Dual Bipolar Power-Supply Considerations for Amplifiers

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Dual bipolar power supplies are paired with amplifiers to widen their input and output ranges. Additionally, well-designed, dual power supplies like TPS7A39 can also prevent power supply noise from adversely affecting conditioned signals. This note covers these benefits and other considerations regarding bipolar supplies.

Improved input range

The common-mode voltage range of amplifiers is very much dependent upon the amplifier topology. Traditional amplifiers have a common-mode range that is narrower than the supply voltage range. This presents a problem when the input nears one or both of the supply rails.

Violating the common-mode range will yield different types of distortion, or damage, depending on the type of op amp. Figure 1 shows the time domain representation of one type of distortion:

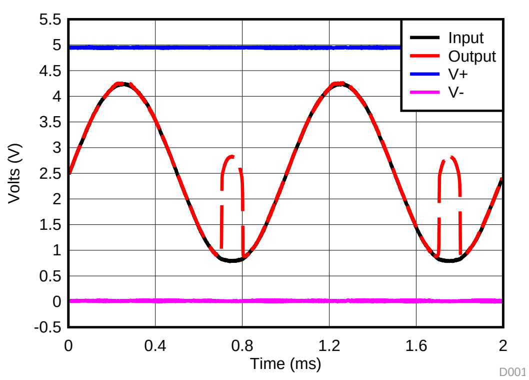

Figure 1. A signal violating the common-mode voltage range (G=1)

There are few methods to avoid such distortion. One involves attenuating the input signal and/or level-shifting it in such a way that it occurs within the specified common-mode range.

If this is not possible, the supply voltage rails can be extended in order to extend the common-mode range. For a single-supply op amp, this means extending the negative rail slightly below ground. In Figure 2, TPS7A39 is used to create supply rails of -0.25 V and +5.25 V to avoid non-linearity.

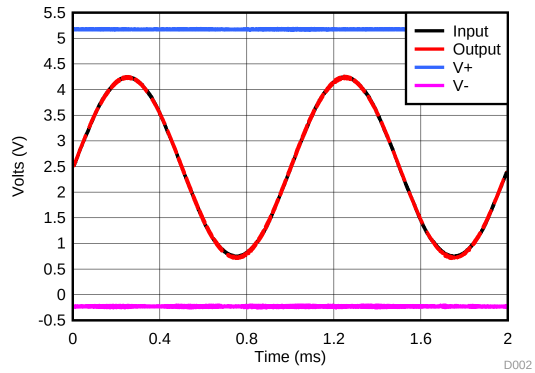

Figure 2. Widened supply rails to accommodate the signal (G=1)

It is worth noting that many newer amplifiers, such as OPA388, offer rail-to-rail input ranges. These op amps have a common-mode range that extends slightly beyond the supply voltage rails and do not necessarily require adjusting the supply rails to avoid damage. However, the signal could still experience non-linearity as it nears the supply rails.

Improved output range

The output range of amplifiers is also limited by the supply voltage range. Even amplifiers with 'rail-to-rail' output ranges cannot truly swing from V+ to V- as the output approaches the positive or negative supply before being limited by the load-dependent voltage drop across the internal output transistors.

The distortion caused by saturation can be measured with a differential ADC in the circuit shown in Figure 3.

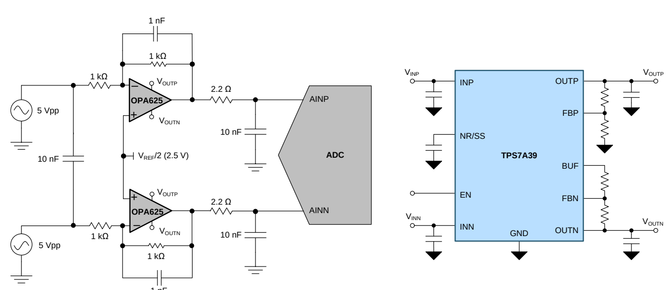

Figure 3. ADC differential input signal driver powered by TPS7A39

The drive circuitry generates the differential voltage of two 5 Vpp sinusoids with a frequency of 1 kHz and a phase offset of 180°. This is subsequently sampled by a differential ADC (ADS8900B) which should ideally encode a 10 Vpp, 1 kHz sinusoid. However, if the OPA625 devices are powered by 0 V and 5 V supply rails, their outputs will encounter some non-linearity when attempting to output 0 V or 5 V. The FFT of the signal is shown in Figure 4:

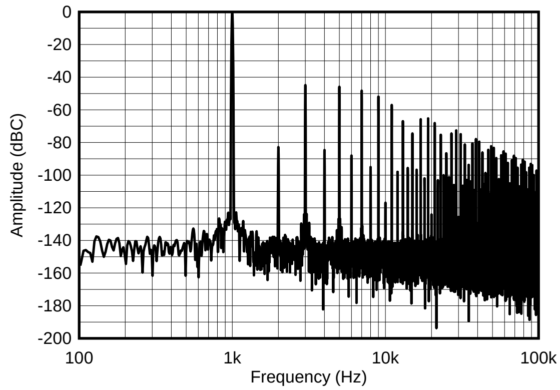

Figure 4. FFT of the ADC output when V_{OUTN} = 0 V and V_{OUTP} = 5 V

This yields an SNR of 54.89 dB and a THD of -40.86 dB. The supply rails are then extended to -0.2V and 5.2V and the FFT is taken once again in Figure 5:

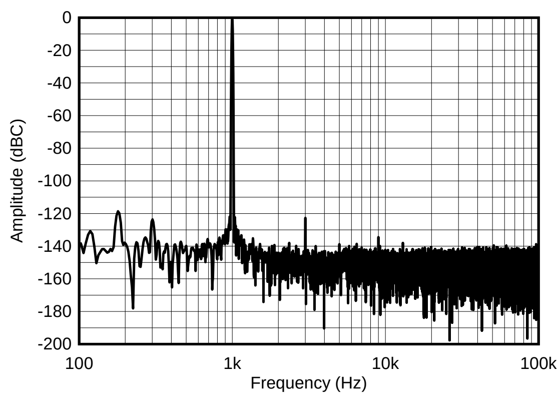

Figure 5. FFT of the ADC output when V_{OUTN} = -0.2 V and V_{OUTP} = 5.2 V

The SNR improves to 102.535 dB while the THD is now -121.66 dB. By extending the supply rails slightly above 5V and slightly below 0V, the full scale range of the ADC can be realized and distortion avoided.

Improved PSRR

Perhaps the greatest advantage of a low-noise, dual power supply is the rejection of ripple voltage emanating from switched-mode power supplies. Unimpeded, switching noise has the potential to couple into the output signal.

Op amps reject a good deal of noise of their own accord. However, it should be noted that most PSRR plots are taken with the op amp in unity gain. PSRR plots like these do not take into account how a gain greater than 1 will affect overall PSRR. Plotting PSRR against several gain ratios yields different results as shown in Figure 6:

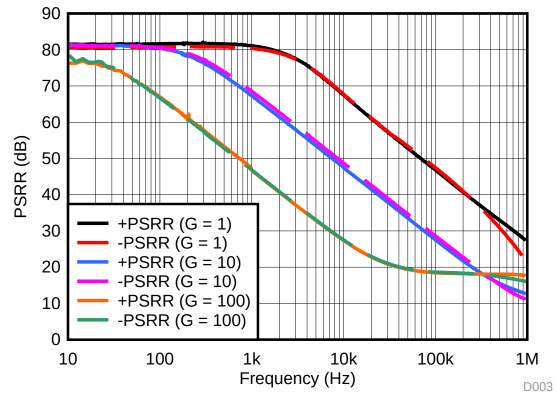

Figure 6. Op Amp PSRR vs frequency and gain

Since PSRR decreases with gain, it is necessary to preemptively filter power supply noise to prevent its coupling onto the output. Using a low-noise LDO like TPS7A39 is an effective way to ensure the supply rails are free of switching noise. By creating the supply rails with TPS7A39, we measure PSRR once again:

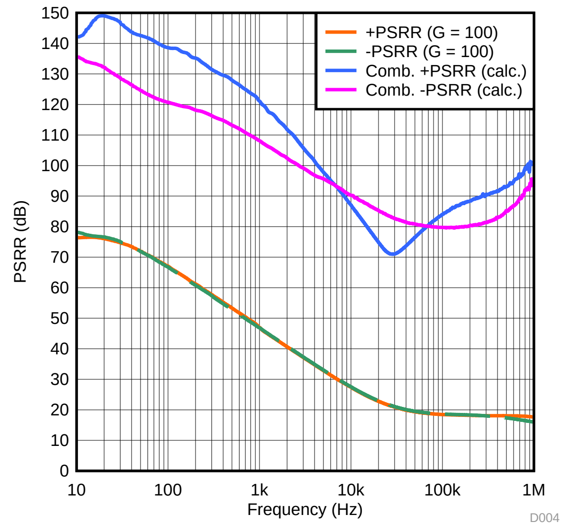

Figure 7. Op Amp & TPS7A39 PSRR vs frequency

As shown, PSRR is improved greatly with the implementation of TPS7A39. This is especially true at higher frequencies (> 500 kHz) where switching noise is more likely to occur.

In conclusion, using a low-noise dual bipolar power supply is safe bet to ensure minimal distortion and optimal signal integrity.

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