SMART POWER SWITCHES PROVIDE A WAY FOR LOW-POWER DEVICES TO INTELLIGENTLY SWITCH BETWEEN POWER SUPPLIES AND SAVE POWER AT THE SAME TIME.

Choosing a power supply, automatically

Many electronic devices today operate from two power sources. Computer peripherals, PDAs (personal digital assistants), digital cameras, and video cameras typically are powered from either a battery or an ac adapter. IAPCs (instantly available PCs) and NICs (network interface cards) also operate from two power supplies. A NIC draws less current from one power source when a PC is asleep. Upon receiving an incoming network message, however, a NIC switches to the main power supply and wakes the entire system to process the message.

Such dual-power devices need a means of switching from one power supply to the other. This power switch should have two inputs and one power output. The key is to provide the device with continuous power, automatically switching to the appropriate power supply. In most cases, it is necessary to give a higher priority to one of the supplies. When both power supplies are present, typically the main supply has a higher priority than the standby supply (for example, a battery). Various options are available to perform this switching function. The traditional way is to use two Schottky diodes in a wired-OR configuration. A better way is to use a “smart” power switch to automatically select either supply. Vendors offer integrated power switches for a variety of applications.

Before looking at the differences between integrated smart switches and switches made from Schottky-diode pairs, consider the characteristics of a basic power-supply switch.

SWITCH CHARACTERISTICS

The basic power switch shown in Figure 1 has dual inputs and a single output. You can model each input channel as an ideal switch in series with a resistor. (Note that only one switch may be closed at one time.) The power switch has two main characteristics. The first is its on-resistance. When you turn the switch on, it exhibits a series resistance, $R_{SW(ON)}$, which is equal to either $R_{SW1}$ or $R_{SW2}$. This resistance has a voltage drop, $V_{DROP}$, across it equal to the current flowing through the switch times $R_{SW(ON)}$. A good switch has a low $R_{SW(ON)}$, typically much less than 1Ω. The second characteristic of a power switch is its selection scheme, or how it...
automatically switches from one power source to the other. The switching scheme uses threshold voltage and hysteresis to determine when to switch between supplies. You select these parameters based on the target application. To understand the benefits of the integrated power switch over a Schottky-diode-pair switch, consider these two characteristics in each design.

Figure 2 shows a switch built with two Schottky diodes. Whenever supply voltage is greater than the Schottky diode to be forward-biased, thereby connecting the supply to the output. One voltage source has no priority over the other. Therefore, you cannot control which supply is selected when V1 and V2 are equal. Figure 3 illustrates a power changeover when V1 rises to greater than and then less than V2. If V1 does not exceed V2, it will never power the output. VDROP is the forward voltage drop of the Schottky diode.

A 1A Schottky power rectifier typically demonstrates the forward-voltage characteristic shown in Figure 4. The I-V curve is in logarithmic scale measured under dc conditions. A Schottky diode with a forward current of 400 mA will have a forward voltage of about 300 mV. At higher current, the diode heats up and shows a current increase at a fixed bias voltage.

Figure 5 shows a simplified electrical schematic of a fixed-threshold smart switch. Each switch is a MOSFET whose gate is driven by a comparator with hysteresis. VTH is the primary input, which you normally connect to the main supply. The switch manufacturer presets the VTH select threshold to a specific level, VTH. As soon as VTH exceeds this threshold, VOUT is connected to the output. The transition occurs independently of V2.

When V1 drops below VTH by more than the hysteresis voltage, VHYST, the switch selects the greater of V1 and V2 (Figure 6). A typical value for VHYST is about 90% of the nominal voltage. Typically, the hysteresis is 100 to 200 mV. The advantage of a fixed-threshold smart switch is that it selects V1 when V1 reaches a particular value, independent of V2.

Figure 7 shows a simplified electrical schematic of a relative-threshold smart switch. The comparator with hysteresis senses the difference between the two inputs and turns on the MOSFET switch.

The switch selects the primary input, V1, when its value approaches V2 by less than the select voltage, VSEL (Figure 8). When V1 drops below V2 by more than the deselect voltage, VDESEL, the switch selects V2.

**TABLE 1—VENDORS PROVIDING INTEGRATED SMART-POWER SWITCHES AND SCHOTTKY DIODES**

<table>
<thead>
<tr>
<th>Vendor</th>
<th>Product</th>
<th>Features</th>
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<tbody>
<tr>
<td>California Micro Devices</td>
<td>CMPWR025</td>
<td>500-mA, dual 2.8 to 5.5V input SmartOR power switch</td>
</tr>
<tr>
<td>Enter No. 349</td>
<td><a href="http://www.calmicro.com">www.calmicro.com</a></td>
<td></td>
</tr>
<tr>
<td>Fairchild Semiconductor Corp</td>
<td>MBRS130L</td>
<td>1A, 30V Schottky power rectifier</td>
</tr>
<tr>
<td>1-207-775-8100</td>
<td><a href="http://www.fairchildsemi.com">www.fairchildsemi.com</a></td>
<td></td>
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<tr>
<td>Enter No. 350</td>
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<tr>
<td>On Semiconductor</td>
<td>MBRS130L</td>
<td>1A, 30V Schottky power rectifier</td>
</tr>
<tr>
<td>1-602-244-6600</td>
<td><a href="http://www.on-semi.com">www.on-semi.com</a></td>
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<tr>
<td>Enter No. 351</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Semtech Corp</td>
<td>SC1543</td>
<td>400/200-mA, dual 3.3V input smart power switch</td>
</tr>
<tr>
<td>1-805-498-2111</td>
<td><a href="http://www.semtech.com">www.semtech.com</a></td>
<td></td>
</tr>
<tr>
<td>Enter No. 352</td>
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</tr>
</tbody>
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The threshold voltage, Vth, determines the switching point in a fixed-threshold smart switch.

The switch selects the primary input, V1, when its value approaches V2 by less than the select voltage, VSEL (Figure 8). When V1 drops below V2 by more than the deselect voltage, VDESEL, the switch selects V2.

**ANALYZING THE SWITCHES**

As an example, California Micro Devices’ CMPWR025 smart power switch has a typical RON of 0.2Ω on both channels. A dc analysis of the switch under a 400-mA load yields a voltage drop of:

\[ V_{DROP} = I \times R_{ON} = 0.4 \times 0.2 = 80 \text{ mV}. \]

Compare this VDROP with the 300-mV drop across the Schottky diode under the same load condition. You can see that the CMPWR025 switch significantly reduces the voltage loss.

For both smart switches (fixed and relative threshold), the output voltage is at its lowest level, VOUT(MIN), when V1 drops to the deselect threshold.

\[ V_{OUT} = V_{DESEL} - IR_{DSS}. \]

To keep the output voltage greater than the minimum operating voltage of your device, keep the load current at less than a maximum value. If you don’t, your device may behave unpredictably. For example, suppose your de-
vice has an operating range of 3 to 3.6V and a load of 200 mA. Assuming a secondary supply voltage of 3.2V and using typical values for a CMPWR025 switch, Equation 1 yields a minimum output voltage just greater than the minimum required.

\[ V_{\text{OUT}} = V_{\text{C2}} - V_{\text{CIDESEL}} - IR_{\text{DS(ON)}} = 3.2 - 0.125 - (0.2 \times 0.2) = 3.035V. \]  

**EFFECTS OF RESISTANCE**

Consider the effect of impedance and resistance on smart switches. Until now, this article has ignored these parameters for the sake of simplicity. When a power source is selected, the corresponding switch input sees a voltage drop across the power-supply impedance and interconnect resistance. Because of the drop, the output voltage varies during power changeover. Keep the impedance and resistance as low as possible to minimize voltage fluctuations at the output. Keep line parasitic inductances at a minimum as well.

**Figure 9** shows an application circuit with a 3.3V main supply (VCC) on channel 1 and a 3.3V auxiliary supply (VAUX) on channel 2. A 200-mA load connects to the output. The combined power-supply and interconnect series resistance, \( R_1 \), on channel 1 is 0.2 \( \Omega \). On channel 2, the combined series resistance is much lower, and you can neglect it. When you turn on channel 1, the voltage at the CMPWR025’s input is the supply voltage minus the voltage drop across \( R_1 \). When you turn on channel 2, the voltage at the input is the same as \( V_{\text{VAUX}} \).

Consider the situation in **Figure 10**, in which \( V_{\text{C1}} \) ramps up from 0 to 3.3V and \( V_{\text{C2}} \) remains constant at 3.3V. As soon as \( V_{\text{C1}} \) reaches the select threshold, the CMPWR025 selects channel 1 and current starts flowing through \( R_1 \). The output voltage at \( V_{\text{OUT}} \) drops because \( V_{\text{C1}} \) is less than \( V_{\text{C2}} \) at this point, and because of the voltage drop across \( R_1 \).
As long as the drop is less than the hysteresis level (typically around 100 mV), the channel will remain selected, and no oscillation will occur.

Figure 11 shows what happens when \( V_{C1} \) falls from 3.3 to 0V, and \( V_{C2} \) again remains constant at 3.3V. As soon as \( V_{C1} \) reaches the deselect threshold, current stops flowing through channel 1, and more voltage drop is seen at the CMPWR025’s input. \( V_{OUT} \) experiences the same voltage change as before but in the opposite direction.

**CALCULATING POWER CONSUMPTION**

What is the power dissipation in a switch with a 400-mA load? For the Schottky-diode switch, the power equals the current times the forward voltage drop across the diode:

\[
P_D = V_{FORWARD} \cdot I = 0.3 \times 0.4 = 120 \text{ mW}.
\]

For the CMPWR025 switch, because the quiescent current is extremely small (less than 50 \( \mu \text{A} \)), a good approximation is simply the switch resistance times the square of the current:

\[
P_D = R_{DS(ON)} \cdot I^2 = 0.2 \times (0.4)^2 = 32 \text{ mW}.
\]

As \( V_{C1} \) falls below the deselect threshold, the output voltage drops during switching.

The CMPWR025 dissipates nearly one-fourth the power of the Schottky diode switch. You can realize significant power savings using an integrated-power-switch approach over a traditional approach.

When implementing a dual power system, pay careful attention to the supply voltage and its maximum operating range, the overall load current, source impedance, and interconnect series resistance. You can use these parameters to calculate the maximum tolerable drop across the switch as well as the select and deselect thresholds. The ideal power switch guarantees that the output voltage stays within the minimum and maximum operating-voltage range of the application’s components. With smart switches, you can also give priority to the main supply when both supplies are present. Smart switches provide integrated solutions targeting specific power requirements.

**Author’s biography**

Fabien Franc is a senior applications engineer at California Micro Devices (Milpitas, CA). He is a member of the development team for power-management products. He has an MSEE from École Polytechnique Fédérale de Lausanne (Swiss Federal Institute of Technology; Lausanne).