CHAPTER 8

Shunt Regulator–Based Compensators

In the previous chapters, we have studied compensators that deliver an error voltage, $V_{err}(s)$, which controls either the duty ratio D (voltage mode control) or the peak current setpoint (peak-current mode control). Popularized by Power Integrations over the past 15 years, the TOPSwitch® is a high-voltage switcher implementing the *shunt regulator*. Rather than controlling the duty ratio by changing a voltage level on a pin, the company combined the V_{cc} and the feedback pins together so that a single input could not only supply the control section but also drive the duty ratio excursion by monitoring the injected current: a three-pin integrated switcher was born. Even if the loop is controlled by a TL431 or a Zener diode, we dedicated a chapter to describe the compensator implementation given the peculiarity of the circuit. Figure 8.1 shows the representation of the shunt regulator as it can be found in a TOPSwitch device [1].

The circuit works like an active Zener diode featuring a dynamic resistor R_d of 15 Ω. When there is almost no injected current in the feedback pin (FB), the delivered duty ratio is maximum (67 percent). On the contrary, when more than 6 mA are injected, the duty ratio drops to its minimum value or 1.8 percent. Varying the injected current depending on the input/output conditions is the adopted means to adjust the duty ratio. To improve the noise immunity and also to shape the compensator response, a 7-kHz pole was included in the modulator path. We will need to account for its presence during the ac analysis. The curve depicting the modulator transfer function, D versus I_{FB}, appears in Figure 8.2.

Due to the information displayed on the curve, the small-signal gain of the whole modulator can be deduced. It is simply

$$S_{PWM} = \frac{\Delta D}{\Delta I_{FB}} = \frac{1.8-67}{6-2} \approx -16\%/\text{mA} \tag{8.1}$$

However, in the models we use, the duty ratio value is usually expressed in volts: a 1-V dc signal represents a 100 percent duty ratio. As current is primarily expressed in amperes rather than milliamperes, (8.1) needs to be reformulated to cope with our simulation models:

$$S_{PWM} = \frac{0.017-0.67}{6m-2m} = -163\ \text{V/A} \tag{8.2}$$

Expressed in decibels, this slope becomes a gain of

$$G_{PWM} = 20\log_{10}(163) \approx 44\ \text{dB} \tag{8.3}$$

This specific arrangement requires a little bit more of analysis compared to a traditional voltage-mode feedback. However, experience shows that it does not prevent