A universal speaker protector

Here's a very flexible module which can protect your expensive speaker system from damage due to a fault in your stereo amplifier. As a bonus it also provides an initial delay, to eliminate turn-on "thump", plus visual indication of overload conditions. You can either build it into your amplifier, or as a separate free-standing unit.

It's quite a while since we described a free-standing loudspeaker protection circuit – November 1975, in fact. Later circuits were built into our very successful stereo amplifier designs, such as the MOSFET Stereo Amplifier of December 1980 – February 1981 and the Series 200 Amplifier of January – May 1985. Needless to say these weren't of much help to people with existing amplifiers, who simply wanted to provide themselves with the same protection facilities.

Why do you need to protect your loudspeakers? Well, most modern hifi amplifiers are DC coupled, to provide optimum performance at low frequencies. This is fine when the amplifier is working correctly, because the biasing and feedback circuits ensure that the speaker is fed only with the correct signals. But if the amplifier should develop a fault, the same DC coupling can result in the speakers being damaged – before you're even aware that there's a problem.

For example if the fault is such as to upset the DC operating conditions of one of the amplifier's output stages, you mightn't notice this immediately in terms of increased distortion. But there could well be a hefty direct current fed into your speakers, and before you know it a nasty burning smell – followed by a very unpleasant bill for a new speaker!

Much the same disastrous result can occur if the amplifier system develops a low frequency instability, and starts feeding massive amounts of almost-inaudible low frequency energy into the speakers.

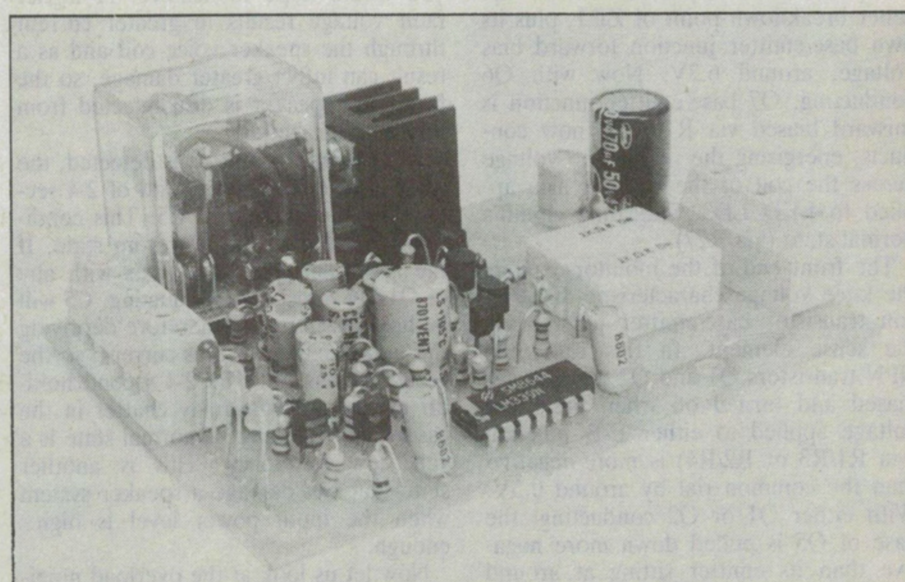
So if you do have an expensive high performance speaker system, and a DC-coupled amplifier that doesn't feature internal speaker protection circuitry, adding a loudspeaker protection unit could be a very sensible investment. The new protection circuit design described in this article has been developed from the original November 1975 design, but with a number of refinements and "frills". Like the earlier design it provides not only protection against DC offset voltages and excessive low frequency drive, but a turn-on delay to provide muting of the initial "thump" often produced when direct-coupled amplifiers are first turned on.

In addition, however, it also provides a dual signal level monitor circuit, with visual indication via LEDs. This can be used as a clipping indicator, to show when the amplifier system has reached its clipping level, or as a warning indicator to show when the amplifier's output level has reached the rated power handling ability of your speaker system.

An added feature of the design is that it can be either built up as a self contained free standing unit, for external use with any amplifier, or left as a small PCB module and built into your existing amplifier – operating from the amplifier's own power supply. It is because of this flexibility that we've called it the "Universal" Speaker Protector.

By the way, the design and development work for this project has been carried out by the R & D Department at Dick Smith Electronics, and as a result the PCB design is proprietary – no other organisation may sell it.

Needless to say, kits for the project will be available through all Dick Smith Electronics stores, and from selected



General view of the unit built up in the form suitable for fitting inside an existing amplifier, and powered from the amplifier.

dealers as well. We understand that the price of a kit for the basic PCB modules will be $37.95.

How it works

To understand how the circuit works, let's look first at the detector stages of the protector section. This is the circuitry around Q1, Q2, Q3, Q4 and Q5.

This section of the circuit monitors the DC component of the amplifier's ouput. Any constant voltage, either positive or negative, as a result of offset or fault condition can cause damage to a speaker system if the level is high enough. It may result in overheating of the voice coil, or it may cause physical damage if the voice coil/cone system is forced to travel beyond its normal range.

With modern balanced solid state, DC coupled amplifiers the output centres around a balanced dual polarity power supply. After power-up and a short period of stabilisation, the output stage should settle to within a few millivolts from the common rail (i.e., "earth").

To cater to this unstable amplifier power-up sequence (that normally results in a "thump" in the speakers), the relay of the monitor remains energised so that the speakers are disconnected. This hold-off period of around 2-4 seconds is provided by the time constant of R8/C5.

After power-up, the regulated 12V supply line is ready within a few milliseconds. C5 is charged from this line via R8. Transistor Q6 will not conduct until the potential on its base reaches the zener breakdown point of ZD1, plus its own base/emitter junction forward bias voltage, around 6.3V. Now with Q6 conducting, Q7 base/emitter junction is forward biased via R10. Q7 now conducts, energising the relay. The voltage across the coil of the relay is also applied to LED LD3, indicating circuit's normal state (via R27).

The front end of the monitor exploits the knee voltage characteristic of a silicon transistor base/emitter junction as the sense element. In this case, the NPN transistors Q1 and Q2 are forward biased and turned on when the input voltage applied to either E-B junction (via R1/R3 or R2/R4) is more *negative* than the common rial by around 0.5V. With either Q1 or Q2 conducting, the base of Q5 is pulled down more negative than its emitter sitting at around 6-6.5V. This causes Q5 to conduct and thereby discharges C5 via R7.

Component table for various amplifier power supply values

Input Voltage Range	1 Watt ZD2, ZD3	5 Watt WW R28, R29
60 — 70V	9V1, 9V1	1k,1k
52 — 60V	9V1,9V1	820,820
46 — 52V	9V1,9V1	680,680
40 — 46V	9V1,9V1	560,560
32 — 40V	8V2,8V2	390,390
15 — 32V	none	link

When the voltage of C5 and the base of Q6 drops below the zener voltage of ZD1 plus the B-E junction, Q6 drops out of conduction and deprives Q7 of base current thereby turning it off and denergising the relay.

Transistors Q3 and Q4 operate in a similar manner to that described above except that in this case, the input voltage to the B-E junction has to be more *positive* than 0.5V. With either Q3 or Q4 conducting, C5 is again discharged via R7.

In order that the detector circuit discriminates between the normal AC signals (audio signals) and very low frequency sub-audible (below 20Hz) or DC offset voltages, a low-pass filter has to be added. The filter networks R1/C1,R3/C3 and R2/C2,R4/C4 have a time constant that prevents the knee voltage on Q1-Q4 ever being reached for signal half-cycles of less than 50ms. The actual detection period is a function of the input voltage amplitude and the filter time constant with respect to the 0.5V threshold voltage. The higher the fault condition voltage, the faster the response of the detector. This is what you would hope to achieve. A higher fault voltage results in greater current through the speaker voice coil and as a result can inflict greater damage, so the faster the speaker is disconnected from this state the better.

After a fault condition is detected, the relay is held off for a period of 2-4 seconds by the discharged C5. This condition is similar to the power-up state. If the abnormal state still exists with any of Q1-Q4 transistors conducting, C5 will be held discharged – therefore depriving the output circuit of bias current; so the relay remains off. The 2-4 second hold-off period prevents relay chatter in the case where the input abnormal state is a very low frequency. This is another state that can damage a speaker system when the input power level is high enough.

Now let us look at the overload monitor section. This circuit uses an LM339 quad comparator as the basis of operation. Input voltage levels from 15V to 60V peak can be catered for by the adjustment of VR1 or VR2.

To detect both negative and positive voltage excursions in excess of the preset level on both channels, four comparators are used.

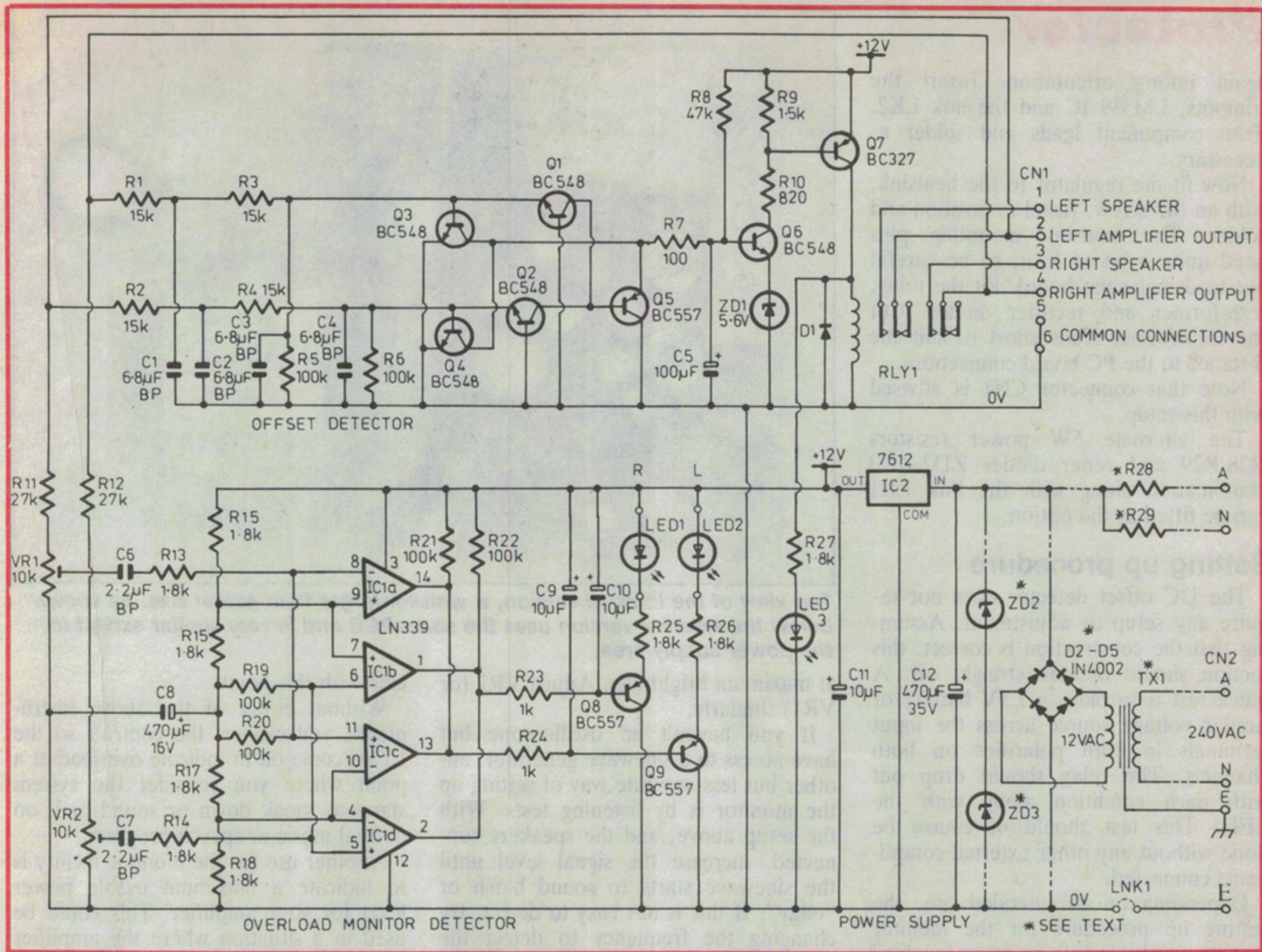
Two comparator reference levels are provided to sense both the positive and negative voltage swings about the common rail. This is achieved by tying one input of each comparator to a tap on a voltage divider (R15-R18) across the regulated 12V Vcc rail. The other inputs are tied to a common point at 1/2-Vcc (6V). With equal resistors in the R15-R18 divider chain, the reference values are 3V and 9V with respect to 0V. Or, another way of looking at it, plus or minus 3V above and below the common 1/2 Vcc point.

Because these comparator levels are with respect 1/2 Vcc and the input signal is with respect to 0V, AC coupling by C6,C7 is provided in order to allow the necessary level shift. Capacitor C8 provides AC decoupling between the two levels.

Sections a and b of the LM339 detect the positive excursions above the 3V reference point for each channel, while sections c and d detect the negative swings of greater than 3V.

The output stage of each comparator is the uncommitted collector a grounded NPN transistor requiring pull-up resistors (R21,R22). This allows a wired-OR state to combine the positive and negative detection signals from the two channels. When an overload excursion is detected, the output at either pins 14,1,13 or 2 goes low.

A positive overvoltage input on the right channel will cause pin 1 of section b to go low, for example. Capacitor C10 is now charged through R232. This voltage on the base of Q8 is "followed" at the emitter (less the B-E knee voltage) and turns on LD LD1 via current limit resistor R25. After the overvoltage on the input disappears, the output transistor in the b section comparator is turned off. The stored energy in C10



The complete circuit schematic, showing the alternative power supply arrangements for internal and "free standing" versions.

can now only be discharged via R23/R22 and the B-E junction of Q8. The current through the B-E junction is low due to the action of the emitter follower, so that the greater portion of the discharge current is through the resistors. This results in a slow discharge of C10, producing a fading out of LD1 over a period of 1 to 3 seconds.

Operation is very similar for a negative overvoltage peak, in either channel, which will cause LD2 to flash.

Power supply

With a fully self-contained system, power is derived from a small PC board mounted M-2851 transformer and full wave rectifier. In this case, R28,R29 resistors and zener diodes ZD2,ZD3 are not used. The raw DC from rectifier D2-D5 is supplied to 12 volt three-terminal regulator IC2. A small heatsink is provided on this IC to dissipate heat.

Where the system is to be connected to an existing amplifier's power supply, the transformer and rectifier diodes are left out.

It is worth noting at this point that this unit draws around 90mA and has to have a minimum supply voltage of not less than 15V. See the table for various supply voltages and the component changes. Some variation of the resistor values may be necessary to result in a potential of around 15V to the regulator when the relay is energised.

If there is any doubt about as to suitability of your amplifier's power supply to provide the necessary voltage, it would be advisable to use the stand-alone version with the transformer and rectifier components on board. In this case, all you have to do is connect the mains supply of the Monitor/Protector to the secondary side of the amplifier's mains power switch.

Construction

In order to keep the PC board down to a reasonable size so that it may be fitted internally to an amplifier, most components are mounted vertically to gain maximum use of available PC board real estate. The board has also been designed to fit the Dick Smith H-2503 plastic case.

Firstly, the components inserted around the power supply section will depend on how the PCB module is to be used. If it is to be a stand-alone system outside the case of an existing amplifier, the transformer and four rectifier diodes D2-D5 are installed. Fitted to an existing power supply, resistors R28,R29 and zener diodes ZD2, ZD3 are used in place of TX1, D2-D5. See the table and alternative overlay diagrams for details.

Preform all carbon resistors by bending one lead back along its own axis so that it becomes a single-ended component. Insert so that the body end sits on the PC board surface. Bend over the legs under the board to hold the component in place vertically. Insert all electros, noting those with polarity have specific orientation.

Then fit the transistors and diodes,

again noting orientation. Insert the trimpots, LM339 IC and the link LK2. Trim component leads and solder as necessary.

Now fit the regulator to the heatsink, with an M3 screw. Instal in position and solder. The heatsink mounting pins need quite a bit of heat, so be careful not to damage the board. Fit the relay, transformer and rectifier diodes. Cut the transformer leads short to suit the distance to the PC board connections.

Note that connector CN1 is advised with this setup.

The alternate 5W power resistors R28,R29 and zener diodes ZD2,ZD3 combination along with the link LK1 can be fitted as the option.

Setting up procedure

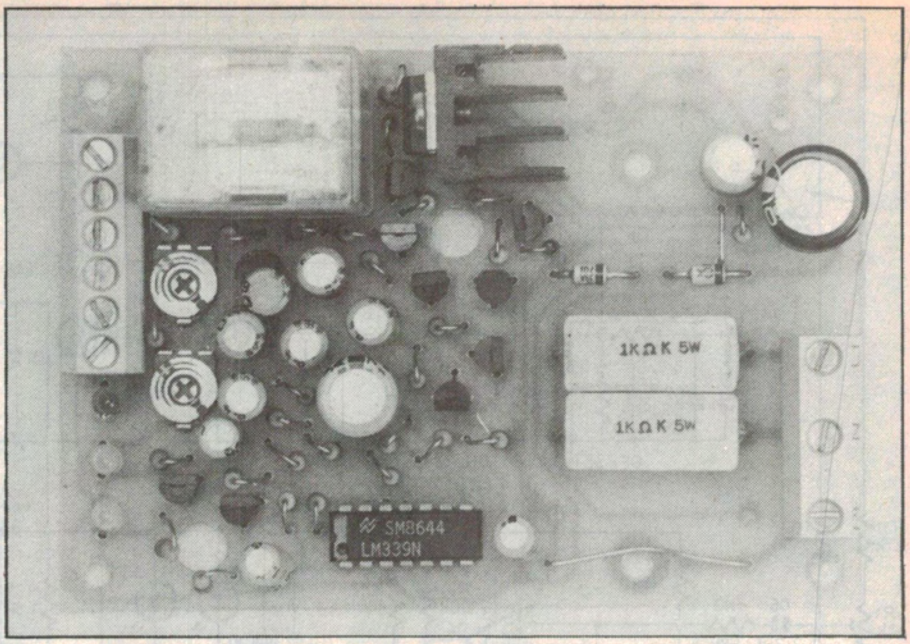
The DC offset detector does not require any setup or adjustment. Assuming that the construction is correct, this section should operate straight off. A quick test is to place a 1.5V battery or similar voltage source across the input terminals in both polarities on both channels. The relay should drop out with each condition along with the LED. This test should of course be done without any other external components connected.

Depending on its intended use, the setting up procedure for the monitor section can be simple or more involved if precise monitoring is required.

The point at which the amplifier's output signal reaches its maximum level and the peaks of the waveform start to flatten out is referred to as the *clipping point*. The onset of clipping in the output stage is where the power supply can no longer support the power level being demanded of it, or the output stage itself starts to limit for some reason.

The only way of monitoring the condition is to use an oscilloscope to view the output waveform, so connect the Monitor/Protector to the amplifier/speaker system. If you have available suitable 8ohm dummy loads to replace the speakers (to save your ears), fit these.

Connect a sinewave generator to both inputs of the amplifier and the oscilloscope to one output. Set the audio generator to around 400Hz (or some frequency you can put up with if you have to listen to it) and increase the level until the sinewave at the output just starts to flatten out on the peaks. This is the clipping point. Adjust the monitor preset VR1 (or VR2) until the LED is



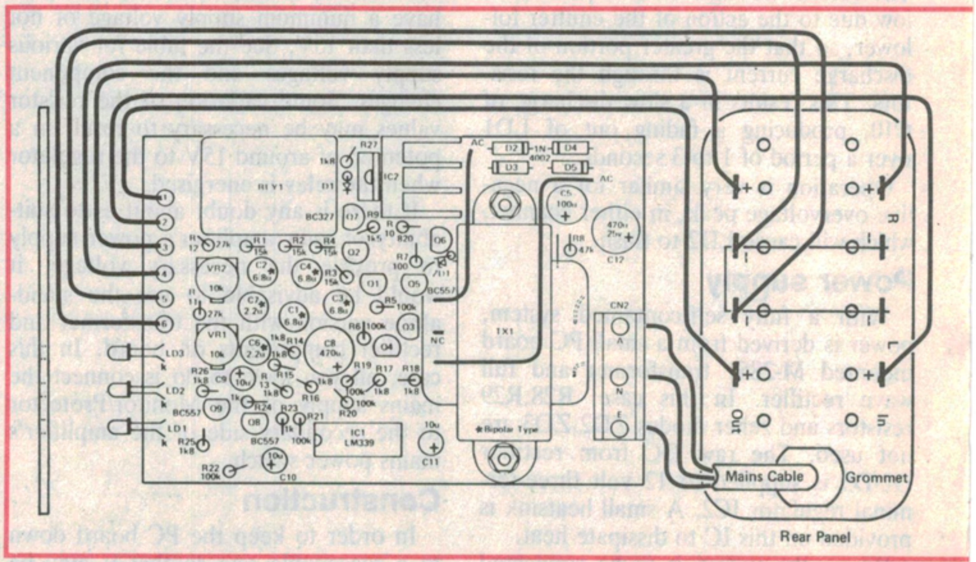
Top view of the internal version, a whisker larger than actual size. As shown below the external version uses the same PCB and is very similar except in the power supply area.

at maximum brightness. Adjust VR2 (or VR1) similarly.

If you haven't an oscilloscope but have access to a sinewave generator, another but less accurate way of setting up the monitor is by listening tests. With the setup above, and the speakers connected, increase the signal level until the sinewave starts to sound harsh or "edgy". If this is not easy to detect, try changing the frequency to detect the change in sound. Assuming you can hear this point and your ears haven't fallen off or your neighbour battered down your front door, set VR1 and VR2 so that the LEDs come on to coincide with this point.

Without either of the above instruments, you can set the controls so the LEDs come on to indicate overload at a point where you consider the system starts to break down or sound bad, on normal music or speech program.

Another use for the monitor facility is to indicate a maximum usable power level for your amplifier. This could be used in a situation where the amplifier power output is greater than the speaker system's handling capability; or a maximum level for the kids to use when friends come to visit; or a maximum level for party music. In these



How the PCB is wired up and connected inside a small box, in the external "free standing" version. This uses its own small power transformer and bridge rectifier, on the PCB.

cases, simply set the monitor controls by listening to music or program material at the level you consider maximum.

With the input voltage dividers shown (R11,VR1 & R12,VR2), the minimum input voltage that the comparators will accept is around +/−12-13V (equivalent to around 8W into 8 ohm loads).

By reducing the value of R11 and R12, this input detection level can be reduced. Change R11 & R12 to 15k for 5W to 70W operation, or 8.2k for 2.5W to 30W.

If you intend to use the power supply of an existing amplifier as the source for the Monitor/Protector, firstly measure the voltage available at the positive rail. Note that the negative rail cannot be used in this application. From the table given, fit the necessary components to the PC board.

Decide on a suitable mounting position inside the amplifier case, connect the positive power rail.

Divert the wiring from the output stage to the speaker terminals, through the Monitor/Protector relay switching terminals. Wire the indicator LEDs to a suitable panel mounting position, insulating the LED lead connections as necessary.

Switch on the system to check operation. See the setup procedure for detail. Note that it may be necessary to change the values of R28,R29 slightly from those shown so that the voltage to the input of the regulator (across C12) is not less than 15V or greater than 18V with the relay energised.

It may be easier (and safer), if you are not sure of this power supply connection and suitability, to use the self powered system by including the transformer and rectifiers on-board. In this case, the mains supply to the protector circuit's transformer is taken from the secondary side of the amplifier's main power switch.

With this setup you need some form of housing. The board has been designed to fit the Dick Smith H-2503 plastic case. The connector block CN1 is not used in this case and the terminations are wired to terminal strips on the back panel. We used two of the Dick Smith H-6624 screw terminals. These along with a H-1724 cord clamp grommet for the mains cable made a tight but neat rear panel layout.

The three indicating LEDs LD1-3 can be soldered directly into the board and bent at right angles to penetrate the front panel. Needless to say this must have 3 x 3.175mm holes drilled in the appropriate position.

To get the board to fit neatly into the case, one of the small posts has to be cut from the front bottom RHS of the case (viewed from the front). In the top half, cut off the mounting boss nearest the centre and cut the shoulder off the corner brace that sits over the relay.

The wires from the amplifier speaker output terminals are connected to the input terminals of the Monitor/Protector. The output terminals are then connected to the speakers. The mains lead is connected to the same power switch as the amplifier. Remember to switch on the amplifier's own switch first.

If your amplifier has a switched AC output socket, connect the Monitor/Protector to this, to ensure correct operation.

PARTS LIST

Resistors

(¼W 5% unless stated)

4 1.5k ¼W
2 100k
1 100Ω ¼W
1 47k ¼W
1 1.5k ¼W
1 820Ω ¼W
2 27k ¼W
6 1.8k
4 100k ¼W
2 1k ¼W
3 1.8k ¼W
2 5 Watt wire wound resistors (see text)
2 10k 10mm horizontal trimpots

Capacitors

4 6.8uF 50V bipolar
1 100uF 16V electrolytic
2 2.2uF 50V bipolars
1 470uF 16V electrolytic
3 10uF 25V electrolytics
1 470uF 35V or 50V

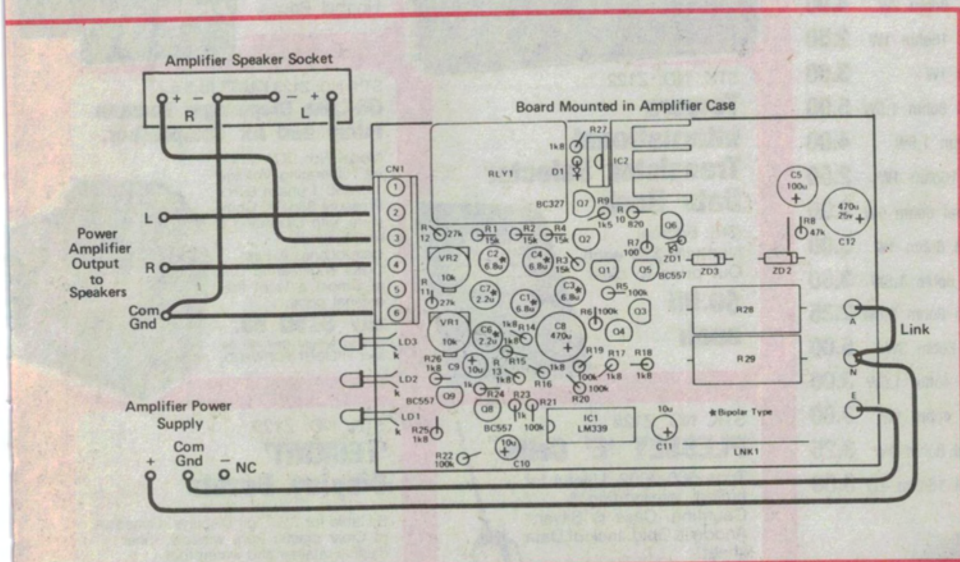
Semiconductors

1 LM339 quad comparator
1 7812 voltage regulator
1 1N4148 silicon diode
4 1N4002 PWR Diodes (see text)
1 1N752 5V6 400mm Zenner diode
2 1 watt zenner diodes (see text)
1 3mm oramer led
1 3mm red led
1 3mm green led
4 BC548 or BC547 transistors
1 BC557 Transistor
1 BC548 or BC547 transistor
1 BC327 Transistor
2 BC557

Miscellaneous

1 M-2851 12Vac/120 mt Transformer (see text)
1 12V Coil DPDT power relay
1 6-way PCB mount screw connector
1 3-way mains PCB screw connector
1 100 × 70mm printed circuit board.
1 case (optional – see text)
1 mains cable (see text)

screws, nuts, washers, copper wire, etc



The corresponding wiring arrangement for the internally mounted version, which uses power derived from the amplifier via series resistors and zener diodes.