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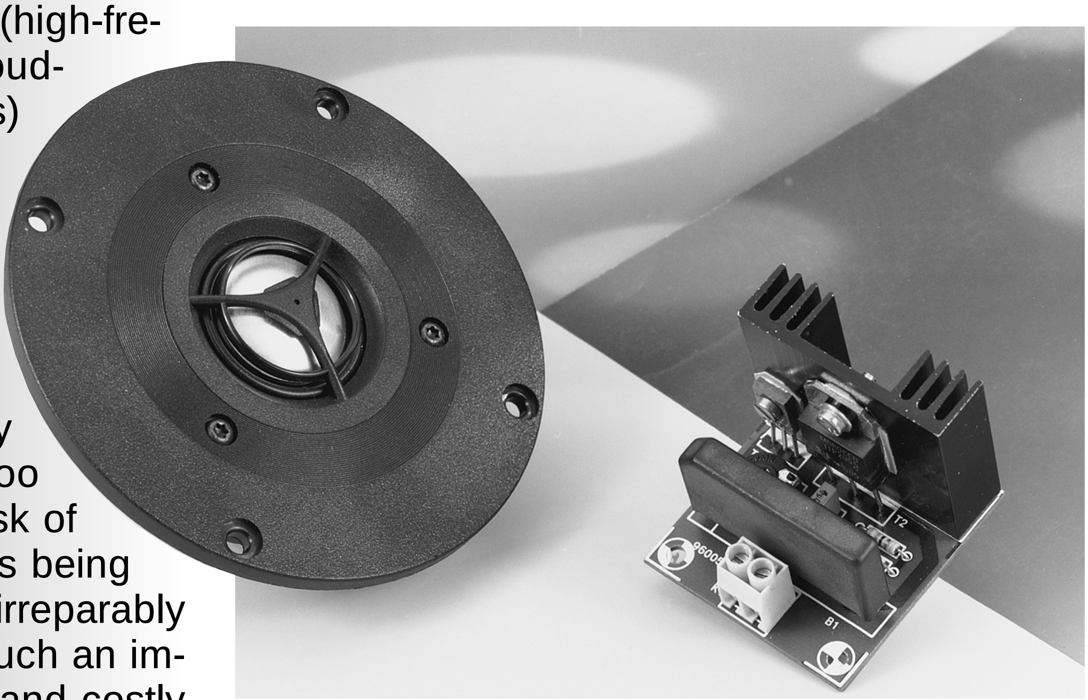
a.f. power limiter

protects tweeter

Owing to their relatively low rating, tweeters (high-frequency loudspeakers) form the weak link in an audio system. If the volume is suddenly turned up too high, the risk of the tweeters being damaged irreparably is high. Such an impetuous and costly mistake, can, however, be avoided in two different ways. The first is to curb your desire to turn up the volume to levels that the loudspeakers cannot handle. The second is to build the power limiter presented in this article…it's much safer than controlling yourself when you're adjusting the volume of your beloved audio system.



Design by T. Giesberts

There will be many readers who, after reading the introduction to this article, will say that this does not concern them. They have a 100 W amplifier and the loudspeakers are also rated at 100 W. So, nothing can go wrong. Really?

Unfortunately, things can go wrong, since the rating given by the loudspeaker manufacturers is true only for *average* music signals. In arriving at this rating, account is taken of the fact that the energy contained in music signals is strongly dependent on frequency. Of the power delivered by the output amplifiers roughly 75 per cent is applied to the woofers (low-frequency loudspeakers), 25 per cent to the mid-frequency loudspeakers, and only 5 per cent to the tweeters. This means that of the power output of 100 W only about 5 W is applied to the tweeters.

Equally unfortunately, not all music signals are average. For in-stance, in the case of synthesizer music it can happen that a sudden burst of high-frequency music is produced, which at that instant contains more than half the total emitted energy. This means in this example that some 50–60 W of music power is applied to the tweeters instead of the *average* 5 W. Many tweeters just cannot cope with this sort of power.

There is yet another aspect concerning the specified rating of tweeters. Although in the case of woofers and mid-frequency speakers the 'true' rating is given by the manufacturers, this is not so in the case of tweeters. For these units, the specified rating applies only if they are used with a cross-over filter! On close examination, it appears that a rating of, say, 50 W applies only if the speaker is used with a 2nd-order high-pass filter with a cut-off frequency of 4000 Hz. If, however, the cut-off frequency is, say, 2000 Hz, the rating is lowered to 20 W. Without a filter, the rating appears to be only 5 W!

All this is, of course, reasonable, since, at lower frequencies, a diaphragm has to move over a larger distance and tweeters just are not designed for this. Nevertheless, it goes to show that loudspeaker constructors should be well aware of how ratings are specified.

FUSE OR ZENERDIODE?

The question that arises in view of the foregoing is how the tweeters can be protected effectively.

The simplest way is merely to connect a fuse in series with the tweeters. However, this gives only a limited degree of protection, and also introduces a few drawbacks. If a fast fuse is used, chances are that it will blow at the first peak in the music signal. A slow fuse on the other hand does not guarantee that it will always be faster than the tweeters. In other words, the tweeters might still give up the ghost before the fuse blows. Add to this that any fuse introduces a certain resistance, which may vary from some tenths of an ohm to more than an ohm. This should undoubtedly be borne in mind, since, unless compensating measures are taken, it will inevitably lead to some attenuation of the high-frequency sound.

A variation of the standard fuse is a special device with positive temperature coefficient (PTC), which is available from many loudspeaker dealers. It is a semiconductor element that reacts just like a slow fuse when the current through it becomes too high. Unlike a fuse, however, it recovers when the danger is past: it need not be replaced, therefore. Unfortunately, its resistance is slightly higher than that of a fuse.

It is clear that series current limiting by a fuse or PTC device has its drawbacks. What other means are there?

One is a voltage limiter *across* the tweeter. In its simplest form, this could consist of two anti-series connected zener (power) diodes, assuming that the necessary series resistor is already present in the cross-over filter (damping resistor). A possible arrangement is shown in **Figure 1**, in which the zener diodes are at the right. Resistor R_1 is the series (damping) resistor mentioned earlier. If the zener ratings are 5.6 V, the power applied to the tweeter is restricted to about 5 W.

It may be asked whether such a simple protection is sufficiently effective, to which the answer is yes and no. The difficulty is that this sort of protection is too effective. This is because the zener action normally commences at fairly small currents when the zener voltage is nowhere near its nominal value. This results in untimely limiting, which causes a compression effect even at fairly small signals. Another, practical, problem is that power zener diodes are not easy to come by.

SIMULATED ZENER DIODE

What we need is a protection that is faster and more reliable than a series element and does not have the disadvantages of a pair of zener diodes in parallel. This requirement could be met by a sort of simulated power zener diode that has a sharply defined starting point.

The simple circuit in **Figure 2** is such a zener diode, consisting of two discrete darlington transistors. Connector K_1 is simply connected in parallel with the tweeter terminals. There is no need of a supply voltage, because this is drawn from the loudspeaker signal.

The alternating signal across the loudspeaker is rectified by B_1, so that a pulsating direct voltage exists across network R_1-R_2-P_1, which is averaged (to a degree) by capacitor C_1. When the alternating signal increases, transistor T_1 begins to conduct at a given value determined by the setting of P_1. Transistor T_1 turns on the power transistor, T_2, which consequently short-circuits part of the alternating signal. A part only, of course, because if the signal were short-circuited completely, T_1 would be cut off, leaving T_2 without drive. All this means that there is a limiting effect which stabilizes itself at a certain signal level, just as a zener diode does. The difference is that the simulated zener diode has a defined starting voltage, so that signals below that level are not affected. Thus, compression effects do not occur. In Figure 2, the values of R_1, R_2, and the preset have been chosen to ensure that the zener voltage can be set with P_1 between 5 V and 9 V, roughly corresponding to powers between 3 W and 10 W into 8 Ω.

In the design stages, it was considered to expand the circuit with an indicator LED, but in practice it was found that the music peaks are too short to make an LED light visibly. It is, of course, possible to lengthen the signal peaks electronically, but bear in mind that the required energy must be drawn from the loudspeaker signal and this may lead to an increase in distortion.

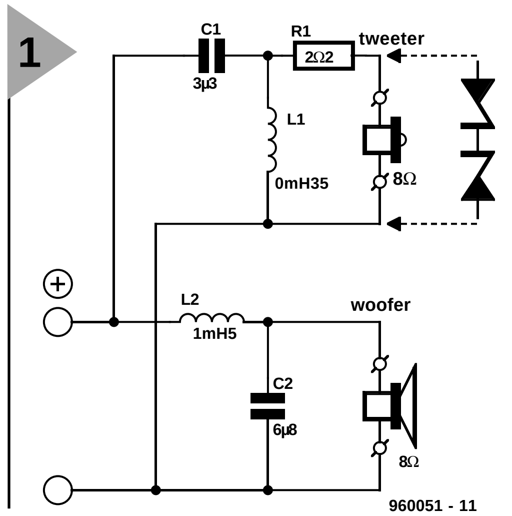


Figure 1. If the cross-over filter contains a damping resistor, R1, for the tweeter, the voltage may be limited by two anti-series-connected zener diodes.

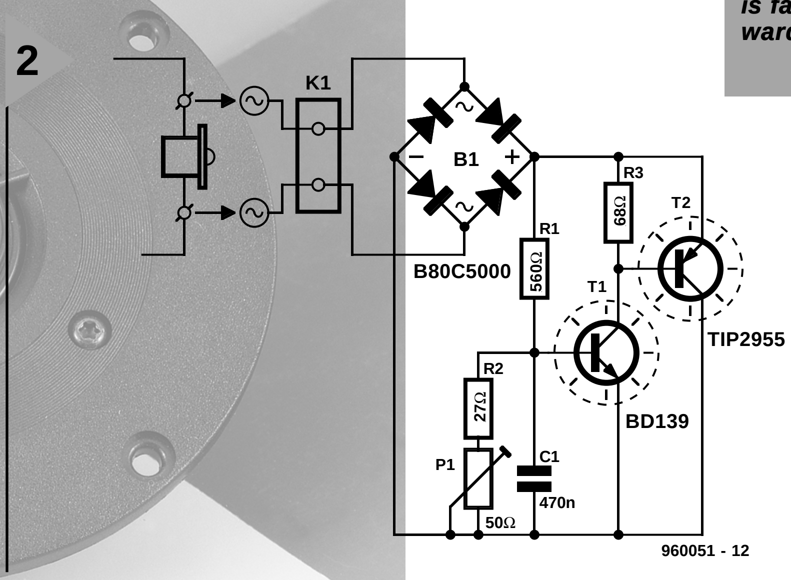


Figure 2. The design of a power diode with variable zener voltage is fairly straightforward.

CONSTRUCTION

The limiter is best built on the printed-circuit board shown in **Figure 3**, but it is, of course, just as easily built on a small prototyping board. The only aspect that needs attention is that the two transistors are to be fitted on to a common heat sink of about 6.5 K W^{-1}. This is necessary, because when the twee-ter is overloaded, there is quite a heat dissipation. The transistors must be electrically isolated from the heat sink with the aid of insulating washers

Setting up

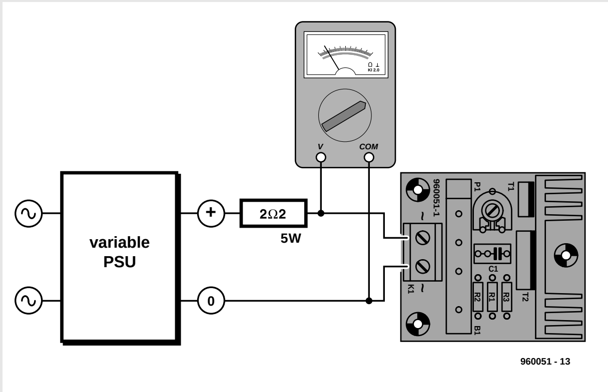
Much thought was given to the control range of P_1. The data books of a number of loudspeaker manufacturers showed that the majority of tweeters are normally rated at 3–5 W, with some as high as 8 W. This led to the decision to make the range 3–10 W into 8 Ω, corresponding to a signal voltage range of 5–9 V. If you have no suitable measuring equipment available, take it as a rule of thumb that the power restriction is about 3 W with P_1 fully anticlockwise, about 5 W with the preset turned one third of its travel clockwise, and about 10 W with it fully clockwise.

Setting the zener voltage of the limiter requires a variable power supply and a multimeter. Connect the power supply across K_1 via a 2.2 Ω, 5 W resistor, and the multimeter in parallel with this as shown in the diagram.

If we assume a power limit, P, of 5 W into a (loudspeaker) impedance, R, of 8 Ω, the signal voltage, u, is:

$$u = \sqrt{PR} = 6.3\ V$$

The power supply provides a direct voltage, which, as far as level is concerned, is equal to $\sqrt{2}$ = 1.414 times the r.m.s. value of an alternating voltage. Thus, for the above values of 5 W into 8 Ω, the preset must be set to give a meter reading of 1.414×6.3 = 8.9 V. Make sure, of course, that the power supply output level is sufficiently high.



and non-metallic screws and nuts. The photograph shows what the finished limiter looks like. A good place for it is on or close to the cross-over filter board. A good alternative is beside the tweeter on the inside of the front panel of the enclosure. Connect K_1 to the tweeter terminals with medium-duty, flexible, insulated circuit wire.

USAGE

As stated earlier, in the design it is assumed that the cross-over filter contains a resistor in series with the tweeter. This resistor is essential, because the surplus voltage when the limiter is active is dropped across it.

If you are worried by the thought that when the limiter is active the amplifier is virtually short-circuited as far as high frequencies are concerned and that it may not be able to cope with this, connect a 500 mA fuse in series with the tweeter. This protects the amplifier against a full short-circuit: its resistance of 0.3 Ω is, in this case, negligible.

The setting of P_1 is described in the box.

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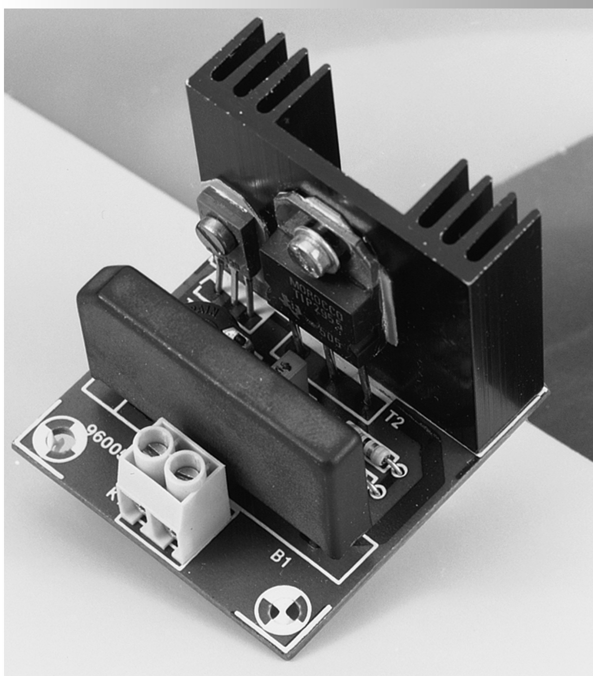

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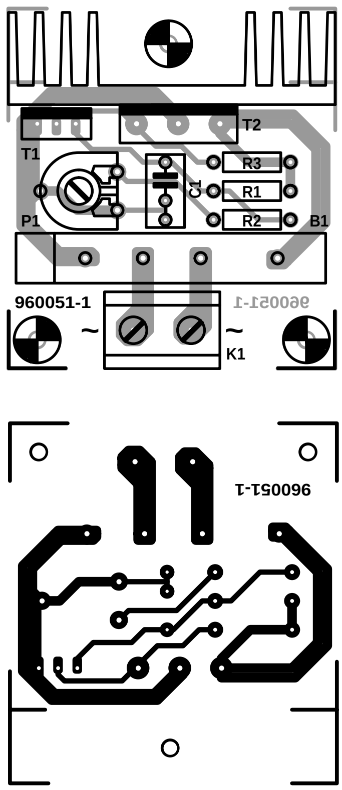

PARTS LIST

Resistors:
R_1 = 560 Ω
R_2 = 27 Ω
R_3 = 68 Ω
P_1 = 50 Ω preset

Capacitor:
C_1 = 470 nF

Semiconductors:
T_1 = BD139
T_2 = TIP2955

Miscellaneous:
K_1 = 2-way terminal block for board mounting, pitch 7.5 mm
B_1 = B80C5000
Heat sink, 6.5 K W^{-1}, e.g., Fischer SK59 (37.5 mm) (available from Dau, telephone 01243 553 031)
Insulating washers, and non-metallic screws and nuts for T_1 and T_2

Figure 3. The printed-circuit board for the limiter shows how simple the construction is.