 By Fabien Franc, California Micro Devices

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

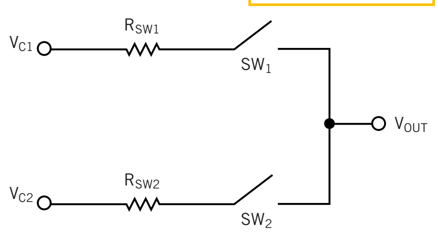
Choosing a power supply, automatically

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.

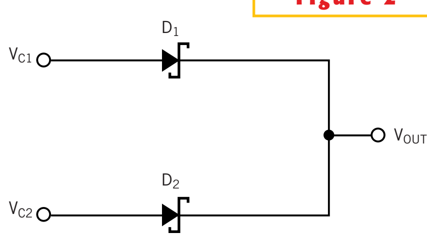
Before looking at the differences between integrated smart switches and switches made from Schottky-diode pairs, consider the characteristics of a basic power-supply switch.

Figure 1



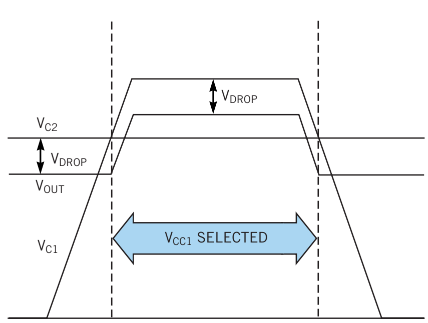
A basic power switch selects between two power sources.

Figure 2



You can use a Schottky-diode pair to switch between two supplies.

Figure 3



The Schottky diode switch switches to V_{C1} when V_{C1} is greater than V_{C2}.

SWITCH CHARACTERISTICS

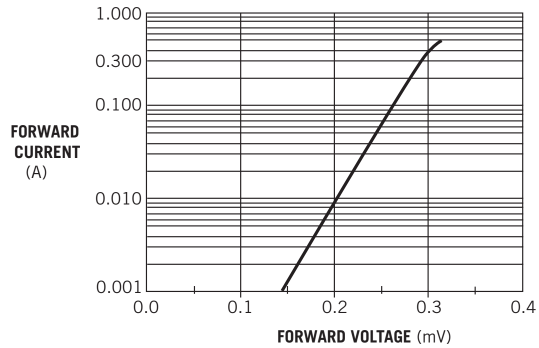
The basic power switch shown in **Figure 1** has dual inputs and a single output. You can model each input channel as an ideal switch in series with a resistor. (Note that only one switch may be closed at one time.) The power switch has two main characteristics. The first is its on-resistance. When you 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. Whichever supply voltage is greater causes that 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 V_{C1} and V_{C2} are equal. **Figure 3** illustrates a power changeover when V_{C1} rises to greater than and then less than V_{C2}. If V_{C1} does not exceed V_{C2}, it will never power the output. V_{DROP} 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 mA. At higher current, the diode heats up and shows a current increase at a fixed bias voltage.

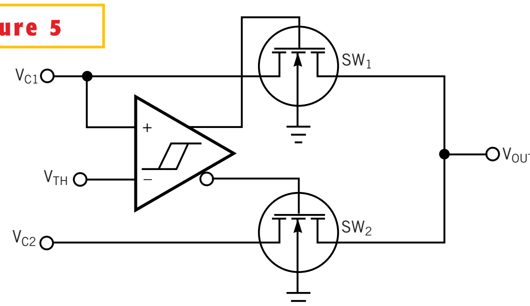
Figure 5 shows a simplified electrical schematic of a fixed-threshold smart switch. Each switch is a MOSFET whose gate is driven by a comparator with hysteresis. V_{C1} is the primary input, which you normally connect to the main supply. The switch manufacturer presets the V_{C1} select threshold to a specific level, V_{TH}. As soon as V_{C1} exceeds this threshold, V_{C1} is connected to the output. The transition occurs independently of V_{C2}. When V_{C1} drops below V_{TH} by more than the hysteresis voltage, V_{HYS}, the switch selects the greater of V_{C1} and V_{C2} (**Figure 6**). A typical value for V_{TH} 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 V_{C1} when V_{C1} reaches a particular value, independent of V_{C2}.

Figure 4



Current varies nearly linearly with forward voltage in a Schottky diode.

Figure 5



The threshold voltage, V_{TH}, determines the switching point in a fixed-threshold smart switch.

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, V_{C1}, when its value approaches V_{C2} by less than the select voltage, V_{C1SEL} (**Figure 8**). When V_{C1} drops below V_{C2} by more than the deselect voltage, $V_{C1DESEL}$, the switch selects V_{C2}.

ANALYZING THE SWITCHES

As an example, California Micro Devices' CMPWR025 smart power switch has a typical $R_{SW(ON)}$ of 0.2Ω on both channels. A dc analysis of the switch under a 400-mA load yields a voltage drop of:

$$V_{DROP} = I \bullet R_{DS(ON)} = 0.4 \times 0.2 = 80 \text{ mV}.$$

Compare this V_{DROP} 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, $V_{OUT(MIN)}$, when V_{C1} drops to the deselect threshold.

$$V_{OUT} = V_{DESEL} - IR_{DS(ON)}.$$

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-

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

Vendor	Product	Features
California Micro Devices 1-408-263-3214 www.calmicro.com Enter No. 349	CMPWR025	500-mA, dual 2.8 to 5.5V input SmartOR power switch
Fairchild Semiconductor Corp 1-207-775-8100 www.fairchildsemi.com Enter No. 350	MBRS130L	1A, 30V Schottky power rectifier
On Semiconductor 1-602-244-6600 www.on-semi.com Enter No. 351	MBRS130LT3	1A, 30V Schottky power rectifier
Semtech Corp 1-805-498-2111 www.semtech.com Enter No. 352	SC1543	400/200-mA, dual 3.3V input smart power switch

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.

$$V_{OUT} = V_{C2} - V_{C1DESEL} - IR_{DS(ON)} = 3.2 - 0.125 - (0.2 \times 0.2) = 3.035V. \quad (1)$$

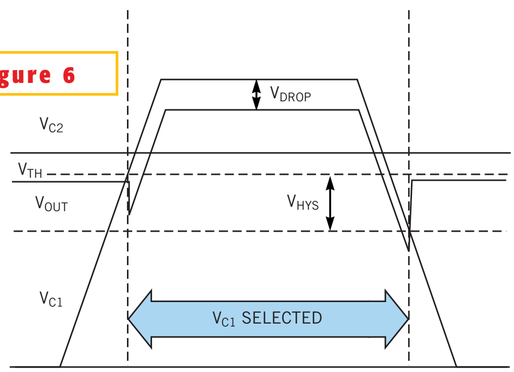
EFFECTS OF RESISTANCE

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 access 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 (V_{CC}) on channel 1 and a 3.3V auxiliary supply (V_{AUX}) 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 0.2Ω. 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_{AUX}.

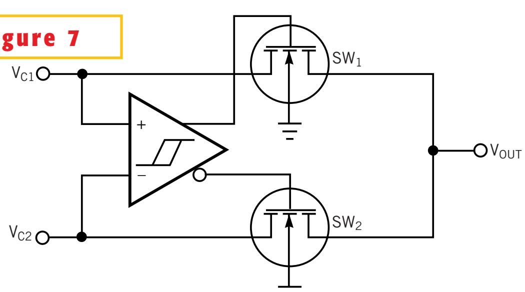
Consider the situation in **Figure 10**, in which V_{C1} ramps up from 0 to 3.3V and V_{C2} remains constant at 3.3V. As soon as V_{CC} reaches the select threshold, the CMPWRO25 selects channel 1 and current starts flowing through R_1. The output voltage at V_{OUT} drops because V_{C1} is less than V_{C2} at this point, and because of the voltage drop across R_1.

Figure 6



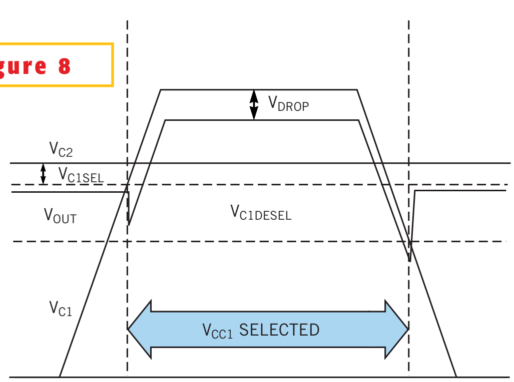
The fixed-threshold smart switch selects V_{C1} when V_{C1} is greater than V_{TH}.

Figure 7



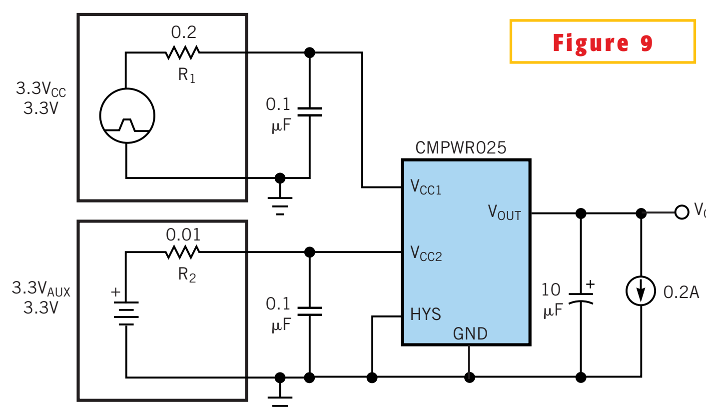
The difference between V_{C1} and V_{C2} determines the switching point in a relative-threshold smart switch.

Figure 8



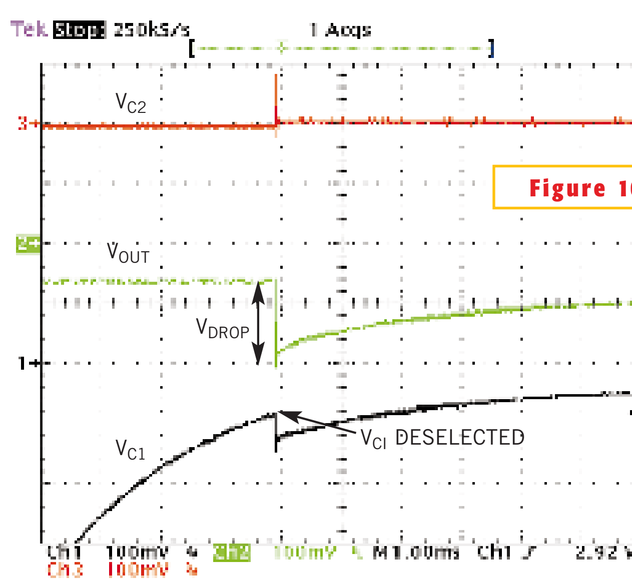
The relative-threshold smart switch selects V_{C1} when V_{C1} approaches V_{C2}.

Figure 9



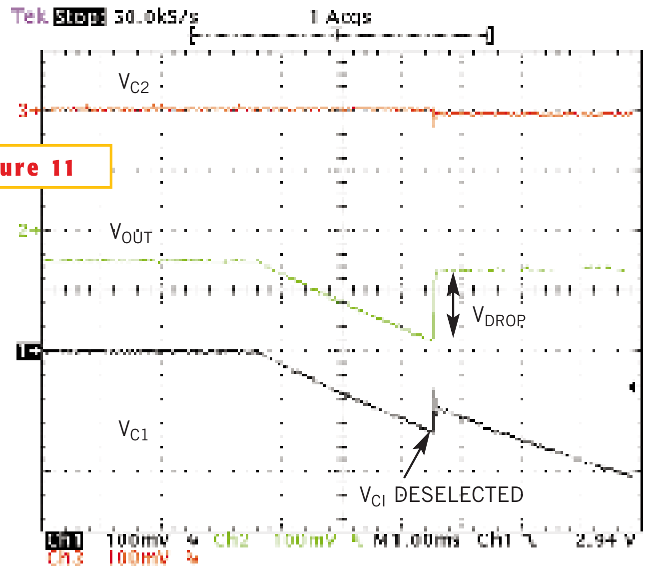
The CMPWR025 smart-power switch is connected to a switchable and constant power supply.

Figure 10



As V_{C1} rises above the select threshold, the output voltage drops during switching.

Figure 11



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

$$DROP = (V_{C2} - V_{C1SEL}) + IR_1.$$

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:

$$P_D = V_{FORWARD} \bullet I = 0.3 \times 0.4 = 120 \text{ mW}.$$

For the CMPWR025 switch, because the quiescent current is extremely small (less than 50 μA), a good approximation is simply the switch resistance times the square of the current:

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

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 Ecole Polytechnique Fédérale de Lausanne (Swiss Federal Institute of Technology; Lausanne).