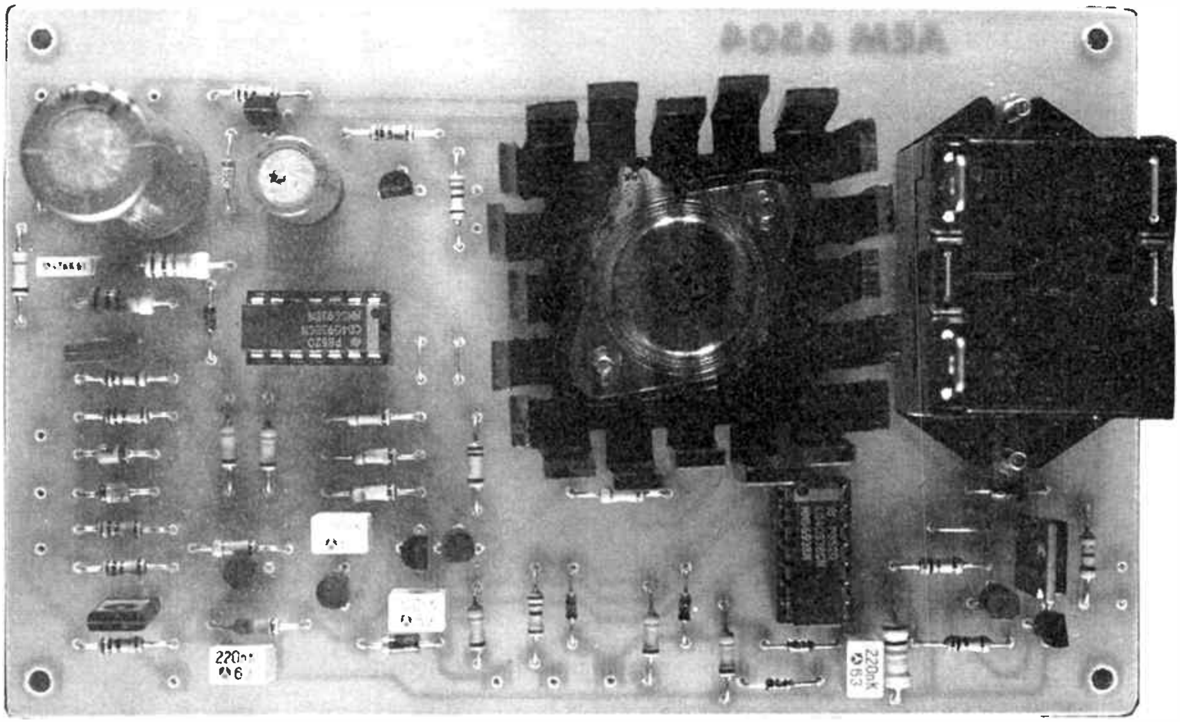


A power amp 'status monitor'

David Tilbrook

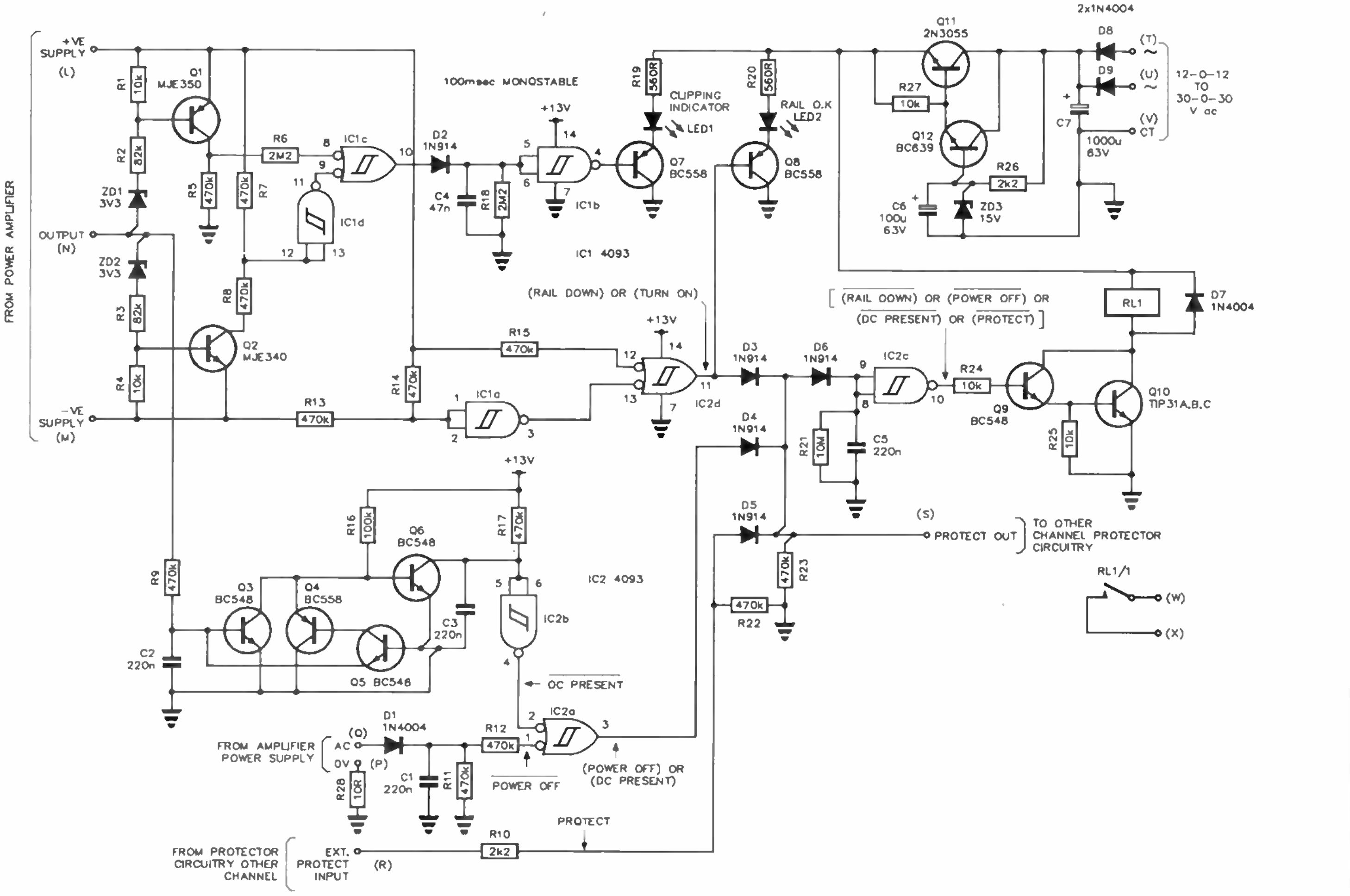
Designed to team with the 6000 MOSFET amp module, but usable with any power amp, this project prevents dc fault conditions or excessive clipping from exterminating amps and speakers alike.

VIRTUALLY ALL modern solid state power amplifiers employ dc-coupled output stages with no dc blocking capacitor in series with the output of the power amplifier. In a valve power amplifier, the loudspeaker is protected from dc by the output transformer. Similarly, earlier transistor designs, particularly those types employing a single supply rail, used an output coupling capacitor which isolated the loudspeaker from the dc supply in the event of failure. The modern transistor power amplifier, however, has neither of these and can place the loudspeaker at risk in the event of an output stage or other type of failure which results in a net dc voltage being applied to its output terminals.

A power amplifier rated to deliver 200 W RMS into an 8 ohm load will usually be provided with a supply rail of around +/- 60 volts. This means that, in the event of power amplifier failure it is possible, in fact quite likely, that there will be either positive or negative 60 volts present on the output terminal. A loudspeaker rated nominally at an 8 ohm impedance usually has a dc resistance under 6 ohms. The 60 volts dc applied to this load results in a dc current of around 10 amps through the voice coil of the bass driver which must therefore dissipate 600 watts. This level of power dissipation will destroy even the highest power bass drivers and so some method of protection against this condition must be provided for high power solid state power amplifiers.

Most modern power amplifiers employ dual supplies which are provided with independent fuses. If either of these fuses blow, the resulting output signal waveform is severely clipped on one half-cycle. This results in an enormous amount of distortion, and once again has an effective net dc offset. This is another condition from which the loudspeaker should be protected. Similarly, many power amplifiers can exhibit a significant short term dc offset at the moment of turn-on or turn-off while the power amplifier circuitry is stabilising.

This project monitors the 'status' of the power amplifier and disconnects the loudspeaker if the conditions produced by the power amp are likely to damage it. The Power Amp Status Monitor looks for the presence of dc on the output stage, monitors the two supply rails and provides the facility for turn-on and turn-off de-thump. In addition, it provides the additional feature of an accurate clipping indicator which warns when the maximum output power of a power amplifier has been achieved. At this point, the signal peaks are clipped as the output or drive stage rams against one or other of the supply rails, generating large quantities of high frequency distortion. If excessive, this can damage the high frequency driver. If the power amplifier is driven into clipping for more than 100 milliseconds the circuitry detects this and ▶



CIRCUIT OPERATION

The power amp status monitor works by detecting a number of fault conditions which can occur with power amplifiers employing dc coupled output stages. The circuit uses various detection systems to determine the presence of these faults and deactivates a relay which disconnects the loudspeaker from the output of the power amplifier in the event of a fault.

CLIPPING DETECTOR

The clipping detector operates by measuring the differnce in voltage between the power amp output and the power amp suply rails. The function is performed by Q1, Q2, resistors R1-R4 and zener diodes ZD1 and ZD2. As long as the output signal voltage is well away from either supply rail, current flows through R1, R2, R3 and R4 and the zener diodes to the output of the amplifier. This current forward biases transistors Q1 and Q2. Since Q1 is "on", the voltage across R5 is approximately equal to the supply rail of the power amplifier and this voltage is applied via a current limiting resistor (R6) to one of the inputs (pin 8) of a CMOS two-input NAND gate.

As long as Q1 remains on then the voltage applied to pin 8 of IC1c will be high and pin 10 of the CMOS gate will remain low. If, on the other hand, the output of the power amplifier approaches the positive supply rail too closely then transistor Q1 will be biased off and the voltage drop across R5 will decrease applying a low to pin 8 of IC1c.

The circuit detects clips against the negative rail in a slightly different manner. Transistor Q2 works in the same way as Q1, except that if Q2 is biased on then resistors R7 and R8 form a potential divider between the positive and negative supply rails. Since these rails are approximately equal, the voltage on the output of this potential divider will be around 0 V and this is applied to IC1d which is configured as a simpler inverter. The output of this inverter is connected to the other input of IC1c. Since the input of IC1d is low, the output will be high and hence pin 9 of IC1c will be high. If the output of the power amplifier approaches the negative suply too closely, Q2 will be biased off and the input of IC1d will be pulled toward the positive supply rail. The inverting function of IC1d results in its output going low and hence pin 9 of IC1 going low.

IC1c in this case performs the function of an OR gate for active-low signals. If either pin 8 or pin 9 goes low, indicating that a clip at either the positive or negative supply rails has occurred, then the output of IC1c (pin 10) will go high. Diode D2, in conjunction with C4 and R18, perform the function of a simple monostable. Even the shortest clip that results from a signal within the audio passband will result in C4 becoming charged to a voltage higher than the Schmitt level of IC1b.

The resulting low on pin 4 biases-on Q7, turning LED1 on to indicate a clipping condition. The value of C4, in conjunction with R18 is chosen so that it takes approximately 100 msec for the voltage across C4 to fall below the Schmitt level of IC1b which, in turn, turns LED1 off. This monostable function ensures that the clipping indication remains active for around 100 msec longer than the duration of the clip so that adequate indication is given, even of the shortest duration clip.

RAIL INTEGRITY SENSORS

The power amplifier positive and negative supply rails are also applied via resistors R13, R14 and R15 to the input of CMOS gates IC1a and IC2d. These gates monitor the integrity of the power amp supply rails, and together with Q8 and LED2, provide a visual indication that the supply rail voltages are intact. The positive supply rail is applied via resistor R15 to pin 12 of IC2d. Resistors R13 loudspeaker will be disconnected.

Once the loudspeaker has been disconnected it will remain in this state for approximately two seconds longer than the fault condition remains, and then automatically reconnects the load.

Although the project has been specifically designed for operation with the AEM6000 Ultra-fidelity Power Amplifier Module it has universal application and can be used virtually with any power amplifier employing dual supply rails. Unlike many clipping indicators, the 6504 features a novel circuit which detects clipping not by measuring the output signal voltage, but by *measuring the voltage between the output signal and the supply rails of the power amplifier*. The circuit will therefore validly indicate a clipping condition *regardless of whether the power amplifier is rated at 50 or 250 watts.*

The relay necessary for this unit presents particular problems. The contacts must be heavy enough to ensure to degradation of the performance of the power amplifier, and rated to break a powerful dc arc. Direct current is much more difficult to switch than alternating current and the ac rating of a relay contact must be significantly decreased when it is intended for dc operation. The relay specified for use with this project is a single pole type with heavy contacts rated for high current operation. We have included a data sheet later in this issue.

Design background

A detailed description of the operation of the project is included in the Circuit Operation section. There are however, a number of interesting problems associated with the design of this monitor which warrant particular mention because they highlight the improvement in performance that can be expected from this circuit in comparision to many older designs. I have already discussed briefly the operation of traditional clipping indicator and mentioned that this project detects clipping by measuring the difference in voltage between the supply rails and the output of the power amplifier.

The circuit shown here will reliably indicate clipping regardless of the output power of the amplifier and without necessitating any adjustments. This is a decided advantage over many earlier clipping indicator designs which tended to measure the output signal level with respect to earth, making it impossible to correct for the different rail voltages that result from different mains supply voltages. The clipping in- ▶

and R14 form a potential divider between the positive and negative supply rails.

If both rails are present then the output of this potential divider which is connected to pins 1 and 2 of IC1a will be around 0 V, hence pin 3 will be high. If the positive supply rail fuse in the power amp blows, for example, the voltage applied to pin 12 of IC2d will drop to zero. If the negative supply fuse blows, R14 pulls the input of IC1a high and hence pin 3 goes low, taking pin 13 of IC2d low.

As with IC1c, IC2d performs the function of an OR gate for active-low signals on its inputs; its output goes high if either of its inputs goes low. A high on the output of IC2d biases transistor Q8 off and the "Rail O.K." LED is deactivated. The high is also coupled via diode D3 to the input of D6 and to the protect output which is otherwise held low by resistor R23. The high applied to the anode of D6 causes C5 to charge so that the input if IC2c, which performs the function of a simple inverter, is also taken high. The output if IC2c goes low removing the drive from the current-amplifying Darlington pair, Q9 and Q10, which deactivates the relay RL1.

Components of C5, R21 and diode D6 ensure that the voltage on pin 13 of IC2d remains low for approximately two seconds after the power is switched on. This ensures that the relay remains deactivated for this time and provides a turn-on delay which allows the power amp to settle before the loudspeaker is connected.

DC SENSOR

One of the most dangerous faults that can occur with a power amplifier employing a dc-coupled output stage is one which results in a nett dc voltage being applied to the power amp output, and hence to the loudspeaker. In order to protect the loudspeaker in the event of such a failure, the AEM6504 monitors the output of the power amp for the presence of dc and deactivates the relay if a fault is detected.

The detector circuitry is based around transistors Q3, Q4, Q5 and Q6, and the associated passive components together with IC2b. Whenever the output of the power amp is driven to more than +0.6 V by an ac or dc signal, then Q3 is biased on. Similarly, when ever the output of the power amp is less than –0.6 V, then Q5 and hence Q4, will be biased on. The presence of a voltage on the output of the power amplifier, the absolute voltage of which exceeds 0.6 V, results in a low voltage being applied to the base of Q6 since the current provided by resistor R16 will be shorted to ground by the activated transistor Q3 or Q4. Q6 will therefore be biased off and capacitor C3 is allowed to charge via resistor R17.

The time constant associated with R17 and C3 causes the Schmitt input level of IC2b to be reached after approximately 0.1 sec. If the absolute value of the voltage on the output of the power amp remains greater than 0.6 V for longer than this time period then the Schmitt level of IC2b is reached and its output is taken low indicating a dc fault.

If the output voltage from the power amp is due to an ac signal with a frequency greater than around 5 to 10 Hertz, then the signal voltage will pass through 0 V within the manditory time period, biasing Q3 and Q4 off. The current flowing through R16 biases Q6 on, which discharges C4 before it has time to reach the Schmitt voltage required to activate IC2b.

IC2a functions as an OR gate for active-low signals so that a high will result on pin 3 if either pin 2 and pin 1 is taken low. A dc fault condition results in a low on pin 2 and the resulting high in pin 3 is coupled via D4 to the anode of D6, deactivating the relay.

POWER OFF DETECTOR

The other input of IC2a (pin 1) is used to detect whether the power to the power amplifier has been switched off. The ac input to the 6504 status monitor is connected to either of the secondaries of the power transformer used to supply the power amplifier.

If ac is present it is rectified by diode D1 and charges capacitor C1 to the peak voltage of the ac signal. The resulting voltage is applied to pin 1 of IC2a via the 470k current limiting resistor. If the power to the power amplifier is switched off the secondary voltage from the transformer drops to zero and R11 discharges C1 resulting in the application of a low voltage to pin 1 of IC2a causing a high on pin 3 and a consequent deactivation of the relay.

EXTERNAL PROTECT INPUT

The external protect input is connected directly to the protect out of the Status Monitor used for the other channel in the case of a stereo power amplifier. This line and the "protect out" are used so that the two status monitors can be interconnected so that a fault on either chanel will result in both relays being deactivated.

If the external protect input is unused it is held low by the 470k resistor R22 and hence does not interfere with the operation of the circuitry.

POWER SUPPLY

The supply voltage required by the status monitor is derived from a simple voltage regulator employing the zener diode ZD3 together with transistors Q11, Q12 and their associated passive components. The zener is biased on by resistor R26, while C6 filters the reference voltage. Transistors Q11 and Q12 are connected as a current amplifier and supply a voltage around 13.8 V to the rest of the circuitry. This regulator enables the pc board to be powered from a fairly wide range of transformer voltages.

dicator section also provides a pulse stretching facility which ensures that the clipping indicator LED will be activated for a long enough period so that the clipping condition can be noticed. Very short transient pulses with large amplitudes can easily drive a power amplifier into overload, and because the clipping indicator is activated for such a short time it is impossible to see that overload has occurred. To overcome this problem a monostable is included which ensures the clipping indicator LED will be activated for at least 100 milliseconds as a result of any overload that results from signals within the audio passband.

Another aspect of the design which is of particular interest is the dc detector circuitry. The problem with all dc detectors is that they must be able to separate what can be considered a dc condition on the output from what is in fact a low frequency ac signal. Some older designs employed either a first- or second-order low-pass filter with a -3 dB point set at some frequency below the audio passband. The problem with this scheme is that the filter cannot provide a fast enough rolloff outside of its passband. The circuitry must accommodate a full power 20 Hertz sine wave for example, which is equivalent to a peak signal voltage or around 60 volts in the case of our 200 watt amplifier.

If it is desired to allow no more than one volt dc to be present on the output, then the filter must provide sufficient attenuation to reduce the 60 volt peak signal present during the 20 Hertz sine wave to a voltage of less than one volt when dc is present. In other words, the filter must provide approximately 36 dB of attenuation between the 20 Hertz frequency point and the frequency at which the protector will operate if the output signal voltage exceeds one volt. If a 6 dB (first-order) filter is employed, the frequency at which the protection circuitry will operate must be approximately six octaves below the 20 Hertz frequency point. The protection circuitry would have to be set to operate at a frequency only below 0.31 Hertz.

This is equivalent to saying that if a dc voltage suddenly appeared on the output of the power amplifier, the dc protector would take over *three seconds* before it would trigger; rendering the circuit completely useless! The circuit protector must operate as quickly as possible, and preferably in less than one tenth of a second.

In order to accomplish this and still have the protector sensitive enough to disallow the application of any more than one volt to the loudspeaker, a low-pass filter with a 3 dB point at 20 Hertz must be a high order Chebyschev-type filter, necessitating multiple operational amplifiers and a considerable amount of circuitry. The circuitry developed for this project solves this problem in a different way. The solution makes use of a fundamental difference between an ac and a dc signal and that is that an ac signal periodically goes through zero as the signal voltage changes from positive to negative, or vise-versa. The repetition rate of these zero crossings is monitored and if the rate falls below the level set within the protection circuitry the relay is de-activated to protect the loudspeaker. For a more detailed description of the operation of the dc detector circuitry, read the circuit operation section.

In order to provide protection from turn-off 'thump', the circuitry monitors the presence of ac on the secondary of the power transformer.

The moment the power amplifier is switched off the secondary voltage reduces to zero and the relay is again activated. The turn-on delay ensures that the protection relay will not be activated for several seconds after the power amp is turned on. The turn-on delay time is established by a simple RC time-constant within the protection circuitry.

AEM6504 PARTS LIST

Semiconductors

IC1, IC2	4093
Q1	MJE350
Q2	MJE340
Q3	BC548
Q4	BC558
Q5, Q6	BC548
Q7, Q8	BC558
Q9	BC548
Q10	TIP31A, B, C
Q11	2N3055
Q12	BC639
D1	1N4004
D2-D6	1N914
D7-D9	1N4004
LED1, LED2	TL4211
ZD1, ZD2	1N746
ZD3	1N965

Resistors all 1/4W, 5% unless noted.

R1	10k
R2, R3	82k
R4	10k
R5	470k
R6	2M2
R7, R8, R9	470k
R10	2k2
R11-R15	470k
R16	100k
R17	470k
R18	2M2
R19, R20	560R
R21	10M
R22, R23	470k
R24, R25	10k
R26	2k2
R27	10k
R28	10R

Capacitors

C1-C3	220n MKT
C4	47n MKT
C5	220n MKT
C6	100µ/63 V RB electro.
C7	1000µ/63 V RB electro.

Miscellaneous

RL1 .... single pole relay, 15 A contacts rated at 55 A inrush current, with 12 V coil — National type JA-1TMP-DC12V or similar.

AEM6504 pc board, heatsink, TO3 insulation kit, wire, solder.

Expected cost: $44-$49

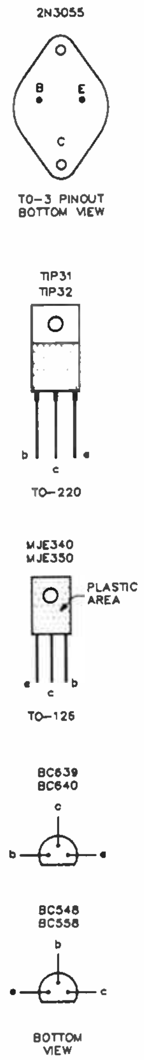
A final feature worthy of mention is the presence of an external protect input. The AEM6504 power amp status monitor is intended as a single channel monitor. A monitor is used for each channel within the power amplifier so that a stereo power amp requires two of these units. The external protect input and the protect output provided by the unit provides a facility whereby two or more power amp status monitors can be interconnected so that a fault on either channel will lead to activation of the protection circuitry for both channels simultaneously. Among other things, this ensures that the turn-on and turn-off delay for the two channels within the stereo power amplifier will be identical. If this facility is not required, the interconnection between the two Status Monitors can simply be omitted.

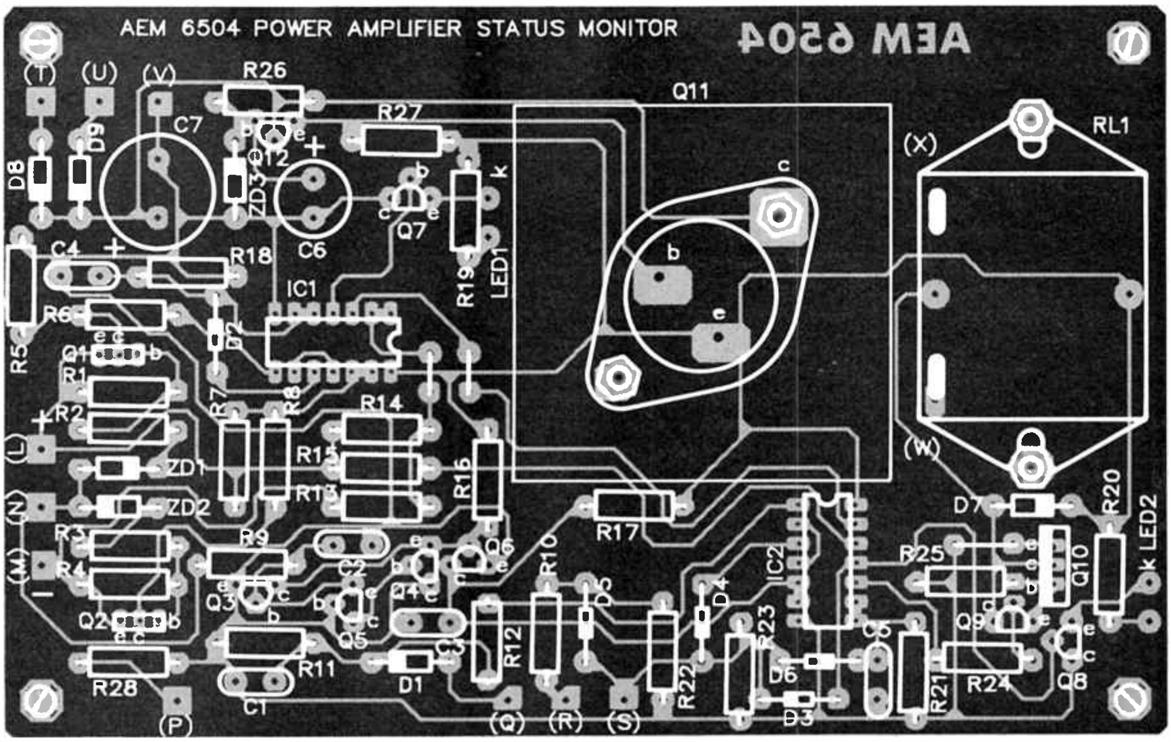
Construction

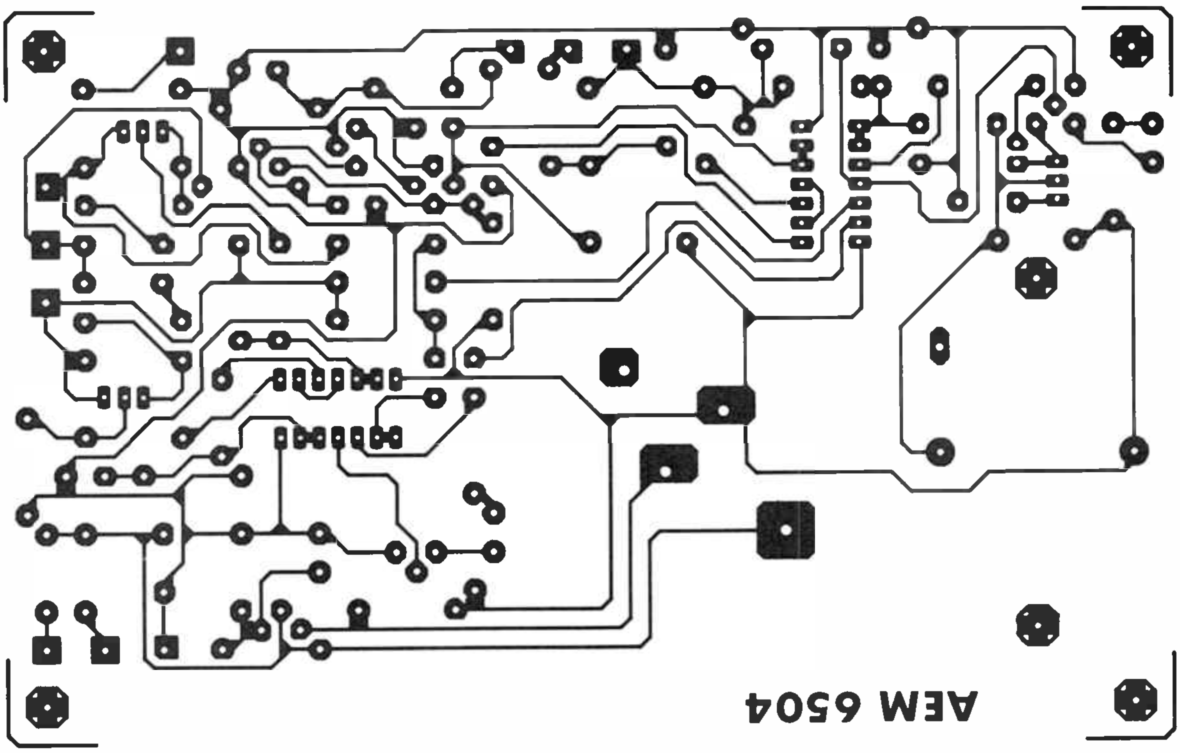
The project is not difficult to build or install, particularly if the AEM pc board is used. The pc board holds all of the com-

TABLE OF CONNECTIONS FOR THE AEM6504 PC BOARD

From power amp.	+ve supply	(L)
	−ve supply	(M)
	output	(N)
Power amp supply	0 V	(P)
	ac	(Q)
Status Monitor transformer	12-30 Vac	(T)
	12-30 Vac	(U)
	centre-tap	(V)
Other Status Monitor	from protect out (S) on other Status Monitor	(R)
	to ext. protect in (R) on other Status Monitor	(S)







ponents, including the power supply components and the relay itself. The relay is a pc board mounting type which provides the very convenient feature whereby the contacts for the relay coil pass through the pc board and can be soldered directly to it. The relay contact terminals are provided on the top of the relay, which simplifies the wiring from the power amplifier and to the loudspeaker output terminals.

Commence construction by soldering the resistors and the small capacitors to the pc board. Next, solder the transistors in place being sure not to confuse the BC548 and the BC558 types. These are NPN and PNP types respectively and if the unit is powered-up with these devices inserted in the wrong positions, damage can result. Similarly, be careful not to confuse the MJE350 and the MJE340 devices. The two CMOS ICs can be used. Solder the diodes in position, being careful not to confuse the zener diodes ZD1-ZD3, the small signal diodes, and the IN4004 power diodes. Be careful to insert these components with the correct orientation. Solder the electrolytic capacitors into place, again being careful to ensure that these are the right way round. ▶

The two LED indicators must be mounted on the front panel of the power amplifier and wired to the Power Amp Status Monitor using lengths of hookup wire. The LEDs must be connected the right way round. It is particularly easy to wire these incorrectly, so use lengths of different coloured hookup wire for this purpose.

Complete the construction by mounting the relay to the pc board. This is best accomplished by positioning the relay on the board and securing it in place using a pair of 6BA nuts and bolts. The pc board mounting pins should be soldered only after the relay has been securely fastened. If the pins are soldered first and then the relay is bolted into position it is possible to break the solder joint or lift the copper pad from the fibreglass of the pc board.

Using the Status Monitor

The Status Monitor requires connections to a transformer delivering somewhere between 15 and 30 volts. A larger voltage transformer than this could be used except that the power dissipation in the power supply pass transistor tends to become excessive. Nevertheless, if a higher voltage transformer is available and it is inconvenient to provide a small second transformer to power the Status Monitor then it is possible to use the higher supply voltage although it may prove necessary to increase the size of the heatsink to which the pass transistor is bolted.

There are three connections that must be made between the Status Monitor and the power amp. There are a further two connections to be made to the power amplifier power supply and a further two connections which must be made to the other Status Monitor where a stereo pair are employed. These connections are:

1. **+Ve supply. (L)**
This point on the status monitor must be connected to the positive rail of the power amplifier. The connection should be made as closely as possible to the power amplifier printed circuit board, and certainly on the power amplifier side of any supply fuse in the power amplifier supply line. In the case of AEM6000 power amplifier module, this point is connected to point H on the module's board.
2. **Output. (N)**
This point on the status monitor connects to the output of the power amplifier module. The connection should be made as closely as possible to the power amplifier module and certainly on the power amplifier side of any fuses or relays in series with the power amplifier output. In the case of the AEM6000 module this point connects to point G.
3. **-Ve supply. (M)**
This point connects to the negative supply rail of the power amplifier. As with the positive supply, the connection should be made as closely as possible to the power amplifier module. On the AEM6000 module, this point should connect to point J.
4. **0 V. (P)**
This point connects to the 0 volts of the power supply used to supply the power amplifier. The best point to make this connectio is at the centre point of the main power supply filter capacitors.
5. **ac. (Q)**
This point on the Status Monitor must connect to one of the two secondaries of the power transformer used to supply the power amplifier. A convenient place to make this connection in most power amplifiers is on either of the ac terminals of the bridge rectifier.

2N3055 HEATSINKING

The 2N3055 power transistor used in the power supply for the status monitor must be mounted to a heatsink before being bolted into position on the printed circuit board. If there is no danger of this heatsink coming into contact with the chassis or any other earthed portion of the power amplifier, then the transistor need not be insulated from the pc-mounted heatsink. Use a smearing of thermal paste between the transistor and the heatsink, and bolt them in place on the printed circuit board before soldering the leads of the transistor. The connection to the collector of the transistor is made via one of the two mounting bolts.

There is sufficient area on the printed circuit board to accommodate a variety of TO3 heatsinks. The particular type specified in the Parts List provides a thermal rating of around five degrees C per watt, so when the unit is operated with the 30 volt transformer, the heatsink temperature of around 40 or 50 degrees Celsius is quite warm, but not intolerable.

6. **Ext. protect in. (R)**
If the Status Monitor is used in conjunction with a mono power amplifier, this point is unused. In the case of a stereo power amplifier this point connects to the 'protect out' of the other power amp status monitor.
7. **Protect out. (S)**
This point on the Status Monitor connects to the Ext. Protect of the other Status Monitor as described in note 6.

Conclusion

The AEM6504 Power Amplifier Status Monitor is a flexible and powerful power amplifier monitor which provides significant protection for the loudspeaker. When used with the relay specified it is suitable for connection to power amplifiers rated to deliver up to approximately 300 watts into an 8 ohm load. The unit does not provide protection for the loudspeaker from overpower since this is more the role of a traditional loudspeaker protector and is of course dependant on the particular loudspeakers used. The 6504 will nevertheless, protect the loudspeaker from the vast majority of faults associated with modern dc-coupled power amplifiers.