keeping things from blowing up

Limiters are used in all forms of signal processing to stop operational parameters from being exceeded. In this way they are no different from the limit systems put onto machinery:

- a door stop is a very simple limiter which stops a door from damaging the whatever is behind it should be opened too wide.
- a limiter on a recorder or transmitter will stop a signal from overdriving the recorder of transmitter and causing distortion (or even damage to a transmitter).
- a limiter on a loudspeaker/amplifier system stops too much power from getting into the loudspeaker and causing damage to it.

Here we are only looking at setting limiters in loudspeaker processing although the principles can apply to any similar system.

how to damage a loudspeaker

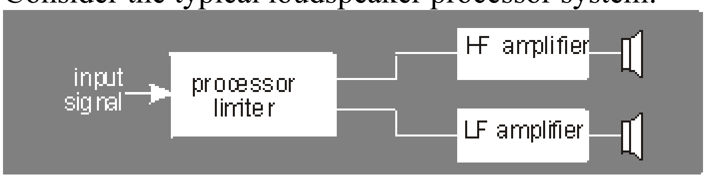
There are two ways of damaging a speaker through normal use - putting your foot through it or pouring beer on it are not counted for here! These are:

- Overheating the coil until it literally burns out
- Over excursion - tearing or otherwise damaging the mechanical suspension

How this damage occurs depends on the way the loudspeaker is used. If you consider a kick drum which has a high output but the driver is only working for short bursts of time - *high dynamic range*, then there is plenty of time for the coil to cool between beats. In this case fatigue in the suspension is more likely to be the cause of failure. On the other hand highly compressed dance music which has a very high level and *low dynamic range* the coil will have no time to cool and thermal stress is more likely to be the cause of failure as the coil burns out. The technical term for this is *crest factor*. This is equal to the peak amplitude of a waveform divided by the RMS value. Typical crest factors are:

signal type	typical crest factor
highly compressed music	2.7
pink noise	3.5
highly dynamic music	5.0

The other thing to remember is that all loudspeakers will fail eventually - they are a mechanical device just like a car or a washing machine and eventually things will wear out and need to be replaced. All you can do with a limiter is ensure that safe operating parameters are not exceed and thus a reasonable working life can be maintained. With a well built loudspeaker driver and a high quality limiter to ensure that RMS power isn't exceeded for two long this can be achieved. Consider the typical loudspeaker processor system:



Since the amplifier gain is known and fixed (see below) then setting the maximum input level to the amplifier will also set the maximum level that can be fed to the speaker.

finding the limit point value

Because dB are so easy to use we simply need to work out the maximum voltage that we can safely feed into the loudspeaker, convert this to dBu then subtract the *amplifier voltage* from this figure to get the limit point in dBu. This figure can be entered into your system processor and your limiter is set.

maximum safe loudspeaker voltage

Most loudspeakers quote a maximum RMS *power* rating and a nominal impedance. This can be converted into voltage using $V=\sqrt{(PZ)}$, where:
V is the voltage you are looking for,
P is the RMS power rating,
and Z is the nominal impedance.

For example an 8Ω loudspeaker with an RMS power rating of 850W has a maximum voltage input of $\sqrt{(850 \times 8)} = 82.5$V.

This needs to be converted to dBu (referenced to 0.775V) using dBu=20log(V/0.775). So in our example this is 20log(82.5/0.775)=40.5dBu.

If we have a an amplifier with a voltage gain of 30dB then the limit point needs to be:
40.5-30=+10.5dBu
The '+' before the 10 isn't necessary but it avoids confusion.

So we have the limit point formula:

$$L = 20\log\frac{\sqrt{PZ}}{0.775} - G$$

where L is the limit point in dBu, P is the RMS power rating of the loudspeaker in Watts, Z is the loudspeaker nominal impedance in Ohms and G is the amplifier voltage gain in dB.

maximum amplifier gain

It is very important that the amplifier gain is set in such a away that it cannot be set any higher than the value you used to calculate the limit point. If it isn't there is nothing to stop somebody from just turning the amplifier up and so adding more gain after the limiter and thus sending too much power into the loudspeaker.
If there are *gain range* switches (usually hidden on the rear panel of the amplifier somewhere) these should always be set as low as possible. There are two reasons for this:

- it keeps the overall system noise as low as possible
- it keeps digital system processors running as close to their optimum resolution as possible

For more details see gain structure and optimisation

maximum amplifier power

So far we have assumed here that the world is perfect and that there is no such thing as maximum amplifier power. Since that isn't the case we need to ensure that we aren't expecting the amplifier to deliver more power than it is capable of and thus drive it into *clip*. The easiest way to do this is to specify amplifiers which are at least 25% over the maximum loudspeaker power; 25% only gives you about 1dB headroom, so if your budget can stretch that far you should aim to be 50% or more over for greatest headroom and performance. The other alternative is to reduce the limit point to stop the amplifier clipping, although this could start to have a detrimental effect on your sound quality.
The simplest way to check the limit point is to put the amplifier output power and the impedance this is quoted for, into the formula above, ignoring G (voltage gain) and see check that this value is over the limit point for the speaker system. If it isn't, either change your amplifier or use this value (usually at least -1db) instead.

I have a little spreadsheet to help you work all this out limit point calc in Excel format or limit point calc in Open Office format.
For information and download of Open Office visit www.openoffice.org