Active-filter circuit and oscilloscope inspect a Class D amplifier's output

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The increasing acceptance of Class D amplifiers has helped them gain market share from their linear Class AB brethren. That acceptance is no surprise; the advantages of Class D amplifiers are legion, but such amplifiers also require new techniques for evaluation. For example, consider a basic sine-wave test of a linear amplifier. You apply power, apply a sine wave of suitable amplitude to the input, and connect an oscilloscope probe to the output. You'll see a replica of the input, usually offset by about half the power-

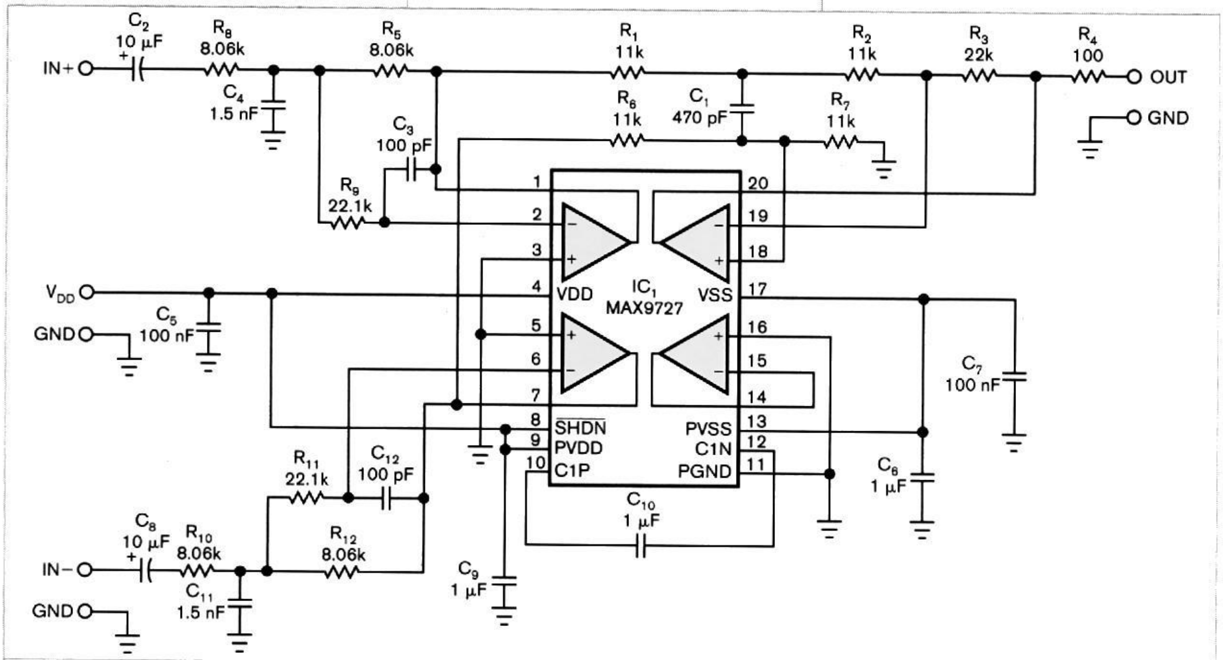

Figure 1 Use this third-order, 30-kHz filter circuit to observe a Class D amplifier's output signal on an oscilloscope.

supply voltage. Even if the linear amplifier drives a BTL (bridge-tied load), you'll still see a recognizable replica of the input at either end of the load, albeit at half of the output signal that's available.

Testing a Class D amplifier poses more difficulties. The amplifier's output comprises a PWM (pulse-width-modulated) signal that swings between ground and the supply voltage at a frequency that's usually 200 kHz to 2 MHz. However, when you view this PWM output on an oscilloscope, you'll see no resemblance to the sine-wave input.

You can observe a Class D audio amplifier's output if you introduce the filter circuit in **Figure 1**. Based on Maxim's (www.maxim-ic.com) MAX-9727 quad-audio-line driver, IC_1, the circuit combines separate single-ended filters—one for each of the BTL outputs' phases—with a third amplifier that provides a difference signal with additional filtering. The first stage of each single-ended-filter section contributes the complex-conjugate pole pair of a third-order, 30-kHz multiple-feedback Butterworth filter, for which many design guidelines and equations are available. Each third-order-filter section comprises a complex-conjugate pole-zero pair and one real pole.

To improve the match between the signal paths, the two separate multiple-feedback filters share a real pole, which 470-pF capacitor C_1 and 11-kΩ resistors R_1 and R_6 provide. The circuit implements that pole as a difference amplifier, thereby producing a filtered output that presents a single-ended version of the BTL amplifier's outputs. The filters' signal paths present 5.5-kΩ impedances to each of the A and B amplifier sections' inputs. By inspection, the net 5.5-kΩ impedance from Section B's output to C_1 comprises the Thevenin-equivalent impedance of resistors R_6 and R_7. Similarly, the net impedance from Section A's output to C_1, also 5.5 kΩ, comprises the Thevenin impedance of resistors R_1 and R_2. Note that the virtual ground from Amplifier D's inverting input effectively grounds resistor R_2.

Matched resistors attenuate each of Amplifier D's differential inputs by 6 dB (IN+ by R_1 and R_2 and IN− by R_6 and R_7). A 22-kΩ feedback resistor, R_3, provides Amplifier D with a gain of two, which sets a unity-gain-transfer function in the circuit's passband. The circuit's single-ended output with respect to ground allows the oscilloscope's ground to also serve as the output signal's ground. A version of this circuit using conventional op amps would require a negative-power-supply-voltage source, but Maxim's MAX9727 already includes a negative-voltage source, which its internal charge-pump circuit generates. When you operate the circuit from a 5V supply, the circuit's output delivers more than 2.5V rms. Although its third-order filter is inadequate for precise measurements of distortion or noise, the circuit provides an excellent tool for troubleshooting and evaluating Class D-amplifier circuits and inspecting their outputs on an oscilloscope. EDN