Power Management Solutions for Different Circuitry Blocks

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Portable and battery-powered applications are continually driven to increase battery life and reduce size. Analog circuitry and ultra-low-power microcontrollers (MCU) often reside on the same circuit board, each having their own particular power requirements. This article explores available options and design trade-offs when selecting a power management solution for microprocessors or data acquisition circuitry in low-power applications. Power supply design issues such as noise, efficiency, transients, and regulation accuracy are addressed to help the designer choose the best solution for powering each block of circuitry.

Low drop-out regulators versus switching regulators for low-power applications

The first type of power management device that comes to mind for low-power applications is the linear regulator, which are most useful for applications where there is a low input to output voltage difference. Linear regulators with a very low difference are called low drop-out regulators (LDOs). LDOs are known for their fast transient response time, tight regulation accuracy, and extremely low-noise performance. Some LDOs have better performance in certain categories than others based on the type of pass element employed. However, the ease of design, low external component count, and the cost per watt often make the LDO the designer’s first choice when designing for low-power applications.

Alternatively, a switching regulator offers improvements in efficiency and power density when the input-to-output voltage difference is wide. For applications that experience higher ambient temperature or a high-input voltage with space constraints, a switching regulator, which requires an inductor to store energy, is the better choice. However, the switching regulator design is more difficult and the inherent output ripple and noise are problematic to certain applications.

Analog and digital circuits have different power requirements. To achieve the best performance possible, look at the key specifications advertised for the linear regulator or switching converter under consideration to help choose the most appropriate power solution.

Low-power digital microcontrollers
MCUs continue to consume less current, increase functionality, and reduce board space requirements. When designing for low-power applications, be careful not to choose a power circuit that consumes much more current than the MCU itself, thereby defeating the purpose. State-of-the-art low-power linear regulators under 150mA typically have 4 uA or less operating quiescent current at their rated load. Higher current LDOs have a higher quiescent current, so proper sizing is important. Noise is not a critical design consideration when powering digital processors, so switching regulators are a valid option when the power dissipation of a linear regulator is undesirable due to higher available input voltage. A step-down switching regulator rated at 300mA, such as the TPS62240, has a typical operating quiescent current of 15uA, but the efficiency is much higher at full-load and light-loads, which comes at the expense of an inductor to store energy as the integrated power MOSFETs switch.

Linear regulators and switching converters designed to power MCUs usually have a tight reference voltage accuracy, which is driven by process geometry advancements. A reference voltage tolerance of one-to-two percent meets most requirements for a three percent total output voltage accuracy. Older DC/DC converters may not be able to achieve the voltage tolerance required, so it is wise to check specification tables of the DC/DC converter. Some processors require a voltage tolerance over AC transient conditions. LDOs and switching regulators designed to power processors have a fast transient response with a small voltage over and undershoot, while maintaining the accurate output voltage. Look for transient response performance and output voltage accuracy to be highlighted on the front page and in the application section of the datasheet. Figure 1 shows the output voltage accuracy versus output current for the TPS62240, especially as the device changes from pulse width modulation (PWM) to pulse frequency modulation (PFM).

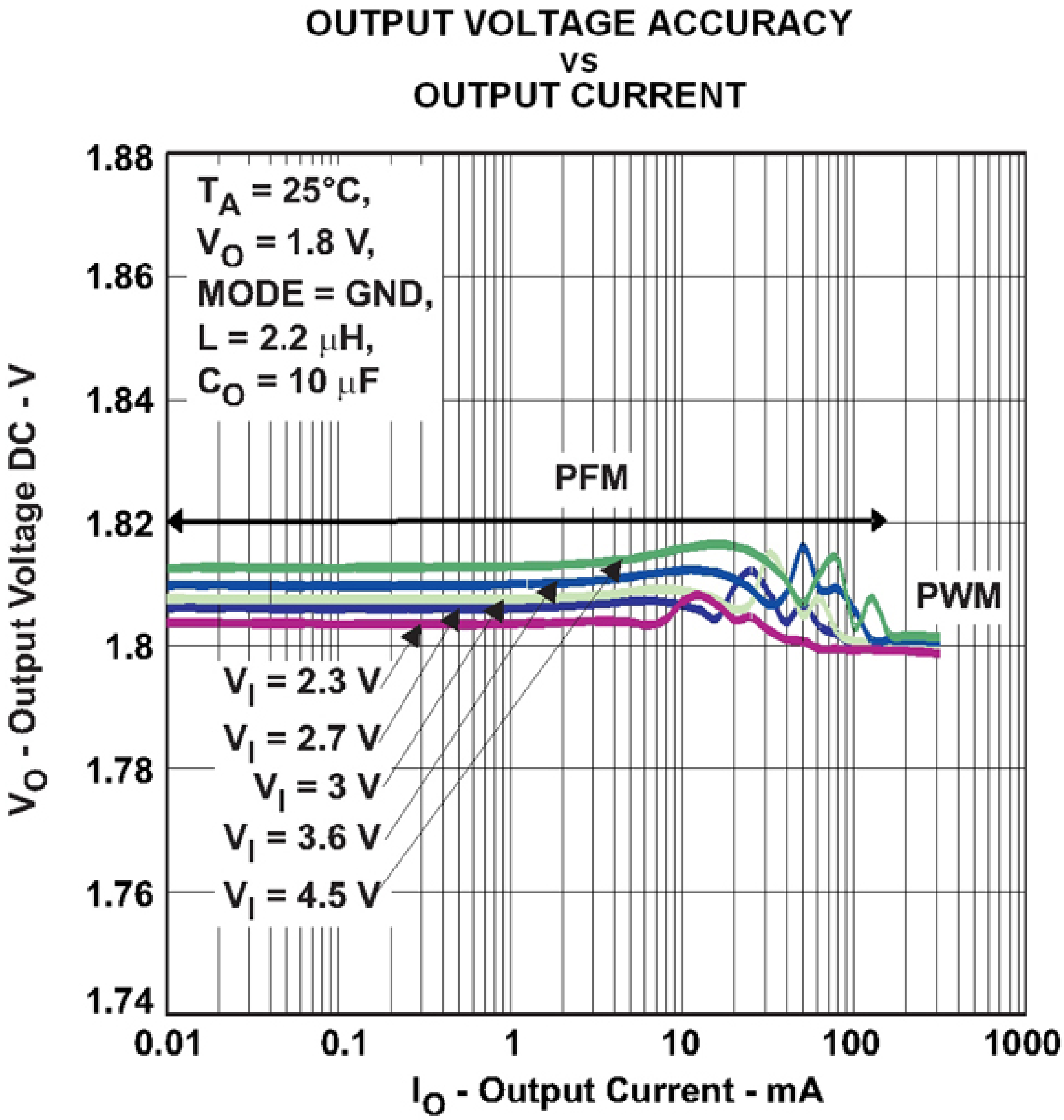

Figure 1: TPS62240 output voltage accuracy versus output current.

Processors manufactured in the latest deep submicron process geometries suffer from excess standby leakage power1. Technologies such as dynamic voltage scaling2 or SmartReflexTM allow a MCU to operate at a lower voltage and frequency to reduce its power consumption when higher processing speed is not needed. Simple communication between the power management device and the MCU facilitates the dynamic adjustment of the MCU’s voltage requirement to reduce its leakage power. Several power devices support SmartReflex and dynamic voltage scaling such as the TPS65950, a highly integrated power management unit, and the TPS780 family of linear regulators, respectively.

Power for analog circuitry

Analog circuits such as digital-to-analog converters (DACs), analog-to-digital converters (ADCs), and operational amplifiers (op amps) in high-precision instrumentation applications are very sensitive to noise and ripple. Noise is characterized by spectral noise density (nV/?Hz) and output noise voltage (uVrms). Power supply ripple rejection (PSRR) refers to the amount of ripple on the output coming from ripple on the input3. Most designers choose a linear regulator to provide a clean voltage rail to maximize system performance. Linear regulators that advertise the power supply rejection ratio (PSRR) and noise performance specifications on the front page of the datasheet are optimized to power noise-sensitive analog integrated circuits. Note that the main source of noise in a linear regulator is usually the bandgap. Linear regulators with a noise reduction pin allow a small external capacitor to facilitate a low-pass filter at the output of the bandgap, which blocks noise to the gain stage.

Finding the ripple source can be time-consuming, but usually comes from the 50/60Hz power supply, a shared power supply from other circuit blocks or a nearby switching regulator4. Linear regulators with high PSRR help alleviate voltage ripple issues. Older linear regulators are known to have poor high-frequency PSRR performance. Fortunately, newer linear regulators are on the market with PSRR greater than 40dB at 5MHz.

When the input voltage is much higher than the output voltage, selecting a linear regulator is not always the better option for powering analog circuitry, even in low-power applications. For example, when the input voltage is 24V and a clean 5V rail is needed to provide 100mA, a switching regulator can step the voltage down from 24V to 5.5V, and a LDO regulator with high PSRR, low noise, and a low drop-out voltage can accept the 5.5V input and provide 5V, with only 50mW of power dissipation. Choosing a LDO with an even lower drop-out voltage specification can further reduce power dissipation and increase efficiency. To provide a low-noise negative rail, a switching regulator (such as the TPS54060) can be configured in an inverting buck/boost topology to provide a negative output voltage5. The ripple voltage inherent to the switching regulator is filtered by the TPS7A3001 negative voltage linear regulator and its bipolar pass element.

Conclusion

Low-power analog and digital integrated circuits pose different power management design challenges. Processor advancements require a more stringent power management solution. A good rule of thumb is to choose a power management device that is released to market about the same time that the processor is released, rather than reuse an older power solution from a previous generation. Analog circuits are being pushed to higher speeds, and selecting a power management device to reduce or eliminate the affects of noise and ripple can save valuable design time.

References

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