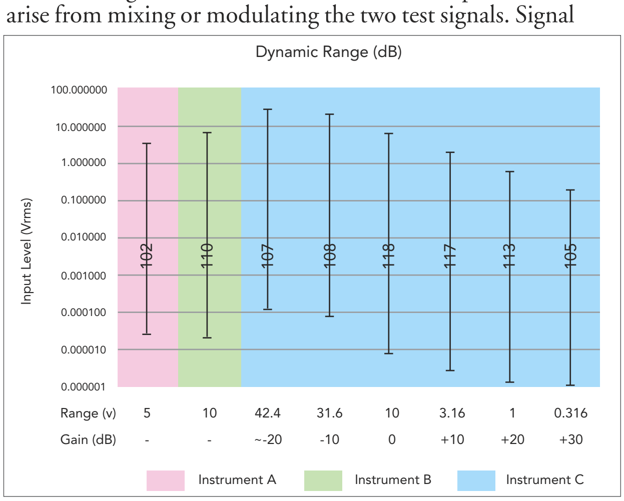
THE DATA DETECTIVE

Use Sound Judgment with Dynamic Range

Almost everyone has heard the difference in the quality of sound produced by movie-theater system and that produced by home-theatre audio equipment. The difference can arise from audio-signal distortion that human ears can detect at low levels. Thus, rigorous testing must occur during product design and during manufacturing to ensure companies ship good MP-3 players, cell phones, sound cards, and so on. Testing involves measuring many characteristics, such as signal-to-noise ratio, total harmonic distortion, dynamic range, and intermodulation distortion.

Although distortion may seem like a qualitative criterion, instruments can readily measure energy at harmonic frequencies that we hear as distorted sound. To help quantify distortion, engineers use instruments that detect low-amplitude signals produced by combinations of standard test signals in audio electronics. Intermodulation distortion (IMD) measurements, for example, compute the ratio of the root-mean-square (rms) value of two test signals, f_1 and f_2, to the rms value of "products" that arise from mixing or modulating the two test signals. Signal mixing takes place in non-linear circuits and components that exist to some extent in all electronics. Second-order IMD frequencies exist at f_2+f_1, f_2-f_1, $2f_2$, $2f_1$. Third-order IMD frequencies exist at $2f_1+f_2$, $2f_1-f_2$, f_1+2f_2, and f_1-2f_2. Good design and testing techniques ensure electronic equipment produces harmonics at low levels, which minimizes distortion.



The plot above shows the range of measurement voltages and the corresponding dynamic range for three instruments. Instrument C offers six gain settings. Note the dynamic range varies from one gain setting to the next.

Often, the second-order IMD frequencies exist some distance from f_1 and f_2, but two third-order IMD frequencies occur close to f_1 and f_2. Thus, filtering can remove second-order IMD components but not third-order IMD frequencies, which exist too close to f_1 and f_2. The change in amplitude of the test signals f_1 and f_2 also affects the amplitude of the IMD-generated signals. An increase of 5 dB in a fundamental frequency increases the amplitude of its second harmonic by 10 dB and the amplitude of its third harmonic by 15 dB. To ensure IMD frequencies will not distort audio signals, engineers require audio test equipment that can accurately measure IMD frequencies over as large a dynamic range as possible.

Dynamic range expresses how well an instrument can detect small signals in the presence or large signals. Because an IMD measurement requires simultaneous measurement of stimulus signals and their low-amplitude harmonics, instruments require a wide dynamic range. The comparison of the largest measurable signal to the smallest detectable signal in a ratio, expressed in decibels (dB), provides a dynamic-range value. The ratio does not specify that an instrument can measure a specific signal. In many cases, dynamic range will equal an instrument's signal-to-noise ratio because the smallest detectable signal amounts to noise. Audio specifications may refer to an A-weighted dynamic range, which involves measurements on filtered signals between 20 Hz and 20 kHz, the range of human hearing.

Most instruments provide adjustable signal-input settings, say from ±10V down to ±10 mV. Each setting specifies the maximum signal the instrument can work with, and each setting provides its own dynamic range. Exercise care when you determine the gain for a measurement. Say you have a 0.5 Vrms signal to measure and you can choose either a 10-V input range with a 118 dB dynamic range, or a 1-V input range with a 113 dB dynamic range. The higher dynamic range of the 10-V setting seems attractive, but do the math and you'll find that range lets you measure only down to about 12 µV. The noise floor of the instrument may hide low-amplitude harmonics and distortion produced by a device under test. On the other hand, the 1-V range with a 113 dB dynamic range lets you measure signals as low as 2 µV.

Distortion Contortion

When Bonnie substituted a new amplifier in a prototype audio circuit, several of her colleagues said they detected distortion. Bonnie wants to determine which harmonics dominate the signal and how much distortion they cause.

How should Bonnie test her circuit to get quantitative distortion results?

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