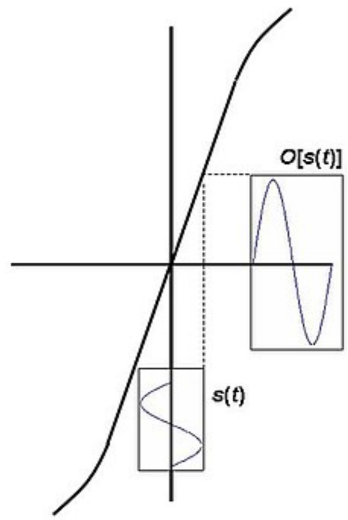
P1dB vs. OIP3 Calculation

Cross specifies the P1dB in our datasheets for our converters (as appropriate). Compliance to OIP3 is assumed by analysis (to be ~10 dB greater than the P1dB point). The following analysis is the basis for this position:

Amplifier Transfer Function;

The third-order intercept point (TOI) is a property of the device transfer function *O* (see diagram). This transfer function relates the output signal voltage level to the input signal voltage level. We assume a “linear” device having a transfer function whose small-signal form may be expressed in terms of a power series containing only odd terms, making the transfer function an odd function of input signal voltage, i.e., $O(-s) = -O(s)$. Where the signals passing through the actual device are modulated sinusoidal voltage waveforms (e.g., RF amplifier), device nonlinearities can be expressed in terms of how they affect individual sinusoidal signal components. For example, say the input voltage signal is the sine wave



“Linear” device transfer function, with input and output signals

$$S(t) = V\cos(\omega t),$$

and the device transfer function produces an output of the form

$$O(s) = Gs - D_3 s^3 + \ldots,$$

where *G* is the amplifier gain, and D_3 is cubic distortion. We may substitute the first equation into the second and, using the trigonometric identity

$$\cos^3(x) = 3/4\cos(x) + 1/4\cos(3x),$$

we obtain the device output voltage waveform as

$$O(s(t)) = (GV - 3/4D_3V^3)\cos(\omega t) - 1/4D_3V^3\cos(3\omega t).$$

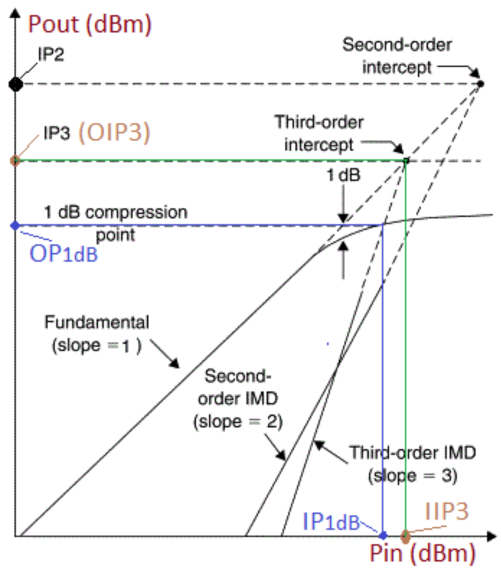
The output waveform contains the original waveform, cos(*ωt*), plus a new harmonic term, cos(3*ωt*), the *third-order term*. The coefficient of the cos(*ωt*) harmonic has two terms, one that varies linearly with *V* and one that varies with the cube of *V*. In fact, the coefficient of cos(*ωt*) has nearly the same form as the transfer function, except for the factor 3/4 on the cubic term. In other words, as signal level *V* is increased, the level of the cos(*ωt*) term in the output eventually levels off, similar to how the transfer function levels off. Of course, the coefficients of the higher-order harmonics will increase (with increasing *V*) as the coefficient of the cos(*ωt*) term levels off (the power has to go somewhere).

If we now restrict our attention to the portion of the cos(*ωt*) coefficient that varies linearly with *V*, and then ask ourselves, at what input voltage level *V* will the coefficients of the first- and third-order terms have equal magnitudes (i.e., where the magnitudes intersect), we find that this happens when

$$V^2 = 4G/3D_3,$$

which is the third-order intercept point (TOI). So, we see that the TOI input power level is simply 4/3 times the ratio of the gain and the cubic distortion term in the device transfer function. The smaller the cubic term is in relation to the gain, the more linear the device is, and the higher the TOI is. The TOI, being related to the magnitude squared of the input voltage waveform, is a power quantity, typically measured in milliwatts (mW). The TOI is always beyond operational power levels because the output power saturates before reaching this level.

The TOI is closely related to the amplifier's "1 dB compression point", which is defined as that point at which the *total* coefficient of the cos(*ωt*) term is 1 dB below the *linear portion* of that coefficient. We can relate the 1 dB compression point to the TOI as follows. Since 1 dB = 20 $\log_{10}$ 1.122 (Recall: decibel figure = 10 dB × $\log_{10}$(power ratio) = 20 dB × $\log_{10}$(voltage ratio)), we may say, in a voltage sense, that the 1 dB compression point occurs when;



$$1.122\,(GV - 3/4D_3V^3) = GV,$$

or

$$V^2 = 0.10875 \times 4G/3D_3,$$

or

$$V^2 = 0.10875 \times \text{TOI}$$

In a power sense (V^2 is a power quantity), a factor of 0.10875 corresponds to −9.636 dB, so by this approximate analysis, the 1 dB compression point occurs roughly 9.6 dB below the TOI.