Technical Article

Power Tips: Voltage Mode or Current Mode?

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There are two types of fixed-frequency pulse-width modulation (PWM) control: voltage mode (VM) and current mode (CM). Figure 1 shows a diagram that explains both control types. This simple block diagram is very useful in understanding the different parts of the loop.

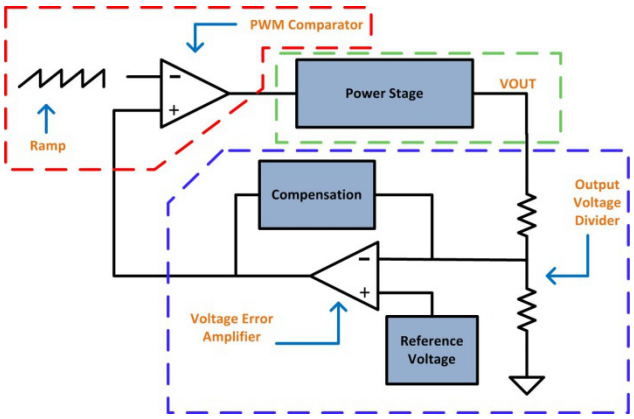

Figure 1. Block Diagram of a Fixed-frequency PWM-controlled Power Supply

One of the major differences between VM and CM is the ramp that inputs to the PWM comparator. In VM, this ramp is a sawtooth waveform generated inside the PWM controller. In CM, the ramp is generated proportionally to a measured current. This small difference in how the PWM signal is generated leads to major differences in the behavior of the control loop.

Consider a simple nonisolated buck converter. When using VM, the power stage will have a double-pole response related to the inductor value and output capacitor. When using the same power stage but implementing CM control, the response becomes a single pole related to the output capacitor and load resistance. This means that for VM and CM, you need different types of compensation.

Remember that CM control uses a ramp proportional to an actual current, so you must have some way to measure that current. Measuring the current and getting a clean signal is the most challenging part of CM control. The main issue is switching noise that the current-sense signal picks up. You can combat this noise problem in a number of ways. Leading-edge blanking basically ignores the first 50-100ns of the current-sense signal. This is effective, but causes issues with minimum on time and fault protection. Using a RC resistor and capacitor network to filter the signal is also an option, but you will again have issues with fault protection. So even though compensation is easier for CM control, it is not always the best choice.

How do you choose the method that might be right for you? Table 1 shows some trade-offs between the two methods.

Table 1. Advantages (Yellow) and Disadvantages (Blue) of VM and CM Control

	VM control	CM control
Bridge topologies	Requires a DC blocking cap to ensure that the transformer does not build up DC current and saturate	Balance is natural because of the current measurements
Compensation	Compensator design is more complex and will likely have to be type 3	Reduces the order of the power-stage system to allow for easier compensation, usually type 2
Current measurement	Not required	Can be complicated based on which current needs to be measured/will also impact efficiency
Current measurement noise	Not susceptible	Requires filtering, leading-edge blanking or other methods for reducing switching jitter
Fault protection	Requires extra circuitry	Easy to implement pulse-by-pulse current limit because the current is already measured
Frequency	Not affected	Because of noise, leading-edge blanking and filtering can limit the high end of the switching frequency, reducing minimum on time by at least 200ns
IC design	Easier because there is no current measurement required	More difficult due to current sensing
Isolated converters	Can be used, but needs careful design and extra circuitry for fault protection	Usually more suitable because of the desire to control the primary peak current and provide fault protection
Resonance (LC filter)	Can cause stability problems	Eliminated by CM
Slope compensation	Not required	Required to prevent subharmonic oscillations for duty cycles greater then 50%; too much makes the supply behave like VM control
Transient response	Lower-output impedance can lead to better response	Could be worse than VM control
Voltage feed forward	Needs extra circuitry (either external or internal to the IC) to provide instantaneous duty-cycle changes for input-voltage changes	Happens naturally because the inductor current ramp increases as the input voltage increases

Power Design Services has completed a number of TI Designs reference designs in both VM and CM:

- VM control – PMP8962, PMP9559, PMP11140.
- CM control – PMP9727, PMP10288, PMP10979, PMP10852, PMP10871, PMP9581_REVB.

The choice between CM and VM control is not always easy or obvious, hopefully the topics discussed here will help you to make the right choice for your system.

Additional Resources

- For more information about CM vs. VM, see my Power Tips post on EETimes.
- Watch the Power Tips video series.
- Read more Power Tips blogs.

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