Power Supply Effects on Noise Performance

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Nicholas Gray
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Understanding the PSRR (Power Supply Rejection Ratio) of analog circuits is an important step to improving overall mixed-signal system performance. Once you know the effects of PSRR, you can compensate for them. The fact is that the PSRR of analog circuits, including ADCs (Analog-to-Digital Converters), DACs (Digital-to-Analog Converters) and op amps, is usually much worse at high frequencies than the DC PSRR generally seen on data sheets.

Why the Apparent Discrepancy?

The reason for the apparent discrepancy is the fact that most products' PSRR specification indicates the variation in a particular parameter for a given change in DC power supply voltage. For example, an ADC may specify the PSRR as the ratio of the change in full-scale gain or offset error with a given change in the DC supply voltage, usually expressed in dB. If a change in supply voltage from 4.75V to 5.25V (a 500mV delta) results in a change in the full-scale ADC gain error of 0.6mV, the PSRR is found to be

$$\text{PSRR} = 20 \bullet \log\left(\frac{\Delta\ \text{Gain Error}}{\Delta\ \text{Supply}}\right) = 20 \bullet \log\left(\frac{0.6}{500}\right) = -58\text{dB}$$

That is, the difference in gain error is determined by taking two gain error measurements. One reading is taken with a stable, noise-free supply of 4.75V and the other is with a stable, noise-free supply of 5.25V. This information only shows how this one specified parameter can be expected to change with individual power supply variations. However, other parameters may have more or less sensitivity to noise on the power supply, so the usefulness of such a specification is questionable.

Generally, the PSRR of an active component will be worse with an AC signal riding on its supply than it will be with a change of the power supply's DC level.

Why the Low AC PSRR

Any signal or noise on the supply lines will couple into the active circuitry through the stray capacitances and gain of the bias network and be amplified by the active circuitry on the die. These unwanted signals are noise and, therefore, degrade the device's noise performance. *Figure 1* shows a simplified amplifier stage with stray capacitances. Actual circuits use many techniques to improve PSRR, but no analog circuit is totally immune to supply noise.

One source of power supply noise comes from the output switching of an ADC. The change of output states will cause supply current transients as the output drivers charge the capacitance on the output pins.

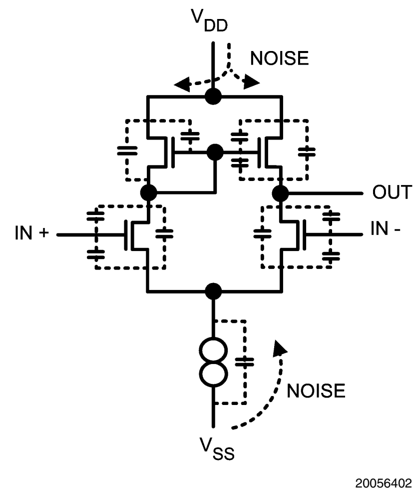

FIGURE 1. Supply noise can couple into the active circuitry of a device and degrade its performance

Without adequate supply bypassing, these current transients will cause voltage fluctuations on the supply line. The resulting high frequency noise on the supply line causes noise in the bias circuitry, which further degrades the SNR of the ADC.

PSRR Variation with Frequency

Figure 2 shows a plot of AC PSRR for the ADC12040 (a 12-bit, 40Msps ADC) vs. supply noise frequency. The test data for this plot was gathered by injecting 200mV$_{P-P}$ of the noise at various frequencies onto the power supply lines of the ADC and using an FFT plot to measure the magnitude of this signal at the output of the ADC.

With 38dB AC PSRR at 30MHz, the ADC12040's performance is actually quite good. Analog components often have PSRRs in the 10 to 20 dB range at these frequencies.

PSRR Variation with Frequency

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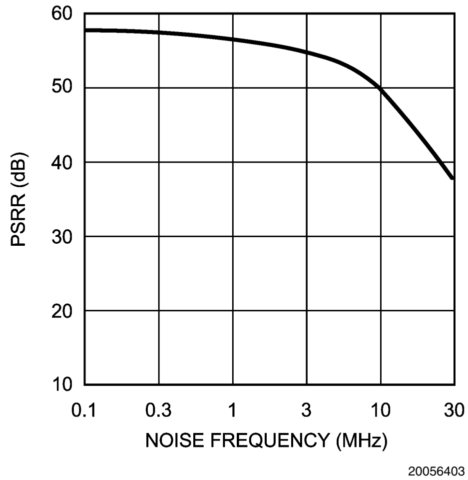

FIGURE 2. Plot of PSRR vs. supply noise frequency for the ADC12040

Minimizing Noise Problems

To minimize the effects of noise on the power supply, the analog and digital supply pins should be separately decoupled for both high and low frequencies. Typically, a parallel combination of a 10µF capacitor and a 0.1µF monolithic capacitor will suffice. The optimum values may vary with the particular IC selected and the frequency of operation, so be sure to follow the manufacturer's recommendations. Additionally, for mixed-signal products such as ADCs, it is good practice to bring the power directly to the analog supply pins first, then to the digital supply pins through a choke. For high-speed ADCs, a ferrite choke with 2.5 turns will do well. The choke usually only needs to isolate the output driver pins from the other supply pins. If the output driver supply pins are not explicitly shown on the data sheet, isolate all of the digital supply pins. In any case, the analog and digital supply pins of a mixed signal device should have separate bypass capacitors as shown in *Figure 3*.

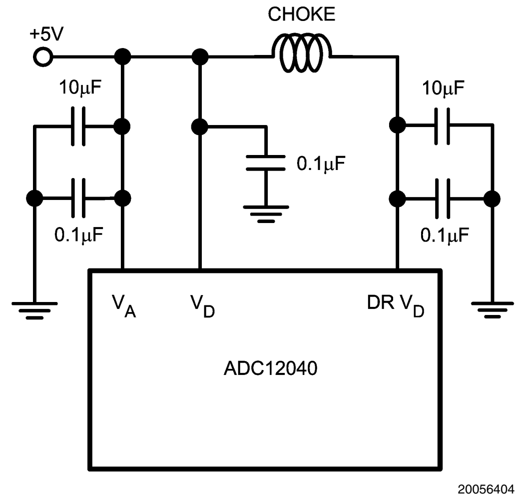

FIGURE 3. Separately bypass the power supply at both low and high frequencies. Isolate digital output driver supply line with a small choke. A ferrite choke with 2.5 turns will do well.

Power supply noise can be further reduced by keeping the analog power plane over the analog ground plane, when a split ground plane is used, or by routing the power trace away from any digital components when a single ground plane is used.

Finally, as popular as they are for their efficiency, the noise generated by switching power supplies can wreak havoc with mixed signal components. If it is necessary to have a switching supply in the system, be sure to lay it out for minimum RFI/EMI and keep it as far away from analog and mixed signal areas of the system as possible.

National Semiconductor Corporation
Americas
Email: support@nsc.com

National Semiconductor Europe
Fax: +49 (0) 180-530 85 86
Email: europe.support@nsc.com
Deutsch Tel: +49 (0) 69 9508 6208
English Tel: +44 (0) 870 24 0 2171
Français Tel: +33 (0) 1 41 91 8790

National Semiconductor Asia Pacific Customer Response Group
Tel: 65-2544466
Fax: 65-2504466
Email: ap.support@nsc.com

National Semiconductor Japan Ltd.
Tel: 81-3-5639-7560
Fax: 81-3-5639-7507

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