pair. The principle of operation is much the same as in the 3-plus 3 Stereo Amplifier, described earlier.

The input transistor is a silicon NPN type which provides voltage amplification. Negative AC and DC feedback is applied to the emitter from the emitter resistors of the output transistor pair.

The quiescent voltage at the junction of the output transistor emitter resistors should be about half a volt less than half the supply voltage, which it will normally be with standard tolerance components. If need be, it can be set, with the aid of a suitable voltmeter, by varying the 1.5K emitter resistor of the first transistor. Increasing the resistor will increase the voltage and vice versa. When set thus, a sine-wave signal should clip symmetrically at the point of overload, thus resulting in maximum power before the onset of clipping. If the necessary equipment is available, operation can be double-checked by observation of the waveform with an oscilloscope.

The class-A driver stage is a germanium PNP transistor, AC128, operating with a collector current of 50-mA. At this current the usual flag heatsink is insufficient and the flag heatsink must be mounted on an aluminium plate which, in turn, is attached to the printed board.

The output transistors are a complementary germanium pair AD161/162 operated in the normal push-pull complementary-symmetry mode. These transistors have the advantage of being able to deliver high power with a relatively low supply voltage, because of low IR losses in the transistors themselves. The quiescent current of the output stage is nominally 10mA which, again, will not normally require setting up. If it does prove to be necessary, however, it can be altered by variation of the 68-ohm resistor be-

SPECIFICATIONS

A transistorised stereo amplifier capable of being fully driven by ceramic cartridges or other "flat" signal source with an output of at least 100mV. Output and regulator transistors are protected against damage.

Power: 10 watts music power or 8 watts RMS per channel into 8 ohms, each channel driven separately or both together; 5 watts RMS per channel into 16-ohm loads. 4-ohm speakers may not be used.

Distortion: Less than 0.85 per cent THD at 1KHz at 8 watts; less than 0.5 per cent THD at 1 watt at 1KHz.

Signal-to-noise ratio: 58dB with respect to 8 watts.

Separation between channels:—43dB or better, with respect to 8 watts at any frequency between 100Hz and 10KHz.

Frequency response at 1 watt:—3dB points at 25Hz and 17KHz (—4dB at 20KHz).

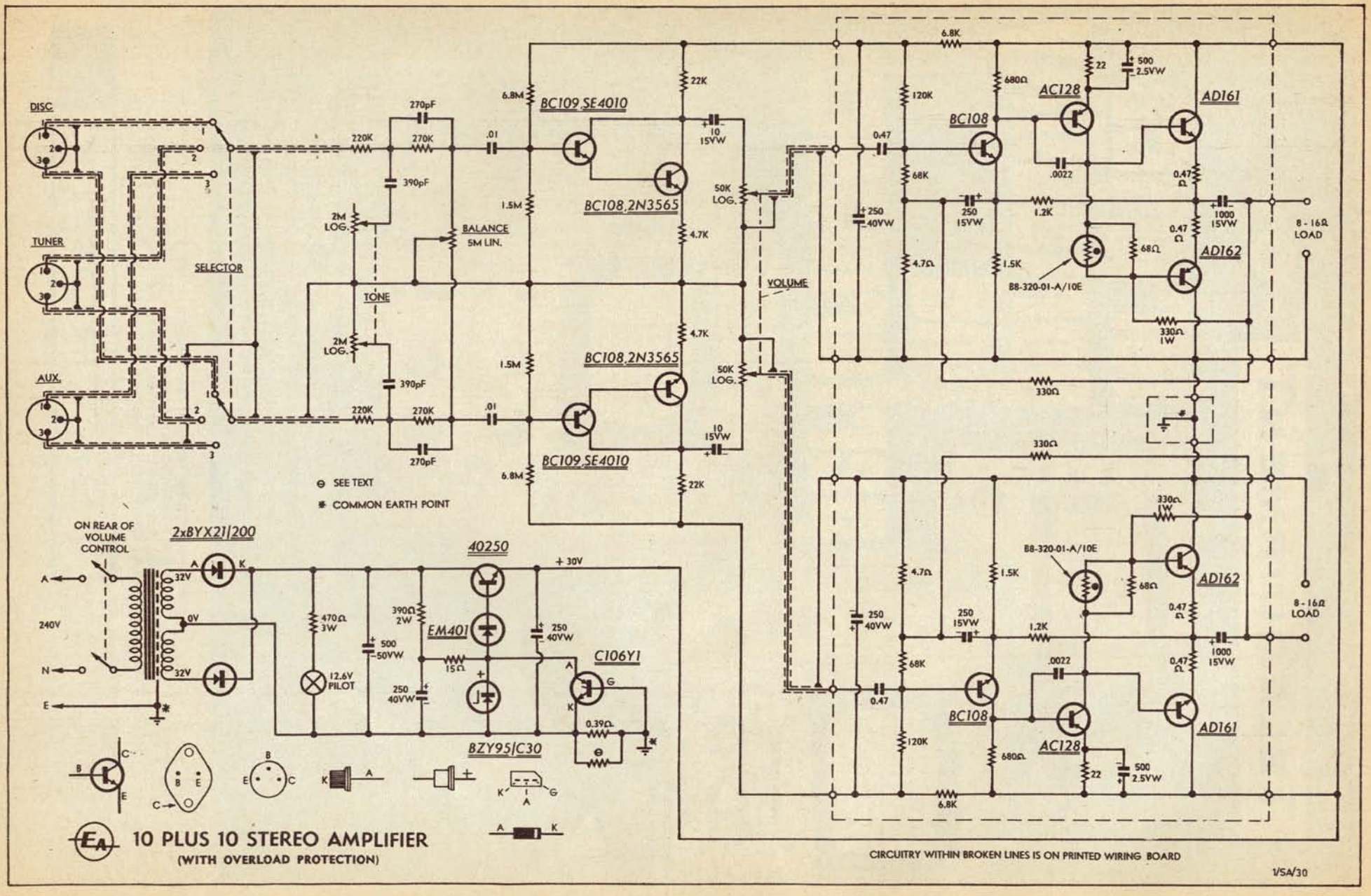
Tone Control: 13dB cut at 10KHz.

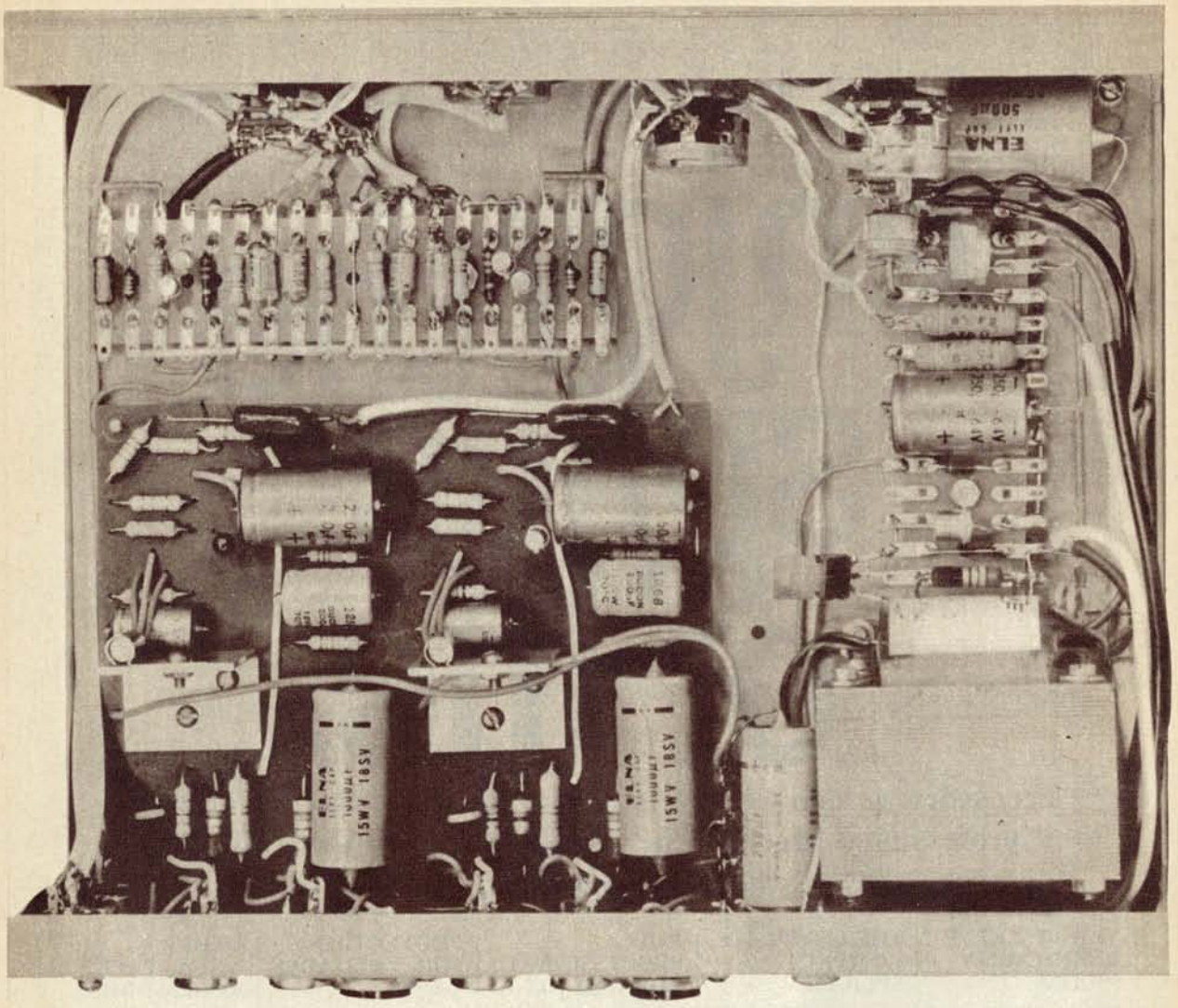
Input impedance: 1 megohm, all inputs.

The prototype amplifier fitted with a brushed aluminium cover. Its compact dimensions and simple appearance belie its high performance. The complete circuit diagram is on the right.

In operation, if the amplifier is overloaded by a short-circuit or is grossly overdriven, the power supply to the amplifier is automatically disabled. To restore the amplifier to working condition, the cause of the overload is simply removed, the amplifier switched off for ten seconds or so, and then switched on again. Circuit operation will revert to normal.

The main power amplifier for each channel, assembled on the printed wiring board, is based on a design pub-


DISC
TUNER
AUX.
SELECTOR
BALANCE 5M LIN.
2M LOG.
TONE
VOLUME
50K LOG.
BC109,SE4010
BC108,2N3565
BC108,2N3565
BC109,SE4010
AC128
AD161
BC108
AD162
B8-320-01-A/10E
8 - 16Ω LOAD
⊖ SEE TEXT
✱ COMMON EARTH POINT
ON REAR OF VOLUME CONTROL
2xBYX21/200
40250
EM401
C106Y1
BZY95/C30
12.6V PILOT
240V
+ 30V
10 PLUS 10 STEREO AMPLIFIER
(WITH OVERLOAD PROTECTION)
CIRCUITRY WITHIN BROKEN LINES IS ON PRINTED WIRING BOARD
1/SA/30



An overall view of the interior of the amplifier. The main amplifier board is at bottom left, the preamplifier board above it. The power supply board is to the right. The thyristor is soldered directly into circuit, no heatsink being necessary. All connecting leads should be kept short but arranged in a tidy fashion.

tween the two output transistor bases. Increasing the resistance will increase the current and vice versa.

Note that the quiescent current of the output stage cannot be set unless a load is connected, since the load forms part of the biasing network for the output transistors.

All the above-mentioned circuitry is mounted on the printed wiring board, which uses the same copper pattern as that for the 3-PLUS-3 Stereo Amplifier. However, the sensitivity for full output is of the order of 150mV, with an input impedance of 60K. This means that an extra stage of amplification is required to obtain the necessary sensitivity and high input impedance, to enable the amplifier to be driven to full output by the lower output, higher quality ceramic cartridges which constructors may well wish to use.

The input stage employs two transistors connected as a "Darlington pair." In this mode of operation, the emitter of the first transistor is connected to the base of the second and they share a common colletcor load. This provides high input impedance, the required gain and a low noise content.

The volume control follows the input stage, coupled to it via a 10uF electrolytic capacitor. The volume control will thus attenuate any noise generated in the input stage at its normal settings, making for lower background noise in typical use.

However, having the volume control in this position means that the input stage may be overloaded if fed with too large a signal. The stage overloads with an input signal of 2 volts RMS (sine wave) and this means it is not directly suitable for high-output crystal cartridges — as opposed to ceramic cartridges which usually have considerably lower output.

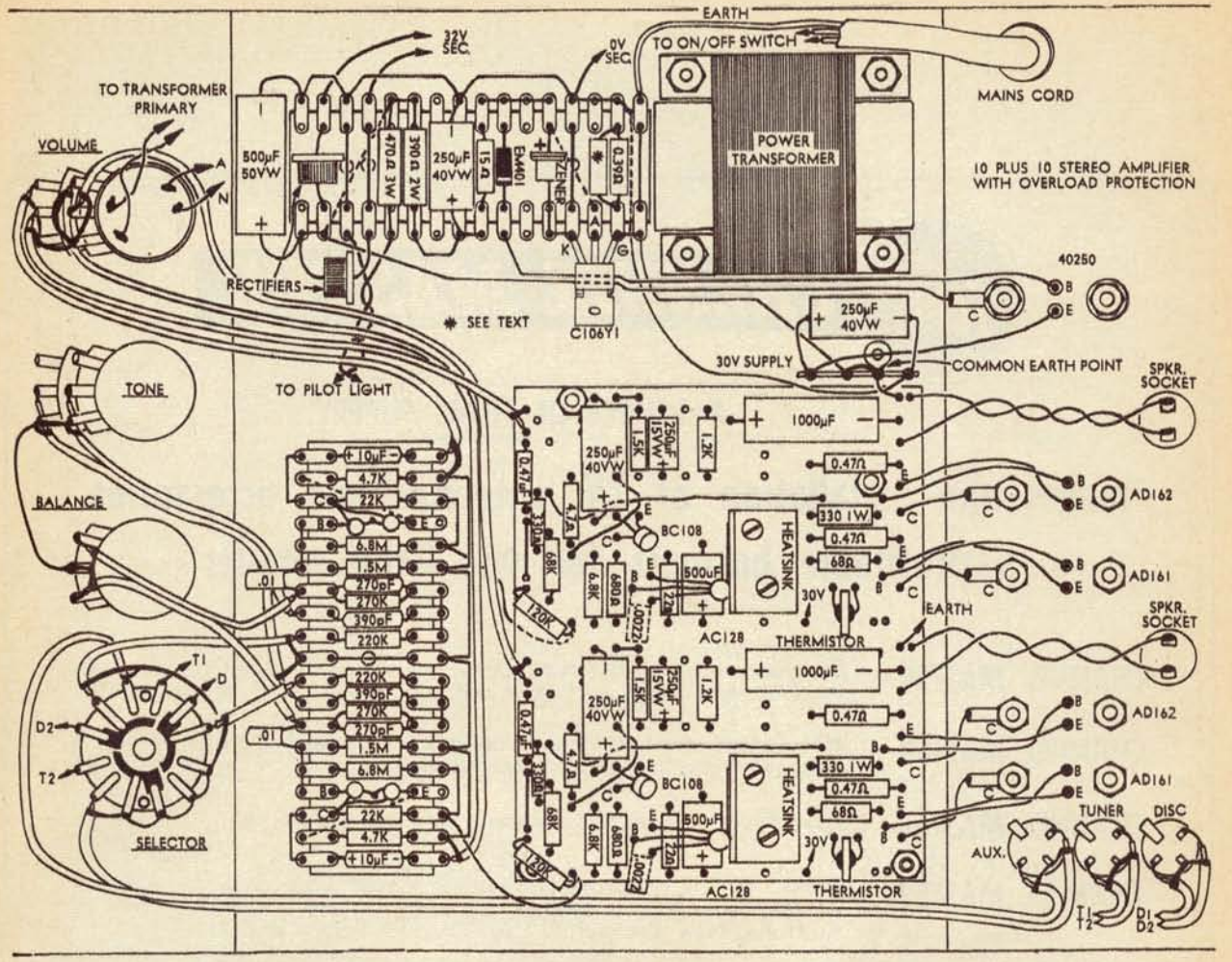
If a crystal cartridge must be used it should be connected via a high impedance divider, say 2 megohms and 270K. Alternatively, one can shunt the cartridge with a suitable capacitor (say 0.0047uF) which will reduce the output voltage, while improving the effective bass response. To obtain the best reproduction from the amplifier, however, one of the better quality ceramic cartridges should be used.

The power supply is basically a conventional full-wave rectifier system followed by a series regulator. When both channels of the amplifier are driven to full power, the total current drain is over 1.2 amps. while the current under "no-signal" conditions is of the order of 130 milliamps. This large variation in current drain, plus the fact that the output transistors have a relatively low collector-emitter voltage rating of 32 volts, means that a regulated power supply is mandatory.

The transformer rectifier combination supplies 40 volts DC to the input of the regulator. Having two separate secondary windings, the transformer can be connected to suit a bridge rectifier or the conventional "centre-tapped winding" rectifier. Instructions on the method of connection are normally packaged with the transformer. We used two BYX21/200 20-amp automotive diodes as rectifiers, these being about the cheapest high current diodes available. Offsetting their economy is the disadvantage that it is necessary to make a soldered connection to the case, which tends to be a little untidy. A suitable bridge rectifier is the silicon type MB1 made by ITT.

The series regulator consists of a silicon NPN power transistor connected in the "emitter-follower" configuration. This takes care of voltage regulation, filtering and overload protection.

A low value resistor in the negative supply line senses the amount of current drawn from the supply. If the



The above wiring diagram and the accompanying photographs will make construction straightforward. Do not forget the mains cord clamp which is not shown above. The amplifier earth returns should be connected to the chassis at the common earth point.

current exceeds a certain value, the voltage developed across the sensing resistor triggers the thyristor (in parallel with the zener diode) into conduction, thereby removing the forward bias from the transistor and interrupting the current drain. The actual "switch-off" time is dependent upon the particular transistor and thyristor but can be expected to be of the order of a couple of micro-seconds. This should provide adequate protection against even the most catastrophic overload.

The value of current at which the thyristor is triggered should lie between the maximum peak current drain of about 1.7 amps and the maximum current rating of the output transistors, which is 3 amps. The optimum current at which the thyristor triggers might thus be nominated as 2 amps. The maximum triggering voltage of the C106Y1 thyristor used is 0.8 volts so that a sensing resistor of 0.39 ohm would seem to be a suitable choice. However, individual C106Y1 thyristors may trigger, in this circuit, at voltages as low as 0.45 volts which would mean premature triggering if a sensing resistor of 0.39 ohms is used. For this reason, we have specified 0.39 ohms but with the proviso that it will have to be shunted down, in most cases, so that the thyristor triggers at about 2 amps.

The value of the shunting resistor can be determined with an ammeter and a load resistor, connected across the supply to draw 2 amps. Alternatively, it may be selected so that the thyristor triggers when both channels are driven to just over full power, i.e., past the onset of clipping. If facilities are not available to measure power output or observe clipping, the shunting resistor can be selected so that the thyristor triggers when the amplifier is driven to loud levels on normal signal.

The power diode connected between the zener diode and the base of the transistor ensures that the transistor is turned completely "off." The thyristor remains in a state of conduction after the transistor is turned off, supplied with current via the 390-ohm and 15-ohm resistors. The only way that normal operation can be restored is to stop the current through the thyristor by switching off the mains supply for about ten seconds, which allows the filter capacitors to discharge. Normal operation can then be restored by switching on again.

The ripple content from the supply, even at maximum current drain, is quite low due to the capacitance amplification of the regulator. However, while the effective capacitance of the supply is very high in terms of filtering, the intrinsic output impedance of the supply is not as low as might be desired, due to the sensing resistor and the dynamic resistance of the collector-emitter junction of the transistor. To reduce the effective output impedance of the supply, a 250uF capacitor has been specified across the output.

It may be thought that the 250uF capacitor could cause damage to the regulator transistor at "switch-on," due to the fact that it would act as a temporary short-circuit and is not included in the loop which is monitored by the sensing resistor. In fact, the time-constant formed by the 390-ohm bias resistor and the 500uF capacitor in the base circuit of the transistor causes it to turn "on" gradually, effectively limiting the surge current. For the same reason, there is no "plop" from the loud-speakers as the amplifier is turned on—an effect which is noticeable with some transistor amplifiers.

CONSTRUCTION: The amplifier is assembled in a chassis with overall dimensions of 9¾ x 7⅞ x 3¼ inches. It is U-shaped, with a ¼-inch flange all round. The prototype was made of 18-gauge aluminium. We would not advise a reduction in the metal thickness, as it would reduce the potential effectiveness of the chassis as a heatsink for the power transistors.

The four output transistors are mounted on the rear of the chassis, mica washers being used to insulate them electrically from the chassis. If the chassis has been painted, the area to which the transistors are mounted

must be rubbed back to bare metal to ensure efficient heat transfer.

Actually, under normal "program" conditions, "heatsinking" requirements are not exacting and, even on hot days, the output transistors will be merely warm to the touch. However, we would not advise extended full power testing on hot days, since the chassis — and of course the output transistors—will become rather warm.

If an application is envisaged where the full RMS power of the amplifier is used continuously, a more efficient heatsink for the transistors should really be provided. For normal music reproduction in the home, the chassis itself will be quite adequate, however.

When purchasing the transistors, be sure to obtain the mica washers and nylon bushes, the latter being required to insulate the retaining nuts from the chassis. When mounting the transistors, silicone grease should be lightly applied to both the transistors and the heatsink (chassis). Connection to the collectors of the transistors is made to a solder lug placed under one of the retaining nuts. The same mounting instructions apply for the regulator transistor.

Polarised two-pin sockets are used for loudspeaker connection, since they simplify speaker phasing and are easier and safer to use than terminal lugs. Three 3-pin DIN sockets are provided for the inputs and these are connected to the selector switch via dual shielded cable. The shield for each channel input is connected to the centre pin (pin 2) of the DIN socket but no connection is made to the outer shield of the socket.

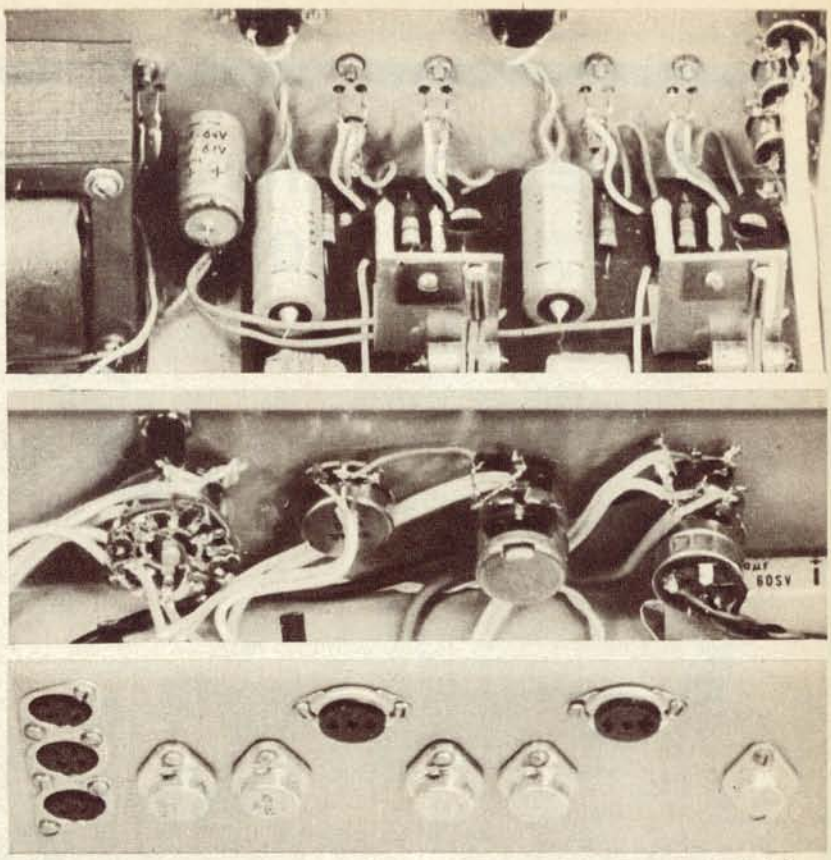
All the circuitry for the input stage is mounted on a piece of miniature tagboard.

Similarly, the power supply circuitry, apart from the transistor and 250uF capacitor at the output are mounted on tagboard. The thyristor is soldered directly to the tagboard, no heatsink being necessary. The electrostatic screen of the power transformer and the earth wire of the mains cord are connected directly to the single common earth point on the chassis, via the tagboard. They should not be connected to chassis via the current sensing resistor. The 250uF capacitor is mounted on a four-way tagstrip which also serves as the common earth point to the chassis. The negative connection for this 250uF should not be made directly to earth but via the sensing resistors.

The pilot lamp is supplied from the output of the rectifiers via a 470-ohm 3-watt resistor. This will have to be varied according to the voltage rating and current drain of the lamp. The lamp in the prototype drew about 70 milliamps at 8 volts — it was rated at 12 volts. It is good practice to run these lamps at reduced voltage to obtain longer life and reduce brightness so that it is not obtrusive. A 560-ohm resistor should be suitable for typical 6-volt lamps.

The third pole of the 3-pole selector switch is used for shield terminations. As the circuit and wiring diagrams indicate, only one of the two shields of the dual input cables and the signal cable to the input stage is connected to the third pole of the selector switch, to decrease the possibility of earth loops.

The input wiring shield must not be



At top is a view showing the location of the power transistors and the input and output sockets. Below this is a view of the control wiring: Particular care needs to be taken with the earth returns. Below this, again, is an oblique view of the rear of the amplifier.

PARTS LIST

1 chassis with overall dimensions 9¾ x 7 7/8 x 3¼ inches made of 18-gauge metal.
1 metal cover with dimensions to suit chassis (optional).
1 front panel.
1 power transformer, 240V to 32V at 2A DC.
3 3-pin DIN sockets.
2 2-pin polarised sockets.
1 printed board, 68/a8.
Miniature tagboard, 1 19-lug, 1 16-lug.
1 3-pole 3-position rotary switch.

SEMICONDUCTORS

2 AD161/162 complementary matched transistor pairs.
1 40250 silicon NPN transistor.
2 BC109, SE4010 or similar low-noise silicon NPN transistor.
4 BC108, 2N3565 or similar silicon NPN transistor.
2 AC128 germanium PNP transistor (with flag heatsinks).
2 BYX21/200 power diodes or MB1 bridge rectifier.
1 EM401, AD100 or similar power diode.
1 BZY95-/C30 zener diode.
1 C106Y1 thyristor.
2 B8-320-01A/10E or E215AB/15E thermistors.

POTENTIOMETERS

1 50K (log) dual ganged, with rotary power switch.
1 2M (log) dual ganged.
1 5M (lin).

RESISTORS

(½ or ¼-watt, 5% tolerance.)
2 x 6.8 M, 2 x 1.5M, 2 x 270K, 2 x 220K, 2 x 120K, 2 x 68K, 2 x 22K, 2 x 6.8K, 2 x 4.7K, 2 x 1.5K, 2 x 1.2 K, 2 x 680 ohm, 2 x 68 ohm, 2 x 22 ohm, 1 x 15 ohm, 2 x 4.7 ohm.

(½-watt unless specified.)
1 x 470 ohm/3 watt (to suit pilot lamp).
1 x 390 ohm/2 watt.
1 x 330 ohm (2 x 1 watt, 2 x ½-watt).
2 x 0.47 ohm, 1 x 0.39 ohm.

ELECTROLYTIC CAPACITORS

2 x 1000uF/15VW, 1 x 500uF/50VW, 4 x 250uF/40VW, 2 x 500uF/2.5VW, 2 x 250uF/15VW, 2 x 10uF/15VW.

CAPACITORS

(Low voltage polyester, polystyrene or metallised polyester)
2 x 0.47uF, 2 x 0.01uF, 2 x 2200pF, 2 x 390pF, 2 x 270pF.

SUNDRIES

4 turned aluminium knobs, 4 rubber feet, 8 x ¼in fibre rod spacers, tapped right through for 1/8in Whit. screws, 1 4-terminal tagstrip, mains cord and plug, mains cord clamp, grommet, miniature bezel and lamp, dual shielded cable, hook-up wire, spaghetti sleeving, screws, nuts, silicone grease, solder, etc.

connected to the chassis at any point apart from the connection made via the printed boards.

All the above wiring details are shown on the wiring diagram. It is good practice to check your wiring against the circuit diagram. If the details of the wiring layout are not noted and duplicated, instability or, at the very least, failure to obtain the performance of the prototype, may result.

The power transformer used in the prototype was a Ferguson, type PF 2876, which is rated 32 volts at 2 amps DC. Other manufacturers have equivalent types available. It should be mounted in the way shown in the illustration.

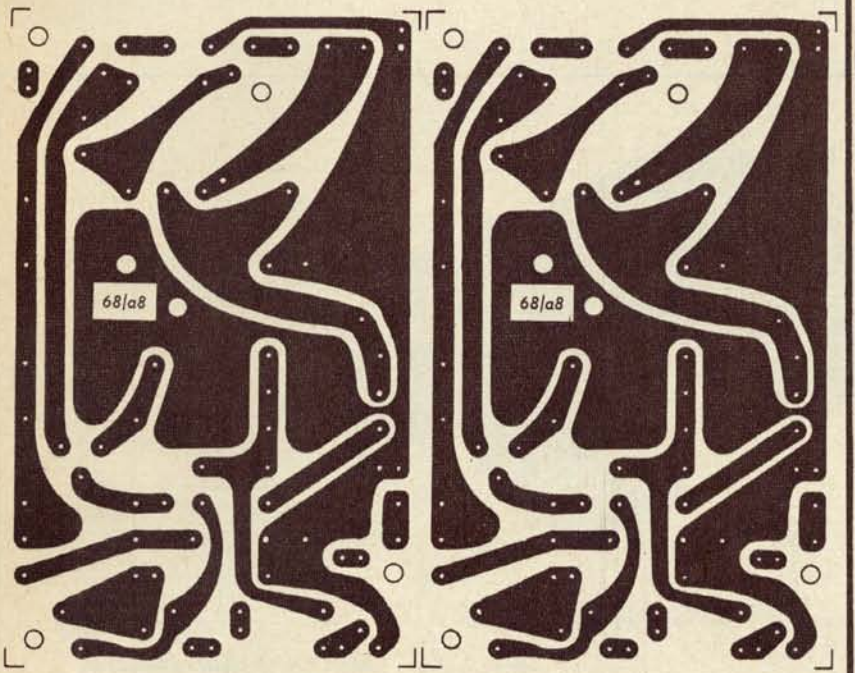
A suitable order of assembly would be as follows: First, wire all the components and connecting wires into the printed board. The 2200pF capacitor connected from base to collector of the driver transistor is wired on the copper side of the board, as is the positive supply connection for the input stages. The heat sinks for the driver transistors are made of 18 gauge metal, 1¼ inches wide by 2-3/16 bent at right-angles 13/16 inches from the end, with holes drilled for mounting screws. The two tagboards are also pre-wired as noted previously.

Note that all the boards are mounted on the chassis so that they have at least ¼-inch clearance of the same. This can be done using fibre rod spacers tapped right through for 1/8in whitworth or, alternatively, using just ¼-in screws and nuts.

Having wired the boards, attention can be turned to the chassis. The rubber feet are retained with a screw and nut, the nut being held in the foot itself. The potentiometer and selector switch shafts should be cut to suit the knobs. Having installed the controls and input sockets, transformer and rectifier, etc., the appropriate wiring can be installed. The mains cord should be passed through a grommeted hole in the rear of the chassis, then between the chassis side flange and the transformer stack and finally terminated at the switchpot. It is anchored by a clamp held by the same screw which retains one of the transformer lugs.

The five power transistors may now be mounted, as detailed earlier. Then install the supply board and make inter-connections to it. Next, install the printed wiring board and 4-terminal tagstrip for the earth and supply connections.

The quiescent current is most easily checked at this stage. It should be between 65 and 75 milliamps for each channel. Next, the input stage tagboard can be installed. The "half-supply" voltage at the junction of the emitter resistors of the output transistors may now be checked and adjusted if need be, as described earlier. The final adjustment is that of the sensing resistor which is described above.



Above is the copper pattern of the amplifier board. Actual size of the board is 5½ x 4¼ inches.

Finally, a front panel and knobs can be fitted. The prototype had a panel with a glossy black background and white lettering which contrasts with the turned aluminium knobs.

The amplifier may be installed in a cabinet or used in a free-standing situation, in which case a cover is required. In both cases care must be taken to ensure that air can circulate freely around the rear of the chassis. The cover was made of 18-gauge aluminium, suitably bent and with a slight overhang at front and rear. Ventilation, in the form of a row of holes at top and sides or louvres, must be provided, to allow the interior of the amplifier to remain cool. The transformer was the main source of heat in the prototype, and if this is not allowed to escape the case can be become quite warm to the touch.

Used with a high quality ceramic cartridge and good quality speakers, the amplifier is capable of really excellent sound.