Texas Instruments:

Impact of Power Supply on ADCs & DACs

Choosing the best power supply for your requirements

Xavier Ramus // Product Definer // Telecom LDO

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<td>• N-Channel MOSFET Transistor</td>
<td>• Low-side Driver</td>
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<td>• Step-down (buck)</td>
<td>• P-Channel MOSFET Transistor</td>
<td>• Half-bridge Driver</td>
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<td>• Charge Pump</td>
<td>• Step-up (boost)</td>
<td>• Buck/boost negative output module</td>
<td>• Isolated Gate Driver</td>
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<tr>
<td>(External FET)</td>
<td></td>
<td>• Isolated module</td>
<td>• Power MOSFET Module</td>
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<td></td>
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WEBENCH® design tools available [http://webench.ti.com](http://webench.ti.com)
Agenda

• BIAS circuit vs. Mixer circuit
• Linking basic signal-chain building blocks & data converters
• Understanding signal-chain component PSRR
  – ADC PSRR
  – DAC PSRR
• Ripple versus thermal noise
• System level impact:
  – When Powering ADC
  – When Powering DAC
Bias vs. Mixer Circuit

NPN example:
- This is true for all bipolar or CMOS transistors.
- All transistors have parasitic paths that can transform a BIAS function into a Mixer function.
- The sensitivity of the component is dependent on the process & architecture used. The lower the voltage process, the less headroom there is, and thus it is less likely an architecture solution to improve PSRR can be implemented.
Differential pair is a very versatile block that can be used for:

- ADC sample & hold
- Buffer
- Current steering DAC output stage
- Also mixer, clock, etc.

So any transistor, regardless of its designed function, can be a point of entry for undesired signal present on a power supply.
Understanding Signal-Chain Component: ADC PSRR
ADC34J45 vs ADC3444 as example

ADC34J45 vs ADC3444
Current steering DAC output have a PSRR of 0dB and Mixer PSRR of 0dB as the power supply is connected directly to the output.
Ripple versus Thermal Noise

• PSRR is measured using sinewave and in that way can emulate ripple of DC/DC converters.

• Thermal & 1/f noise originating from any power supply are attenuated by the ADC or DAC PSRR. Note that current steering DAC output have a PSRR of 0dB and Mixer PSRR of 0dB as the power supply is connected directly to the output. AC-coupling would improve low frequency PSRR, but has no effect on Mixer PSRR.

• Power supply noise and its impact on the ADC can only be calculated due to measurement methodology that by suppressing the input-signal phase-noise eliminates the power supply noise.

• Ripple noise of DC/DC converters are easily eliminated by using ferrite beads. The DC/DC converter 1/f and thermal noise is NOT. Powering an ADC with a DC/DC converter is possible, but should be recommended only in oversampling system, system that can be post-processed and system that do not mind using a 16bit converter to achieve 10 bit resolution. If a system wants both the highest resolution available and real-time data acquisition, then an LDO must be used.
ADS3444 powered from TPS54320 + TPS7A81

3 conditions tested:
- Reference (2x low noise LDO)
- Light load on TPS54320
- Heavy load on TPS54320

<table>
<thead>
<tr>
<th>Power supply noise</th>
<th>Noise (µV RMS)</th>
<th>PSRR (dB)</th>
<th>Noise (nV/√Hz)</th>
<th>Result SNR (dBFS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADC Component</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AVDD DC Component</td>
<td>22</td>
<td>50</td>
<td>0.2</td>
<td>72.4</td>
</tr>
<tr>
<td>AVDD Fund Component</td>
<td>2x 22</td>
<td>28</td>
<td>5.5</td>
<td>72.2</td>
</tr>
<tr>
<td>DVDD DC Component</td>
<td>22</td>
<td>75</td>
<td>0.0</td>
<td>72.4</td>
</tr>
<tr>
<td>Total</td>
<td>24.5</td>
<td>72.2</td>
<td></td>
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</tr>
</tbody>
</table>

No SNR & SFDR degradation.
No difference with heavy DC/DC load.
DAC Example

- Not sensitive with internal PLL on
- Might want to consider LDO for best performance when using external PLL
- Not sensitive, Passive filter best for high frequency
- Very sensitive supply
- Should use LDO
**Conclusion:**

- 1/f and thermal noise as ripple noise is much easier to solve.

- The faster the clock, the lower the supply noise ($\mu$VRMS) needs to be.
  - DC/DC $V_{RMS} = 2\mu V_{RMS}$
  - LDO $V_{RMS} \leq 100\mu V_{RMS}$

- LDO is needed if:
  - Real time system
  - Get all the ENOB you paid for.

- DC/DC can be used if:
  - Oversampled system with long acquisition time.
  - Lower performance need.
You can spend a lot of time finding problems and solving them only with passive components, possibly reducing production cost (but not guaranteed) and at the expense of increase development cost and time.

Or take a much simpler approach and…

**USE AN LDO!**

The only side effect is a faster design cycle!
Low Noise, High Performance LDO Portfolio

TPS7A87
Dual 0.5A, 3.8uVrms
1.4V-6.5V, 4x4

TPS7A88
Dual 1A, 3.8uVrms
1.4V-6.5V, 4x4

TPS7A89
Dual 2A, 3.8uVrms
1.4V-6.5V, 4x4

TPS7A87
Dual 0.5A, 3.8uVrms
1.4V-6.5V, 4x4

TPS7A88
Dual 1A, 3.8uVrms
1.4V-6.5V, 4x4

TPS7A89
Dual 2A, 3.8uVrms
1.4V-6.5V, 4x4

TPS7A91
1A, 4.7uVrms
1.4V-6.5V, 2.5x2.5

TPS7A92
2A, 4.7uVrms
1.4V-6.5V, 2.5x2.5

TPS7A93
2A, 6uVrms
1.1V-6.5V, 3.5x3.5

TPS7A94A
3A, 6uVrms
1.1V-6.5V, 3.5x3.5

TPS7A95A
4A, 6uVrms
1.1V-6.5V, 3.5x3.5

TPS7A85
4A, 4.4uVrms
1.1V-6.5V, 3.5x3.5

TPS7A84
3A, 4.4uVrms
1.1V-6.5V, 3.5x3.5

TPS7A83A
2A, 4.4uVrms
1.1V-6.5V, 3.5x3.5

TPS7A84A
3A, 6uVrms
1.1V-6.5V, 3.5x3.5

TPS7A85
4A, 6uVrms
1.1V-6.5V, 3.5x3.5

TPS7A83
2A, 6uVrms
1.1V-6.5V, 3.5x3.5

TPS7A84
3A, 4.4uVrms
1.1V-6.5V, 3.5x3.5

TPS7A85
4A, 4.4uVrms
1.1V-6.5V, 3.5x3.5

TPS7A8xA
No sequencing requirement
Start with negative bias on V_{OUT}

→: pin-to-pin compatible

Available
In Development
Concept

Output Current per channel

0.5A → 1A → 2A → 3A → 4A
Resources

LDO Overview
www.ti.com/ldo

Power House LDO Blogs
http://e2e.ti.com/blogs_/b/powerhouse/archive/tags/ldo

Frequently Asked?
ANYOUT
Powering ADCs
Powering PLL/VCO
Paralleling LDOs

Video
https://training.ti.com/engineer-it-what-adc-psr
https://training.ti.com/engineer-it-why-not-dcdc-converter
https://training.ti.com/engineer-it-how-design-best-dcdc-power-supply

Selection Guide
http://www.ti.com/lit/slyt228

App Note Overview
http://www.ti.com/lit/sbva026