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Using high-current integrated-switch power-regulator ICs

LEARN THE THERMAL CONSIDERATIONS SO YOU DON'T GET BURNED.

Switching regulators with integrated power transistors provide simplicity, require few components, and make compact step-down power supplies. Few of these devices can supply more than 5A load current, so, when designing with these high-current integrated-switch regulators, you must consider thermal management, bypassing of the supply voltage, and board layout. At load currents of 5A or more, these topics become critical, and you must understand them before selecting a power-management architecture.

Simplicity and size are the biggest advantages of combining the power switch with the control circuitry on one IC. In addition, you can use the MOSFET the semiconductor company selected to go with the control circuitry, and you can minimize the required PCB (printed-circuit-board) area because the power supply requires only one IC instead of a controller IC and one or more power-switch ICs. A disadvantage of an integrated design, however, is that high-power output currents are present on the sensitive control die. Also, the thermal dissipation of the power switch instantaneously heats up the control circuitry.

With these advantages and drawbacks in mind, you can decide whether to use an integrated power switch. **Figure 1** shows a step-down dc/dc converter with an integrated power switch, or regulator IC. Designs with an external power switch comprise a controller IC plus a discrete power switch, usually a MOSFET.

For thermal considerations, you must determine through direct measurement how much electrical power turns into heat inside the regulator IC. Alternatively, you can assume total power-supply efficiency and then break down the losses into conduction losses and switching losses. You then assign them to the components on the PCB (**Reference 1**). A switching regulator at 5A of output current typically dissipates 2W of power. To prevent the silicon from exceeding its maximum temperature limit, you must dissipate the power away from the silicon through the package to the PCB and, ultimately, to the surrounding air. You must optimize PCB layout to achieve the best flow of heat. Fans effectively cool circuits, but, for most applications, using a fan is unacceptable due to cost, noise, and maintenance issues. Getting by without a fan often requires the use of convection air cooling or large heat sinks.

A thermal plot of an IC with 15V input, 3.3V output, and a 5A load current shows hot spots (**Figure 2**). The hottest area is freewheeling diode D_1. To aid in the thermal dissipation of the diode, choose a Schottky diode with a low package thermal resistance. You might replace the SMC-packaged diode of **Figure 2** with a D-Pak or D2Pak that has lower thermal resistance than the SMC package.

Choosing a package requires a trade-off between pin count and the thermal resistance. Standard packages have either many pins and higher thermal resistance or fewer pins and lower thermal resistance. A good package for high power dissipation is the TO-263 thin package, which has a large exposed pad like the classic TO-263 package but is much thinner.

THERMAL CONSIDERATIONS

When you incorporate thermal considerations into the design of a PCB, your primary goal is to efficiently conduct energy away from the heat source. If you effectively achieve this goal, the whole board has an even temperature distribution. Your next concern is moving heat from the PCB into the surrounding air or adjacent materials, such as the product casing. The more copper a PCB has, the better the heat transfer away from any hot spots is. Copper also helps heat transfer

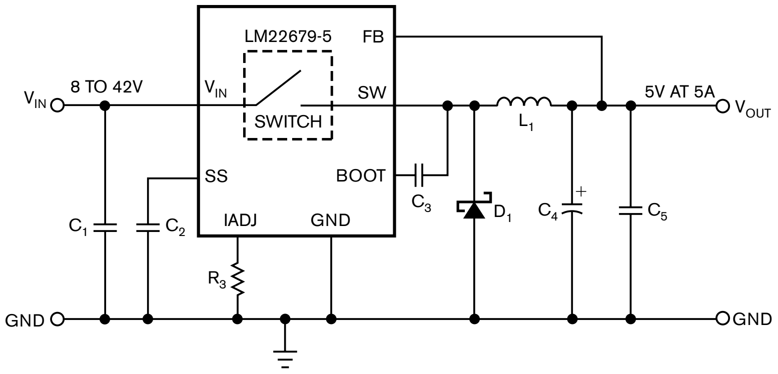

Figure 1 This step-down buck dc/dc-converter IC features an integrated power switch.

away from the board. More layers within the PCB enable better heat transfer than does one or two layers. A common PCB standard uses two ounces of copper per square foot of board area. You are better off with thicker copper, larger copper areas, and more PCB layers.

Use vias between the hot spots and the bottom of the board to effectively conduct the heat away. You should also fill the vias with solder, which does not have the best thermal conductivity but conducts heat much better than does air. However, not all board-manufacturing processes allow for solder-filled vias. Manufacturers often place small vias next to each other for good thermal transfer. The most thermally effective vias are those that are as close to the heat source as possible—often right below a thermal pad of the regulator IC. Unfortunately, not all manufacturing processes allow such a placement. You should spread the heat-generating components around the PCB to avoid hot spots, but the electrical considerations call for close placements. You must find a compromise.

ELECTRICAL CONSIDERATIONS

It is difficult to keep the voltage supply for the regulator's internal rails clean. Many circuit blocks in the IC, such as the internal bandgap reference and the comparators for the feedback loop, need low noise to perform correctly. In a buck regulator, the input trace is a noisy node because it quickly switches from full current to no current. Integrated power regulators often use separate pins for the supply voltage of the internal rails and as the input to the main power switch. With packages having low thermal resistance, the IC may have only one supply pin for the internal voltage and the power stage. In such cases, you must filter the input-voltage pin to keep the switching noise low. Use a high-quality ceramic bypass capacitor and connect it close to the input-voltage and ground pins. This rule is among the most important for step-down voltage regulators, and it is especially important for regulator ICs with integrated power switches.

The second important rule is to keep ac traces as short as possible. Circuits in which the current flow changes as the power switch changes state are ac traces. It is important to keep these traces especially short to minimize trace-inductance-generated voltage offsets. The shorter these traces are, the less voltage offset the IC generates across them, and the resulting system noise is lower. You can find the ac traces by printing the schematic of a circuit three times. Use a pen on one of the printouts to draw along the traces in which current flows when the power switch is on. Use the second printout and mark where current flows when the power switch is off. On the third printout, mark all the traces that you marked on the previous two printouts but not on both of them. This approach yields a plot with all the ac traces.

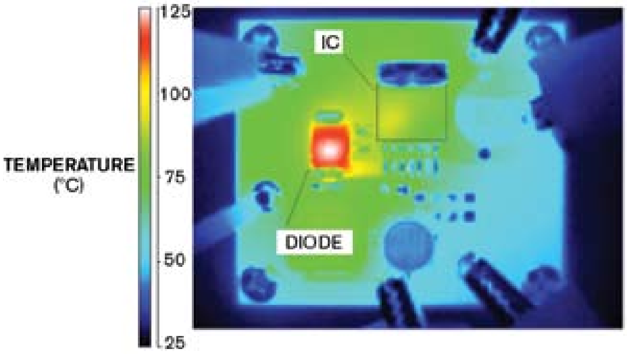

Figure 2 A thermal camera takes an image that shows hot spots on a PCB.

Several ac current flows occur in a buck regulator, including the most critical traces: those during the on-state of the switch, the off-state of the switch, and between the two switch states (**Figure 3**). Small circuit loops and thick traces minimize the parasitic trace inductance. In contrast to thermal design, the electrical requirement is to keep components, especially along the ac traces, as close together as possible.

To decide whether you can use an integrated power-MOSFET step-down regulator, you must do more than look at the maximum input-voltage range and load current. Thermal considerations are important because they can rule out the implementation of an integrated power switch. Integrated-switch power-management circuits can well serve systems with forced airflow with low ambient temperatures or short peaks at maximum load current. **EDN**

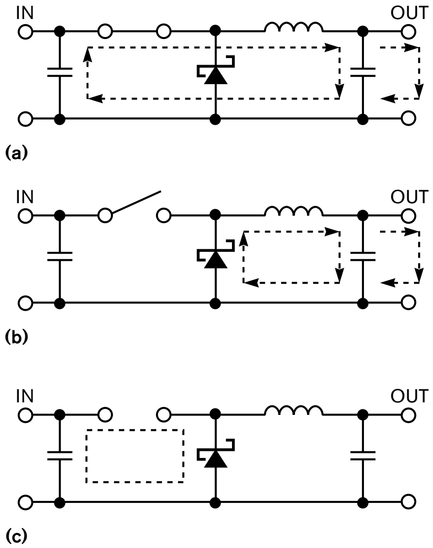

Figure 3 The ac current flows in a buck-regulator circuit during the on-state of the switch (a), the off-state of the switch (b), and between the two switch states (c).

REFERENCE

1 Dostal, Frederik, "Techniques for Thermal Analysis of Switching Power Supply Designs," Application Note 1566, National Semiconductor, February 2007, www.national.com/an/AN/AN-1566.pdf.

AUTHOR'S BIOGRAPHY

Frederik Dostal is an application engineer at National Semiconductor's design center (Phoenix). He joined the company in 2001, and his responsibilities have included support for Europe and Central Europe and coverage of many automotive accounts. Dostal's current position involves product development and support for switching regulators and controllers. He holds a degree in electrical engineering from the Friedrich-Alexander-Universität (Erlangen, Germany) and is a member of the IEEE.