Adjusting VOUT in USB Type-C™ and wireless charging applications, part 1

For applications using USB Type-C Power Delivery (PD) and wireless charging, the output voltage (V_{OUT}) from the charger can fluctuate higher or lower than the input voltage. Four-switch buck-boost regulators are popular in these applications because adjusting their feedback signal can dynamically change the V_{OUT}.

A buck-boost regulator's output voltage can be adjusted either by varying the error amplifier's reference voltage (V_{REF}) or by varying the feedback voltage. If monolithic pulse-width modulation (PWM) four-switch buck-boost controllers such as TI's LM34936 and LM5176 do not provide the ability to access V_{REF}, however, varying the feedback voltage becomes the only way.

To help you design systems using buck-boost controllers with dynamic output voltages, in this series I will discuss a few options for using the feedback signal to adjust the output voltage. The first installment will focus on using switched resistors, while the second installment presents a different approach that requires fewer components and signal lines.

Understanding the V_{OUT} setting and feedback signal

Figure 1 shows a typical V_{OUT} setting for the controller and error amplifier. By looking up the V_{REF} for the error amplifier in the data sheet, Equation 1 calculates V_{OUT} by setting the values of R_1 and R_2:

$$V_{OUT} = \left(1 + \frac{R_2}{R_1}\right) \cdot V_{REF} \quad (1)$$

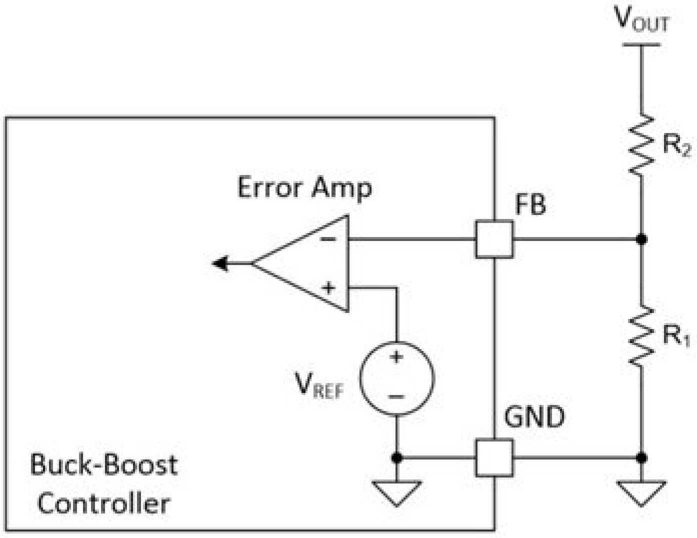

Figure 1: Feedback circuit and V_{OUT} setting

Using switched resistors to adjust V_{OUT}

Figure 2 shows a simple option to dynamically adjust V_{OUT} between two voltage levels by incorporating a switch, S_1. Assume that S_1 is an ideal switch, and that its impedance is infinity when off and 0 Ω when on. When switch S_1 is turned off, R_3 is not in the picture of the V_{OUT} setting, and is simply the same as given in Equation 1. To avoid confusion in this discussion, let's assume that the voltage is V_{OUT1}, as expressed by Equation 2:

$$V_{OUT1} = \left(1 + \frac{R_2}{R_1}\right) \cdot V_{REF} \qquad (2)$$

If S_1 is turned on, it will place R_3 in parallel with R_1. The new output voltage, V_{OUT2}, will satisfy Equation 3:

$$V_{OUT2} = \left(1 + \frac{R_2}{R_1//R_3}\right) \cdot V_{REF} \qquad (3)$$

where

$$R_1//R_3 = \frac{R_1 \cdot R_3}{R_1 + R_3}$$

This results in V_{OUT2} being greater than V_{OUT1}. By solving Equations 2 and 3, you can determine the resistor values. By toggling S_1, you can switch V_{OUT} between V_{OUT1} and V_{OUT2}.

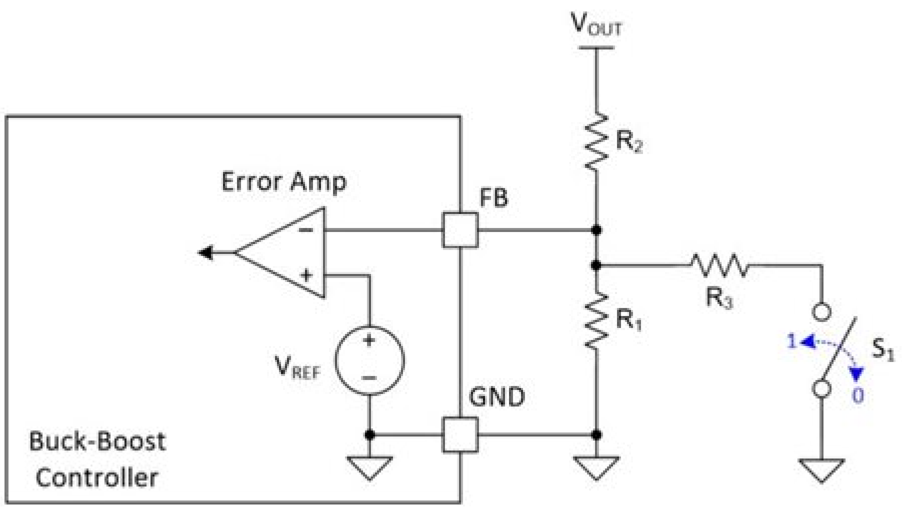

Figure 2: V_{OUT} adjustment with a switched resistor

Preventing a false OVP trigger

Some PWM controllers like the LM34936 and LM5176 have built-in output overvoltage protection (OVP), implemented by monitoring the feedback (FB) pin voltage. If the FB pin sees >10% above V_{REF}, the controller riggers OVP and stops switching until after the FB voltage falls below the hysteresis of the OVP threshold. Because of this feature, any abrupt resistor switching should be prevented, since turning off S_1 suddenly will cause the FB voltage to jump up instantaneously and create a false OVP event. The solution is to switch S_1 gradually, where R_5 and C_1 delay the on/off command of S_1 to engage or disengage R_3 gradually.

There are a couple of factors involved in selecting the resistor-capacitor (RC) delay time constant; the RC needs to match up with the loop response time, as well as the transition time between V_{OUT} levels specified by the application, in order to enable proper transition between the two voltage outputs.

Multivoltage programming

Adding switched resistor branches can program additional V_{OUT} levels. Figure 3 shows an approach employing three switched resistor branches to set the four V_{OUT} levels for USB Type-C PD applications.

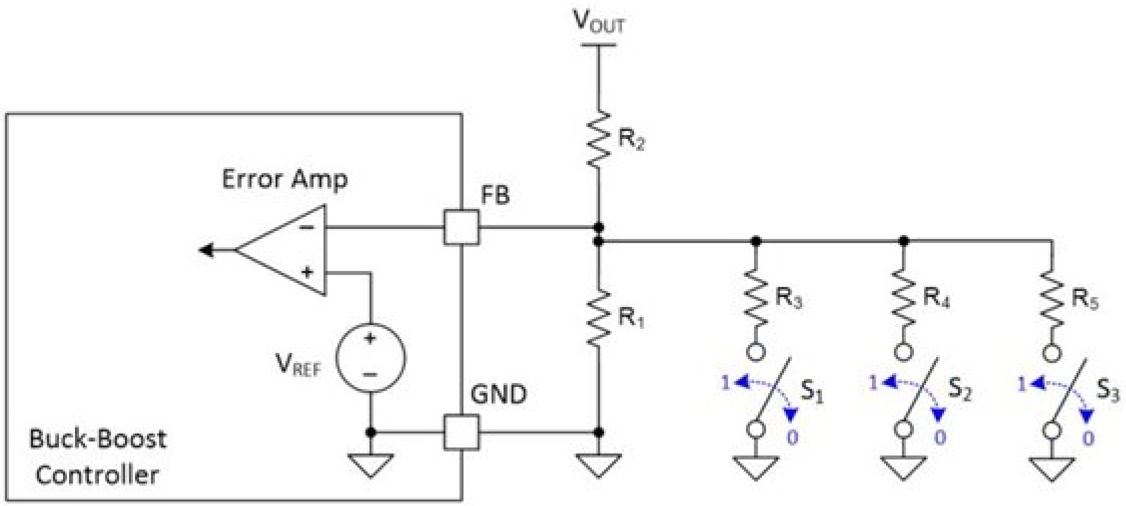

Figure 3: Three switched resistor branches for four V_{OUT} settings

Table 1 summarizes the programming schemes for the four different voltages.

S_3	S_2	S_1	V_{OUT} setting	Comment
0	0	0	$V_{OUT1} = \left(1 + \frac{R_2}{R_1}\right) \cdot V_{REF}$	For 5 V
0	0	1	$V_{OUT2} = \left(1 + \frac{R_2}{R_1//R_3}\right) \cdot V_{REF}$	For 9 V
0	1	1	$V_{OUT3} = \left(1 + \frac{R_2}{R_1//R_3//R_4}\right) \cdot V_{REF}$	For 15 V
1	1	1	$V_{OUT4} = \left(1 + \frac{R_2}{R_1//R_3//R_4//R_5}\right) \cdot V_{REF}$	For 20 V

Table 1: Programming switched resistors for USB Type-C PD

As shown in Figure 4, it is important to make sure that switching to different resistors won't trigger a false OVP event in the feedback loop. Incorporating an RC for each of the switches will help avoid an OVP event while switching to the proper voltage rail at the appropriate time.

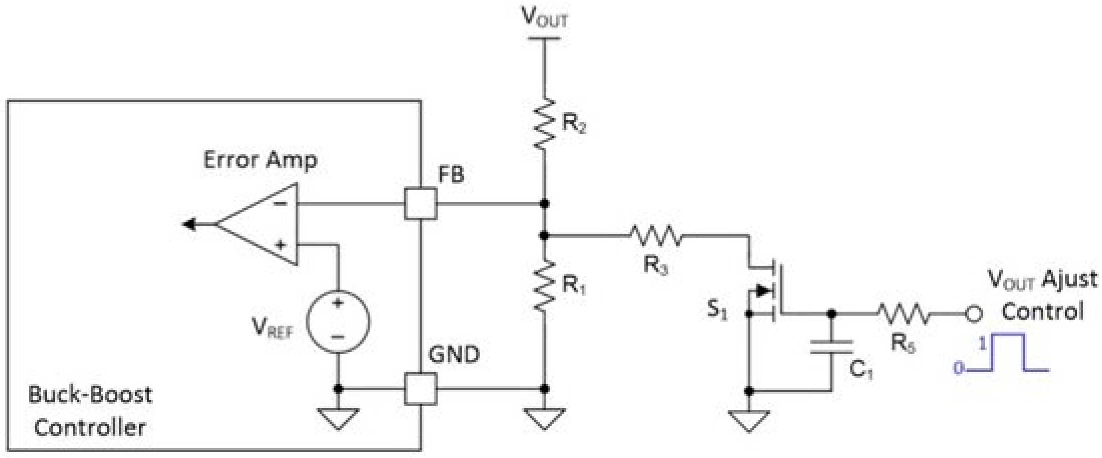

Figure 4: Gradually switching the resistor to avoid triggering an OVP event during dynamic V_{OUT} adjustment

Conclusion

By incorporating switches and resistors into the feedback loop, buck-boost converters can dynamically adjust the V_{OUT} for USD Type-C PD and wireless charging applications. This approach is straightforward, simple and easy to implement. Controlling the speed of the switches is a requirement when using four-switch buck-boost controllers.

For a different approach using fewer components and signal lines, see the second installment of this series.

Additional resources

- See TI's USB Type-C PD reference designs at www.ti.com/product/LM5175/toolssoftware
- Check out the LM34936 and LM5176 controller data sheets.