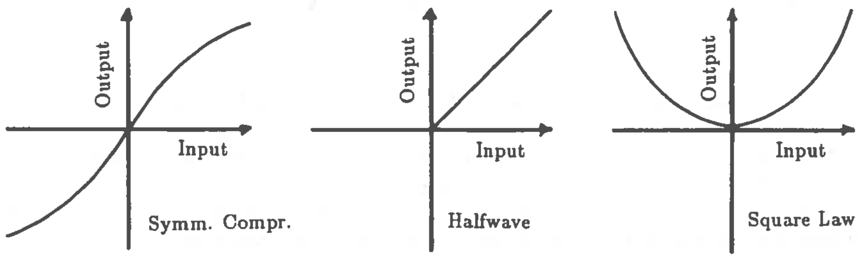
Demonstration 33. Distortion (2:17)

This demonstration illustrates some audible effects of distortion external to the auditory system. These effects are of interest, not only because distortion commonly occurs in sound recording and reproducing systems, but because distortion is an important topic in auditory theory. This demonstration replicates one presented by W.M.Hartmann in the "Harvard tapes" (Auditory Demonstration Tapes, Harvard University, 1978). Both harmonic and intermodulation distortion are illustrated.

Our first example presents a 440-Hz sinewave tone, distorted by a symmetrical compressor.



A symmetrical compressor has an input-output relation such as that shown at the left. The important property is that the function describing the relation between input and output is an odd function–that is, f(x) is equal to -f(-x). Because of the symmetry, only odd harmonics of the original sinewave are present in the output. A simple example of a symmetrical compressor would be a limiter. In this demonstration, the distorted tone alternates with its 3rd harmonic (which serves as a "pointer").

Next the 440-Hz tone is distorted asymmetrically by a half-wave rectifier, which generates strong even-numbered harmonics. The distorted tone alternates with its 2nd harmonic.

When two pure tones (sinusoids) are present simultaneously, distortion produces not only harmonics of each tone but also tones with frequencies $nf_1 - mf_2$, where m and n are integers. The prominent cubic difference tone $(2f_1 - f_2)$ which occurs when tones of 700 and 1000 Hz are distorted by a symmetrical compressor alternates with a 400-Hz pointer in the third example.

As a general rule the ear is rather insensitive to the relative phase angles between low-order harmonics of a complex tone. Distortion, however, especially if present in the right amount, can produce noticeable changes in the perceived quality of a complex tone when phase angles are changed. This is shown in the last demonstration in which the phase angle between a 440-Hz fundamental and its 880-Hz second harmonic is varied, first without distortion and with the complex fed through a square-law device.

Commentary

"First you hear a 440-Hz sinusoidal tone distorted by a symmetrical compressor. It alternates with its 3rd harmonic."

"Next the 440-Hz tone is distorted asymmetrically by a half-wave rectifier. The distorted tone alternates with its 2nd harmonic."

"Now two tones of 700 and 1000 Hz distorted by a symmetrical compressor. These tones alternate with a 400-Hz pointer to the cubic difference tone."

"You will hear a 440-Hz pure tone plus its second harmonic added with a phase varying from minus 90 to plus 90 degrees. This is followed by the same tones, distorted through a square-law device."

References

- J.L.Goldstein (1967), "Auditory nonlinearity," J. Acoust. Soc. Am. *41*, 676-89.
- J.L.Hall (1972), "Monaural phase effect: Cancellation and reinforcement of distortion products $f_2 - f_1$ and $2f_1 - f_2$," J. Acoust. Soc. Am. *51*, 1872-81.