

CASE STUDY

MOSFETs: Increased Efficiency In Bridge Rectifiers

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THE CHALLENGE

Electronic engineers know the common mantras when it comes to creating new designs: Make it cheaper. Make it smaller. Make it faster. These goals, along with technological evolution, keep most engineers challenged—as well as employed. Another major push in the industry is reducing power loss by increasing efficiency. One constant source of power loss in circuits they have always contended with is the “bridge rectifier,” a series of diodes arranged such that the output will be a positive signal, regardless of the incoming signal’s polarity (Figure 1). Unfortunately, this has one major drawback: The diode drop. Up to 2 volts per leg that translates to wasted power. Because the trend in electronics is always moving towards higher efficient and portable products, recouping the power loss from the bridge rectifier is becoming a much higher priority.

THE SOLUTION

The efficiency of diode-based bridge rectifiers has not kept pace with other technologies. So, in lieu of diodes, one can take advantage of recent MOSFET improvements and use these devices in a similar bridge-rectifier construction. Furthermore, since MOSFET prices started dropping in recent years, simultaneously with their $R_{DS(ON)}$ and package size, this bridge rectifier solution is becoming increasingly attractive—both in size and cost.

The schematic in Figure 2 shows an example of this MOSFET approach. Arranging the two N- and two P-channel MOSFETs as illustrated creates a bridge rectifier using Q1 and Q4 for the positive portion of the signal, and Q2 and Q3 for the negative portion. Resistors and Zeners are used to turn on the MOSFETs as well to limit the gate voltage to obey the MOSFETs maximum V_{gs} specification. For standard MOSFETs, a 15V zener diode will suffice since the usual maximum V_{gs} is ~20V.

Here is how the circuit works: When V1 goes positive with respect to V2, current initially flows through Q1’s body diode, then through the output load, and finally through Q4’s body diode back to V2. Almost instantaneously, Q1 turns on because the gate-source voltage is now greater than the turn-on threshold (Q1’s gate is a virtual ground because it is tied to V2 through the resistor). Similarly, Q4 is also turned on. When the input voltage is reversed, V2 is now higher than V1, Q1 and Q4 turn off, and Q2 and Q3 now activate to rectify to a positive polarity DC output voltage. This ensures a positive polarity DC output voltage.

Many applications could increase efficiency by using this MOSFET approach. Take for example a typical 48V Power Over Ethernet (POE) application where the DC voltage is transferred over the spare pairs of CAT-5 cables. POE has a working output power of 15W

PROFILE:
DESIGNS IP
TELEPHONY PROD-
UCTS, WI-FI ACCESS
POINTS, AND
OTHER PERIPHERALS
USING POE AS THE
POWER SOURCE

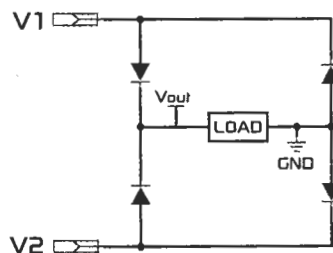


Figure 1: Traditional Bridge Rectifier

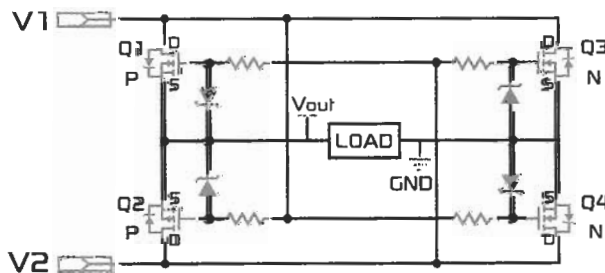


Figure 2: Example of Bridge Rectifier Approach Using MOSFETs.

maximum, or about 300mA. Since we cannot assume correct polarity throughout the system, a bridge rectifier would assure the proper DC output voltage. Using higher voltage FETs, say 60-100V, in a bridge rectifier circuit as shown in Figure 2, could significantly enhance power savings. Table 1 shows the differences in power dissipation after calculating the power loss for three different topologies.

The different approaches compared in Table 1 show that using MOSFETs results in over a half Watt of power savings. This is 96 percent more efficient than the standard diode bridge rectifier solution and 90 percent more than the Schottky version. Devices such as Fairchild Semiconductor's FDS4559 60V complementary pair offers designers an inexpensive, low $R_{DS(ON)}$ (for both the P- (105m Ω) and N-channel (55m Ω) FETs) and compact solution. In large quantities, this circuit is in the 50-cent ballpark and its tiny SO-8-package offers a footprint of

that the engineer should consider. First and foremost, to maximize power savings, the gate resistor should be of high impedance to avoid power loss, especially at higher voltages. In Table 1, for example, the gate resistor is 270K, which translates to only 8mW ($(V_{in}-V_{zener}) / R_g$) of dissipated power for both resistors. Moreover, because of the high gate resistance, switching losses in the MOSFETs will make this solution impractical for high-frequency applications.

Engineers should also consider the possibility of surge currents and/or ESD voltages. MOSFETs should be rated properly for each individual application. In this design, transient voltage suppressors (TVS) are a simple, inexpensive solution for a front-end protection circuit, especially if the connection will be "hot plugged." Additionally, the circuit that connects to the output of this design must be considered. The construction of the MOSFET will allow current to flow in both directions, as well as through the

Bridge Design	Total Power Loss	Size	Cost	Complexity	Typical Part
Single Package	600mW	Small	Lowest	Lowest	MB1-5
Schottky Diode	240mW	Medium	Medium	Low	5B3100
MOSFETs 270K Ω -Rg 8mW-Rg	23mW 15mW-FETs	Medium	Medium	Medium	FDS4559-60V Complementary Pair

Table 1: Power Losses Resulting from Different Bridge Rectifier Designs.

roughly 1cm². Also, the wide selection of available MOSFETs provides the engineer flexibility to tailor his design for efficiency, size, or cost.

Reverse-polarity protection for a battery circuit is another potential application for this MOSFET approach. The bridge rectifier can ensure efficient operation and also protect the circuit, with minimal losses. Where a 2V drop in a low-voltage battery circuit can easily halve system efficiency, a MOSFET bridge solution would maximize usable power. Depending on the input voltage swing, logic-level Vgs MOSFETs may be better for lower voltage applications, such as Fairchild's FDC6327C, which has a 2.5V gate-source threshold and low $R_{DS(ON)}$ for both N- and P-channel FETs.

Now, there are some caveats with this design

body diodes. So designers should be mindful of the output circuit and whether or not the components are capable of creating reverse voltages or current.

THE CONCLUSION

As power consumption becomes more crucial in electronic designs, squeezing every milliwatt of power will continue to be a top priority for engineers. And as technology evolves, semiconductor manufacturers are raising the bar for products that offer efficiency, size and cost. MOSFETs have been one of the fastest growing segments over the years, and for power-sensitive applications that is reason enough to use them as a flexible, inexpensive and efficient alternative to the ubiquitous bridge rectifier. ■