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Cut Your Losses–With an Active Diode

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The always-on power source has become a common requirement for electronic devices to ensure uninterrupted operation of critical loads. The popular use of an ORing function (Fig.1)—the electrical connection of two or more power sources, which ensures that when one fails, the other intervenes—has made the Schottky diode the component of choice for most implementations.

In low-voltage applications, such as portable equipment, it quickly becomes apparent that the supposedly low dropout voltage of the Schottky diode is not so low after all, causing disproportionately high-power losses compared to the rest of the electronics. The Schottky diode's reverse leakage current is also a concern, as it becomes a drain on the device's main power source while also attempting to charge a primary, nonrechargeable battery.

One solution has been to simulate the diode with a properly controlled, low R_{DSON} MOSFET. This solution is bulky and costly, requiring one discrete MOSFET (active diode) or two back-to-back MOSFETs (active switch) and a controller IC.

This article reviews ORing techniques used to switch between two power sources in four popular applications. One application involves use of an alkaline backup battery; another uses an auxiliary power source for redundancy; a third employs a wireless power source in combination with a USB power source; and the last uses a wall adapter and a Li-ion battery. After highlighting the shortcomings of the ORing solutions currently used in these applications, this article introduces a monolithic solution—the MAX40200 ideal diode IC—which overcomes those limitations.

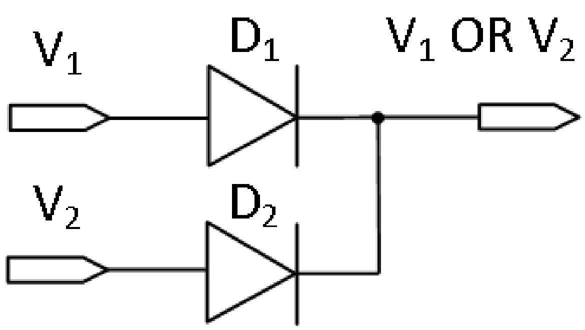

Fig. 1. Diode OR configuration. The Schottky diode has been the component of choice for most ORing implementations, but its dropout voltage and reverse leakage current are concerns in some applications, leading to adoption of active ORing techniques using power MOSFETs and controller ICs.

Battery Backup

Fig. 2 shows a typical backup system where the main power is provided by the wall adapter or a solar cell. In case of a main power outage, three alkaline, nonrechargeable batteries (2 Ah) will keep the system alive while consuming 1 A for 2 hours. Under a 1-A load, the Schottky diode, D_3, will typically create a 300-mV to 600-mV drop, while the three battery cells deliver an average total voltage of 3 V during their two-hour lifespan. A diode drop as low as 330 mV, over a 3-V voltage rail, corresponds to an 11% efficiency loss! This inefficient utilization of the energy stored in the alkaline battery results in a shorter overall system runtime.

Reverse leakage is another concern when using this ORing technique. When the device is connected to the wall adapter or solar cell, the reverse-biased Schottky diode, D_3, dumps tens to hundreds of microamps of leakage current into the alkaline battery. This effectively performs unwanted and unsafe trickle charging of the nonrechargeable battery.

Finally, there is a concern with voltage headroom. With the battery delivering an average voltage of 3 V, the always-on buck converter input will be at 2.4 V, worst case. In this situation, the buck converter is unable to deliver the required 2.5 V to its output.

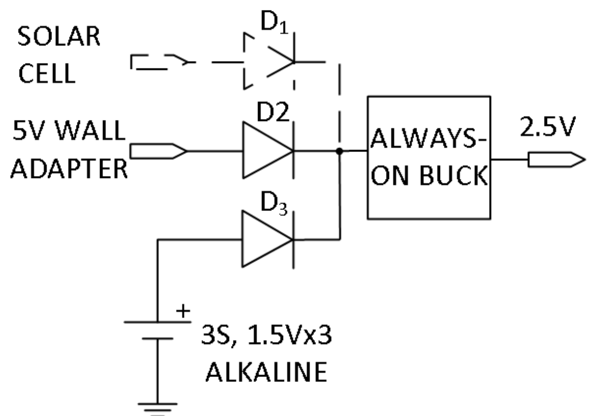

Fig. 2. Battery backup ORing circuit.

The use of a discrete MOSFET-based solution (active switch) will solve these problems, However, it comes at the cost of greater PCB space and the use of additional components since the MOSFET needs a dedicated controller to switch it "on" or "off."

Auxiliary Power

Fig. 3 shows a typical auxiliary system, where both the main and auxiliary power sources operate at 3.3 V. With the main power present, the auxiliary power is disabled; if the main power fails, the auxiliary path is enabled. D_1 and D_2 are active switches, activated by their respective enable (EN) pins. When the main supply is present, the resistor, R_2, pulls EN high, activating D_2, and allowing the main power to flow to the load. The inverter (INV) keeps D_1 "off", disabling the auxiliary power path. When the main power is absent, the series resistors, R_2 and R_3, pull the inverter input low, enabling D_1 via R_1 and apply the auxiliary power to the load.

Here, the two active switches, D_1 and D_2, solve the previously mentioned problems. However, it again comes at the cost of space and added BOM, as each active switch requires a back-to-back MOSFET and a controller IC.

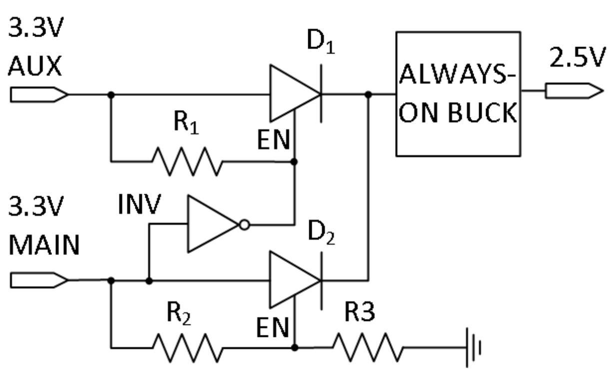

Fig. 3. Auxiliary/main power ORing circuit.

Wireless Power

The system in Fig. 4, typical of a portable device, takes power from a wireless ac source or a USB port. The ORing function (via D_1 and D_2) is necessary to isolate the relatively large capacitor at the receiver's rectifier output from the USB port. If the gadget is a small device, like a smartwatch, the use of regular diodes will compound the efficiency problem, since the device needs to maximize runtime. The use of discrete MOSFETs and the associated controllers is not permitted due to the extremely limited space available.

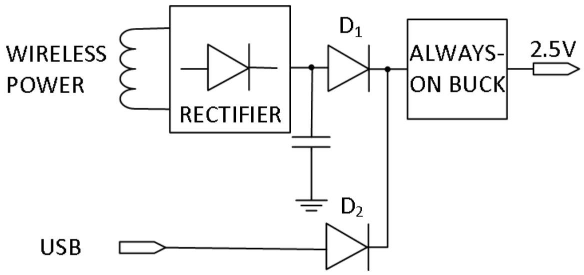

Fig. 4. Wireless/USB power ORing circuit.

Charger/Wall Adapter

In the portable system of Fig. 5, the wall adapter charges the lithium-ion (Li-ion) battery via the charger and supplies power via D_1 with D_2 reverse biased. If the wall adapter is not connected, power is supplied via D_2 by the Li-ion battery. In this case, during untethered operation, the current path through D_2 would greatly benefit from the use of a true low-drop diode. The small voltage drop would enable space and efficiency savings, and provide prolonged untethered operation.

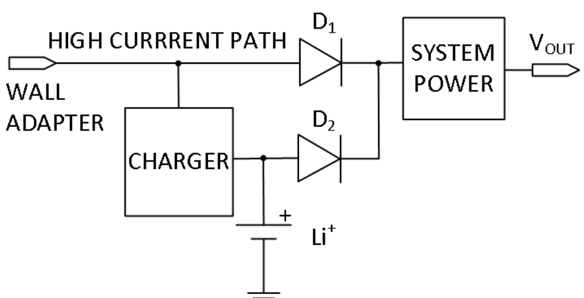

Fig. 5. Charger/wall adapter ORing circuit.

A Single-Chip Active Diode Solution

Each of the applications discussed would greatly benefit from the use of a single component as simple and elegant as the Schottky diode but free from its voltage dropout and reverse leakage shortcomings. The MAX40200 is an ideal diode that drops three times lower voltage (at high current) to ten times lower voltage (at low current) than a Schottky diode. When forward-biased and enabled, the MAX40200 conducts with less than 100 mV of voltage drop while carrying currents as high as 1 A. Fig. 6 shows the comparison between the MAX40200 and a typical Schottky diode, both rated at 1 A.

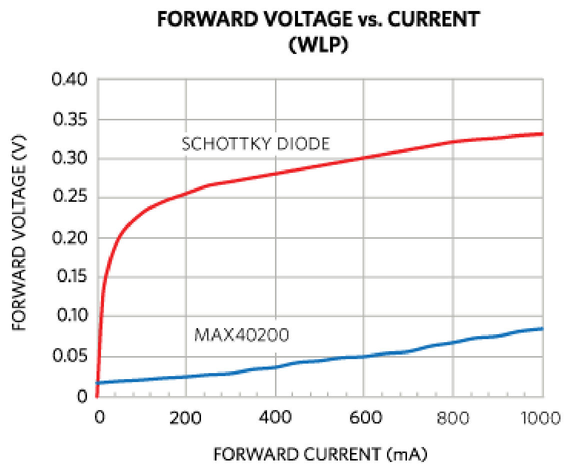

Fig. 6. Voltage drop comparison for the MAX40200 ideal diode vs. a Schottky diode.

The voltage drop at 1 A goes from 330 mV when using a Schottky diode down to 85 mV when using the ideal diode. The corresponding efficiency loss goes from 11% down to 2.8%! When reverse-biased, the MAX40200 exhibits a reverse cathode current 10 to 100 times better than a typical low dropout Schottky diode (Fig. 7).

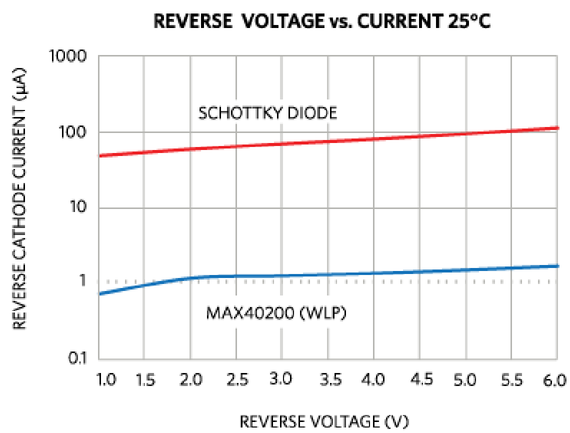

Fig. 7. Reverse cathode current comparison for the MAX40200 ideal diode vs. a Schottky diode.

The MAX40200's minimal reverse leakage current effectively eliminates the unwanted trickle charge of the alkaline battery in a battery backup application.

Ideal Diode Functionality

Looking at the functional diagram in Fig. 8, the ideal diode is based on a low R_{DSON} p-channel DMOSFET. The internal circuitry senses the MOSFET drain-to-source voltage and, in addition to driving the gate, keeps the body diode reverse biased. This additional step allows the device to behave like a true open switch when EN is pulled low, or when the thermal limit is reached.

A positive drain-to-source voltage turns the MOSFET "on" with current flowing in normal mode while the body diode is reverse biased. A negative drain-to-source voltage turns the MOSFET "off" with the intrinsic diode again reverse biased. If EN is low then the device is "off" independent of the V_{DD}-OUT polarity.

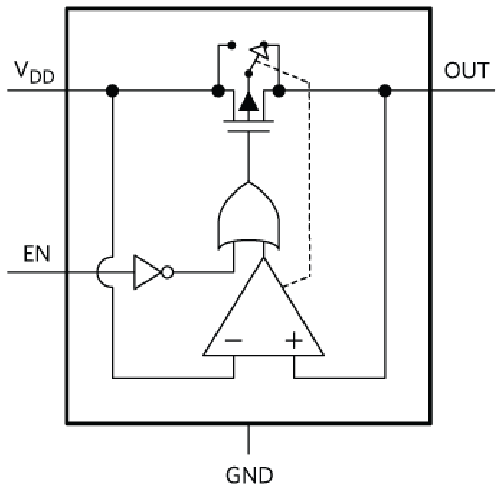

Fig. 8. Functional diagram for the MAX40200 ideal diode.

Ideal Diode Forward Characteristics

To properly sense the drain-to-source voltage at low current, when the intrinsic voltage (R_{DSON} x I_{LOAD}) would be too small to detect, a minimum dropout of approximately 25 mV is maintained across the device by an internal control loop. When the drop exceeds this threshold, the voltage rises linearly according to Ohm's law (R_{DSON} x I_{LOAD}). The logarithmic scale in Fig. 9 highlights the nearly constant voltage across the ideal diode up to around 200 mA.

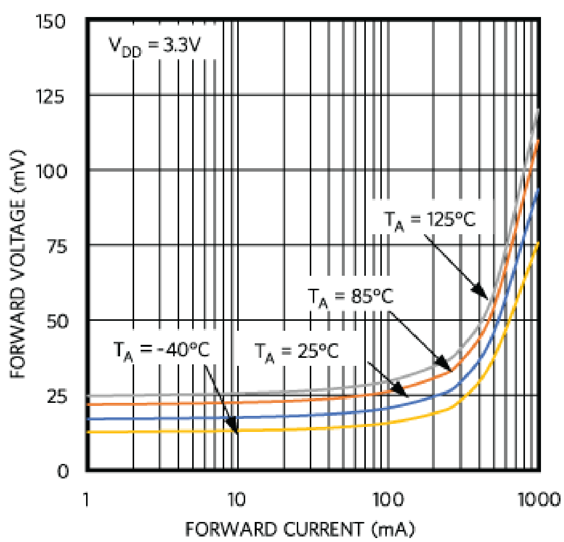

Fig. 9. The MAX40200's forward voltage vs. forward current.

Conclusion

Mobile systems with multiple power sources, such as backup alkaline batteries, auxiliary power supplies, wireless power, or Li-ion batteries, require a diode ORing function to act as the power switch. However, the

ORing function can rob precious power, energy, or space from a mobile system, and in some cases, could compromise its safety or operation.

In low-power applications, the use of the MAX40200 1-A ideal diode provides a simple solution. Housed in a small WLP package, with dropout voltages an order of magnitude lower than Schottky diodes in forward mode, this chip also has dramatically lower leakage current in reverse mode. The MAX40200 minimizes or eliminates the limitations of the traditional ORing implementation for 5-V and sub-5-V systems, providing an elegant and efficient substitution for the typical Schottky diode.

About The Authors

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