How to pick a linear regulator for noise-sensitive applications

By Sureena Gupta
Marketing Engineer

Noise-sensitive applications require a power supply that generates low internal noise and rejects noise from the power source. These applications include test and measurement applications, medical equipment, communication equipment, base stations, and many others. A low-noise power supply is used to power a signal chain that includes data converters, amplifiers, clocks, jitter cleaners, PLLs, analog front ends and many other devices. A low-noise power solution is essential to preserving signal accuracy and integrity. This article addresses criteria and parameters to consider in designing such a power solution, including important specifications for picking a linear regulator.

The terms "power supply ripple rejection" (PSRR) and "linear regulator" often are used together. The linear regulator's high ripple rejection makes it an integral part of a power solution. PSRR is a measure of how well the regulator filters a circuit by rejecting noise or ripple coming from the power-supply input at various frequencies. In both low-dropout regulators (LDOs) and linear regulators, PSRR is a measure of output ripple compared to the input ripple over a frequency range.

Since PSRR is calculated as ripple rejection, it is expected to be a negative number. However, it is represented as a positive number in the datasheet so that a higher number denotes higher noise rejection. Mathematically, it is expressed in decibels as

$$\mathrm{PSRR} = 20 \times \log\left(\frac{V_{IN\_ripple}}{V_{OUT\_ripple}}\right).$$

The PSRR of a linear regulator can be divided into three frequency-range regions. The first region extends from DC to the roll-off frequency. The ripple rejection in this region is mostly dominated by open-loop gain and the bandgap reference. The second region extends from the roll-off frequency to the unity-gain frequency. The PSRR in this region is usually higher than in the first region and is mainly dominated by the open-loop gain of the regulator. The third region's frequency range is above that of the unity-gain frequency. The output capacitor, along with the linear regulator's parasitics (in the V_{IN}-to-V_{OUT} path), dominates this region. Therefore, the values of the selected output capacitor and its equivalent series resistance are quite important. This information can be found in any datasheet.

In addition to V_{IN}, V_{OUT}, and system load requirements, an engineer needs to know the frequency range of ripple and noise in the system or power supply in order to select linear regulators with a good PSRR in that frequency range. For example, a switcher that switches at a frequency of 2 MHz may require a linear regulator that has a high PSRR at around 2 MHz. Figure 1 shows a linear regulator's high PSRR of about 55 dB at 2 MHz that helps to remove input noise. Also, when PSRR graphs in the regulator datasheets are evaluated, it is always good to note the dropout voltage at which the PSRR is measured. High dropout voltage leads to better PSRR but reduces the device's efficiency.

Figure 1. Plot of linear regulator's wide-bandwidth, high PSRR

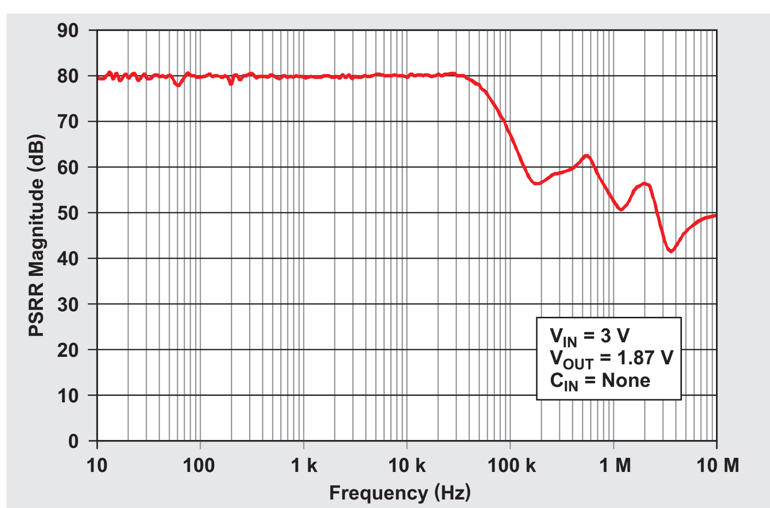


Figure 2 shows a switching regulator's spectral noise that is fed to a linear regulator. It can be seen that the switcher is operating at 500 kHz. Figure 3 shows the output spectrum of the Texas Instruments TPS7A4700 linear regulator. The spike caused by the switcher at 500 kHz has been attenuated. If the power solution is not designed for noise attenuation with high-PSRR linear regulators, the spike may show up at the output of the RF voltage-controlled oscillators, which after mixing affect the PA performance. The spike may also fold back into the audio band and create noise in an audio application.

Usually, noise and PSRR parameters are lumped together in a linear regulator's datasheet, which causes a lot of confusion because noise and PSRR are two very different characteristics. Noise is purely a physical phenomenon that occurs with transistors and resistors

Figure 2. Typical noise spectrum from a switching regulator

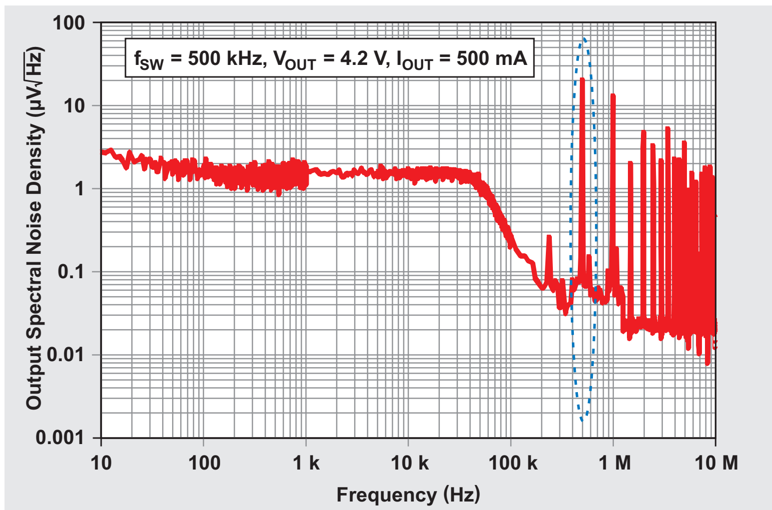
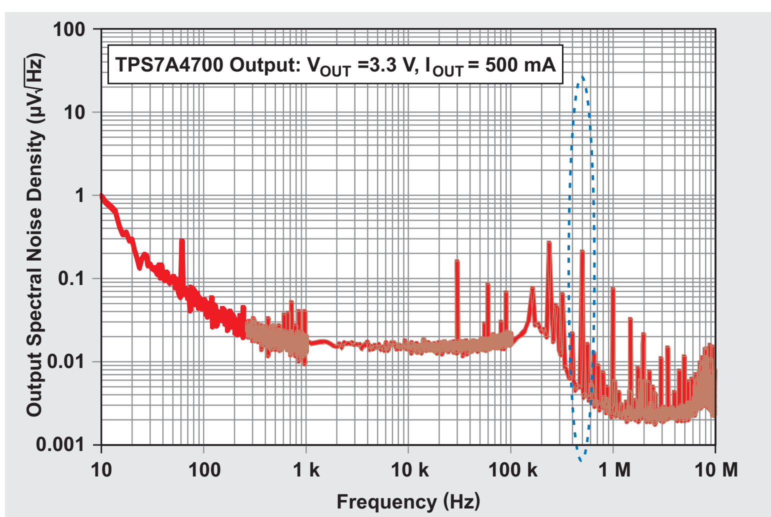


Figure 3. Output noise spectrum of TPS7A4700 linear regulator with attenuated 500-kHz spike



inside the linear regulator on a very fundamental level. This type of noise may include thermal, flicker, and shot noise. Noise is usually indicated as a curve showing spectral noise density (in μV/√Hz) versus frequency (Figure 4). Noise can also be indicated as integrated output noise (in μV_{RMS}), listed under the electrical characteristics table in the datasheet (Figure 5). The output noise (in μVR_{MS}) is the spectral noise density integrated over a certain frequency range and can be seen as the total noise in a specified frequency range.

The next obvious question is whether an engineer should look at spectral noise density or integrated output noise, or both. The answer depends purely on the engineer's application. For example, in RF applications where the signal does not have any dependency on the frequency, it makes more sense to look at the linear regulator's spectral noise density. However, in applications where the noise will be integrated by the system, such as powering DACs and ADCs, the engineer should look at the linear regulator's integrated output noise instead.

Conclusion

This article has discussed the important specifications that design engineers need to consider when picking a linear regulator. It has also covered the criteria and parameters to consider in designing a power solution for low-noise applications. Given these guidelines, engineers should be able to preserve signal accuracy and integrity in their applications.

Reference

1. Thomas Neu, "Power-supply design for high-speed ADCs," Analog Applications Journal (1Q 2010). Available www.ti.com/slyt366-aaj

Related Web sites

Power Management:
www.ti.com/power-aaj
www.ti.com/ldo-aaj
www.ti.com/tps7a4700-aaj

Subscribe to the AAJ:
www.ti.com/subscribe-aaj

Figure 4. Spectral noise density for the TPS7A4700

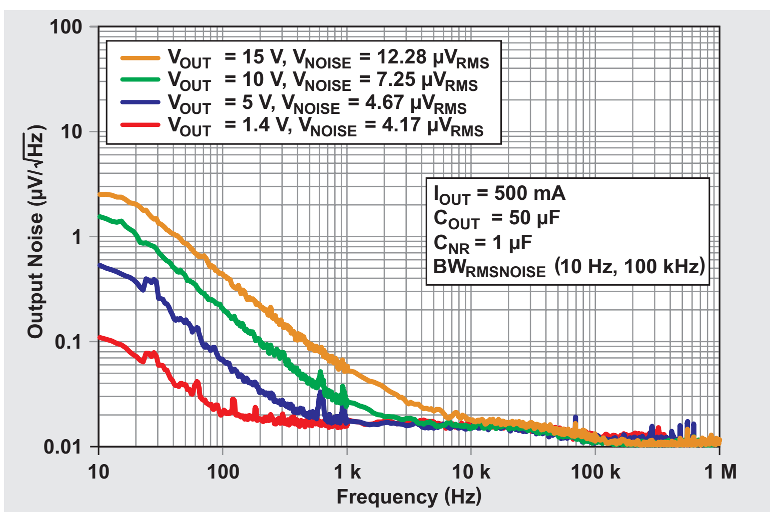


Figure 5. Excerpt from TPS7A4700 datasheet showing integrated output noise voltage

PARAMETER		TEST CONDITIONS	TYP	UNIT
V_{NOISE}	Output noise voltage	V_{IN} = 3 V, $V_{OUT(NOM)}$ = 1.4 V, C_{OUT} = 50 μF, C_{NR} = 1 μF, BW = 10 Hz to 100 kHz	4.17	μV_{RMS}
		V_{IN} = 6 V, $V_{OUT(NOM)}$ = 5 V, C_{OUT} = 50 μF, C_{NR} = 1 μF, BW = 10 Hz to 100 kHz	4.67	μV_{RMS}

TI Worldwide Technical Support

Internet

TI Semiconductor Product Information Center Home Page

support.ti.com

TI E2E™ Community Home Page

e2e.ti.com

Product Information Centers

Americas	Phone	+1(512) 434-1560
Brazil	Phone	0800-891-2616
Mexico	Phone	0800-670-7544
	Fax	+1(972) 927-6377
	Internet/Email	support.ti.com/sc/pic/americas.htm

Europe, Middle East, and Africa

Phone

European Free Call	00800-ASK-TEXAS (00800 275 83927)
International	+49 (0) 8161 80 2121
Russian Support	+7 (4) 95 98 10 701

Note: The European Free Call (Toll Free) number is not active in all countries. If you have technical difficulty calling the free call number, please use the international number above.

Fax	+(49) (0) 8161 80 2045
Internet	www.ti.com/asktexas
Direct Email	asktexas@ti.com

Japan

Phone	Domestic	0120-92-3326
Fax	International	+81-3-3344-5317
	Domestic	0120-81-0036
Internet/Email	International	support.ti.com/sc/pic/japan.htm
	Domestic	www.tij.co.jp/pic

Asia

Phone

International	+91-80-41381665
Domestic	Toll-Free Number

Note: Toll-free numbers do not support mobile and IP phones.

Australia	1-800-999-084
China	800-820-8682
Hong Kong	800-96-5941
India	1-800-425-7888
Indonesia	001-803-8861-1006
Korea	080-551-2804
Malaysia	1-800-80-3973
New Zealand	0800-446-934
Philippines	1-800-765-7404
Singapore	800-886-1028
Taiwan	0800-006800
Thailand	001-800-886-0010

Fax	+8621-23073686
Email	tiasia@ti.com or ti-china@ti.com
Internet	support.ti.com/sc/pic/asia.htm

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as “components”) are sold subject to TI’s terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI’s terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers’ products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers’ products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI’s goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or “enhanced plastic” are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have ***not*** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

Products		**Applications**	
Audio	www.ti.com/audio	Automotive and Transportation	www.ti.com/automotive
Amplifiers	amplifier.ti.com	Communications and Telecom	www.ti.com/communications
Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Security	www.ti.com/security
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Applications Processors	www.ti.com/omap	**TI E2E Community**	e2e.ti.com
Wireless Connectivity	www.ti.com/wirelessconnectivity		

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265