Measure an amplifier's THD without external filters

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Measuring an op amp’s THD (total harmonic distortion) at frequencies below 100 kHz is problematic because modern amplifiers have a THD rating that is much lower than that of most test equipment. The circuit in this Design Idea uses active noise amplification to eliminate the need for external filters. This approach allows you to measure THD at several orders of magnitude lower than the resolution of the test fixture you are using.

Many THD test circuits use passive-amplification techniques to force the DUT (device under test) to correct itself. This approach can generate considerable error by terminating the distortion signal with resistive loads. A preferred way to generate accurate data is to isolate the DUT and measure it using a high-impedance buffer. This method requires active amplification of the distortion at the amplifier’s output.

You can use a secondary operational amplifier for active amplification (Figure 1). You should use a signal source with THD better than −70 dB. Feed this signal through the DUT, which distorts it. The output of the DUT is a combination of the input signal and the distortion from the DUT multiplied by the gain of the DUT stage. You can set the gain and resistive loading of the DUT according to its specification in the data sheet. This signal at the DUT’s negative terminal is the input signal plus the distortion but without any gain. Connect this node to the positive input of the secondary amplifier. You can calculate the output voltage based on the circuit parameters, according to the following equations:

\[
I_{\text{BUFFER}} = \frac{V_{\text{SIG}} - (V_{\text{SIG}} + V_{\text{DIST}})}{100\Omega}
\]

\[
V_{\text{OUT}} = I_{\text{BUFFER}} \times 100 \, \text{k}\Omega + V_{\text{SIG}} = V_{\text{DIST}} \times 1000 + V_{\text{SIG}}
\]

To detect small distortions, set up the secondary amp for a gain of 1000 and connect the amplifier’s gain-setting resistor to the input signal. This step allows amplification of the distortion but nulls out secondary amplification of the input signal. Consequently, when referenced to ground, the circuit’s output is the original input signal plus the secondary gain times the output distortion of the DUT.
If you want to remove the input signal from the circuit's output, you can set up the secondary amplifier in a differential configuration (Figure 2). Some amount of the input signal still reaches the output because of the buffer amplifier circuit’s CMRR. However, the signal decreases so that it does not affect the measurement of the amplified distortion. Exact matching of the input and feedback resistors of the secondary amplifier reduces the CMRR effects.

Calculate the output of this differential circuit using superposition, according to the following equations:

\[
V_{\text{OUTTOTAL}} = V_{\text{OUTSIG}} + V_{\text{OUTSIG+DIST}}
\]

\[
V_{\text{OUTSIG}} = V_{\text{SIG}} \times \frac{100 \, \text{k} \Omega}{100}
\]

\[
V_{\text{OUTSIG+DIST}} = \left[ V_{\text{SIG+DIST}} \times \frac{100 \, \text{k} \Omega}{100 \, \text{\Omega} + 100 \, \text{k} \Omega} \right]
\]

\[
\left(1 + \frac{100 \, \text{k} \Omega}{100 \, \text{\Omega}}\right) = V_{\text{SIG+DIST}} \times \frac{100 \, \text{k} \Omega}{100 \, \text{\Omega}}
\]

\[
V_{\text{OUTTOTAL}} = V_{\text{SIG+DIST}} \times \frac{100 \, \text{k} \Omega}{100 \, \Omega} - V_{\text{SIG}} \times \frac{100 \, \text{k} \Omega}{100}
\]

\[
V_{\text{DIST}} \times 1000.
\]

The circuit makes any minor distortion on the input signal irrelevant because it is measuring the difference between the output and the input of the DUT. It removes from the secondary gain stage any distortion on the input. You can modify the setup to accommodate inverting conditions (Figure 3).