A Simple Solution for Switching Multiple Power Sources in Notebook Computers

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The Si4720CY battery disconnect switch combines trench-gated power MOSFETs and control circuitry in a single package, providing a simple, compact solution for multiple power source switching in notebook computers. Typical solutions for this function are based on Schottky diodes and discrete power MOSFET-based circuits that provide the power switching, level shifting, and slew rate control. By contrast, each Si4720CY contains two independent, level-shifted, slew-rate-controlled p-channel MOSFETs. Used together, they form a single reverse-blocking switch for battery or power source disconnect. The Si4720CY is likewise configured such that each level-shifted MOSFET can be combined with an external MOSFET or Schottky diode to form a reverse-blocking switch.

THE SI4720CY VS. DISCRETE SOLUTIONS

The lowest cost discrete solutions use Schottky diodes either alone or in conjunction with MOSFET-based switching circuits. Even though Schottky diodes are inexpensive, they come at a cost in performance. The forward voltage drop, typically 0.4 V, creates two performance deficiencies when compared to a MOSFET switch. In battery-powered systems, the 0.4-V drop reduces useful battery life and, therefore, reduces the operating time of the system. Second, the power dissipation of the Schottky is significantly higher. A single Schottky diode carrying a current of 2 A will dissipate 0.8 W. In comparison, the two halves of the Si4720CY connected in series, carrying a load current of 2 A, will have a voltage drop of approximately 0.12 V and will dissipate only 0.25 W.

The Si4720CY provides two half-switches in a single SO-16 package. Little design time is required. The control logic has been designed to be self-powered, compatible with 3-V and 5-V logic, and to provide slew rate control. The component count is a single package versus the seven parts required by the discrete version. The required PC board space is minimal. The Si4720CY circuit that is equivalent to the discrete circuit is shown in Figure 2.

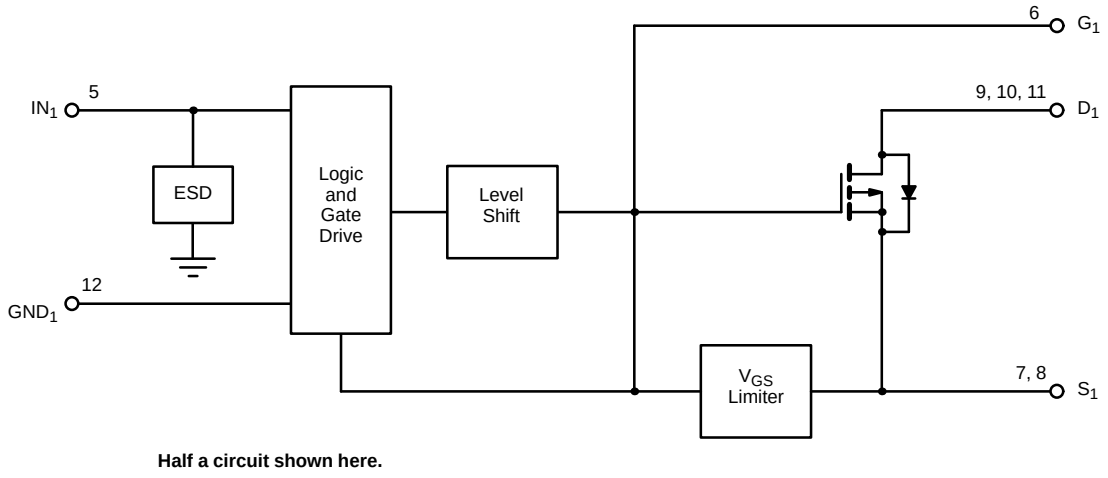


FIGURE 1. Si4720CY Functional Block Diagram

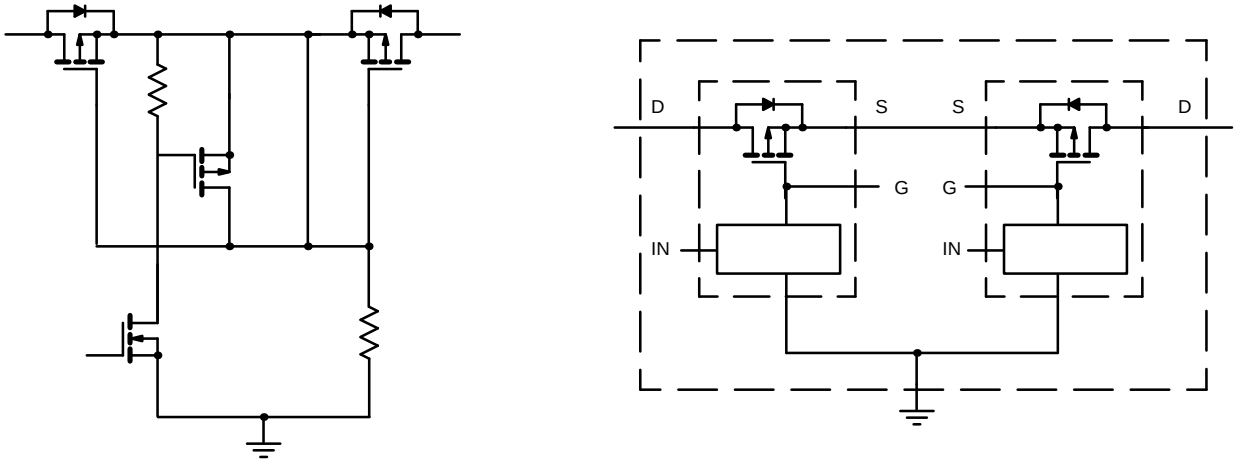
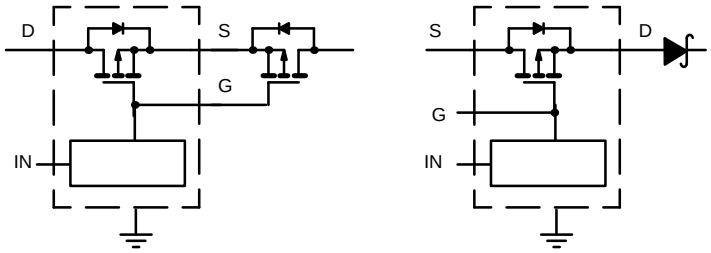


FIGURE 2. Discrete Circuit and Si4720CY Equivalent Circuit



3a 3b

FIGURE 3. Si4720CY Switch, 1/2 Si4720cy with MOSFET, 1/2 Si4720CY with Schottky

SWITCH CONFIGURATIONS

The Si4720CY has been designed to allow three different configurations of the switch: 1) the two halves of the Si4720CY connected as a single switch, 2) the Si4720CY and two external MOSFETs connected as two individual switches, and 3) the Si4720CY with two Schottky diodes connected as two individual switches. Each configuration has its own advantages. The optimal situation may be a combination of the configurations to give the best combination of applied cost and performance.

Using the Si4720CY as a single switch (Figure 2) is the most flexible, compact, and efficient form. It is a single-component solution. It allows individual control of the two MOSFETs, which is important in some startup strategies. The 20-mΩ MOSFETs provide a low voltage drop switch with low power loss.

Using the Si4720CY with external MOSFETs (Figure 3a) provides most of the advantages of the full Si4720CY configuration. A single switch requires half of the Si4720CY and an external p-channel MOSFET such as Vishay Siliconix's Si4435DY. A two-switch configuration requires three components—the Si4720CY and the two MOSFETs—and is still compact compared to a discrete solution. Like the full Si4720CY configuration, this approach provides a low voltage drop switch with low power loss. Individual control of the MOSFETs in the switch is sacrificed, however, since the gate drive for the external MOSFET comes from the control circuit for that half of the Si4720CY.

Combining the Si4720CY and Schottky diodes (Figure 3b) requires the most PCB space, produces the highest drop, and dissipates the most power of the three configurations presented. A 3-A Schottky diode is packaged in an SMD or DPAK package. The one advantage is cost, as a Schottky diode is less expensive than a MOSFET or half of an Si4720CY.

SI4720CY OPERATION

The Si4720CY has been designed to turn on in 1.3 μs and to turn off in 50 ns. The faster turn-off time ensures that no shoot-through will occur if two reverse-blocking switches are switched at the same time (one off and one on). Figures 4, 5, and 6 show this mode of switching for each of the three configurations of reverse-blocking switch. The top trace is the control signal. This signal and its inversion drive the switches. The bottom signal is the switch output, showing a switch from a 7.5-V source to a 12.5-V source. The load is 100 μF and 5 Ω connected in parallel. In all cases, the break-before-make time is at least 1 μs.

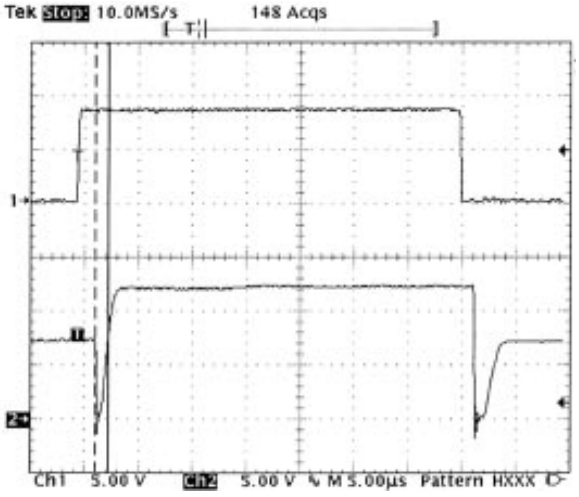


FIGURE 4. Si4720CY Switching

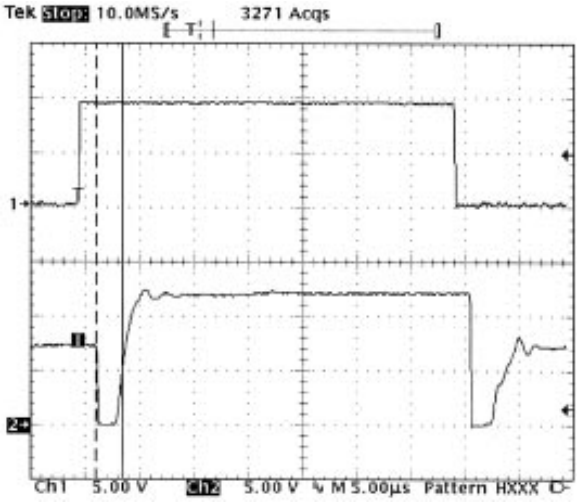


FIGURE 5. Si4720CY/MOSFET Switching

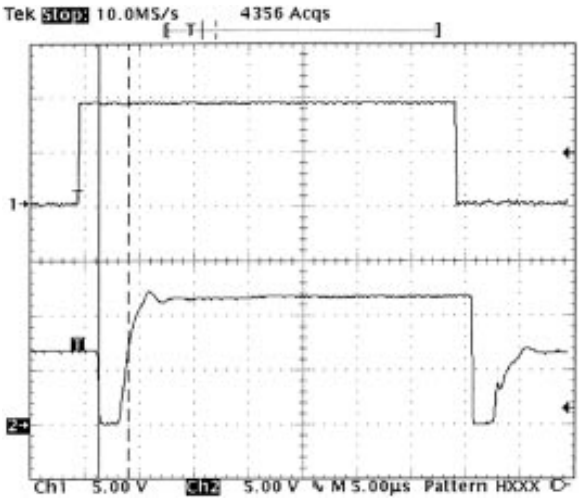


FIGURE 6. Si4720CY/Schottky Diode Switching

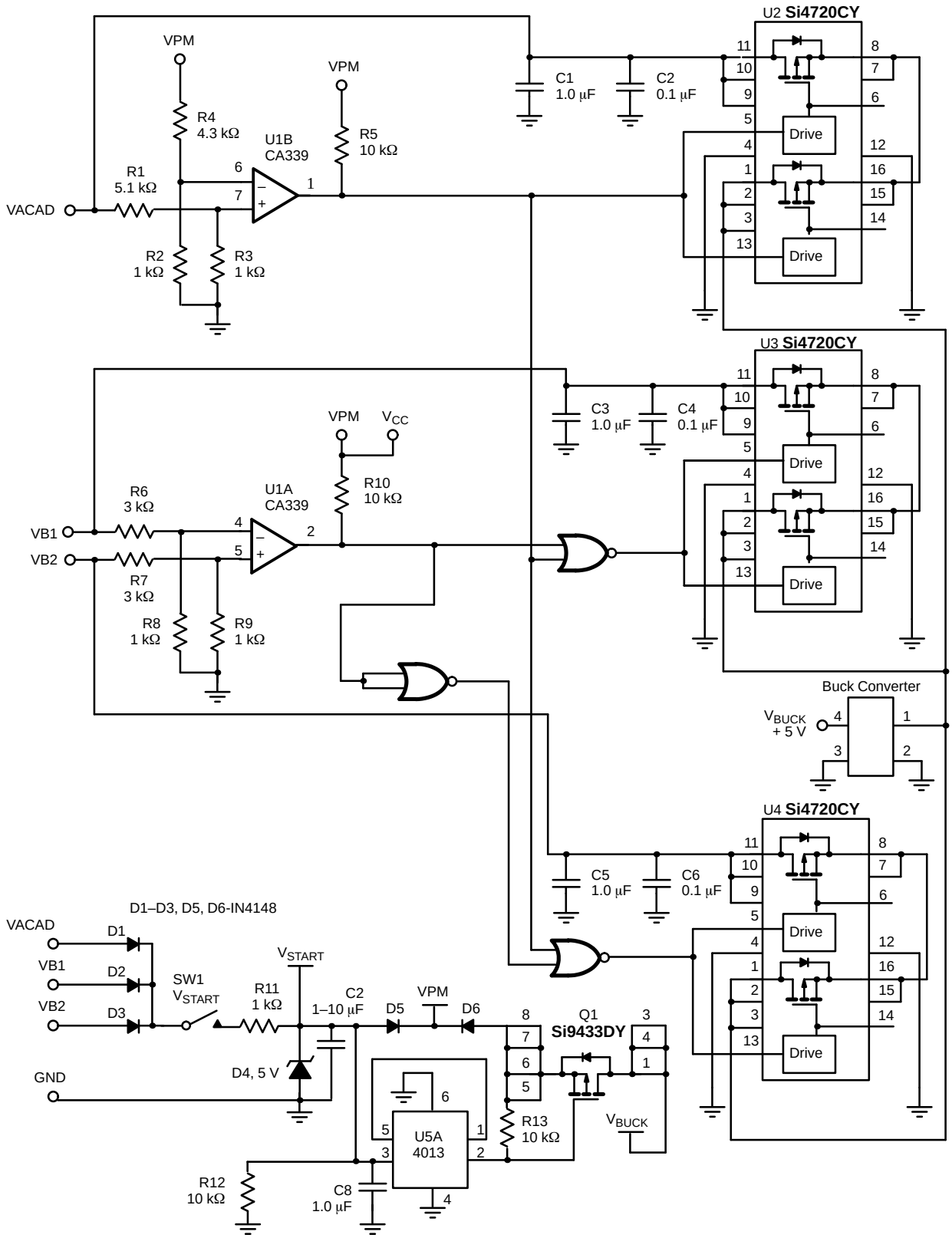


FIGURE 7. Si4720CY Block Diagram

A MULTIPLE POWER SOURCE SWITCHING SYSTEM

Figure 7 shows a power system with two batteries and an ac adapter. Each power source is controlled by a switch in the full Si4720CY configuration. This ensures full isolation of each power source from the other when the switch is off.

The start-up circuit consists of three diodes, a resistor, a zener diode, a capacitor, and the start switch. When the start switch is closed, the highest of the three supply voltages is coupled to the zener regulator. The resultant 5 V is used to turn on the power selection circuitry. This circuitry determines what power sources are available and which source should supply the system. If the ac adapter is present, its Si4720CY switch is turned on, and the switches for Battery 1 and Battery 2 are inhibited. If the ac adapter is not present, one of the batteries will become the power source used. The comparator decides which battery has the highest voltage, and turns on the corresponding Si4720CY switch. With the system powered, the power selection circuitry is powered from the system supply instead of the start-up supply.

Once the system is running, the power management circuitry will monitor what power sources are available and their status. On the basis of this information, the circuitry can decide which power source should be used. When it is time to switch to a new source, the transfer from the current to the new power source must be transparent to the system. The switches break before make to provide the transfer without having two power sources connected simultaneously. But this must occur quickly to avoid any interruption in power to the system. The system capacitance must be large enough to support the system's power requirements for the switching period.

THERMAL PERFORMANCE

There are three operating conditions to be considered when evaluating thermal performance: start-up, switch-on, and switching from one power source to another. In each case,one must use the appropriate form of Rθja to determine the maximum junction temperature rise. The maximum temperature rise added to the maximum ambient temperature must not exceed 150°C for reliable operation.

The start-up condition as described earlier can be the most thermally stressful. At start-up, the system capacitance is at 0 V. A large surge current passes through the MOSFETs to charge this capacitance to the supply voltage. Ignoring lead inductance of the PCB traces and the capacitance on the input power bus, the surge current is defined by I = C*dv/dt. The ac adapter voltage represents the worst-case condition for the surge current.

The start-up surge should be viewed as a single-pulse condition. Figure 8 shows the amount of current the switch can handle for a given pulse-width at ambient temperatures of 25°C, 70°C, and 85°C. It must be remembered that these curves assume the junction temperature will not exceed 150°C; hence, the maximum current capability decreases as the ambient temperature increases.

When the switch is on and normal operating current is flowing, the switch functions in a steady-state condition. With a steady-state Rθja of 83°C/W, the switch can dissipate 1.5 W. In terms of a worst-case $r_{DS(on)}$ an ambient temperature of 25°C, the maximum switch current is 7.0 A. Since the ambient temperature is typically higher than 25°C, the maximum current is lower. Figure 9 shows how maximum current varies with ambient temperature.

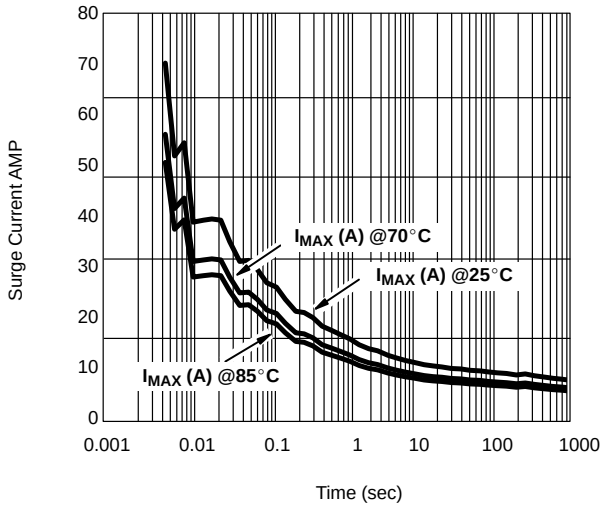


FIGURE 8. Si4720CY Surge Current

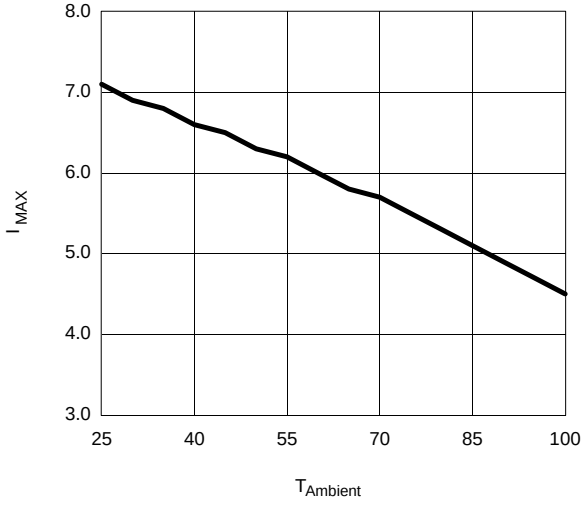
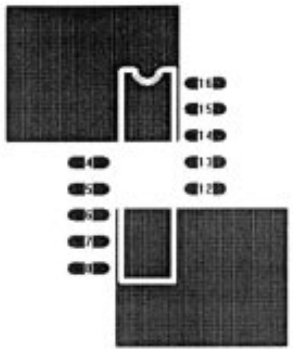


FIGURE 9. Maximum vs.. Ambient Temperature

When switching from one power source to another, there are two components to the current that must be considered. The first component is the current the system is drawing for normal operation. The second is the surge current. The surge current occurs when the new power source voltage is higher than the old voltage, and the system capacitance must be charged to the new voltage. The MOSFET junction must stay below 150°C when subjected to the sum of these currents. The period of the summed currents is a single-pulse condition.

Just like a standard LITTLE FOOT device, the Si4720CY relies on the drain pins to transfer heat from the MOSFET junction to the PC board. Therefore, each MOSFET in the Si4720CY needs planar copper to transfer heat into the PC board. Figure 10 gives the minimum recommended pattern for mounting the Si4720CY. This pattern is based on a standard 16-pin SOIC pattern with spreading copper added to the drain pins. The area required by the Si4720CY is approximately the same as the area required by two individual MOSFETs in SO-8 packages. Using the Si4720CY frees up the PCB area used by the four small-signal MOSFETs, the four resistors, and two capacitors that are used with the two power MOSFETs in the equivalent discrete circuit. If additional PC board area is available, additional copper area will improve heat transfer.



SO-16 with Heat Spreading Pads.
Pad Dimension 0.320 x 0.260

FIGURE 10. Si4720CY Pad Pattern

CONCLUSION

The Si4720CY battery disconnect switch provides a powerful tool for switching multiple power sources. The combination of two Trench MOSFETs and control circuirty in a single package allows the control of high currents with an absolute minimum number of components, simplifying the design process and ensuring that the required PC board area is minimized.