A Cool Circuit: 48V Ideal Diode-OR Reduces Heat Dissipation

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Introduction

High availability systems commonly demand redundant power supplies or backup battery feeds to enhance reliability. Traditionally, Schottky diodes were used to diode-OR these supplies at the point of load. However, as load currents climb, the forward voltage drop of the ORing diodes becomes a significant source of power loss. Designers are thus tasked with creating elaborate thermal layouts and heat sinks to contend with the diodes' rising temperatures.

A better solution for a high current, high availability system is to replace the Schottky diodes with MOSFET-based ideal diodes. This lowers the forward voltage drop of the diode-OR, shrinking thermal layouts and improving system power efficiency. The 4mm × 3mm LTC4355 simplifies the design of MOSFET ORing circuits by controlling two N-channel MOSFETs, which can combine supplies with voltages between 9V and 80V. The LTC4355 also provides the input voltage monitors, input fuse monitors, and forward voltage drop monitors frequently required in these systems.

Operation

The LTC4355's basic operation is straightforward. It uses a linear amplifier and an internal charge pump to maintain a 25mV forward voltage drop across the external N-channel MOSFETs. The MOSFET sources are connected to the input supplies and the drains are joined at the output (Figure 1). When power is first applied, load current flows from the input supply with the higher voltage through the body diode of the MOSFET. The LTC4355 senses the voltage drop and enhances the MOSFET. For small load currents, the voltage across the MOSFET is limited to 25mV. Larger load currents cause the LTC4355 to fully enhance the MOSFET, resulting in a voltage drop of $R_{DS(ON)} \bullet I_{LOAD}$. The linear amplifier provides a smooth switchover between supplies without the oscillations, chatter, and reverse current common to comparator-based designs. If the higher input supply abruptly drops more than 25mV below the output voltage, as may occur during an input short circuit, the LTC4355 pulls the MOSFET gate low within about 0.5µs to limit the amount of reverse current that flows from the output back to the input.

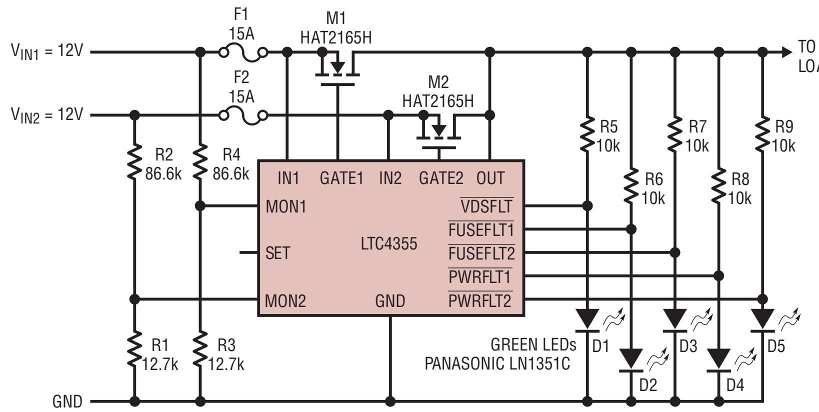

Figure 1. 12V/15A ideal diode-OR application

Fault Monitors

In addition to controlling the MOSFETs, the LTC4355 also performs several system health monitoring functions required in high availability systems. It detects when a fuse is blown, an input supply is low, or the forward voltage across a MOSFET is excessively large. If a fuse blows open, the $\overline{\text{FUSEFLT1}}$ or $\overline{\text{FUSEFLT2}}$ pin pulls low to signal which fuse has opened. Similarly, when an input supply is below its minimum voltage, configured by a resistive divider, the $\overline{\text{PWRFLT1}}$ or $\overline{\text{PWRFLT2}}$ pin pulls low to indicate which supply is out of regulation. The $\overline{\text{PWRFLT1}}$ and $\overline{\text{PWRFLT2}}$ pins also indicate when the forward voltage across a MOSFET exceeds a voltage programmed with the SET pin. Excessive forward voltage is a sign that a MOSFET may have failed or is conducting too much current. The LTC4355 in the DFN-14 package provides a $\overline{\text{VDSFLT}}$ pin, which also pulls low under this condition to allow the system to differentiate between a supply that is out of regulation and a MOSFET with too much forward voltage.

12V/15A Ideal Diode-OR

Figure 1 shows a simple 12V/15A ideal diode-OR application. An MBR1635 Schottky diode would dissipate 8W in this circuit. In contrast, the HAT2165 3.4mΩ MOSFET drops 15A • 3.4mΩ = 51mV and dissipates only 51mV • 15A = 0.765W. The result is a drastic reduction in PCB area and heat sinking required to dissipate the power, not to mention a 4-point improvement in efficiency.

In this circuit, green LEDs indicate normal operation, and fault conditions cause the LEDs to turn off. Resistive dividers connected between the input supplies and the MON1 and MON2 pins configure the supply monitor thresholds near 10V. When a supply is below its minimum voltage, the respective $\overline{\text{PWRFLT1}}$ or $\overline{\text{PWRFLT2}}$ pin pulls low, thus turning off the D4 or D5 LED.

Likewise, the D2 or D3 green LED turns off to signal when a fuse has blown open. Under this condition, the IN1 or IN2 pin is pulled to ground by an internal 0.5mA pulldown current. As soon as the LTC4355 senses that one of these pins is below 3.5V, it pulls the $\overline{\text{FUSEFLT1}}$ or $\overline{\text{FUSEFLT2}}$ pin low. Note that this condition also occurs when an input supply falls below 3.5V. Therefore, it may be necessary to confirm that $\overline{\text{PWRFLT1}}$ or $\overline{\text{PWRFLT2}}$ is high impedance, signaling a valid input supply voltage, before concluding that a fuse is blown open.

In Figure 1, the LTC4355 detects that a MOSFET has failed or is conducting excessive current by sensing the forward voltage drop across the MOSFET. The faults detected include a MOSFET that is open on the higher supply, excessive MOSFET current due to overcurrent on the load, or a shorted MOSFET on the lower supply. When one of these conditions occurs, the LTC4355 pulls the $\overline{\text{VDSFLT}}$ pin (DFN-14 package only) and the $\overline{\text{PWRFLT1}}$ or $\overline{\text{PWRFLT2}}$ pin low to indicate which supply has the fault. The forward voltage threshold is configured at 1.5V by leaving the SET pin open. Tying the SET pin directly to ground or through a 10kΩ resistor to ground configures this threshold at 0.25V or 0.5V, respectively. Note that during startup or when a switchover between supplies occurs, the $\overline{\text{VDSFLT}}$ pin and the $\overline{\text{PWRFLT1}}$ or $\overline{\text{PWRFLT2}}$ pin may momentarily indicate that the forward voltage has exceeded the programmed threshold during the short interval when MOSFET gate ramps up and the body diode conducts.

48V/5.5A High Side and Low Side Ideal Diode-ORs

Many high availability systems require diodes on both the high and low side of the redundant power feeds. Combining the LTC4355 with the LTC4354 provides a complete solution for these applications. In the 48V/5.5A circuit of Figure 2, the LTC4355 and two FDS3672 MOSFETs perform the high side ORing function while the LTC4354 and two FDS3672s perform low side ORing.

At 5.5A, an MBR10100 Schottky Diode in a TO-220 package dissipates over 3W. The current passes through both a high side and a low side diode, resulting in a total power dissipation of over 6W. In contrast, an FDS3672 in a smaller SO-8 package dissipates 0.6W for a total of 1.2W. The ideal diode solution lowers the total power dissipation by 80%, reducing the necessary PCB area and heat sinking.

In the circuit in Figure 2, the LTC4355 and LTC4354 receive power when either input supply is present. The LTC4354's positive supply pin, V_{CC}, is regulated from the output of the LTC4355, always within a diode drop of the higher input voltage (+48VA or +48VB). At the low side, the LTC4355's negative supply pin, GND, connects to the output of the LTC4354, always within a diode drop of the more negative voltage (RTNA or RTNB). Consequently, both parts remain powered even when one of the supplies is disconnected or is out of regulation.

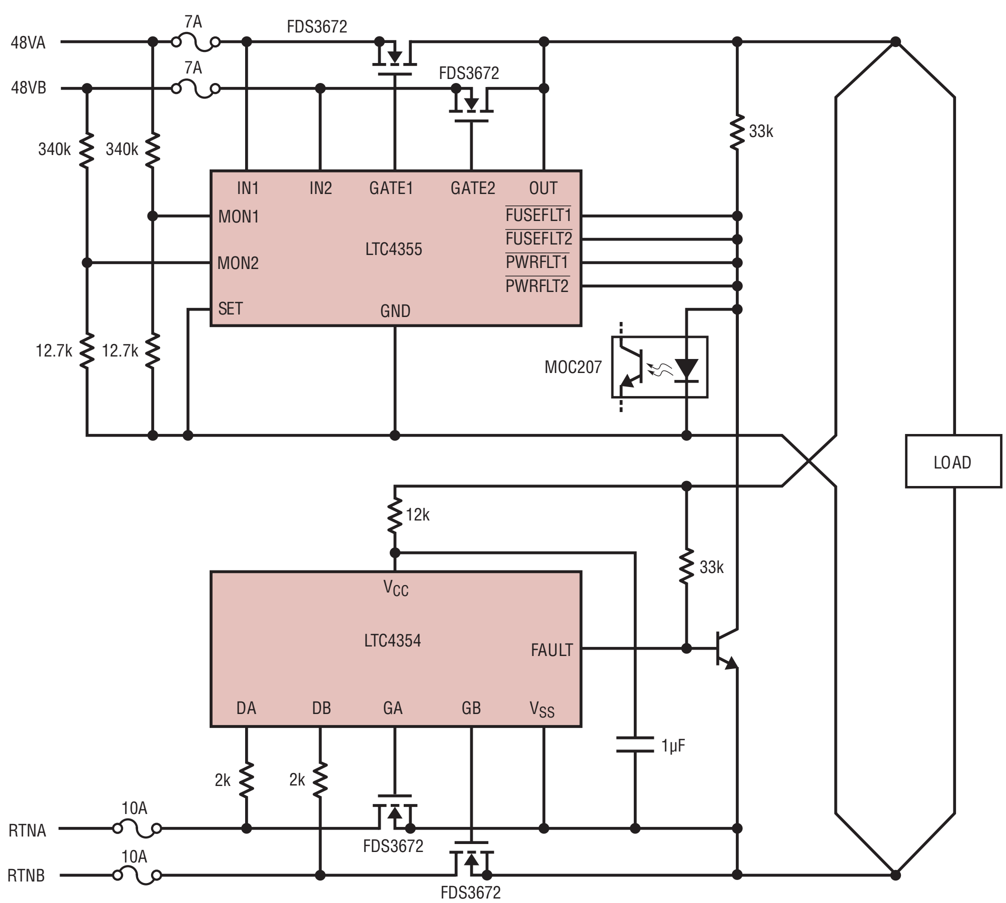

Figure 2. 48V/5.5A positive supply and negative supply diode-ORing with combined fault outputs.

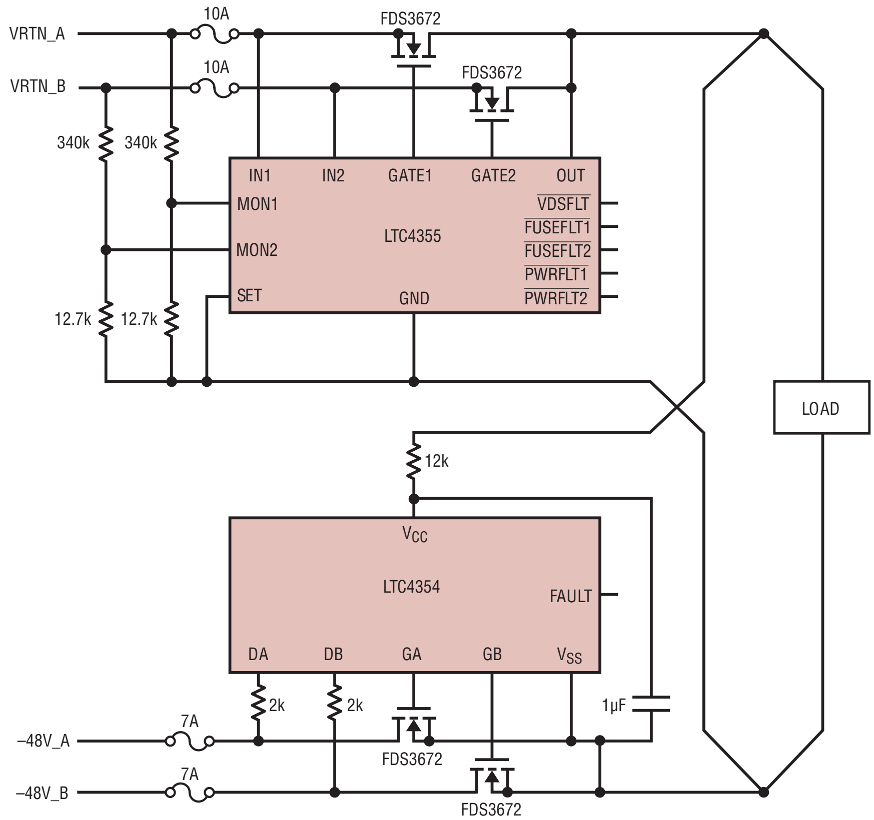

Figure 3. –48V/5.5A positive and negative supply diode-ORing for telecom systems.

Large supply variations and transients are easily accommodated by the wide operating voltage ranges of these two parts, 4.5V to 80V for the LTC4354 and 9V to 80V (100V absolute maximum) for the LTC4355.

This circuit combines all fault indicators to drive one optoisolator. If an input supply falls to less than 36V or the forward voltage drop across one of the positive-side MOSFETs exceeds 0.25V, the LTC4355's $\overline{\text{PWRFLT1}}$ or $\overline{\text{PWRFLT2}}$ pin pulls low to signal the fault. If a positive-side fuse blows open, the LTC4355 indicates a fault by pulling the $\overline{\text{FUSEFLT1}}$ or $\overline{\text{FUSEFLT2}}$ pin low. Finally, if the forward voltage across a low side MOSFET exceeds 0.26V, the LTC4354's FAULT pin drives an NPN that turns off the same optoisolator driven by the LTC4355's pins.

Because the high side fuses have lower current ratings than the return fuses, the high side fuses blow first under most fault conditions. With the return fuses intact, system potentials tend to settle near ground after a fuse blows open.

The $\overline{\text{VDSFLT}}$ pin is not shown in this schematic. Since the $\overline{\text{PWRFLT1}}$ or $\overline{\text{PWRFLT2}}$ pin pulls low when the $\overline{\text{VDSFLT}}$ pin pulls low, $\overline{\text{VDSFLT}}$ is redundant in this application. Furthermore, this schematic is capable of accommodating not just the smaller DFN-14 package, but also the larger SO-16 package. While the SO-16 lacks a $\overline{\text{VDSFLT}}$ pin, it features the wider pin spacing sometimes desirable in higher voltage applications.

–48V/5.5A High side and Low Side Diode-ORs for Telecom

Many –48V telecom systems, including those that conform to the new AdvancedTCA specification, require ORing circuits on both the high and low side of the redundant power feeds. A few simple modifications convert the +48V solution in Figure 2 to the –48V solution in Figure 3. The +48V supply input becomes the return feed, VRTN, and the returns in the +48V system now serve as the –48V input feeds. The 10A and 7A fuses have been swapped, placing the 10A fuse in the high side return path. As a result, most fault conditions cause the high side 7A fuse to blow before the low side 10A fuse. Consequently, system potentials generally settle near VRTN after a fuse blows. The minimal circuit in Figure 3 does not connect the fault pins. If desired, faults can be monitored with a circuit similar to that in Figure 2.

Conclusion

The LTC4355 frees up PCB area by reducing power dissipation and the size of associated heat sinks in applications that require supply ORing. Its wide 9V to 80V supply operating range and 100V absolute maximum rating accommodate a broad range of input supply voltages with ample margin for supply variations and transients. In addition, the ability to provide system health monitoring functions makes it especially well suited to high-availability applications. Those systems that require both high side and low side ORing can combine the LTC4355 with the LTC4354 to form a complete solution.

LT3009, continued from page 9

Conclusion

The LT3009 offers ultralow quiescent current, a shutdown mode, and wide input and output voltage ranges in tiny 2mm × 2mm DFN and SC70 packages without sacrificing performance or reliability. A stable output is available with a wide range of output capacitors, including small ceramics. Internal protection circuitry in the LT3009 eliminates the need for external protections diodes, further saving space and lowering cost. Competing devices can't come close to the performance and advantages that the LT3009 offers in the world of ultralow quiescent current regulators.