Achieving Better than 1% Output Voltage Accuracy with TPS546D24A

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ABSTRACT

It is increasingly difficult for DC/DC converters to achieve tight output voltage tolerances driven by smaller process geometries for new FPGAs, DSPs, and ASIC. As process technology advances, the performance processors require tighter voltage accuracy and lower core voltages. Multiple factors need to be taken into consideration when determining the output accuracy of a DC/DC converter. Most engineers stop at the initial accuracy on the front page of the data sheet of the DC/DC converter. However, designers must consider the tolerance of the voltage feedback resistors used by the following:

- DC/DC converter
- The ratio of the resistor divider
- Routing distance and trace losses of the circuit board
- Input voltage variations
- Voltage ripple
- Temperature swings
- Load transients

Additionally, many designers will want head-room or margin to make sure the solution is always within the tolerance expectation of the processor. The TPS546D24A was developed to help designers achieve higher output voltage accuracy by actually specifying the output voltage accuracy, rather than the initial, reference, or V_{FB} accuracy.

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Trademarks

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1 Processor Voltage Requirements

Table 1 shows an example from a data sheet of a processor stating the recommended operating conditions for the V_{CCINT} supply. The typical voltages required for V_{CCINT} can be 0.9 V, 0.85 V, or 0.72 V. The minimum and maximum variation is within ±3%. It is recommended to provide as well-regulated voltage to V_{CCINT} within ±3% under all conditions, including transient and temperature.

The TPS546D24A is a 16 V input, 40-A stackable DC/DC converter with PMBus™ and is specifically designed to power advanced high-current, low-voltage processors. The device can be operated in a stackable configuration, with up to four devices, to provide 160-A. Since the feedback divider is integrated into the IC, using both the selectable feedback divider and precision adjustable reference to attain output voltages from 0.25 V to 5.5 V. According to Table 1, the TPS546D24A can achieve output voltage accuracy well within 0.1% from a 12 V or 5 V input.

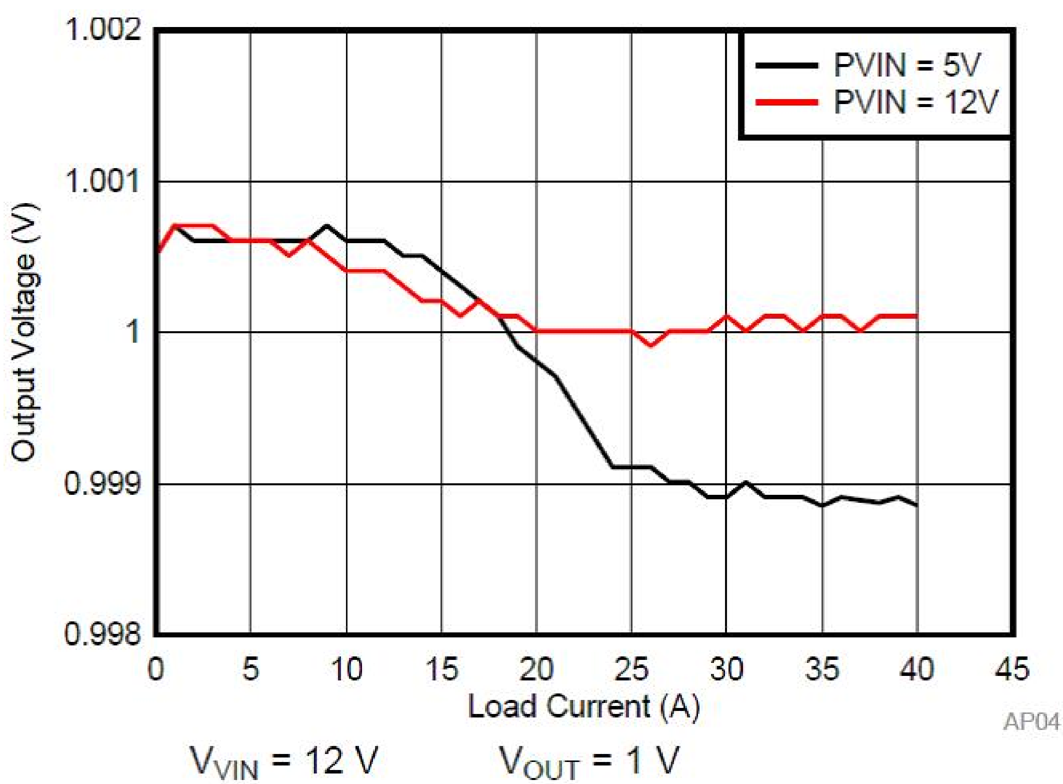

Figure 1. TPS546D24A Load Regulation

Table 1. Recommended Processor Operating Conditions

SYMBOL	DESCRIPTION	MINIMUM	TYPICAL	MAXIMUM	UNITS
V_{CCINT}	Internal supply voltage	0.825	0.85	0.876	V
	For -2LE (V_{CCINT} = 0.72 V) devices: internal supply voltage	0.698	0.72	0.927	V
	For -3E devices: Internal supply voltage	0.873	0.9	0.927	V

2 Selectable Feedback Divider

The TPS546D24A includes an integrated precision feedback divider. The VOUT_SCALE_LOOP command of the TPS546D24A programs the divider, so no external resistors are needed. It can be programmed to ratios of 1:1, 1:2, 1:4, or 1:8, allowing PMBus to map between the commanded voltage and the voltage at the control circuit input. The accuracy is a strong function of the ratio of the output voltage to the reference voltage according to Equation 1. Since the resistor divider is integrated into the TPS546D24A, it makes sense to provide the means to adjust the voltage divider ratios shown in Table 2, and allow high accuracy at both lower and higher output voltages. To summarize, providing good accuracy on low-voltage outputs is not difficult with the TPS546D24A, as low divider ratios are inherently accurate. [(1)].

Table 2. VOUT_SCALE_LOOP and Respective V_{out} Range

VOUT_SCALE_LOOP	V_{out} RANGE (V)
1.0	0.25 to 0.75
0.5	0.5 to 1.5
0.25	1 to 3
0.125	2 to 5.5

$$divider\ accuracy = (1 - Vref / Vout) \times 2 \times resistor\ tolerance \quad (1)$$

3 Precision Adjustable Reference

The default reference voltage of the TPS546D24A is 0.4 V. Note that the reference voltage is adjustable from 0.25 V to 0.75 V with a resolution of 2^{-12} V, but it is not tested in production since there is no test pin available providing access to the reference voltage. However, the actual output voltage is tested in production, and includes the voltage divider and reference voltage inaccuracies. At 1 V output, the minimum voltage is 0.995 V and the maximum is 1.005 V from -40°C to +150°C junction temperature and with VOUT_SCALE_LOOP = 0.5, representing a 1:2 divider ratio. Figure 2 shows the output voltage deviation over the entire operating junction temperature range when the output voltage is set to 1 V and is measured at the input of the remote sense amplifier.

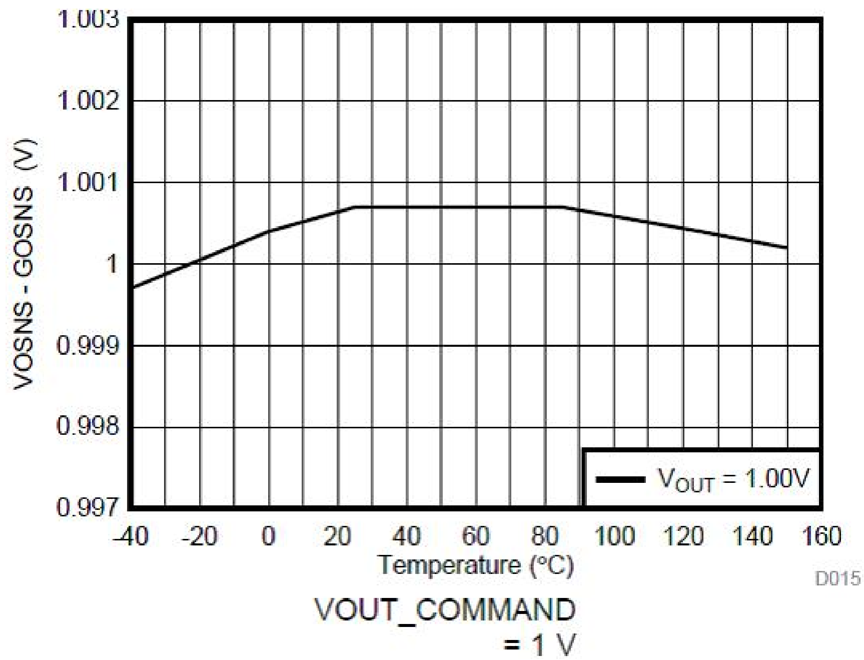

Figure 2. Output Voltage Versus Junction Temperature

(1) Kollman, Robert. “Power Tip #18: Your regulator’s output-voltage accuracy may not be as bad as you think,” EETimes, August 4, 2010

4 Remote Sense Amplifier

The output voltage of the TPS546D24A is sensed through a true differential remote sense amplifier with unity gain and an internal resistor divider, and then compared to an internal voltage reference by an error amplifier. The remote sense amplifier allows the TPS546D24A to account for additional output voltage inaccuracies of the circuit board environment. As a result, the output voltage error of less than 1% over –40°C to +150°C T_J can be achieved.

5 Transient Performance

The TPS546D24A is compared to another DC/DC solution without the integrated voltage divider. Figure 3 and Figure 4 show the transient response graphs for a 12 V input to 1 V output, a 550 kHz operating frequency each in a 2-phase configuration, and a load step from 3 A to 35 A with a time frame of 200 µsec/div. Figure 4 shows the response of the TPS546D24A, which integrates the voltage divider. Note the output voltage returns very close to the respective set-point after the load transient occurs, demonstrating high output accuracy over transient load conditions. The transient response waveform in Figure 3 without an internal voltage divider shows a voltage drop after the load transient, which has a lower total voltage accuracy.

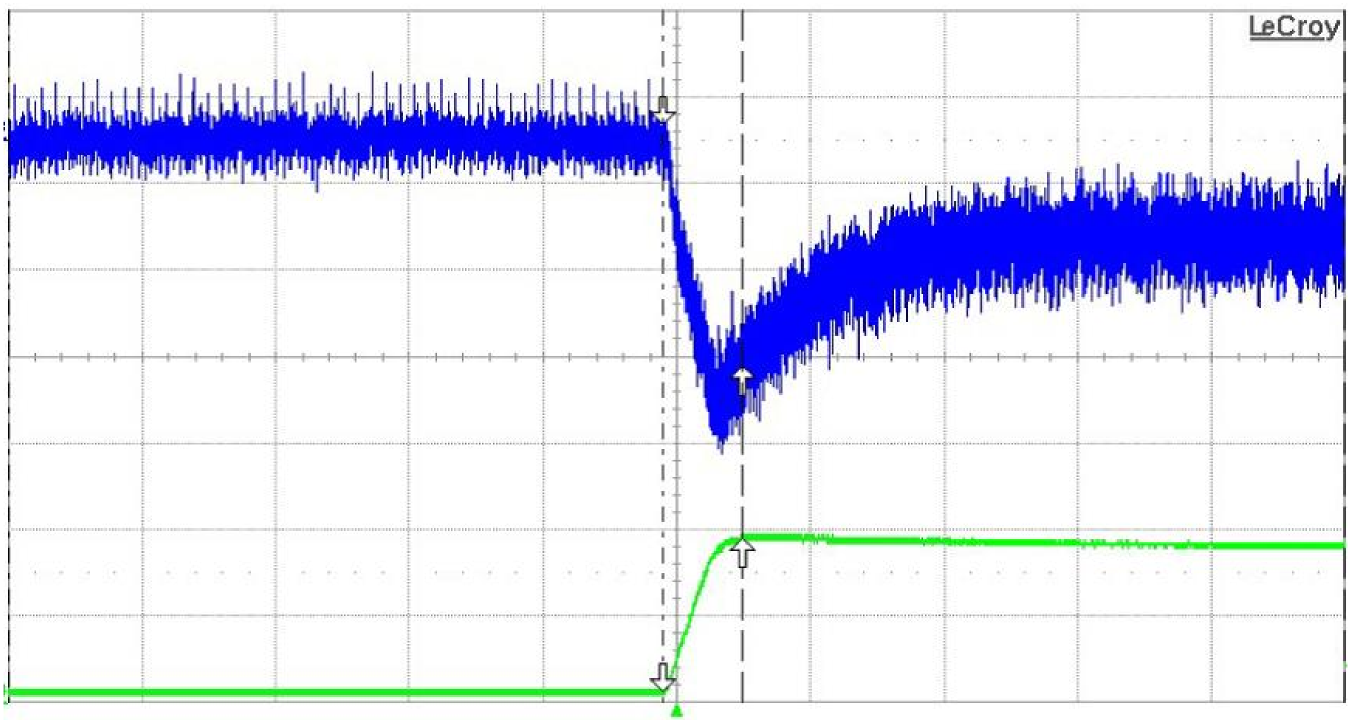

Figure 3. Load Transient for Typical Converter without Internal Voltage Divider

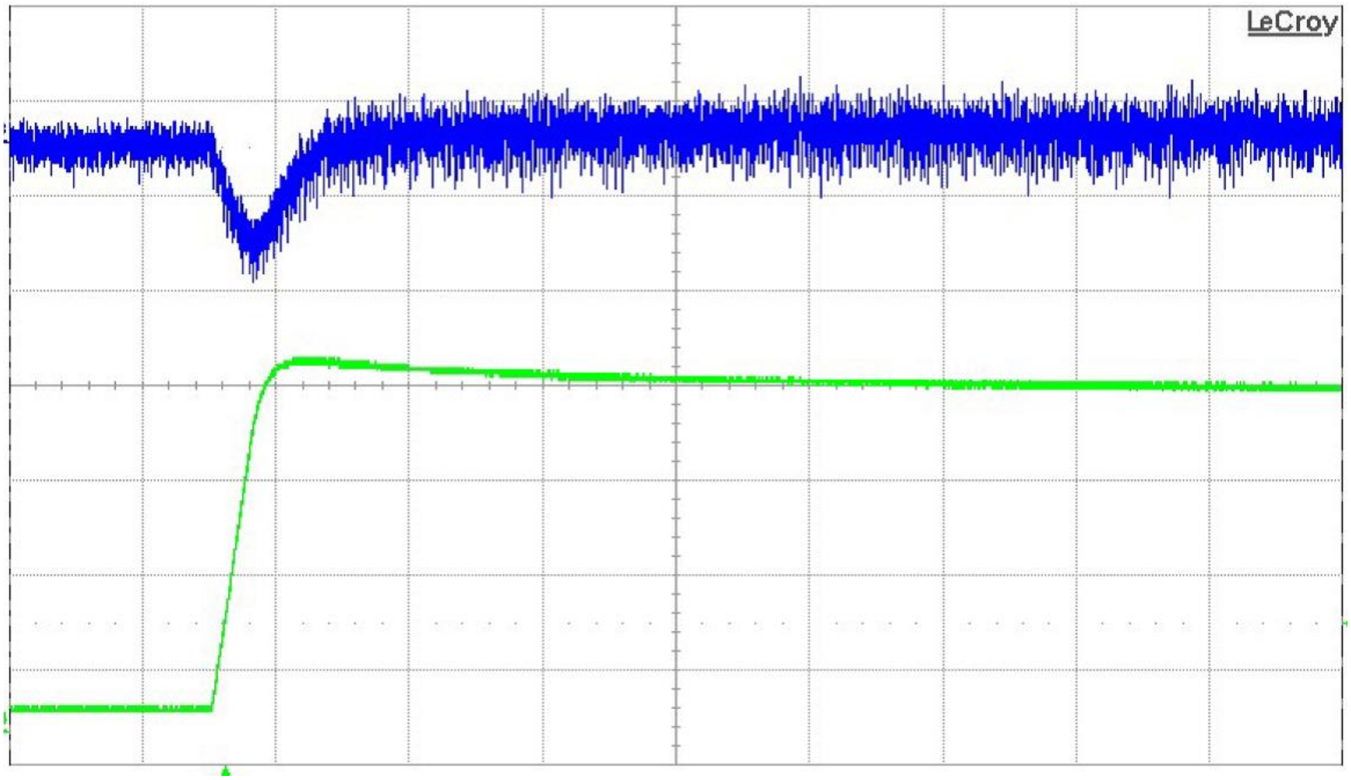

Figure 4. Load Transient with TPS546D24A and Internal Voltage Divider

6 Summary

The TPS546D24A provides high accurate output voltage due to the internal reference, internal voltage divider, and remote sense amplifier. It is ideal for powering performance ASICs, FPGAs, and DSPs requiring low voltage below 1 V and high output currents from 20 A to 160 A. When designing the point-of-load power solution for performance processors, engineers must consider the tolerance of the following:

- DC/DC converter
- The ratio of the resistor divider
- Routing distance and trace losses of the circuit board
- Input voltage variations
- Voltage ripple
- Temperature swings
- Load transients