Technical Article

Why Are There So Many Control Modes for Step-down DC/DC Converters and Controllers?

Rich Nowakowski

One of the questions I receive frequently is why there are so many control modes for step-down DC/DC converters and controllers. Whether hysteretic, voltage mode, current mode, constant on time or D-CAP™ mode control (and all of their derivatives), it seems a new one comes out just as we've gotten comfortable with the last one.

A few months ago, TI released a new control mode called internally compensated advanced current mode (ACM), which is used in the TPS543B20. This 18-V input, 25A DC/DC converter operates at a programmable fixed frequency like current-mode control and does not require loop-compensation components, but employs a feature called asynchronous pulse injection (API) to enable the fast transient behavior of constant on-time control with less output capacitance.

Ultimately, the best control-mode choice depends on the design problems, and that is the answer to the question that I posed in the title. TI is active in the development of leading-edge control circuits to help engineers address tomorrow's design challenges. Figure 1 shows 12 different control modes used by nonisolated DC/DC converters and controllers from Texas Instruments.

Voltage Mode (VM)	Voltage Mode with Feedforward (VFF)	Peak Current Mode	Emulated Current Mode (ECM)	Internally-Compensated Advanced Current Mode (ACM)	Hysteretic
Constant On Time (COT)	COT with Emulated Ripple (COT with ERM)	D-CAP™	D-CAP2™	D-CAP3™	DSC Control™

Figure 1. Control Modes for Nonisolated Step-down Controllers and Converters

In 2011, I was nominated to monitor control modes of nonisolated DC/DC converters and controllers for TI, and it has become an interesting hobby! There were more than 10 different control modes, including control modes from National Semiconductor. Six years later, there are now several new ones, and I maintain a short training presentation and quick reference guide to help differentiate one control mode from another. Each control mode can take hours to effectively present, so the quick reference guide provides useful links to more technical documentation on the TI website. To find products with a particular control mode more easily, our parametric search for step-down converters features a control-mode parameter.

My other role is to act as the control-mode institutional memory, and my journey started in 1999 when TI released a hysteretic controller for the server market, powering the main motherboard processor. The hysteretic controller improved the transient response time with less output capacitance than current- or voltage-mode control, saving board space and cost. But some designers were apprehensive about using a hysteretic nonlinear controller for the first time in their design. A few years later, derivatives of hysteretic control such as constant on-time and adaptive on-time became available. Designers did not have to spend time taking Bode plots or compensating feedback loops with external compensation components as they did with current mode and voltage mode. We were gaining traction. Designers that used simpler internally compensated current- or voltage-mode converters were satisfied with the constant on-time control modes, actually. The limitations of the inductor and output capacitor versions were undesirable, however, as they provided no means to adjust the loop. When higher-value ceramic capacitors like 47µF and 100µF became more available at lower costs, new derivatives of nonlinear control modes came out to support the low equivalent series resistance (ESR) of ceramic capacitors and provide the tighter reference-voltage accuracy that processors require.

On the other hand, many designers still preferred a linear, predictable, fixed-frequency control, since their applications used high-speed clocks, data converters and noise-sensitive analog circuitry such as those found in the industrial and communications markets. Over the years, several derivatives to these linear control modes were released to allow low conversion ratios with a high input voltage and varying line input voltages.

Again, the best control-mode choice depends on the design problems at hand. Check out our quick reference guide and watch our short training presentation and let us know about your favorite control mode.

IMPORTANT NOTICE AND DISCLAIMER

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265