Application Report
SLVA861 – December 2016

How to Dynamically Adjust Power Module Output Voltage

ABSTRACT

This application note outlines how to dynamically adjust a dc-dc converter output voltage. Changing voltage regulator output on the fly can be useful for supply voltage margining, output tracking, optimizing load power consumption, adaptive voltage scaling (AVS), and supporting different system operating modes. Digital voltage programming techniques discussed utilize a current DAC (digital-to-analog converter) or a voltage DAC. The TPSM84A21 power module is used to demonstrate the concepts. This fully integrated voltage regulator combines a dc-dc converter with shielded inductors, input and output capacitors, and other passive components into a low profile package.

1 General Concept

To dynamically adjust output voltage, a small amount of current is injected in the voltage regulator feedback network as shown in Figure 1. This changes the effective gain (V_{FB}/V_{OUT}) of the feedback network. A similar result would be observed if a resistor was connected in parallel with either the top or bottom feedback resistor. In some systems, resistors are switched in and out for output margining. Hence, another way of thinking of the current injected to the feedback node is to view it as adapting a virtual resistance. If positive current is injected at the feedback node (V_{FB}), it appears that the resistance of the top resistor (R_{TOP}) has decreased, and the output voltage decreases as a result. When current is pulled out (negative current), the output voltage increases because the bottom resistor (R_{BOT}) appears to have lower resistance. The following methods based on this concept allow for more control, flexibility, and precision than typical resistor based techniques.

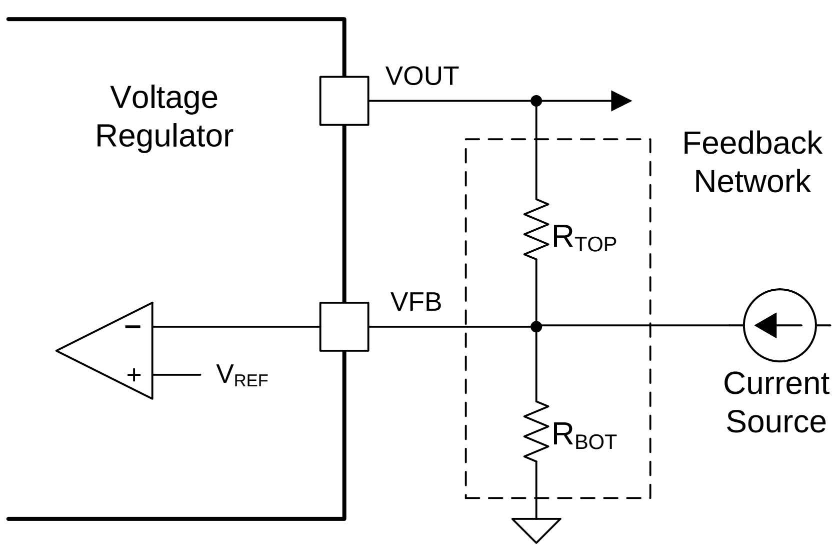

Figure 1. A Current is Injected at the Feedback Pin to Adjust the Output Voltage

2 Current DAC

A current DAC can be used to implement the current source that dynamically adjusts the output voltage. The current DAC output is digitally programmed to source current into the feedback node. An example current DAC is the LM10011. An application note describing several configurations using that current DAC is (SNVA709).

There are two details to consider when using a current DAC with the TPSM84A21. First, there is a 1-kΩ resistor connected internally between the remote sense pin (VS+) and the feedback pin (VADJ) as shown in Figure 2. With the top feedback resistor being a fixed 1-kΩ resistor, the current in the resistor divider can be up to 700 µA with a 1.2-V output. This limits the range that the LM10011 current DAC is able to adjust the output voltage since the current DAC can provide up to 59 µA.

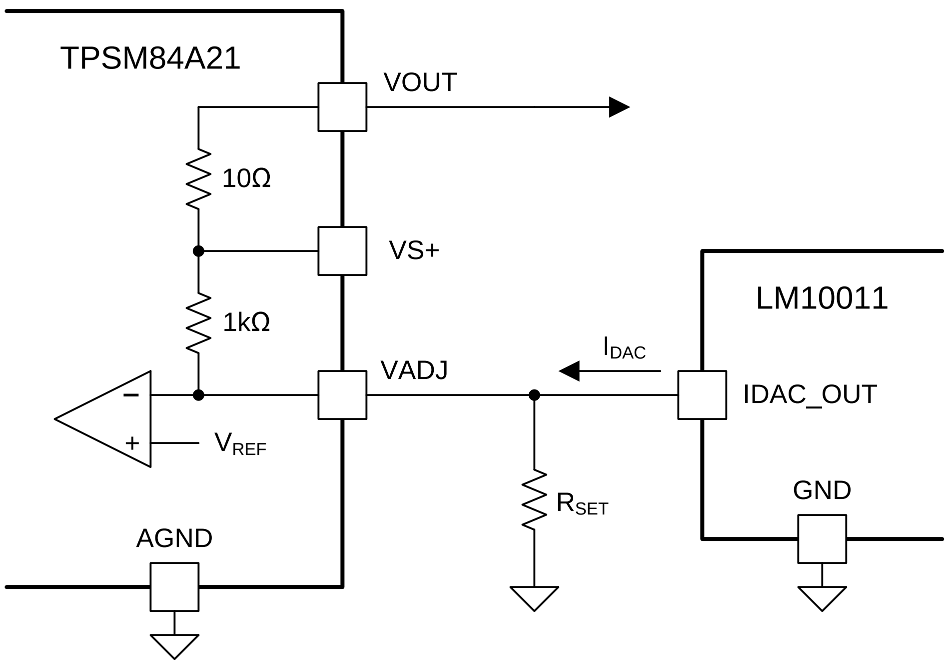

Figure 2. Using the LM10011 Current DAC to Adjust the output Voltage of the TPSM84A21

Second, there is an internal 10-Ω resistor connecting the remote voltage sense pin (VS+) to the output voltage pin (VOUT). This resistor is included to bring the converter output up to the desired voltage even if the remote sense pin is not connected to the output voltage node at the load. The internal resistor between the VS+ and VOUT pins prevents some of the configurations proposed in the SNVA709. The combined result is that the range of output voltage adjustment with the LM10011 is limited to about 60 mV. An equation to estimate the output voltage based on the configuration shown in Equation 1.

$$V_{OUT} = V_{REF} \times \left(1 + \frac{R_{TOP}}{R_{SET}}\right) - I_{DAC} \times R_{TOP} \tag{1}$$

For the TPSM84A21, V_{REF} = 0.508 V and R_{TOP} = 1 kΩ if the remote sense pin is connected to the output voltage regulation point using a trace on the board. If left unconnected, R_{TOP} = 1.01 kΩ. R_{SET} is selected based on the desired output voltage. If the current DAC can only source current, R_{SET} is chosen to set the maximum output voltage; the current DAC will margin the output voltage down.

3 Voltage DAC

A voltage source is an effective option for dynamically adjusting the output voltage of the TPSM84A21. The diagram in Figure 3 shows how a voltage DAC can be connected to the feedback network through a resistor labeled R_{DAC}. When implementing this approach, it is best to place resistors R_{SET} and R_{DAC} as close to the converter VADJ pin as possible for noise immunity. The VADJ pin is a sensitive feedback control pin.

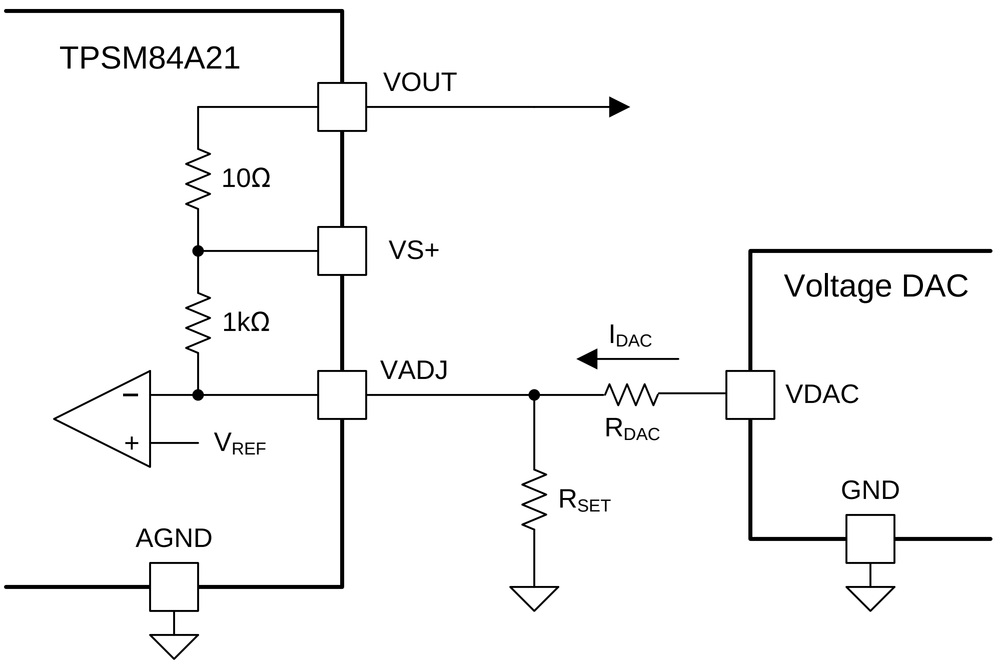

Figure 3. Using a Voltage DAC to Adjust the Output Voltage of the TPSM84A21

The current flowing in to the feedback pin (VADJ) from the voltage DAC is:

$$I_{DAC} = \frac{V_{DAC} - V_{REF}}{R_{DAC}} \tag{2}$$

If V_{DAC} is greater than V_{REF}, the current flowing in to the feedback pin is positive and the output voltage of the converter will decrease. If V_{DAC} is less than V_{REF} and the voltage DAC is capable of sinking current, the output voltage will increase. The output voltage can be estimated using Equation 3.

$$V_{OUT} = V_{REF} \times \left(1 + \frac{R_{TOP}}{R_{SET}}\right) - \left(\frac{V_{DAC} - V_{REF}}{R_{DAC}}\right) \times R_{TOP} \tag{3}$$

Figure 4 shows measured results from an experimental test implementing the Figure 3 setup. The value of R_{DAC} is 10 kΩ, the converter input voltage is 12 V, and the output current is 5 A. The results in Figure 4 also apply to the operating conditions of 8-V to 14-V input, 0-A to 10-A load. The three curves in Figure 3 show the output voltage versus DAC voltage for three different R_{SET} values. As can be seen from the curves, the output voltage adjustment range is a little over 200 mV in each case.

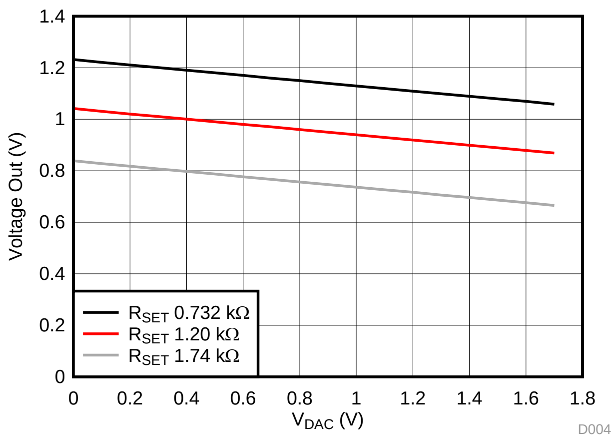

Figure 4. Measured Output Voltage Adjustment with Variation in the DAC Voltage

4 Conclusion

Dynamic output voltage adjustment is a useful feature for many dc-dc converters. This application note has described two methods of implementing dynamic adjustment. One technique provides a current source from a current DAC; the other technique utilizes a voltage source from a voltage DAC. It is important to consider the output voltage range when selecting a design. The slew rate of the voltage adjustment should also be considered. Large, fast changes in the output voltage command can result in the converter hitting an overcurrent limit, especially if there is a large output capacitance. It may be necessary to take a few small steps to reach the new desired output voltage level. Measured results from the TPSM84A21 are included in the note. The same techniques can be applied to other power modules like the TPSM84A22.

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