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DACx3401 Delivers Holistic Solution for Power-supply Margining and AVS

TEXAS INSTRUMENTS

Power-supply margining and control and AVS circuits require good accuracy, smooth step-response, design simplicity, high-density, standard interfaces, and robustness. The DACx3401 family of devices provide a competitive feature set specific to this application while keeping the total cost of the design very low.

Introduction

A power-supply margining or control circuit is used for testing the accuracy of a system at the boundary conditions of the power supply, adjusting the offset and drift of the power-supply output, or programing the power-supply output to different values, depending on the system requirement. High-end processors and computing systems often need to dynamically scale the voltages for power management. This is referred to as adaptive voltage scaling (AVS). Typical applications of power-supply control and AVS include test and measurement, communications equipment, enterprise systems, and general-purpose power-supply modules.

Power supplies, such as low-dropout regulators (LDO) and DC-DC switch-mode power supplies (SMPS) provide a feedback or sense input that is used to set the desired output. This pin is typically used to sense the output voltage using a resistive divider. This feedback network can be made programmable using either a voltage-output digital-to-analog converter (DAC), a current-output DAC (IDAC), a digital potentiometer (DPOT), or a pulse-width modulation (PWM). The DACx3401 family of DACs provide a rich feature set to address key requirements of power-supply control circuits.

Key Requirements of Power-supply Control

Table 1 lists the key requirements of power-supply control.

Table 1. Key Requirements

PARAMETER	VALUE
Accuracy	±1% to ±5%
Start-up mode for control device	Hi-Z
Step response	Slew-rate control
Interfaces	I2C, PMBus™
Others	Small-size, robustness, low-cost

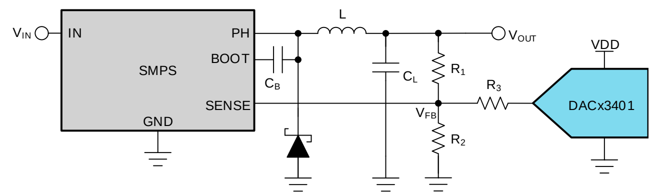

Figure 1. Power-supply Control Using the DACx3401

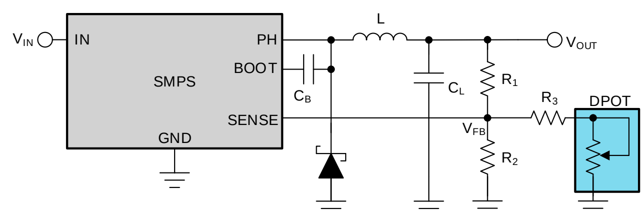

Figure 2. Power-supply Control Using DPOT

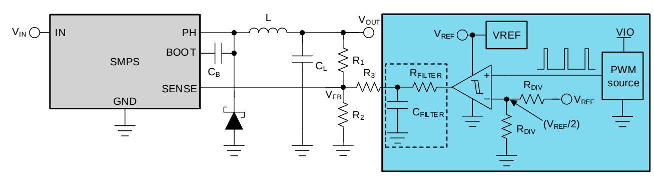

Figure 3. Power-supply Control Using PWM

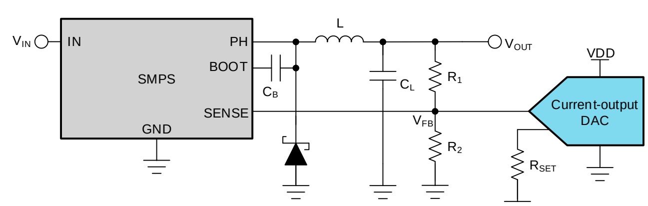

Figure 4. Power-supply Control Using IDAC

Using a DPOT

A simple circuit for power-supply control can be achieved using a DPOT in the feedback path of the power supply as shown in Figure 2. The series resistor, R_3, protects the power-supply from going in to saturation when the DPOT goes to 0 Ω in a failure condition. DPOTs have an initial accuracy of around ±20% and code-to-code glitch much higher than that of a DAC. Because of this, a DPOT-based design suffers both the control accuracy and the step-response. Also, DPOTs do not have a Hi-Z output mode. These drawbacks limit the use of DPOTs in these applications.

Using PWM

Although PWMs are easier to implement in software, substantial analog signal conditioning is required in order to meet these application requirements. PWMs get generated in the digital domain and the high and low levels are defined by the IO voltage of the processor. These IO supplies typically have an accuracy of around ±10% excluding the noise and ripple from the power supply. In order to meet the accuracy and filter the noise and ripple, you need a comparator circuit driven by a precision reference as shown in Figure 3. In addition, the PWM switching frequency must be filtered before feeding it to the power-supply. A complete removal of the switching noise needs a high-order active filter. Figure 5 shows a response with an RC filter. Note that the filtered PWM output does not completely follow the commanded pattern. Finally, the op amp must have a shutdown pin to power up to Hi-Z. Thus, a PWM approach, even though it is simpler in software, requires significant signal conditioning.

Using an IDAC

Another way of controlling the power supply is by sourcing or sinking current into the feedback pin using a current-output DAC (IDAC). Figure 4 shows a power-supply control circuit using an IDAC. Most IDAC implementations do not provide any protection against a failure mode when the DAC pulls the feedback node down either due to a design bug or due to a system failure. Pulling the V_{FB} node down pushes the power supply output to saturation, thereby damaging the load circuits. Some IDACs provide programmable clamping of the current output, but they do not take care of all failure conditions. For example, when an IDAC has a current output range of ±50 µA and the application requirement is ±10 µA, the only way to protect the circuit is by changing the resistors in the feedback network. Assuming a ±10% margining design, the current through the feedback resistors now needs to be 500 µA, which otherwise would have been only 100 µA. With this approach, additional current is consumed in the system, increasing the power budget.

Power-supply Control Using the DACx3401

The DACx3401 family of voltage-output DACs are equipped to address all the requirements of power-supply control. Figure 1 shows a power-supply control circuit using the DACx3401. The DACx3401 has a Hi-Z power-down mode that is selected by default. It has programmable slew-rate control that varies from a few microseconds to a couple of milliseconds. The programmable slew-rate helps achieve a desired step-response in the design. The DACx3401 has an internal reference with ±1% initial accuracy and the DAC has a total unadjusted error (TUE) of ±0.7%. It can work with both I2C and PMBus, enabling seamless integration with existing power-management software. Due to the Hi-Z power-down mode, the DACx3401 can be powered down whenever it is not in use, without impacting the nominal functionality of the power supply. When the DAC is powered up with the output voltage equal to V_{FB}, the nominal condition remains undisturbed. The DAC can then be programmed for margin-high or margin-low using specific commands either through I2C or PMBus. As the current from the DAC is defined by both the DAC voltage and the value of the resistor R_3, the safe current range and accuracy can be easily selected.

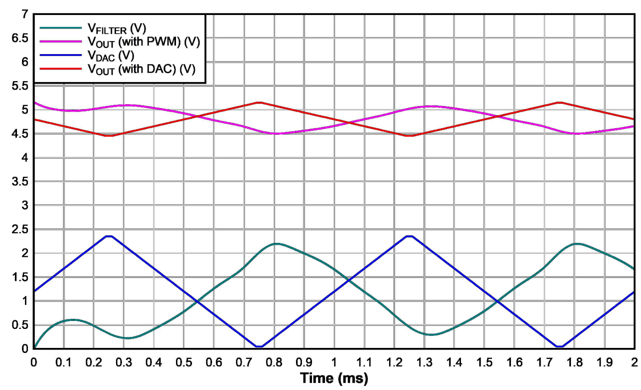

Figure 5. Responses with PWM-based and DACx3401-based Margining

The DACx3401 Family of DACs

The 10-bit DAC53401 and 8-bit DAC43401 (DACx3401) are pin-compatible families of buffered voltage-output DACs. These devices have NVM, internal reference, and PMBus-compatible I2C interface. The DACx3401 operates with either an internal reference or the power supply as a reference, and provides full-scale output of 1.8 V to 5.5 V. These devices communicate through the I2C interface. These devices support I2C standard mode (100 kbps), fast mode (400 kbps), and fast mode plus (1 Mbps). The DACx3401 is available in a tiny 2x2 package.

Conclusion

The DACx3401 is a family of DACs that have been designed with a feature set specifically targeted for power-supply margining and control, and AVS. It delivers highly differentiating performance as compared to the alternative technologies and competitive voltage-output DACs. With the tiny package and ultra-low price point, this DAC is the best choice for precision, high-density, and cost-sensitive applications.

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