Tech Tips

SUPPLY NOISE ATE MY LUNCH!

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Question

Have you ever fought a system-level noise issue that just wouldn't go away? I think we all have at one point or another. Sometimes it seems like all the filtering in the world won't do the trick. If you're lucky, though, a little bit of brute force will make all the difference.

Introduction

We all know that noise in the analog supply to audio circuits will always find its way to sensitive analog circuitry. Call it Murphy's Law. And when it does, you can say goodbye to your target performance ideals.

Take the case of a simple audio CODEC that converts the analog domain to the digital, and the digital domain to analog. You've got analog input buffers, analog output buffers, and the analog section of your audio converter all powered off the same supply. The active input and output stages and data converter can only reject so much supply noise so, if that common supply is too noisy, you can bank on it causing performance problems in your audio path. Of course, many systems will power these analog supplies from the same rail as much of their noisy digital circuitry. If the system isn't designed just right, the digital noise ends up all over what should be your nice clean analog supplies.

If your supply noise is small enough, the converters and analog circuits will be able to reject it. Sometimes it's small enough that it's visible with measurement gear but not audible; in these cases it might be acceptable if left unaddressed. Noise, though, becomes a serious issue when it's easily noticeable to the listener, especially if the noise is spectrally shaped or periodic with audible tones.

This tech tip shows that using a linear low drop-out regulator (LDO) in the analog supply line of an ADC, DAC, or CODEC can be a simple and effective solution that will result in better analog audio performance. While I'll focus mostly on the ADC component of a system, the same concepts apply to the D-A path.

What's an LDO?

An LDO is a variation of a common linear voltage regulator (LVR), a device that we've all used to generate a secondary DC voltage from a primary DC supply. They're most often used to reduce the number of DC voltages that need to be supplied to a system. For example, LVR's could be used to generate internal 3.3V and 5V supplies from a single 12V input supply. Like this, a simple 12V external power supply can be used to supply a system that requires a number of different supply voltages.

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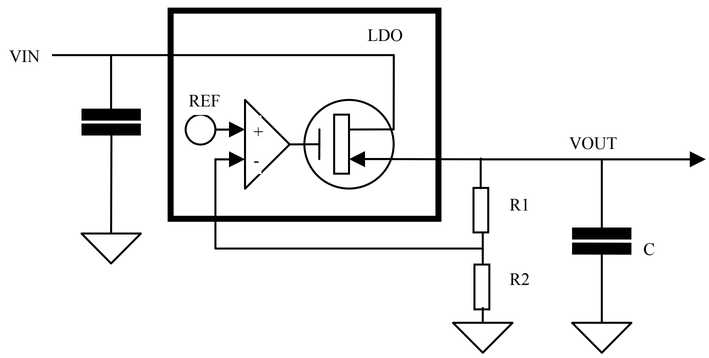


Figure.1

LDO's operate by comparing a fed-back proportion of their output voltage (usually simply a voltage division of the output) to an internally generated precision reference voltage. Like this, LDO's can quickly react to voltage variations on their outputs by modifying their internal drive to their integrated output devices. It's this feedback reaction which allows an LDO to attenuate noise on its output supply.

In Figure 1, R1 and R2 provide the output. A voltage adjustment relative to the internal reference voltage relatively small capacitor C provides output supply smoothing. Since the capacitor value is typically very low, it can be a major advantage in space constrained applications when compared with multiple bulk capacitors and perhaps ferrites as an alternative approach to noise removal.

Other Solutions

A passive solution using carefully chosen and placed capacitors and a dedicated ground plane can only help. If you're really careful, ferrites and inductors can also be used to help squelch supply noise. In fact, if board layout and capacitor placement are engineered well, chances are you won't be looking for ways to suppress supply noise. But sometimes in the case of severe noise, and typically when you don't have time to rethink the board design from the ground up, the supply domain isolation provided by an LDO can be an invaluable tool.

LDO Manufacturers and Types

There are several well known manufacturers of LDOs. National Semiconductor, for example, has a wide range of parts. Many other mainstream manufacturers have similar devices, and there are newer entrants such as California Micro who also offer a wide range of parts.

Many of these are highly suitable for and some even targeted at audio applications. California Micro and others have now integrated LDO's and charge pumps so that an exact 1:1 input voltage to output voltage ratio can be maintained or indeed "pumped" to a higher supply voltage while maintaining the LDO's noise attenuating advantages.

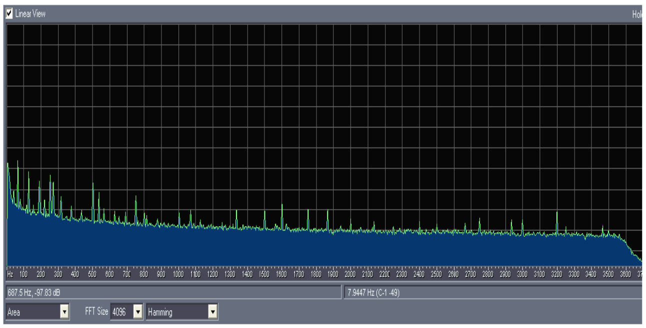
In Practice

I recently used this approach to help a customer solve a problem in one of their new after market automotive audio programs. In their application, they were using a CODEC with an integrated microphone amplifier that was being supplied with a single 3.6V supply. The entire design was done on a very small form factor board with many noisy digital components very close to the CODEC. During the customer's validation of their first prototype, they found that the output of the CODEC's microphone amplifier had a lot more noise than they expected. With just a little investigation, it was clear that the source of the noise wasn't direct through the microphone inputs, but rather through the CODEC/microphone amplifier's power supply.

Working within the bounds of their system's architecture and physical design, no reasonable fitting of capacitors and ferrite beads was able to show enough attenuation of the supply noise to reduce the microphone noise to the expected level.

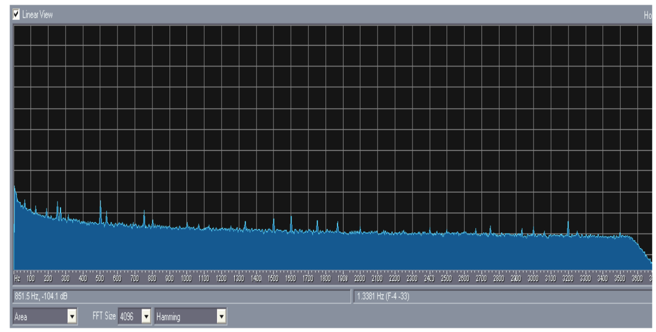
Because of this, we decided to turn our investigation to the use of an LDO. It was possible to put a small footprint device within some spare space on their target board. With just a little bit of prototyping, the results were clear.

The results can clearly be seen in the plots to the right, showing the "before" and "after" measurements of the microphone amplifier output. Each of these plots was taken with the same stimulus applied to the system, and with the microphone inputs connected to ground through a load to simulate the state of the microphone inputs in the system when the connected microphones aren't picking up any sound. As you can see, many of the microphone output noise peaks originally caused by supply noise in the system are almost completely suppressed. This is especially true for the lower frequency tones that are generally more irritating from a listening perspective.



Without LDO

Tones : -73.23dB@250Hz, -80.31dB@266Hz



With LDO

Tones : -95.68dB@250Hz, -93.28dB@266Hz

Conclusions

When you're in a pinch, LDOs can be a high performance and space efficient solution to unwanted audio band noise on the power supply of sensitive analog or mixed-signal audio devices. Keep in mind that LDO's aren't perfectly efficient and do burn a little power, so they might not be suited for the most power sensitive applications. Also, careful power architecture and board design can be used to help prevent tones from the start. However, when the time comes to debug a tricky analog circuit in the noisy environment of a design that's too close to done for a detailed redo, you might think of turning to the trusty LDO.