High Performance Op Amps Deliver Precision Waveform Synthesis

by Jon Munson

Introduction

With the trend toward ever more precise waveform generation using DSP synthesis and digital-to-analog conversion, such as with the LTC1668 16-bit, 50Msps DAC, increasing demands are being placed on the output amplifier. In some applications, the DAC current-to-voltage function is simply resistive, though this is limited to small-signal situations. The more common solution is to use an amplification or a transimpedance stage to provide larger usable scale factors or level shifting. Figure 1 shows one such example, with an LT1722 performing a differential-current to single-ended-voltage amplification for an LTC1668.

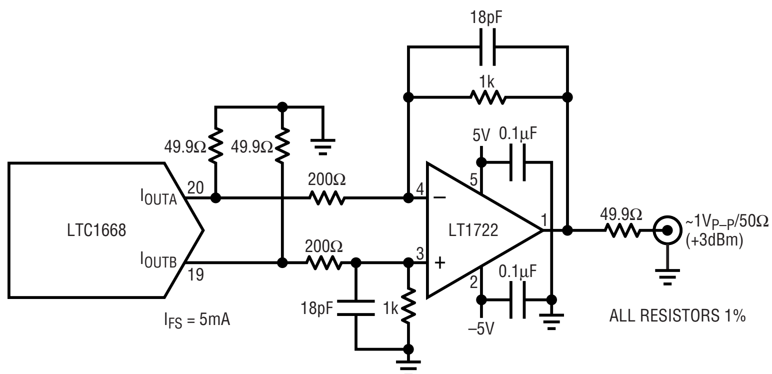

Figure 1. Differential-current to single-ended-voltage DAC amplifier

The LT1722, LT1723 and LT1724 Low Noise Amplifiers

The LT1722, LT1723 and LT1724 are single, dual and quad operational amplifiers that feature low noise and high speed along with miserly power consumption. The parts are optimized for low voltage operation and draw only 3.7mA (typical) per section from ±5V supplies, yet deliver up to 200MHz GBW and quiet 3.8nV/√Hz, 1.2pA/√Hz (typical) noise performance. DC characteristics include sub-millivolt input offset precision and output drive greater than 20mA, excellent for cable driving. The LT1722 single is also available in a SOT-23 5-lead package making it easy to fit into PCB layouts.

DAC Output Amplifier

The circuit in Figure 1 provides ±1V at the amplifier output pin for full-scale DAC currents of 5mA, therefore offering, with the 50Ω series termination shown, a +3dBm sine-wave drive into a 50Ω load (~$1V_{P-P}$). In this particular configuration, the LT1722 is operating at a noise-gain of 5, and provides a small-signal bandwidth of about 8MHz (–3dB). The amplifier contribution to output noise is approximately given by

$$e_n G_n \sqrt{BW} =$$
$$3.8 \bullet 10^{-9} \bullet 5 \bullet \sqrt{8 \bullet 10^6} = 54\mu V$$

for the circuit as shown (resistor noise will increase this to about 75µV). With 16-bit resolution, a one LSB increment at the amplifier output is 31µV, so therefore the LT1722 amplifier noise will have only minimal impact on the available dynamic-range of the converter.

Some applications require amplified differential outputs, such as driving Gilbert-cell mixers (such as the LT5503 IQ modulator) or RF trans-

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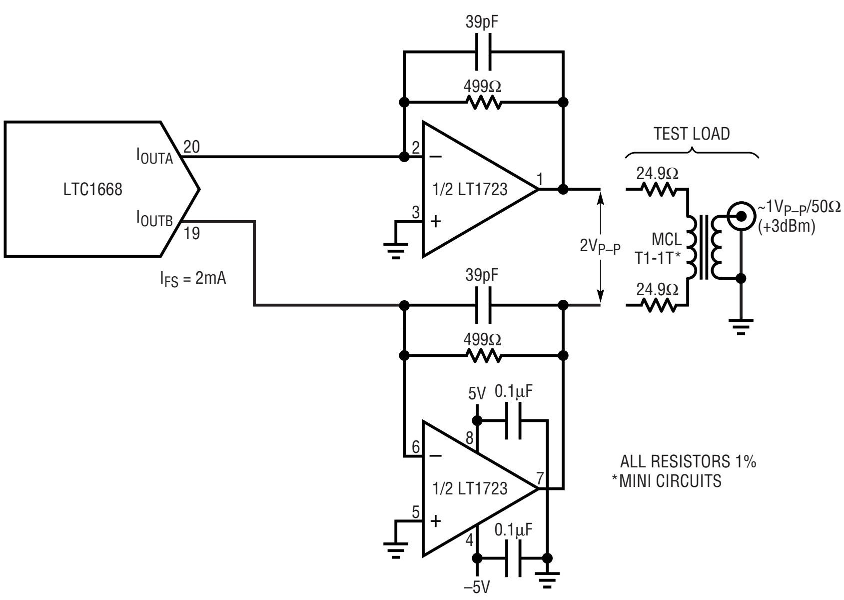

Figure 2. Twin transimpedance differential-output DAC amplifiers

LT1722, continued from page 21

formers. For such applications the LTC1668 differential current outputs can be amplified with twin transimpedance stages as shown in Figure 2, which offers the opportunity to reduce the DAC current without loss of signal swing.

The circuit shown has the DAC full-scale currents reduced to 2mA to achieve a substantial power savings over the standard 10mA operation. The scale factor of the transimpedance amplifiers is set to provide $2V_{P–P}$ differentially. Operating at a noise-gain of unity, this circuit provides a small-signal bandwidth of about 12MHz (–3dB). The noise contributed by the LT1723 amplifiers to the differential load is approximately

$$\sqrt{2}e_n G_n \sqrt{BW} =$$
$$\sqrt{2} \bullet 3.8 \bullet 10^{-9} \bullet 1 \bullet \sqrt{12 \bullet 10^6} = 19\mu V$$

for the circuit as shown (the resistors in the circuit will add some additional noise bringing the total to about 24µV). This compares favorably with the nominal 16-bit LSB increment of 31µV, thus barely impacting the converter dynamic range.

The common mode output voltage of the circuit in Figure 2 is fixed at 0.5V DC, though some loads may require a different level if DC-coupling is to be supported, such as when soft-controlled offset nulling is required. Though not shown here, specific matched currents can easily be introduced to the inverting-input nodes of the two amplifiers to provide common-mode output control.

Each of the amplifier circuits presented will deliver +3dBm into 50Ω with harmonic distortion products below –60dBc for a synthesized full-scale fundamental of 1MHz. The nominal feedback capacitances shown provided ~1% step-response overshoot in the author's prototype configuration, but as with all amplifier circuits, some tailoring may be required to achieve a desired rolloff characteristic in the final printed-circuit layout.

Conclusion

When considering candidate devices for DAC post-amplification, it is important to consider the noise contribution. The LT1722 family of devices offers the low noise and wide bandwidths demanded by modern 16-bit waveform synthesizers, particularly those used for vector modulation, where high-fidelity is paramount.

Additionally, the particularly low noise characteristics of the LT1722, LT1723 and LT1724 op amps provide optimal noise performance for external impedances ranging from several hundred ohms to about 12kΩ, making these parts ideal for a variety of precision amplification tasks.