Replace –48V ORing Diodes with FETs to Reduce Heat and Save Space

by James Herr

Introduction

Critical high availability telecom systems often employ parallel-connected power supplies or battery feeds to achieve redundancy and enhance system reliability. Power supply selection is usually left to ORing diodes, but there is significant forward voltage drop in diodes, which reduces efficiency. The voltage drop also reduces the available supply voltage and dissipates significant power. A better solution would retain the diode behavior without the undesirable voltage drop and the resulting power dissipation.

The LTC4354 is a negative voltage diode-OR controller that replaces ORing diodes by driving two external N-channel MOSFETs as pass transistors. The device maintains a small 30mV voltage drop across the MOSFET at light load, while at heavy load, the low $R_{DS(ON)}$ of the external MOSFET reduces the power dissipation. Lower power dissipation saves the space and cost of extra heat sinks.

For example, in a 10A, –48V application, the voltage drop across a 100V Schottky diode (MBR10100) is around 620mV. Extra PCB space or additional heat sinking is required to handle the 6.2W of power dissipation. A LTC4354 with a 100V N-channel MOSFET (IRFS4710) as the pass transistor dissipates only 1.4W of power—due to the low 14mΩ(max) $R_{DS(ON)}$ of the MOSFET—that can be easily dissipated across the existing PCB. Figure 1 compares the power dissipation of the Schottky diode and the MOSFET.

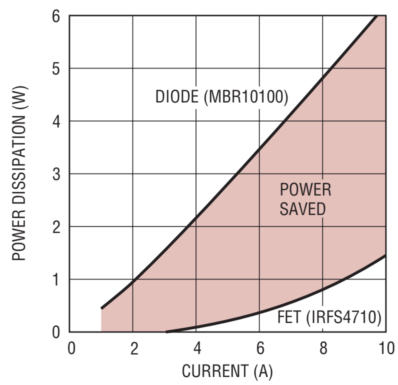

Figure 1. FET-based diode circuit saves power

Regulated MOSFET Drop Ensures Smooth Switchover

The LTC4354 controls two external N-channel MOSFETs with the source pins connected together. This common source node is then connected to the V_{SS} pin, which is the negative supply of the device. The positive supply for the device is derived from –48V_RTN through an external current limiting resistor (R_{IN}). An internal shunt regulator clamps the voltage at the V_{CC} pin to 11V above V_{SS}. At power-up, the initial load current flows through the body diode of the MOSFET and returns to the supply with the lower terminal voltage. The associated gate pin immediately starts ramping up and turns on the MOSFET. The amplifier regulates the voltage drop between the source and drain connections to 30mV. If the load current causes more than 30mV of drop, the gate rises to further enhance the MOSFET. Eventually the MOSFET is driven fully on and the voltage drop is equal to $R_{DS(ON)} \bullet I_{LOAD}$ (see Figure 2).

When the power supply voltages are nearly equal, this regulation technique ensures that the load current is smoothly shared between them without oscillation. The current level flowing through each pass transistor

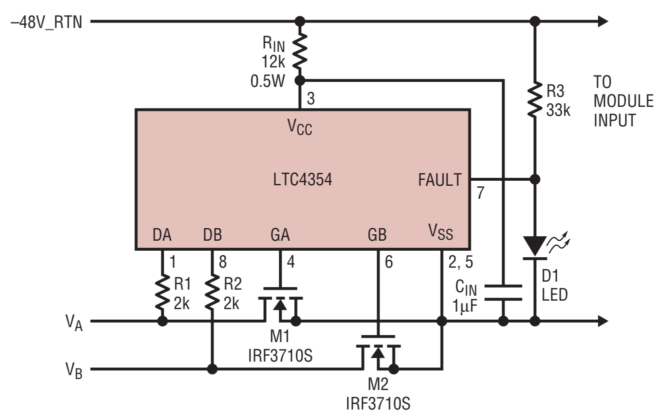

Figure 2. –36V to –72V at 5A typical design example

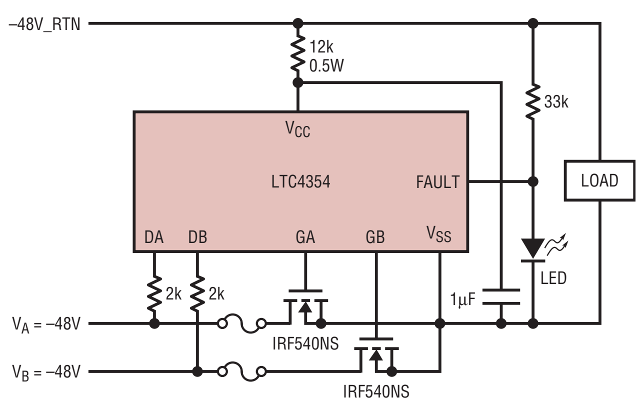

Figure 3. –48V diode-OR controller monitors and reports open fuses

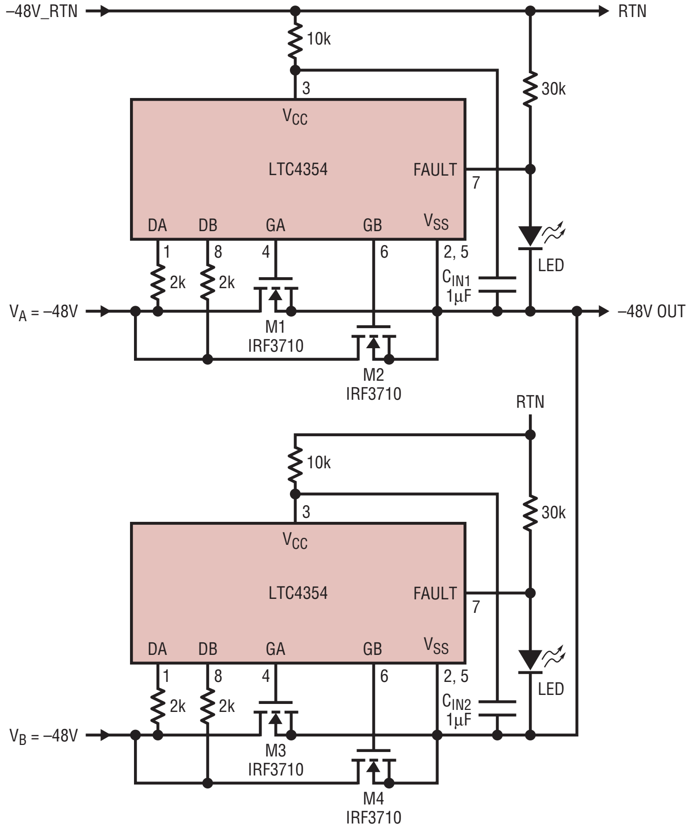

Figure 4. Parallel MOSFETS for high current (up to 20A) application

depends on the $R_{DS(ON)}$ of the MOSFET and the output impedance of the supplies.

In the case of supply failure, such as an input supply short to –48V_RTN, a large reverse current flows from the –48V_RTN terminal through the MOSFET that is on. This charges up the load capacitance, and eventually flows through the body diode of the other MOSFET to the second supply. The LTC4354 detects this failure condition as soon as it appears and turns off the MOSFET in less than 1µs. This fast turn-off prevents the reverse current from ramping up to a damaging level.

Fault Output Detects Damaged MOSFETs and Fuses

The LTC4354 monitors each FET and reports any excessive forward voltage that indicates a fault. When the pass transistor is fully on but the voltage drop across it exceeds the 250mV fault threshold, the FAULT pin goes high impedance. This allows an LED or optocoupler to turn on indicating that one or more of the following conditions exist.

Current overload: The load condition is too high for the $R_{DS(ON)}$ of the MOSFET. Extra heat is being generated due to the large voltage drop across the pass transistor. A larger MOSFET with lower $R_{DS(ON)}$ should be used in the application.

MOSFET open: The MOSFET that was conducting most or all of the current has failed open. The load current is being diverted to the other supply with the higher potential through the remaining MOSFET. This raises the potential at the V_{SS} pin and causes a large voltage drop across the failed MOSFET. This can also indicate a blown fuse in series with the MOSFET (see Figure 3).

MOSFET short: The MOSFET that is conducting most or all of the current has failed short. In normal operation this does not trigger the fault flag. But should the power supply with the lower terminal voltage rise up, due to excessive load current or it is replaced by another supply with higher terminal voltage, a large cross conduction current will flow between the supplies. In this case, the voltage drop across the MOSFET that is not damaged can easily surpass the fault threshold.

Handle Large Currents with Multiple LTC4354s

Multiple LTC4354s can be connected in parallel to accommodate large supply currents (see Figure 4). Multiple MOSFETs can also be connected in parallel to a single gate drive pin but at the cost of a longer turn-off time when the current reverses.

Low Voltage Operation

Multiple low voltage supplies can also be diode-ORed together using LTC4354 to increase reliability. Figure 5 shows the LTC4354 controlling two logic level N-channel MOSFETs providing the diode-OR function for two –5.2V power supplies. The current limiting resistor at the V_{CC} pin is not needed since the LTC4354 can

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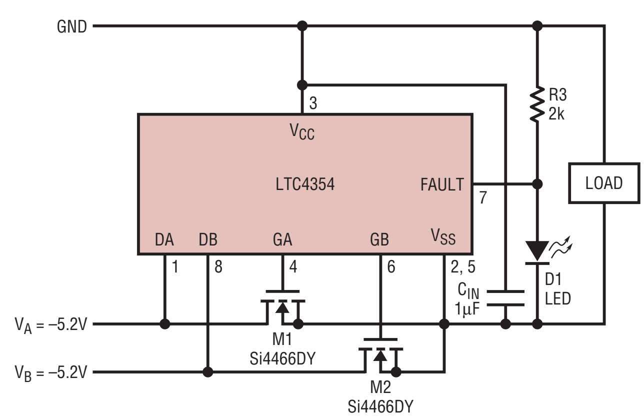

Figure 5. Low voltage diode-OR saves power and improves reliability

increased primary to secondary turns ratio which reduces primary current and allows the use of lower voltage, lower loss primary and secondary MOSFETs.

Operation

The LTC3723 controller's basic features, its flexibility and support for secondary synchronous rectifiers (with adjustable timing) make it an excellent choice for virtually all isolated, synchronous topologies. In this full-bridge application, the SOT23, LTC4440, 100V, 2.4A high side driver is used to translate the gate drive signal to the upper MOSFETs, Q1 and Q2. The LTC3723 integrated driver switches the lower MOSFETs directly. The LTC3723 initial bias voltage is derived via trickle-start resistor R3. Once switching begins, the IC is powered from transformer T1.

Output MOSFETs Q12–Q15 are controlled by the LTC3901secondary side synchronous MOSFET driver, which includes a number of unique features to ensure safe operation of the synchronous MOSFETs under all conditions. The LTC3901 receives a sequence of alternating input positive and negative input pulses from the LTC3723 through T2. Zero voltage on the SYNC input (indicating the freewheeling period) turns both synchronous MOSFETs on after an initial negative pulse. Subsequent positive and negative pulses determine which synchronous MOSFET should be off. Incorrect sequences of pulses cause both synchronous MOSFETs to turn off. Missing pulses initiate a user programmable time-out. This avoids potentially harmful negative output inductor currents result from the synchronous MOSFETs being left on too long (during power down, for example). Finally, the LTC3901 V_{DS} comparators monitor the voltage drop across the synchronous MOSFETs, offering a second level of protection against excessive negative inductor currents.

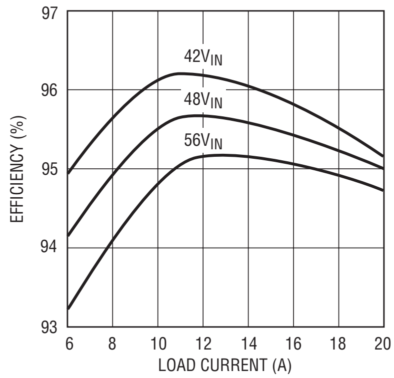

Figure 4. Efficiency of the circuit in Figure 3

Conclusion

The LTC3723-1 controller teams up with the LTC4440 and LTC3901 to squeeze 240W into 3.3 square inches of board space. The 12V application circuit shown takes advantage of the full bridge transformer utilization and reduced input range to increase efficiency beyond 95%.

PoE Port Current, continued from page 33

0.3V outside the supply rails. Thus, the maximum current is 600mA when using a 0.5Ω sense resistor. This is sufficient to handle an overcurrent condition before the recommended 500mA fuse blows. The 2kΩ series resistors limit current in the event of a fault. The LTC2439-1 is trimmed to provide greater than 87dB rejection of both 50Hz and 60Hz, and wideband noise rejection is better than 140dB. 100pF capacitors provide RFI suppression.

Figure 1 shows a typical powered Ethernet application that supports both 802.3af-compliant devices and legacy devices. The LTC4259 controls the actual switching of power to the individual ports. The LTC4257 in the powered device provides classification information to the LTC4259, which is then made available to the host processor via the I^2C bus for power allocation purposes. Up to 16 LTC4259s can be connected to the I^2C bus, and additional LTC2439-1s may be added to the SPI bus by providing each with a separate $\overline{CS}$ line.

LTC4354, continued from page 27

be powered directly from a supply as low as 4.5V.

Conclusion

The trend in today's telecom infrastructure is toward higher current and smaller module space. The traditional Schottky diode ORing circuit is increasingly cumbersome. The LTC4354 provides an improved ORing solution by controlling low $R_{DS(ON)}$ N-channel MOSFETs. The reduced power dissipation saves board space and cost associated with extra heat sinks. Furthermore, the LTC4354 monitors and reports fault conditions, information not provided by a traditional diode-OR circuit.