design FAQs

Synchronous Rectifiers

Sam Davis
Contributing Editor

FREQUENTLY ASKED QUESTIONS

What is a synchronous rectifier?

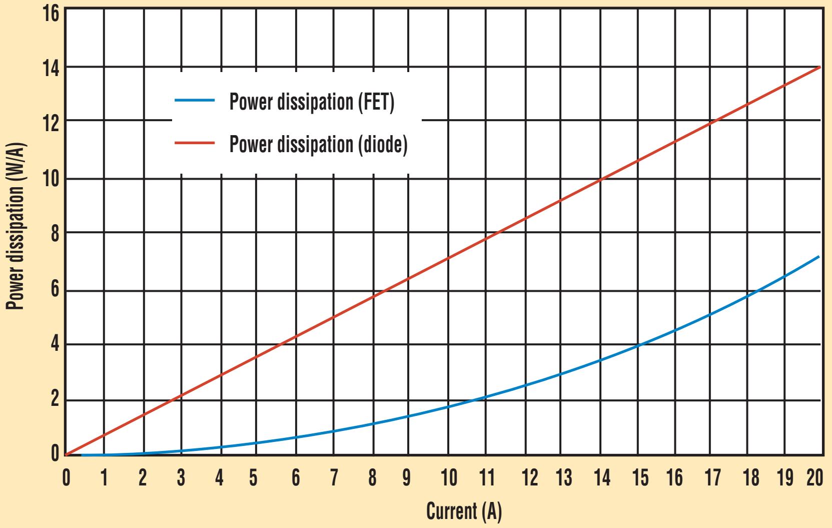
A synchronous rectifier is a circuit that emulates a diode, allowing current to pass in one direction but not the other without the losses associated with junction or Schottky devices. The circuit comprises a pass-element (most often a power MOSFET), a sense element, a sense-signal conditioner, and a driver.

How does a synchronous rectifier work?

There are two broad techniques to implement the synchronous-rectifier function. The first derives a sync signal from the primary controller. But this method often requires the control signal to cross a galvanic barrier, which can be costly, consume a large board area, and limit the converter's upper frequency limit.

The second method derives the control signal independently by sensing the electrical conditions at the pass element. In the off state, the sense element detects the polarity of the voltage applied to the pass element. The signal conditioner amplifies the sense signal and determines the polarity of the sensed voltage. When the applied voltage is of the correct polarity for forward conduction, the signal conditioner turns on the driver, which provides the necessary signal to operate the pass element.

In the on state, the sense element detects the polarity of the current through the pass element. The signal conditioner amplifies the sense signal, as it did in the off state. But here it detects the current zero crossing, shutting off the driver and, as a result, the pass element as close to the zero crossing as possible.



Though rising at a rate proportional to I^2, the conduction loss of an 18-mΩ synchronous rectifier (blue) with ideal timing is significantly smaller than the conduction loss of a typical Schottky diode (red). Implementation-dependent non-idealities include timing errors in the synchronous rectifier that can result in circulating currents in the rectification stage. Non-idealities in the Schottky include reverse recovery charge and leakage current, which also result in circulating current in the power-converter's output stage.

How does the MOSFET-based synchronous rectifier compare with the Schottky diode output rectifier in a switch-mode power supply?

The synchronous rectifier's conduction losses go as $I^2R_{DS(ON)}$. Typical $R_{DS(ON)}$s are a few tens of milliohms or less. The Schottky diode's conduction losses are linear in current, V_FI, resulting in typical dissipation rates in the range of 0.7 to 1 W/A depending on the Schottky's operating temperature. A plot of a typical 18-mW MOSFET and a Schottky diode with $V_F = 700$ mV shows the significant reduction in power dissipation the synchronous rectifier offers *(see the figure)*.

Is there a drawback to the synchronous rectifier compared with a Schottky rectifier?

From a circuit standpoint, a synchronous rectifier is more complicated and usually costs more than the Schottky rectifier. Yet at the system level, the synchronous rectifier competes

Sponsored by International Rectifier and Future Electronics

favorably on cost because of thermal and packaging considerations. Thus, cost comparisons are application-specific.

What are the circuit considerations for a MOSFET-based synchronous rectifier?

Accurately detecting the current zero-crossing is among the most challenging tasks for a synchronous-rectifier design. Delays in detecting and processing the zero crossing allow current to circulate in the secondary circuit, which reduces the converter's efficiency. The signal conditioning and thresholding circuits, therefore, must exhibit good performance over the full operating temperature range.

What are the required MOSFET characteristics for an optimum synchronous rectifier?

Because the MOSFET's conduction losses are ideally proportional to $R_{DS(ON)}$, that parameter is key to synchronous rectification circuits. MOSFET gate charge is also important because the amount of current required to fully enhance the MOSFET channel directly influences non-idealities such as turn-on and turn-off times and propagation delay—all contributors to the circuit's net efficiency.

What is the function of the gate drive?

To optimize efficiency, most synchronous rectifiers employ externally controlled gate-drive ICs. The external gate drivers must supply a current capable of charging the MOSFET's input capacitance. This charging current determines the charging rate of the MOSFET's input capacitance, which controls turn-on, turn-off, and propagation delay times.

Are there ICs that simplify the implementation of synchronous rectification?

Several manufacturers provide special ICs that simplify synchronous-rectifier implementation.

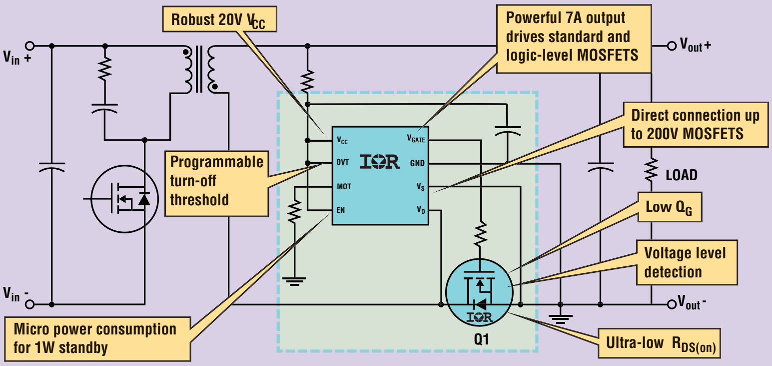
ED ONLINE 14302

ADVERTISEMENT

International
IOR Rectifier

product Q&As

Ditch The Heatsink... Use SmartRectifier™ Chipset



Features

- Can increase system efficiency by more than 1%
- Reduces part count by up to 75%
- Works independently from primary-side control
- No current transformer required
- Industry-leading high-voltage IC technology

SPECIFICATIONS

ICs

Part Number	Package	V_{CC} (V)	V_{FET} (V)	Sw. Freq. Max. (kHz)	Gate Drive	V_{GATE} Clamp (V)	Sleep Current Max. (µA)
IR1167A/SPbF	DIP-8/SO-8	20	<=200	500	+2A/-7A	10.7	200
IR1167B/SPbF	DIP-8/SO-8	20	<=200	500	+2A/-7A	14.5	200
IR1166/SPbF	DIP-8/SO-8	20	<=200	500	+1A/-3.5A	10.7	200

MOSFETs

Part Number	V_{DSS} (V)	$R_{DS(ON)}$ max @ 10V (mΩ)	Q_G(typ/max) (nC)	Package
IRFB3206PbF	60	3.0	120/170	TO-220
IRFB3207PbF	75	4.1	120/170	TO-220
IRF7853PbF	100	18	28/39	SO-8

Future Electronics' Advanced Engineering Program

For more than 30 years, Future Electronics has earned an impressive reputation for providing outstanding design services and developing efficient, comprehensive solutions for customers. The Advanced Engineering Program comprises Certified Electrical Engineering Experts across the globe. Future Electronics' Advanced Engineering Group provides in-depth design services and technical support from concept to production.

Future Electronics' Advanced Engineering program comprises 275 Factory Certified Advanced Engineers located across the globe and 70 System Design Engineers in the three integrated System Design Centers (SDC) in Montreal, London, and Shenzhen. Together, Future's advanced engineers and system design centers offer best-in-class design environments and tools, enabling complex system integration and product development.

Think First!
FUTURE ELECTRONICS