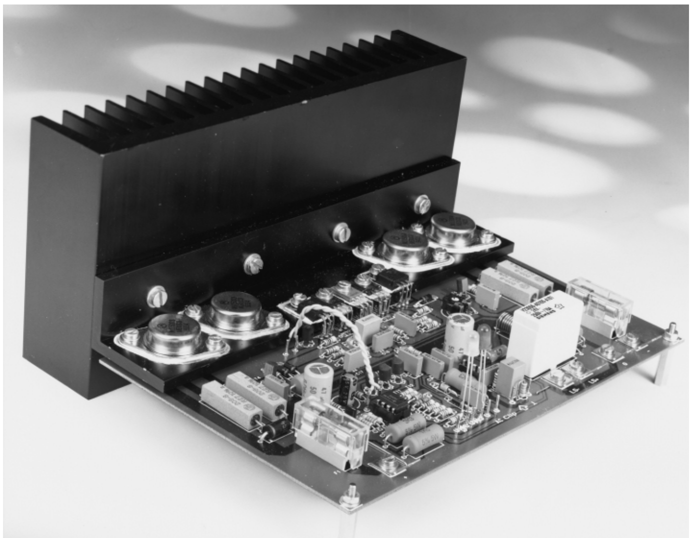
Contents

PA300 POWER AMPLIFIER



Design by A. Riedl

Taken by themselves, the properties of the PA300 amplifier are not revolutionary. But taken in combination, they show something special: a robust 300 watt hi-fi power amplifier that is not too difficult to build.

There are several starting points to the design of a power amplifier: pure hi-fi without any compromise; simplicity and reliability; high output power. The design of the present amplifier is a mixture of these. The result is a unit that does not use esoteric components, is not too complex, and is fairly easily reproduced. In fact, it could well be named a 'Hi-fi public address amplifier'.

There will be a few eyebrows raised at the power output of 300 watts (into 4Ω); it is true, of course, that in the average living room 30–40 W per channel is more than sufficient. However, peaks in the reproduced music may have a power of 10–20 times the average level. This means that some reserve power is desirable. Also, there are loudspeakers around with such a low efficiency that a lot more than 30–40W is needed. And, last but not least, there are many people who want an amplifier for rooms much larger than the average living room, such as an amateur music hall.

Straightforward design

Since every amplifier contains a certain number of standard components, the circuit of Fig. 1 will look pretty familiar to most audio enthusiasts. Two aspects may hit the eye: the higher than usual supply voltage and the presence of a couple of ICs. The first is to be expected in view of the power output. One of the ICs is not in the signal path and this immediately points to it being part of a protection circuit. What is unconventional is an IC in the input stage. Normally, this stage consists of a differential amplifier followed by a voltage amplifier of sorts, often also a differential amplifier, to drive the predriver stages. In the PA300, the entire input stage is contained in one IC, a Type NE5534 (IC_1).

The internal circuit of IC_1 is shown in the box on further on in this article. It may also be of interest to note that the NE5534 is found in nine out of every ten CD players (as amplifier in the analogue section). This is reflected in its price which is low. Its only drawback is that its supply voltage is far below that of the remainder of the amplifier. This means an additional symmetrical supply of ±15 V. Moreover, it restricts the drive capability of the input stage. The supply requirement is easily met with the aid of a couple of zener diodes and resistors. The drive restriction means that the amplifier must provide a measure of voltage amplification after the input stage.

Circuit description

The input contains a high-pass filter, C_5-R_3 and a low-pass filter, R_2-C_6. The combination of these filters limits the bandwidth of the input stage to a realistic value: it is not necessary for signals well outside the audio range to be amplified – in fact, this may well give rise to difficulties.

Opamp IC_1 is arranged as a differential amplifier; its non-inverting (+) input functions as the meeting point for the overall feedback. The feedback voltage, taken from junction D_7-D_8, is applied to junction R_4-R_5 via R_9. Any necessary compensation is provided by C_9, C_{12} and C_{14}. The voltage amplification is determined by the ratio R_9:R_5, which in the present circuit is ×40.

The output of IC_1 is applied to drive stages T_1 and T_3 via R_6. These transistors operate in Class A: the current drawn by them is set to 10 mA by voltage divider R_{10}-R_{13} and their respective emitter resistors. Their voltage and current amplification is appreciable, which is as required for the link between the input and output stages.

The output amplifier proper consists of drive stages T_6 and T_7 and power transistors T_8, T_9, T_{14}, T_{15}. which have been arranged as symmetrical power darlingtons. Because of the high power, the output transistors are connected in parallel. The types used can handle a collector current of 20 A and have a maximum dissipation of 250 W.

The output stages operate in Class AB to ensure a smooth transition between the n-p-n and p-n-p transistors, which prevents cross-over distortion. This requires a small current through the power transistors, even in the absence of an input signal. This current is provided by 'zener' transistor T_2,

Technical data (measured with power supply shown in Fig. 2)

Input sensitivity	1 V_{rms}
Input impedance	17.8 kΩ
Power output (0.1% THD)	164 W into 8 Ω
	275 W into 4 Ω
Music power(500 Hz burst 5 cycles on, 5 cycles off)	176 W into 8 Ω
	306 W into 4 Ω
Power bandwidth (90 W into 8 Ω)	7 Hz–67 kHz
Slew rate	20 V/μs
Signal-to-noise ratio (referred to 1 W into 8 Ω)	>96 dB (A-weighted)
Harmonic distortion (THD+N) (bandwidth 80 kHz)	at 1 W into 8 Ω: <0.004% (1 kHz)
	at 150 W into 8 Ω: <0.001% (1 kHz)
	<0.05% (20 Hz–20 kHz)
Intermodulation distortion (50 Hz:1 kHz; 4:1)	at 1 W into 8 Ω: <0.003%
	at 100 W into 8 Ω: <0.0035%
Dynamic IM (rectangular wave + 15 kHz sine wave)	1 W into 8 Ω: <0.004%
	150 W into 8 Ω: <0.06%
Damping factor (at 8 Ω)	<345 at 1 kHz
	<275 at 20 kHz

which puts a small voltage on the bases of T_6 and T_7 so that these transistors just conduct in quiescent operation. The level of the quiescent current is set accurately with P_1.

To ensure maximum thermal stability, transistors T_1–T_3 and T_6–T_7 are mounted on and the same heat sink. This keeps the quiescent current within certain limits. With high drive signals, this current can reach a high level, but when the input signal level drops, the current will diminish only slowly until it has reached its nominal value.

Diodes D_7, D_8 protect the output stages against possible counter voltages generated by the complex load. Resistor R_{30} and capacitor C_{17} form a Boucherot network to enhance the stability at high frequencies. Inductor L_1 prevents any problems with capacitive loads (electrostatic loudspeakers). Resistor R_{29} ensures that the transfer of rectangular signals are not adversely affected by the inductor.

Protection circuits

As any reliable amplifier, the PA300 is provided with adequate protection measures. These start with fuses F_1 and F_2, which guard against high currents in case of overload or short-circuits. Since even fast fuses are often not fast enough to prevent the

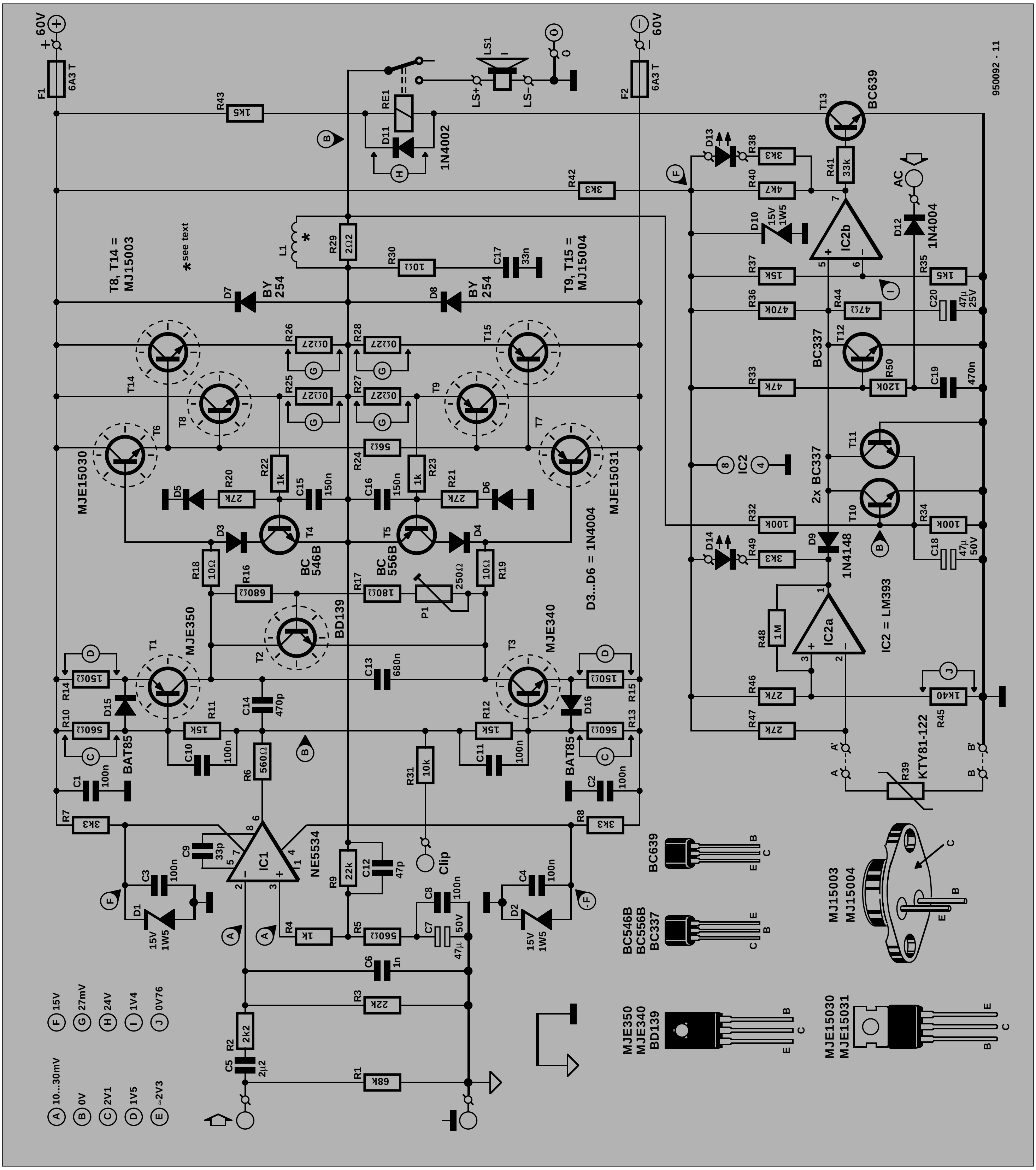


Fig. 1. With the exception of an IC at the input, the circuit of the PA300 amplifier is conventional.

Contents

power transistors giving up the ghost in such circumstances, an electronic short-circuit protection circuit, based on T_4 and T_5, has been provided. When, owing to an overload or short-circuit, very high currents begin to flow through resistors R_{25} and R_{27}, the potential drop across these resistors will exceed the base-emitter threshold voltage of T_4 and T_5. These transistors then conduct and short-circuit or reduce drive signal at their bases. The output current then drops to zero.

If a direct voltage appears at the output terminals, or the temperature of the heat sink rises unduly, relay Re_1 removes the load from the output. The loudspeakers are also disconnected by the relay when the mains is switched on (power-on delay) to prevent annoying clicks and plops.

The circuits that make all this possible consist of dual comparator IC_2, transistors T_{10}–T_{13}, and indicator diodes D_{13} and D_{14}. They are powered by the 15 V line provided by zener diode D_{10} and resistor R_{42}.

The 'AC' terminal on the PCB is linked to one of the secondary outputs on the mains transformer. As soon as the mains is switched on, an alternating voltage appears at that terminal, which is rectified by D_{12} and applied as a negative potential to T_{12} via R_{50}. The transistor will then be cut off, so that C_{20} is charged via R_{36} and R_{44}. As long as charging takes place, the inverting (+) input of comparator IC_{2b} is low w.r.t. the non-inverting (–) input. The output of IC_{2b} is also low, so that T_{13} is cut off and the relay is not energized. This state is indicated by the lighting of D_{13}. When C_{20} has been charged fully, the comparator changes state, the relay is energized (whereupon D_{13} goes out) and the loudspeakers are connected to the output. When the mains is switched off, the relay is deenergized instantly, whereupon the loudspeakers are disconnected so that any switch-off noise is not audible.

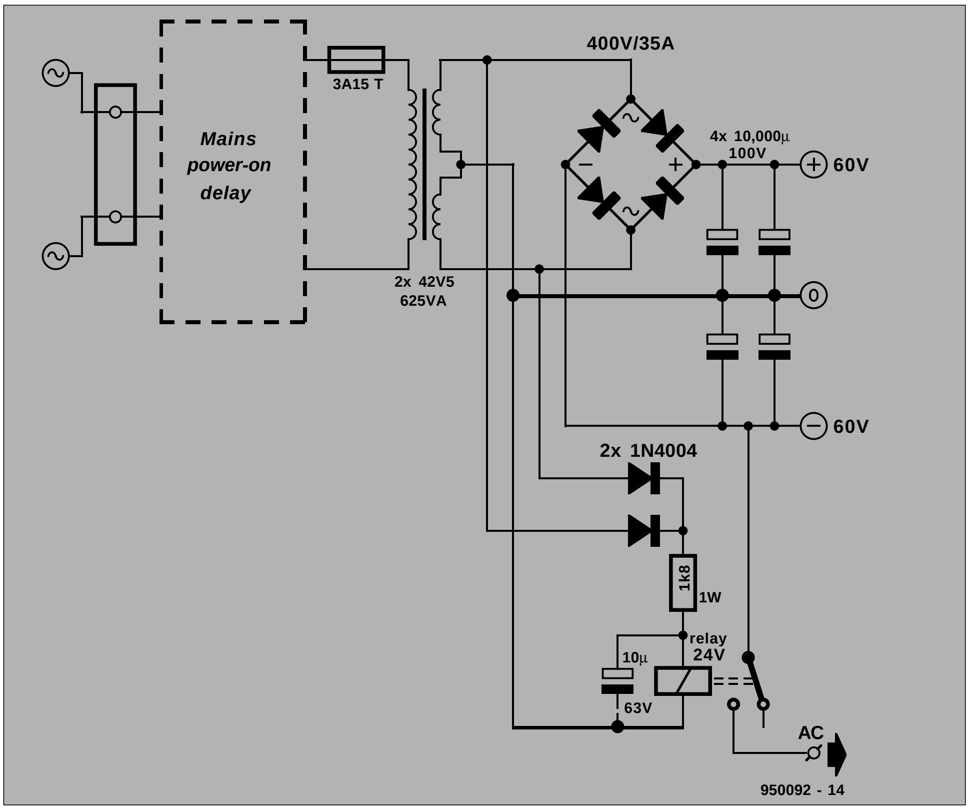


Fig. 2. The power supply is straightforward, but can handle a large current. Voltage 'AC' serves as drive for the power-on delay circuit.

The direct-voltage protection operates as follows. The output voltage is applied to T_{10} and T_{11} via potential divider R_{32}-R_{34}. Alternating voltages are short-circuited to ground by C_{18}. However, direct voltages greater than +1.7 V or more negative than –4.8 V switch on T_{10} or T_{11} immediately. This causes the +ve input of IC_{2a} to be pulled down, whereupon this comparator changes state, T_{13} is cut off, and the relay is deenergized. This state is again indicated by the lighting of D_{13}.

Strictly speaking, temperature protection is not necessary, but it offers that little bit extra security. The temperature sensor is R_{39}, a PTC (positive temperature coefficient) type, which is located on the board in a position where it rests against the rectangular bracket. Owing to a rising temperature, the value of R_{39} increases until the potential at the –ve input of IC_{2a} rises above the level at the +ve input set by divider R_{45}-R_{46}, whereupon the output of IC_{2a} goes low. This causes IC_{2b} to change state, whereupon T_{13} is cut off and the relay is deenergized. This time, the situation is indicated by the lighting of D_{14}. The circuit has been designed to operate when the temperature of the heat sink rises above 70 °C. Any relay clatter may be obviated by reducing the value of R_{48}.

The terminal marked 'CLIP' on the PCB is connected to the output of IC_1 via R_{31}. It serves to obtain an external overdrive indication, which may be a simple combination of a comparator and LED. Normally, this terminal is left open.

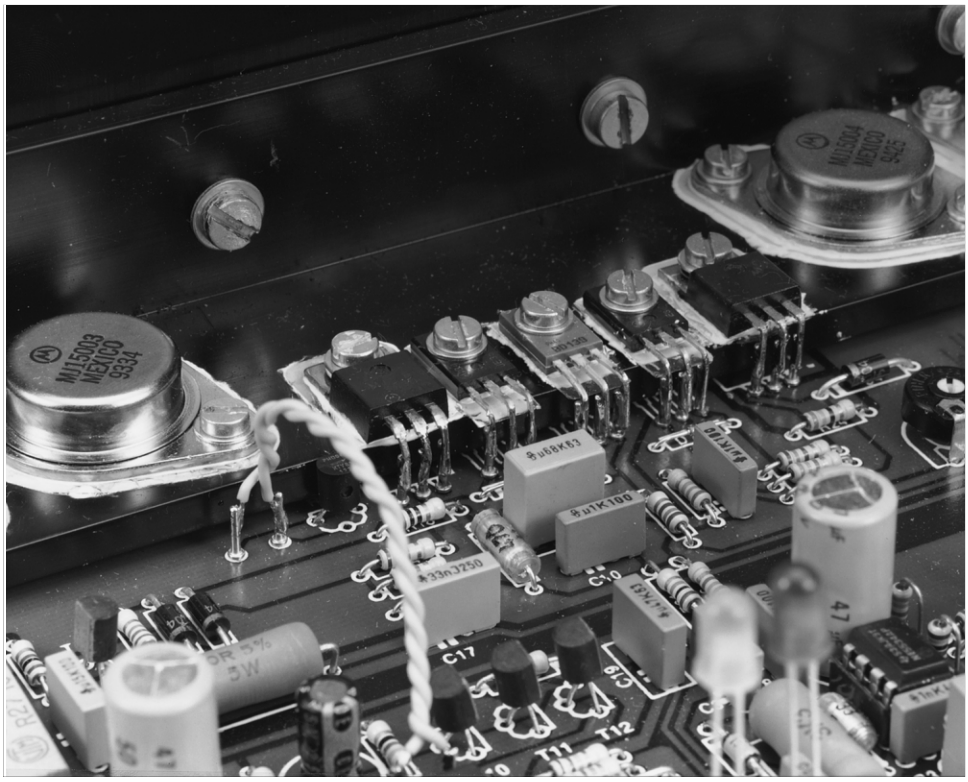


Fig. 3. This close-up photograph shows clearly how the transistors are fitted to the heat sink via a rectangular bracket.

Power supply

As with most power amplifiers, the ±60 V power supply need not be regulated. Owing to the relatively high power output, the supply needs a fairly large mains transformer and corresponding smoothing capacitors—see Fig. 2. Note that the supply shown is for a mono amplifier; a stereo outfit needs two supplies.

The transformer is a 625 VA type, and the smoothing capacitors are 10 000 µF, 100 V electrolytic types. The bridge rectifier needs to be mounted on a suitable heat sink or be mounted directly on the bottom cover of the metal enclosure.. The transformer needs two secondary windings, providing 42.5 V each. The prototype used a toroidal transformer with 2×40 V secondaries. The secondary winding of this type of transformer is easily extended: in the prototype 4 turns were added and this gave secondaries of 2×42.5 V.

The box 'Mains power-on delay' provides a gradual build-up of the mains voltage, which in a high-power amplifier is highly advisable. A suitable design was published in *305 Circuits* (page 115).

The relay and associated drive circuit is intended to be connected to terminal 'AC' on the board, where it serves to power the power-on circuit. If a slight degradation of the amplifier performance is acceptable, this relay and circuit may be omitted and the PCB terminal connected directly to one of the transformer secondaries.

Construction

Building the amplifier is surprisingly simple. The printed-circuit board in Fig. 4 is well laid out and provides ample room. Populating the board is as usual best started with the passive components, then the electrolytic capacitors, fuses and relay. There are no 'difficult' parts.

Circuits IC_1 and IC_2 are best mounted in appropriate sockets.

Diodes D_{13} and D_{14} will, of course, have to be fitted on the front panel of the enclosure and are connected to the board by lengths of flexible circuit wire.

Inductor L_1 is a DIY component; i consists of 15 turns of 1 mm. dia. enamelled copper wire around R_{29} (not too tight!).

Since most of the transistors are to be mounted on and the same heat sink, they are all located at one side of the board. However, they should first be fitted on a rectangular bracket, which is secured to the heat sink and the board—see Fig. 3. Note that the heat sink shown in this photograph proved too small when 4 Ω loudspeakers were used. With 8 Ω speakers, it was just about all right, but with full drive over sustained periods, the temperature protection circuits were actuated. If such situations are likely to be encountered, forced cooling must be used.

As already stated, temperature sensor R_{39} should rest (with its flat surface) against the rectangular bracket. On the board, terminals 'A' and 'B' terminals to the left of R_{39} must be connected to 'A' and 'B' above IC_2 with a twisted pair of lengths of insulated circuit wire as shown in Fig. 3.

The points where to connect the loudspeaker leads and power lines are clearly marked on the board. Use the special flat AMP connectors for this purpose: these have large-surface contacts that can handle large currents. The loudspeaker cable should have a cross-sectional area of not less than 2.5 mm^2.

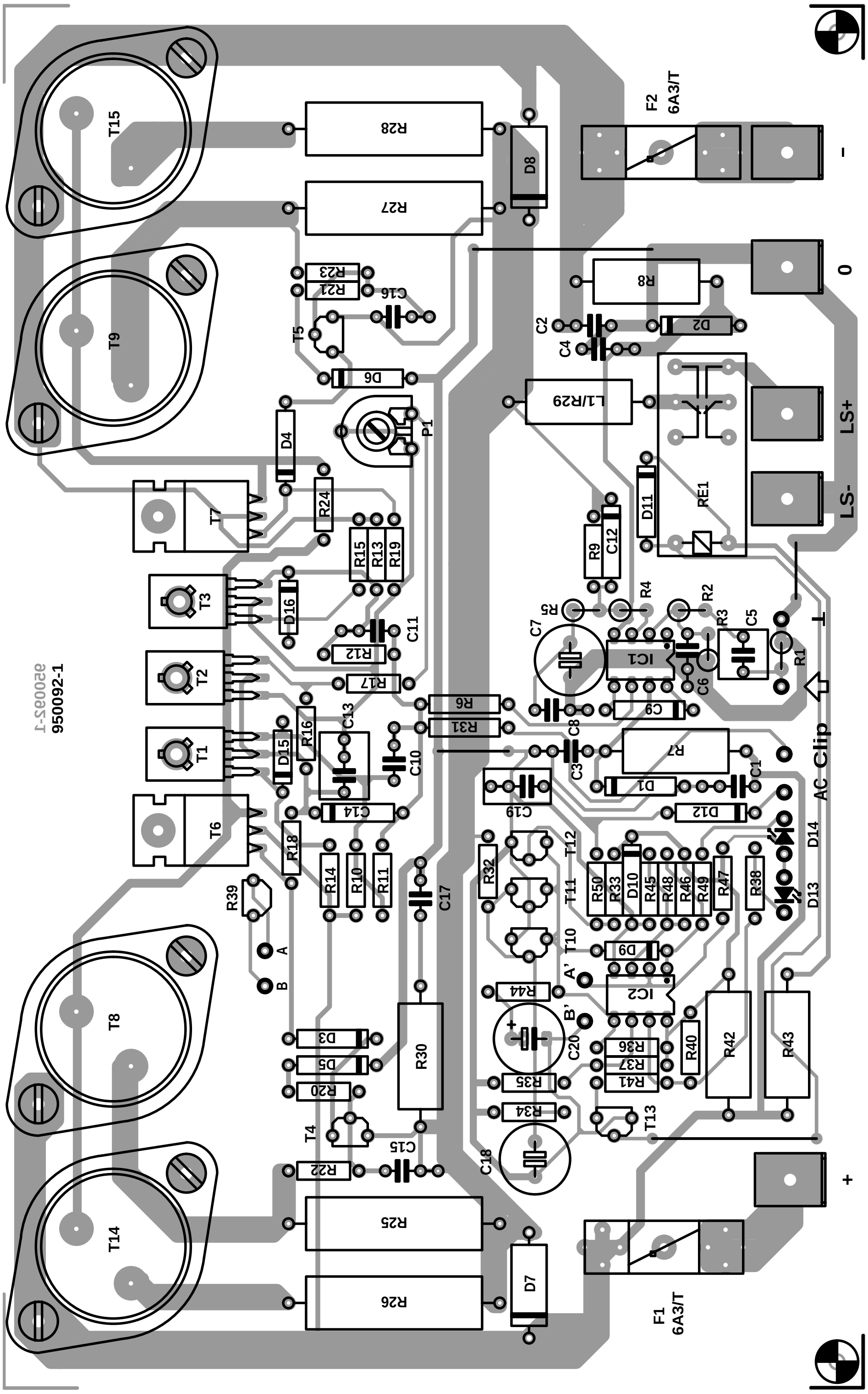


Fig. 4a. Component layout of the printed-circuit board for the 300 W power amplifier.

Finally

How the amplifier and power supply are assembled is largely a question of individual taste and requirement. The two may be combined into a mono amplifier, or two each may be built into a stereo amplifier unit. Our preference is for mono amplifiers, since these run the least risk of earth loops and the difficulties associated with those. It is advisable to make the '0' of the supply the centre of the earth connections of the electrolytic capacitors and the centre tap of the transformer.

The single earthing point on the supply and the board must be connected to the enclosure earth by a short, heavy-duty cable. This means that the input socket must be

Contents

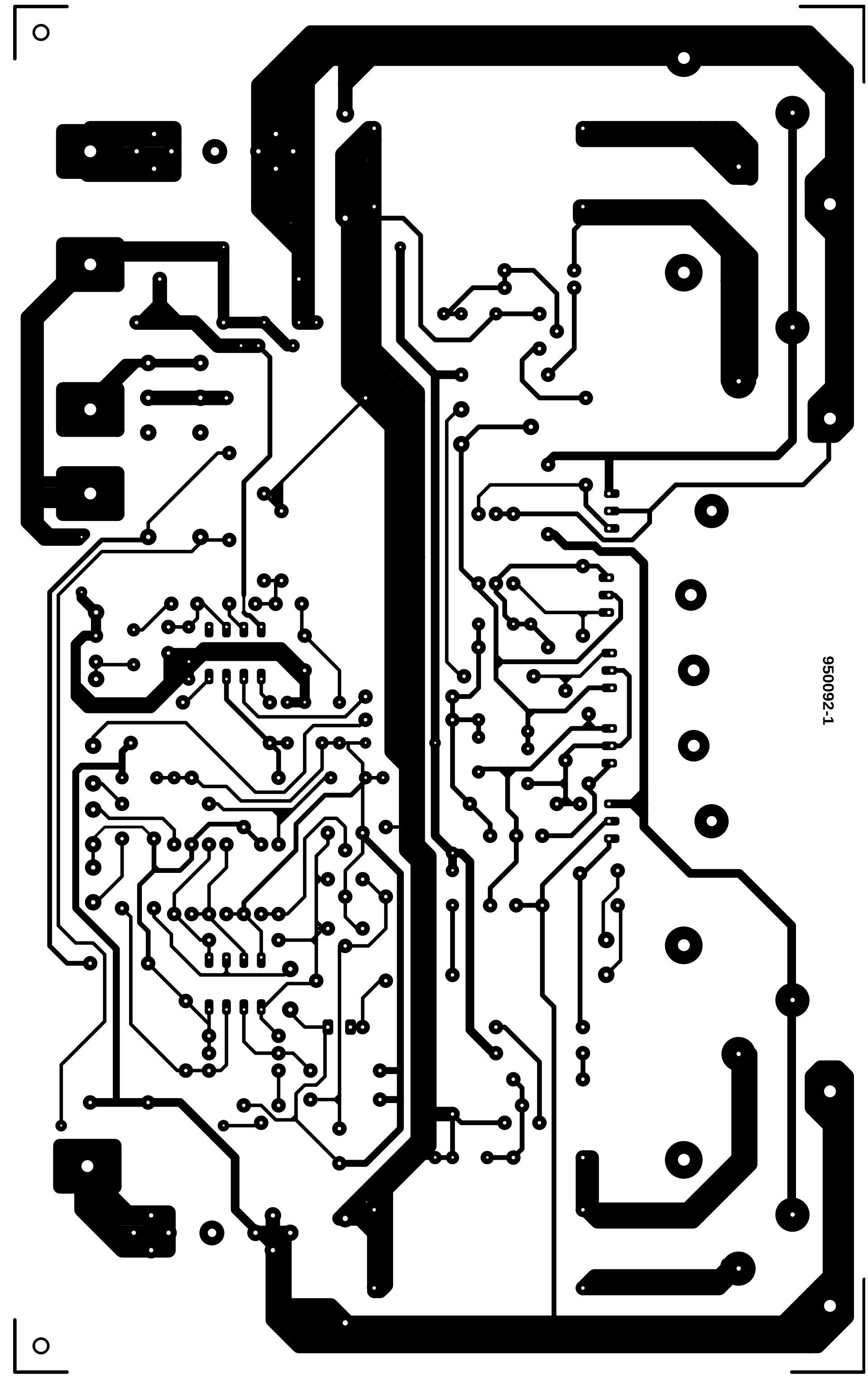


Fig. 4b. Track layout of the printed-circuit board for the 300 W power amplifier.

an insulated type. This socket must be linked to the input on the board via screened cable.

To test the amplifier, turn P_1 fully anti-clockwise and switch on the mains. After the output relay has been energized, set the quiescent current. This is done by connecting a multimeter (direct mV range) across one of resistors R_{25}–R_{28} and adjusting P_1 until the meter reads 27 mV (which corresponds to a current of 100 mA through each of the four power transistors). Leave the amplifier on for an hour or so and then check the voltage again: adjust P_1 as required.

Test results

The technical data given on page0 0 were verified or obtained with a power supply as shown in Fig. 2. They show that in spite (or because?) of its simple design, the amplifier offers excellent performance. The distortion figures are particularly good.

Measurements with the Audio Precision analyser are illustrated in Fig. 5.

Figure 5a shows the total harmonic distortion (THD+N) over a frequency range of 20 Hz to 20 kHz.with a bandwidth of 80 kHz and a power output of 150 W into 8 Ω. Up to 1 kHz, the distortion is very low and then increases, which is usual and caused by the inertia of the semiconductors.

Figure 5b shows the distortion at 1 kHz as a function of the output level at a bandwidth of 22 Hz to 22 kHz. The dashed curve refers to a load of 4 Ω and the solid curve to a load of 8 Ω. The irregularities between 10 W and 100 W are not caused by the amplifier but by the limits of the measuring range of the analyser. From the clipping points, the curves rise almost vertically.

Figure 5c shows the maximum for a distortion of 0.1%. The dashed curve (4 Ω load) is very close to the 300 W line. The small reduction at low frequencies is caused by the imperfectness of the electrolytic buffer capacitors in the power supply.

Figure 5d shows the Fourier analysis of a 1 kHz signal for a power output of 1 W into 8 Ω. The fundamental frequency is suppressed. The 2nd and 3rd harmonics are down by 110 dB and 120 dB respectively referred to the fundamental frequency. The THD+N figure at this measurement was 0.0009%.

Parts list

Resistors:
R_1 = 68 kΩ
R_2 = 2.2 kΩ
R_3, R_9 = 22 kΩ
R_4, R_{22}, R_{23} = 1 kΩ
R_5, R_6, R_{10}, R_{13} = 560 Ω
R_7, R_8, R_{42} = 3.3 kΩ, 5 W
R_{11}, R_{12}, R_{37} = 15 kΩ
R_{14}, R_{15} = 150 Ω
R_{16} = 680 Ω
R_{17} = 180 Ω
R_{18}, R_{19} = 10 Ω
R_{20}, R_{21}, R_{46}, R_{47} = 27 kΩ
R_{24} = 56 Ω
R_{25}–R_{28} = 0.27 Ω, 5 W
R_{29} = 2.2 Ω, 5 W
R_{30} = 10 Ω, 5 W
R_{31} = 10 kΩ
R_{32}, R_{34} = 100 kΩ
R_{33} = 47 kΩ
R_{35} = 1.5 kΩ
R_{36} = 470 kΩ
R_{38}, R_{49} = 3.3 kΩ
R_{39} = sensor Type KTY81-122
R_{40} = 4.7 kΩ
R_{41} = 33 kΩ
R_{43} = 1.5 kΩ, 5 W
R_{44} = 47 Ω
R_{45} = 1.40 kΩ, 1%
R_{48} = 1 MΩ
R_{50} = 120 kΩ
P_1 = 250 Ω preset

Capacitors:
C_1–C_4, C_8, C_{10}, C_{11} = 100 nF
C_5 = 2.2 µF polypropylene, pitch 5 mm
C_6 = 1 nF
C_7, C_{18} = 47 µF, 50 V, bipolar, radial;
C_9 = 33 pF, 160 V, polystyrene
C_{12} = 47 pF, 160 V, polystyrene

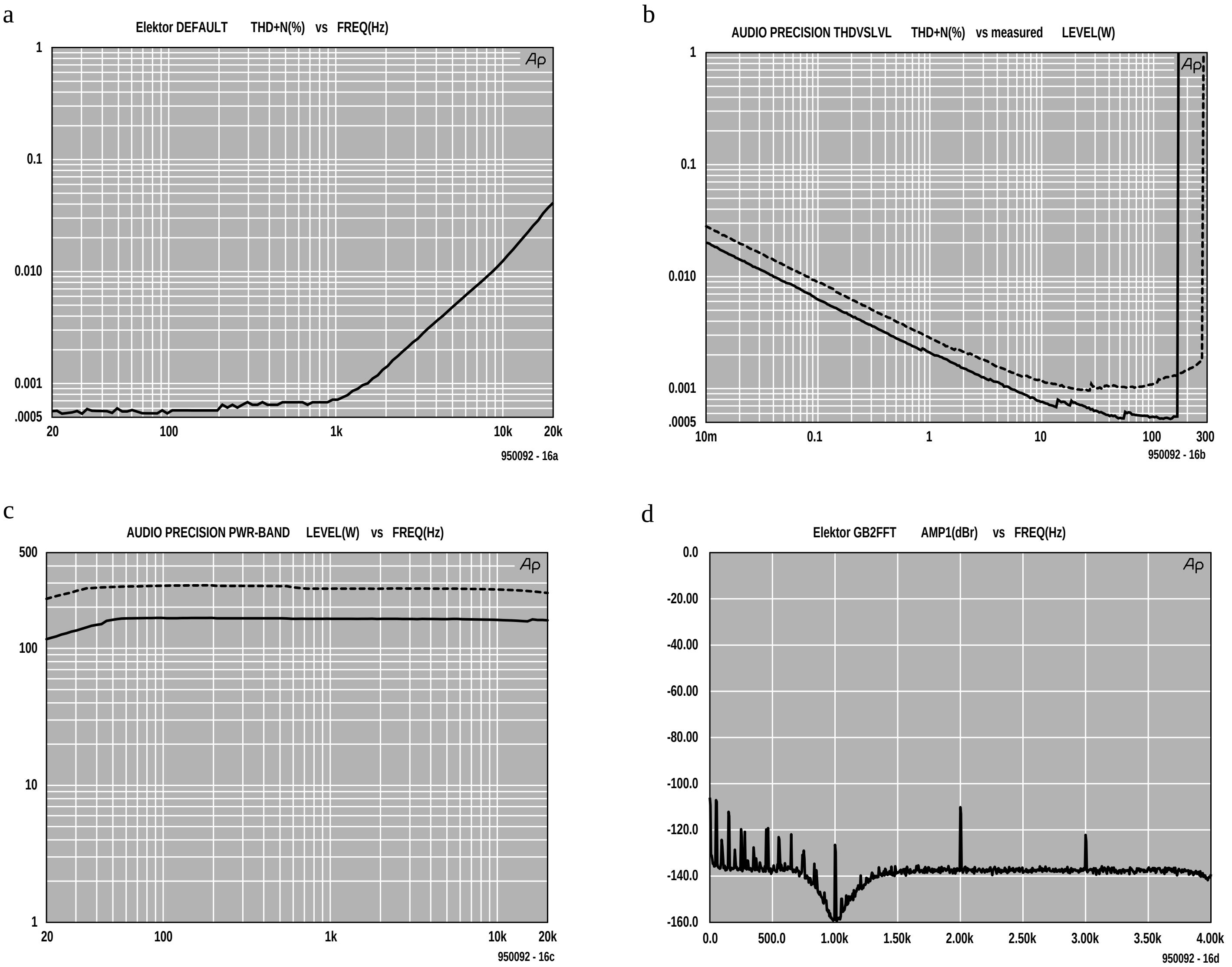


Fig. 5. Curves obtained during measurements on the amplifier with an Audio Precision Analyser (see text).

C_{13} = 680 nF
C_{14} = 470 pF, 160 V, polystyrene
C_{15}, C_{16} = 150 nF
C_{17} = 33 nF
C_{19} = 470 nF
C_{20} = 47 µF, 25 V, radial

Semiconductors:
D_1, D_2, D_{10} = zener, 15 V, 1.5 W
D_3, D_6, D_{12} = 1N4004
D_7, D_8 = BY254
D_9 = 1N4148
D_{11} = 1N4002
D_{13}, D_{14} = LED
D_{15}, D_{16} = BAT85
T_1 = MJE350
T_2 = BD139
T_3 = MJE340
T_4 = BC546B
T_5 = BC556B
T_6 = MJE15030
T_7 = MJE15031
T_8, T_{14} = MJ15003
T_9, T_{15} = MJ15004
T_{10}, T_{12} = BC337
T_{13} = BC639

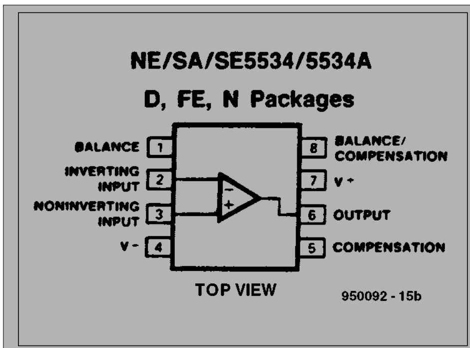
Integrated circuits:
IC_1 = NE5534
IC_2 = LM393

Miscellaneous:
L_1 = see text
Re_1 = 16 A, 24 V, 875 Ω relay (e.g. Siemens V23056-AO105-A101*)
F_1, F_2 = glass fuse, 6.3 A, slow complete with PCB type holder
Loudspeaker and mains connectors for board mounting (AMP - see text)
Mica washers for T_1–T_3, T_6–T_9, T_{14} and T_{15}
Rectangular bracket e.g. SWP40, 20 cm long (Fischer 40×30×5**)
Heat sink <0.4 K W^{-1}
PCB Order no. 950092
Mains transformer, 2×42.5 V, 625 VA (see text)
Fuse (power supply) 3.15 A, slow, $I^2t \geq 400$
Bridge rectifier 400 V, 35 A
4 off electrolytic capacitors, 10,000 µF, 100 V
PCB Order No. 924055

[950092]

* ElectroValue 01784 33603 or 0161 432 4945
** Dau 01243 553 031; trade only, but information on your nearest dealer will be given by telephone.

Contents



The NE5534

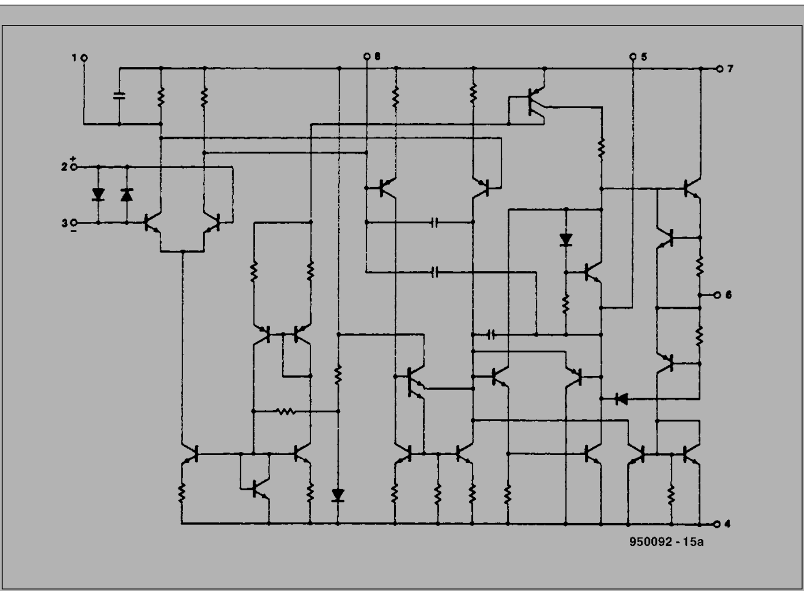
The NE5534 is a good quality, versatile, low-noise operational amplifier which is excellent value for money.

Compared with older types, it has better noise figures, small signal performance, power bandwidth, and output drive capability.

These characteristics make it ideally suited to high-end audio applications. It is found even in the most expensive CD players.

The adjacent simplified diagram gives an idea of the internal structure of this versatile device. It consists of a number of differential amplifiers that are set with the aid of current sources and current mirrors. Well-designed compensation circuits result in excellent linearity and very low distortion.

The standard design gives an amplification of ×3. The frequency response can be optimized for various applications with the aid of an external capacitor. It may be adjusted for a capacitive load, high slew rate, low overshoot or for application as a unity amplifier.



Some technical data

Small-signal bandwidth	10 MHz
Output voltage (at U_b = ±18 V)	10 V_{rms} across 600 Ω
Input noise	4 nV Hz^{-1}
DC voltage amplification	10^5
AC voltage amplification	$6×10^3$ at 10 kHz
Power bandwidth	200 kHz
Slew rate	13 V $μs^{-1}$
Supply voltage range	±3 V to ±20 V