Technical Article

Why Does Current-Mode Control in Switching Regulators Matter?

Frederik Dostal, Power Management Expert

There are thousands of different switching regulators on the market. Selection is based on specifications such as input voltage range, output voltage capability, maximum output current, and a slew of other parameters. This article explains current mode, a differentiating feature commonly listed in data sheets, and its advantages and disadvantages.

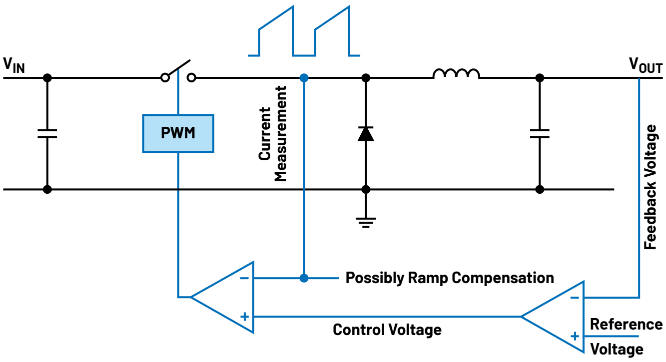

Figure 1. The basic working principle of a current-mode regulator.

Current-Mode Regulators Explained

Figure 1 shows the basic working principle of a current-mode regulator. Here, the feedback voltage is not only just compared with an internal voltage reference but also with a sawtooth voltage ramp for the generation of the necessary PWM signal for the power switch. The slope of this ramp is fixed in voltage-mode regulators. In current-mode regulators, the slope is dependent on the inductor current and is yielded from the current measurement shown in Figure 1 at the switching node. This is what differentiates current-mode regulators from voltage-mode regulators. Current-mode regulators offer many advantages. One is that the inductor current immediately adapts to changes in the input voltage (V_{IN} in Figure 1). Thus, the input voltage change information is directly fed into the control loop, even before the output voltage (V_{OUT} in Figure 1) tracks this input voltage change.

The advantages of current-mode control are so convincing that most switching regulator ICs on the market work according to this current-mode control principle.

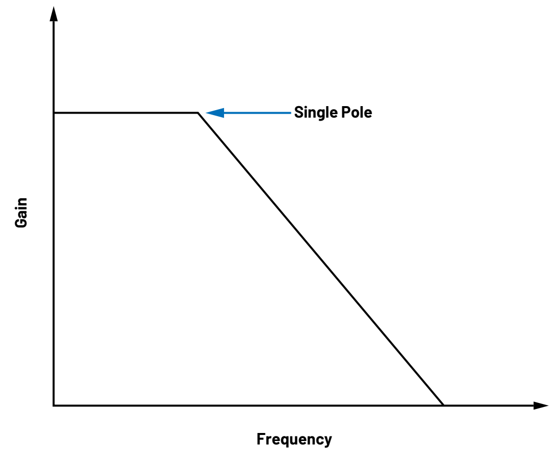

Figure 2. A simplified control loop compensation through current-mode control shown in a Bode plot with just one simple pole in the power stage.

Another key advantage is simplified control loop compensation. The Bode plot of a voltage-mode regulator shows a double pole; a current-mode regulator generates just one simple pole of the power stage at this point. This produces a phase shift of 90°, instead of 180° with a double pole. Thus, a current-mode regulator can be much more easily compensated and thus stabilized. Figure 2 shows the simple transfer function of the power stage of a typical current-mode regulator.

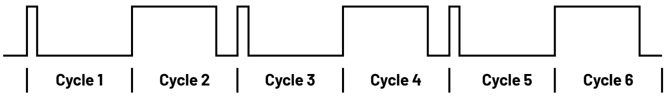

Figure 3. A switch node voltage: a subharmonic oscillation with a current-mode regulator.

However, a few disadvantages exist alongside the mentioned advantages. Current-mode regulators cannot immediately make the required current measurements after a switching transition because the noise will couple into the measurement strongly at this time. It takes a few nanoseconds for the noise caused by the switching to subside. This is called the blanking time. It normally results in a somewhat longer minimum on-time specification than for voltage-mode regulators. Another disadvantage of current-mode regulators is the possibility, in principle, of a subharmonic oscillation. This is shown in Figure 3. If a duty cycle of greater than 50% is required, a current-mode regulator may alternately execute short and long pulses. In many applications, this is considered instability, which should be avoided. To solve this, a certain ramp compensation can be added to the generated current ramp shown in Figure 1. It can shift the critical duty cycle threshold to well above 50% so that even at higher duty cycles, no subharmonic oscillations occur.

Even these earlier mentioned restrictions, due to the blanking time and the resultant duty cycle limitations, can be circumvented through the IC design. For example, one remedy is to incorporate low-side current sensing where the inductor current is measured during the off-time rather than the on-time.

Conclusion

All in all, the advantages of current-mode control in switching regulators outweigh the disadvantages for most applications. And through various circuit innovations and modifications, the disadvantages can be bypassed. As a result, most switching regulator ICs today use current-mode control.

About the Author

Frederik Dostal is a power management expert with more than 20 years of experience in this industry. After his studies of microelectronics at the University of Erlangen, Germany, he joined National Semiconductor in 2001, where he worked as a field applications engineer, gaining a lot of experience in implementing power management solutions in customer projects. During his time at National, he also spent four years in Phoenix, Arizona (USA), working on switch mode power supplies as an applications engineer. In 2009, he joined Analog Devices, where since then he held a variety of positions working for the product line and European technical support, and currently brings in his broad design and application knowledge as a power management expert. Frederik works in the ADI office in Munich, Germany.

TA24006-8/22