

Are Schottky and Conventional Diodes Obsolete?

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When looking at any buck converter point-of-load regulator designed today, chances are that it uses synchronous rectification rather than a conventional diode for freewheeling. Synchronous rectification, using a switch (FET) along with a control circuit to emulate ideal diode behavior, completely dominates this application now.

With the world's focus on energy efficiency now more than ever, it is not surprising that replacing a simple diode with a rectification circuit makes economic sense in many cases. The primary benefit of synchronous rectification circuits is to dramatically reduce diode forward-voltage drop, providing a corresponding reduction in conduction power loss. FETs with on-resistance in the milliohms are readily available and are becoming increasingly cost competitive.

But Schottky and conventional diode sales have not fallen off a cliff just yet, so why aren't synchronous rectifiers replacing diodes in every application? It turns out that designing a cost-effective circuit to make a better diode isn't always so simple and is highly application dependent.

Take, for example, the synchronous buck converter. In years past, a Schottky rectifier was commonly used as the freewheeling diode in a buck converter. As output voltages dropped from 5 V to 3.3 V and now approach 1 V, the half-volt drop of a Schottky diode becomes a large portion of the total output. By replacing the Schottky with an n-channel FET (and switching it on and off at the correct time), the rectifier forward voltage can be reduced by an order of magnitude or more.

But timing the gate-drive signals to switch the FET on or off at the correct moment turns out to be a difficult design challenge in synchronous rectification. Turning the synchronous FET on early results in a high-current shoot-through event in which two FETs are both on, shorting the input voltage and causing large power dissipation.

On the other hand, turning it on late only incurs incremental loss — due to the body diode conducting with a higher voltage drop — until the FET is turned on. To avoid the shoot-through condition, synchronous buck converters insert a dead time between switch control signals, so as to guarantee no overlap of their on-time. Both FETs can be controlled by a single control IC.

Consider an isolated version of this same circuit: the common forward converter. The controller is on the primary side, and the rectifiers are on the secondary side. It is a challenge to get accurate timing signals across the isolation boundary. Magnetic and optical isolation methods both

have their limitations and cost burdens. And when trying to drive the high-side rectifier in a forward converter where the duty cycle is low, timing becomes a major issue. Adding a special gate-drive winding to the power transformer can be an effective way to drive the gate, except when the bus voltage or load varies significantly, as the resulting gate-drive voltage will vary with both duty cycle and bus voltage.

Most recently, circuits that reside on the secondary side, with no communication to the primary side, are becoming popular. These synchronous rectifier circuits measure voltage across (and, indirectly, current through) the switch, and determine when to drive the gate on or off to behave like a diode. More importantly, they can work with a variety of control methods and topologies, because there is no direct link to the primary side.

The major challenge for these secondary-side circuits is how to measure fast low-level analog signals accurately in the presence of noisy high-current signals, all while surviving periodic high-voltage transients (while the diode is off). Moreover, the gate-driver section has to be extremely fast (propagation delay) and able to quickly charge and discharge the FET gate capacitance.

Finally, all of this performance has to be implemented in a technology and package that meets the overall cost goals of the power-supply designer. While today's synchronous rectifier circuits are suitable for buck, resonant and critical-conduction-mode flyback topologies, additional improvements in speed are necessary to address the needs of hard-switched low-duty-cycle applications. I am confident that our semiconductor industry will apply innovative technologies to provide cost-effective synchronous rectifier solutions for future power-supply generations. **PETech**

Eric Persson has more than 20 years experience in power electronics design. He has presented more than 50 tutorials and papers at international conferences, as well as power electronics short courses and lectures at several U.S. universities. He holds 12 U.S. and foreign patents, is a recipient of the IEEE Third Millennium Medal and is a member of Power Electronic Technology's editorial advisory board.

