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PLANET ANALOG

How PSRR and other power-supply factors affect mobile-phone audio quality

By Marie Maurel

REGARDLESS OF THE PROTOCOL used by a mobile phone, whether GSM or TDMA, the RF transmitter switching creates severe noise for the power supply, as the RF power amplifier switches on and off at 217 Hz. At each of these events, a high current (typically, up to 1.7 A) is drawn from the power supply, creating a sudden voltage drop through the battery's equivalent series resistance (ESR). reaching up to 500 mV (see Fig. 1).

For a system-on-chip (SoC) design that embeds high-resolution audio converters with audio amplifiers, or for a high-sensitivity MEMS, such an amplitude jeopardizes the overall performance of the SoC(s). Specifically, the audio quality may be significantly altered by an audible buzzing noise.

Such a noise is particularly audible because it is not random. Indeed, noises with amplitudes as low as 10 μV can be heard if they occur at a fixed rate. They could even be much more disturbing than a random noise of higher amplitude, which will be considered a background noise.

The best approach for preventing GSM noise from degrading audio quality is to use a linear regulator (LR) with very low dropout (LDO), as well as low output noise, to directly supply the audio amplifier from the lithium-ion battery. Such an LDO linear regulator is used as a "clean-up "or filtering module for the amplifier power supply.

The usual key criterion to select the best LR to prevent GSM noise is the capability of the regulator to reject noise from the input voltage, expressed as power supply rejection ratio (PSRR). But PSRR figures should also be considered along with the LR transient responses and dropout characteristics.

Power-supply rejection ratio

PSRR is the ability of the regulator to maintain its output voltage as its input voltage varies. PSRR must be specified over some frequency range, certainly including the critical 217-Hz value, and for the maximum output current for which the regulator is designed. Indeed, the capacity of rejection must be ensured even when the regulator is meeting maximum load demand (dropout is maximal). Usually, PSRR performance is specified at 10 kHz, which may not be appropriate to reflect the expected rejection of noise at 217 Hz.

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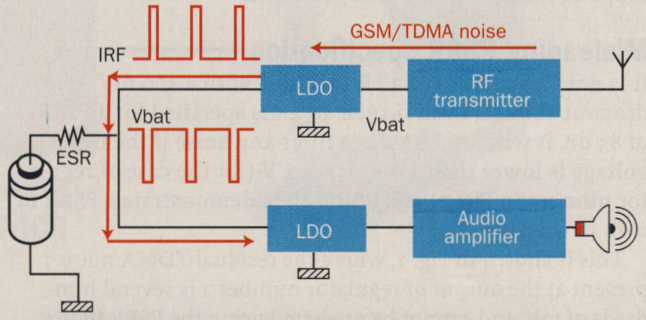

Fig. 1: TDMA noise propagation in a typical Li-ion battery-powered device

Conclusion #1: The PSRR specification must be analyzed over a complete frequency range to compute the sensitivity of the regulator to any possible noise source, including 217 Hz.

Transient response and dropout

PSRR is not the only specification ensuring that no noise will be heard on the audio output. The transient response characteristic of the LR, and thus the capacity of the voltage regulator to maintain the output voltage at the desired regulated value, under sudden supply or load change, also is critical.

Assuming Vin is the input voltage, Vout is the output voltage and Voutreg is the regulated output voltage, the following are important points to consider:

Let Vdrop = minimum dropout of the regulator (minimum difference between Vin and Vout)

- The LR is designed to maintain a fixed output voltage, with a high PSRR, for a varying input voltage
- When Vin > Voutreg + Vdrop, the LR performs normally and regulates the output voltage with a 70-dB PSRR, for example
- When Vin < Voutreg + Vdrop, the LR does not regulate the output any more and Vout = Vin - Vdrop, the PSRR is 0 dB, as the output voltage follows the input voltage

Therefore, a LR exhibits a high PSSR only when the condition Vin > Voutreg + Vdrop is satisfied.

Consider the case shown in Fig. 2, in which the LR provides the interface between a lithium-ion battery delivering 3.6 V and an analog block requiring a regulated 2.8-V supply.

The figure shows how a 500-mV transient on the battery voltage is transferred to the LDO output depending on the effective dropout of the linear regulator. The LR of line 1 (plain blue line) has a dropout of less than 100 mV, and therefore keeps on regulating. In contrast, the LR of line 2 (red dotted line) cannot stand such a voltage drop, as it requires a minimum of 400 mV of difference (dropout) between the input and the output voltages.

Conclusion #2: The demand on a linear regulator with very low dropout is even more critical as the battery voltage decreases over time, for instance, down to 2.9 V. It is important to maintain regulation over the full range of the battery voltage, which leads to the conclusion that the better the dropout, the better the battery runtime.

Misleading PSRR specification

It is not unusual to see a LR specified with a 400-mV dropout voltage. Even if such an LR is specified for a PSRR of 85 dB, it will not be able to filter any noise if the input voltage is lower than 3.0 + 0.4 = 3.4 V (for the case of regulator number in Fig. 2) and it will then demonstrate a PSRR of 0 dB in this case!

This is shown in Fig. 2, where the residual TDMA noise present at the output of regulator number 2 is several hundreds of mV, and cannot be predicted using the PSRR figure.

Conclusion #3: The effective dropout must be considered

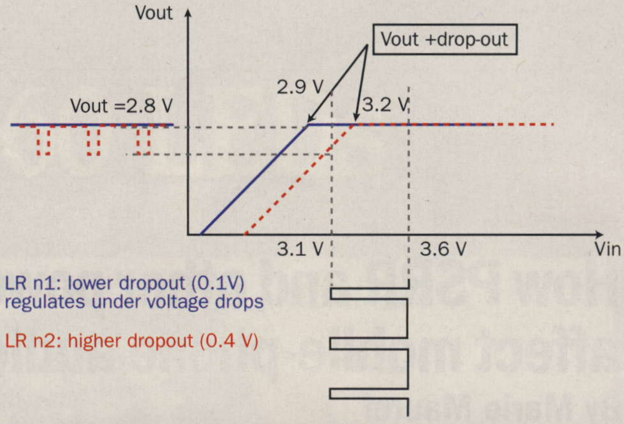

Fig. 2: Relationship between dropout and effective noise rejection of a linear regulator

as well, to evaluate the residual noise at the linear regulator output.

To be useful for a SoC integrator willing to compare two linear regulators, the dropout must be given at the maximum current. This ensures that the LR is properly calibrated to drive the given load, and to properly reject the noise from the input voltage under all operating conditions. ■