AN-1261 Power Supply Effects on Noise Performance

High-Performance Analog

ABSTRACT

While this application report concerns itself with analog-to-digital converters (ADC), it applies equally as well to digital-to-analog converters (DAC), amplifiers and to circuits in general, integrated or otherwise.

Contents

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1   Executive Summary

Power supply rejection ratio (PSRR) is an often misunderstood and little used specification. Understanding the PSRR of analog circuits is an important step toward improving overall mixed-signal system performance. The fact is that the PSRR of analog circuits, including ADCs, DACs and op amps, is usually much worse at high frequencies than the DC PSRR generally seen on data sheets. However, most manufacturers have historically only specified DC PSRR.

Product Applicability:

- All ADCs and DACs

2   Overview

In general, the PSRR of integrated circuits, when specified, indicates how well that device rejects a change in the DC power supply voltage. It describes the change in a given specification, such as input offset, for a given change in the power supply DC voltage. This is what we here call DC PSRR and does not tell us anything about how well the device will reject the effects of a dynamic signal on the power supply, which we here call AC PSRR.

3   What is the Difference?

products' PSRR specification indicates DC PSRR, or 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

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

(1)

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.

AC PSRR, on the other hand, indicates how well a circuit rejects a dynamic signal at a specified frequency is from its output. 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 DC level of the supply.

4   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.
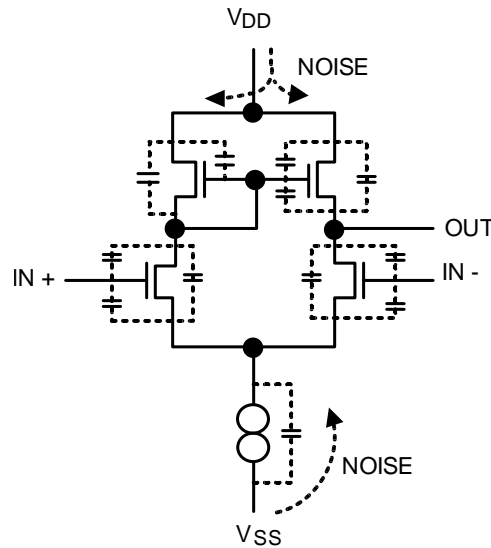
Figure 1. Supply Noise can Couple Into the Active Circuitry of a Device and Degrade its Performance

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.

5   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 200mVP-P of at various frequencies onto the power supply lines of the ADC and using a frequency domain (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.
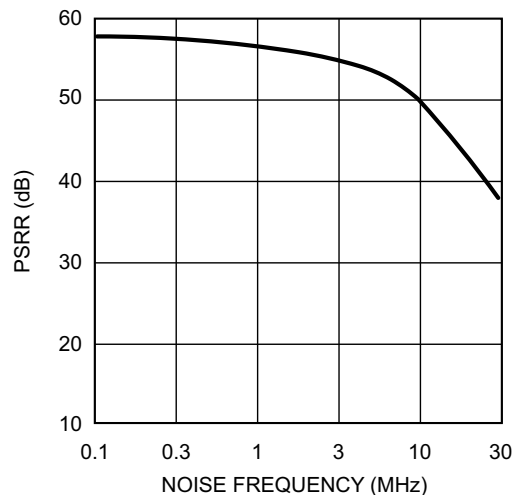

Figure 2. Plot of PSRR vs. Supply Noise Frequency for the ADC12040

6   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 10 µF capacitor and a 0.1 µF 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 device-specific 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.
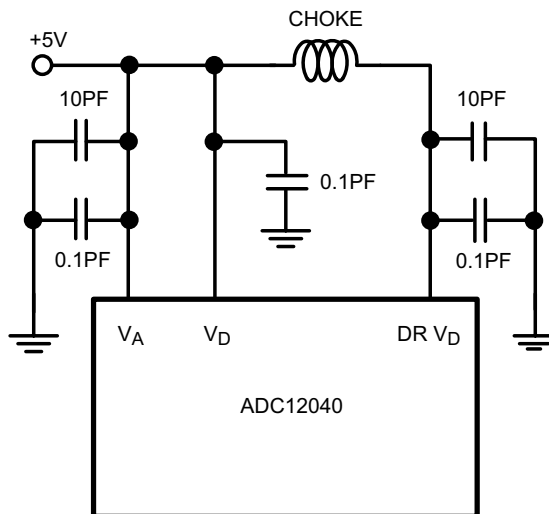

Figure 3. Separately Bypass the Power Supply at Both Low and High Frequencies. Isolate Digital Output Driver Supply Line With a Small Choke. A Ferrite Choke With 2.5 Turns will do Well.

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 out the board for minimum RFI/EMI and keep it as far away from analog and mixed signal areas of the system as possible. The power supply for analog and mixed-signal components should be filtered well. Keep in mind that switching supplies typically have ringing frequencies in the hundreds of Megahertz which can be difficult to filter out because of the ESL of a lumped capacitance. Using a linear regulator, such as an LDO (low drop out regulator), between a switching supply and the linear or mixedsignal circuit may not solve this problem because that regulator may not have a high enough PSRR at the high ringing frequencies to be effective.

Revision History

Changes from B Revision (April 2013) to C Revision   **Page**

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

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