Q. How does a compressor work?

Could you explain (slowly!) the basic principles of how a compressor works, and what each control does, the ratio control in particular? How is it that some people talk about using compression to raise the level of a signal, when the effect of a compressor would seem to be to reduce it?
SOS Forum Post

Technical Editor Hugh Robjohns replies: In basic terms, a compressor is a device which pulls the levels of loud signals down by applying gain reduction. What qualifies as a loud signal is defined by the threshold control: a loud signal is one which is greater than a reference level set by the threshold control.

How much gain reduction is applied — in other words, how much the signal is pulled down — is determined by the ratio control. A ratio of 2:1 means that if the level of the input signal exceeds the threshold level by 6dB, the compressed output signal will exceed it by only 3dB. Thus the dynamic range of the source is reduced in a controlled and predictable way. The higher the ratio, the greater the amount of compression applied to signals that exceed the threshold.

If the ratio is more than 10:1 the compressor is usually referred to as a limiter, since in practice typical signal peaks above the threshold are reduced to negligible output peaks.

The transition from no gain reduction to applying gain reduction is often referred to as the 'knee'. If this transition happens abruptly it is referred to as a hard knee and this characteristic tends to give a punchy, aggressive kind of sound. A soft knee characteristic is far more subtle and gentle, and tends to be employed where a more 'transparent' effect is required.

It is often the case that, rather than reduce loud sounds, you want to raise the level of quiet sounds instead. In other words, to maintain the peak level of the audio material but still reduce its dynamic range in order to raise the level of the quieter sounds. This is achieved by boosting the gain of the signal after the compression has been applied. In reality, the loud sounds above the threshold are still reduced, thus reducing the dynamic range, but then the overall level is raised to restore the original peak levels. This pulls up the quieter sounds by the amount of gain introduced.

The control that performs this is usually called make-up gain, and features on most compressors designed for serious studio use, though by no means all. In some cases, make-up gain is added automatically in an amount determined by the setting of the threshold control.

Applying gain reduction to an audio signal is a dynamic process. The amount of gain reduction applied is dependent on the changing envelope of the signal (the overall shape of the audio waveform), and compressors usually have adjustable attack- and release-time controls.

The attack control determines the rate at which the gain is reduced once the signal exceeds the threshold. A fast attack maintains good peak level control but can make the processed signal sound flat by squashing its attack transients too aggressively. A slow attack setting allows some of the initial transients to pass uncontrolled, which can give a more punchy and interesting sound, at the expense of peak level control. The correct setting can only be found by listening critically to the effect of the processing, and it may even require adjustment during each passage of audio. Some compressors feature automatic or 'programme-controlled' adjustment of the attack time for this very reason.

The release time determines how quickly the gain is restored to normal after the signal falls back below the threshold. If this is set too fast, the changes in level caused by compression being applied and released become overtly audible, and the signal appears to 'pump' or 'breathe'. This can sound very fatiguing, but subjectively loud. A slow release setting is far more subtle, but a brief high transient peak will result in a lot of gain reduction that takes a long time to recover, resulting in the quieter material immediately following the peak being made even quieter. In effect, this punches big holes in the apparent level of the signal. Again, the correct setting can only be found by critical listening, and it may also require adjustment during each passage of audio. Similarly, many compressors feature automatic or program-controlled adjustment of the release time too.

As with all of the signal processing tools available to us, understanding what each of the controls — both generically and in the context of a specific device — is essential to being able to use that tool effectively. In terms of compressors and limiters, it is vital to understand how each control changes the way the compressor treats the program material if you want to use this very powerful form of signal processing effectively. The appropriate compressor settings are entirely dependent on the level and dynamics of the material being processed and the artistic effect you are trying to achieve by compressing it. This is why the library settings provided in a lot of digital mixers and intended for various generic sound sources are inherently pointless!

Most compressors include a meter to show the amount of gain reduction being applied at any moment, and comparing this with the levels of the input and output signals can be very instructive in understanding what each control does. Ultimately, though, this is an audible effect and so only your ears are able to judge the effectiveness, and appropriateness, of your chosen settings. As with all signal processing, it is usually better to under-process than over-process — if the material sounds compressed, you are applying too much gain reduction. Reduce the ratio, increase the threshold, slow down the release time and/or the attack time.

There have been lots of articles about both basic and advanced compression techniques in Sound On Sound over the years, which should provide you which plenty more information about this much-talked-about but often misunderstood subject. I suggest you do a search for Technique articles via the search page of the Sound On Sound web site. By Hugh Robjohns, SOS 2004