No Blocking Diode Needed to Protect Sensitive Circuits from Overvoltage and Reverse Supply Connections

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What would happen if someone connected 24V to your 12V circuits? If the power and ground lines were inadvertently reversed, would the circuits survive? Does your application reside in a harsh environment, where the input supply can ring very high or even below ground? Even if these events are unlikely, it only takes one to destroy a circuit board.

What can you do to protect your sensitive circuits from voltages that are too high, too low, or even negative? To block negative supply voltages, system designers traditionally place a power diode in series with the supply. However, this diode takes up valuable board space and dissipates a significant amount of power at high load currents.

Another common solution is to place a high voltage P-channel MOSFET in series with the supply. The P-channel MOSFET dissipates less power than the series diode, but the MOSFET, and the circuitry required to drive it, drives up costs.

One drawback to both of these solutions is that they sacrifice low supply operation, especially the series diode. Also, neither protects against voltages that are too high—protection that requires more circuitry, including a high voltage window comparator and charge pump.

UNDERVOLTAGE, OVERVOLTAGE AND REVERSE-SUPPLY PROTECTION

The LTC4365 is a unique solution that elegantly and robustly protects sensitive circuits from unpredictably high or negative supply voltages. The LTC4365 blocks positive voltages as high as 60V and negative voltages as low as –40V. Only voltages in the safe operating supply range are passed along to the load. The only external active component required is a dual N-channel MOSFET connected between the unpredictable supply and the sensitive load.

Figure 1 shows a complete application. A resistive divider sets the overvoltage (OV) and undervoltage (UV) trip points for connecting/disconnecting the load from V_{IN}. If the input supply wanders outside this voltage window, the LTC4365 quickly disconnects the load from the supply.

The dual N-channel MOSFET blocks both positive and negative voltages at V_{IN}. The LTC4365 provides 8.4V of enhancement to the gate of the external MOSFET during normal operation. The valid operating range of the LTC4365 is as low as 2.5V and as high as 34V—the OV–UV window can be anywhere in this range. No protective clamps at V_{IN} are needed for most applications, further simplifying board design.

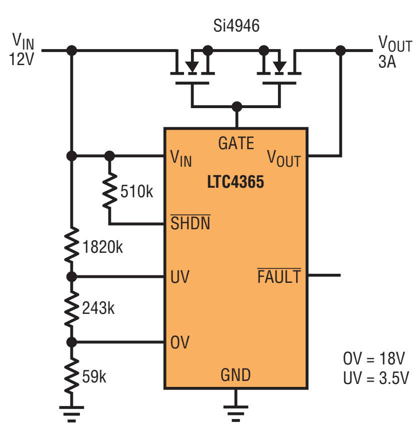

Figure 1. Complete 12V automotive undervoltage, overvoltage and reverse-supply protection circuit

Accurate and Fast Overvoltage and Undervoltage Protection

Two accurate (±1.5%) comparators in the LTC4365 monitor for overvoltage (OV) and undervoltage (UV) conditions at V_{IN}. If the input supply rises above the OV or below the UV thresholds, respectively, the gate of the external MOSFET is quickly turned off. The external resistive divider allows a user to select an input supply range that is compatible with the load at V_{OUT}. Furthermore, the UV and OV inputs have very low leakage currents (typically < 1nA at 100°C), allowing for large values in the external resistive divider.

Figure 2 shows the how the circuit of Figure 1 reacts as V_{IN} slowly ramps from –30V to 30V. The UV and OV thresholds are set to 3.5V and 18V, respectively. V_{OUT} tracks V_{IN} when the supply is inside the 3.5V–18V window. Outside of this window, the LTC4365 turns off the N-channel MOSFET, disconnecting V_{OUT} from V_{IN}, even when V_{IN} is negative.

Novel Reverse Supply Protection

The LTC4365 employs a novel negative supply protection circuit. When the LTC4365 senses a negative voltage at V_{IN}, it quickly connects the GATE pin to V_{IN}. There is no diode drop between the GATE and V_{IN} voltages. With the gate of the external

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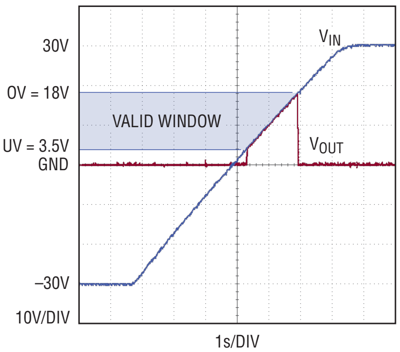


Figure 2. Load protection as V_{IN} is swept from –30V to 30V

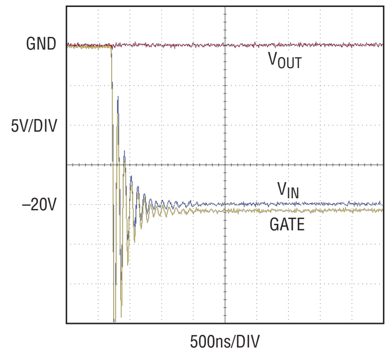


Figure 3. Hot swapping V_{IN} to –20V

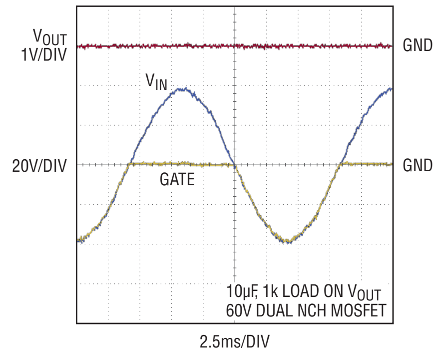


Figure 4. 36ms recovery timer blocks 28V, 60Hz AC line voltage

N-channel MOSFET at the most negative potential (V_{IN}), there is minimal leakage from V_{OUT} to the negative voltage at V_{IN}.

Figure 3 shows what happens when V_{IN} is hot plugged to –20V. V_{IN}, V_{OUT} and GATE start out at ground just before the connection is made. Due to the parasitic inductance of the V_{IN} and GATE connections, the voltage at V_{IN} and GATE pins ring significantly below –20V. The external MOSFET must have a breakdown voltage that survives this overshoot.

The speed of the LTC4365 reverse protection circuits is evident by how closely the GATE pin follows V_{IN} during the negative transients. The two waveforms are almost indistinguishable on the scale shown. Note that no additional external circuits are needed to provide reverse protection.

AC BLOCKING

The LTC4365 has a recovery delay timer that filters noise at V_{IN} and helps prevent chatter at V_{OUT}. After either an OV or UV fault (or when V_{IN} goes negative) has occurred, the input supply must return to the desired operating voltage window for at least 36ms in order to turn the external MOSFET back on.

Figure 5. OV fault with large V_{IN} inductance

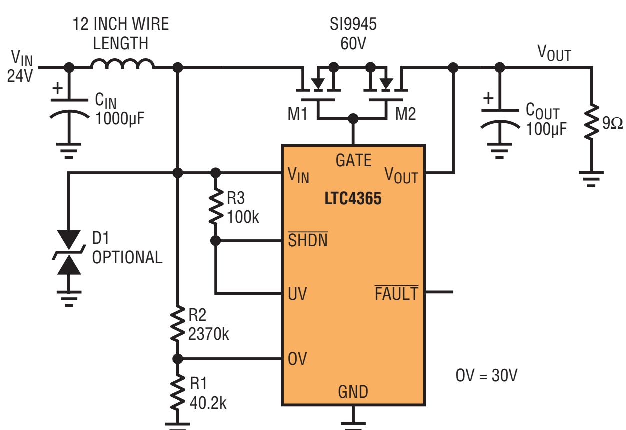
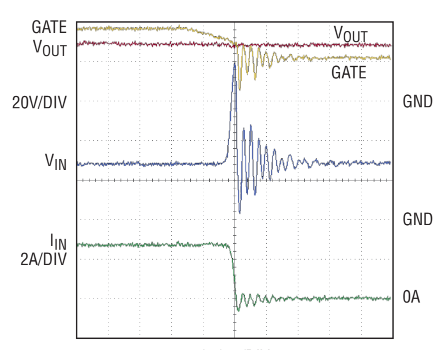


Figure 6. Transients during OV fault when no TranZorb (TVS) is used



The LTC4365's novel architecture results in a rugged, small solution size with minimal external components, and it is available in tiny 8-pin 3mm × 2mm DFN and TSOT-23 packages.

Going out of and then back into fault in less than 36ms keeps the MOSFET off.

Figure 4 shows the LTC4365 blocking an AC line voltage of 40V to −40V. The GATE pin follows V_{IN} during the negative portions, but remains at ground when V_{IN} goes positive. Note that V_{OUT} remains undisturbed.

HIGH VOLTAGE TRANSIENTS DURING FAULT CONDITION

Figure 5 shows a test circuit designed to produce transients during an overvoltage condition. The nominal input supply is 24V with an overvoltage threshold of 30V. Figure 6 shows the waveforms during an overvoltage condition at V_{IN}. These transients depend on the parasitic inductances on the V_{IN} and GATE pins. The circuits survived the transients without damage, even though the optional power clamp (D1) was not used during the experiments.

SELECT BETWEEN TWO SUPPLIES

With the part in shutdown, the V_{IN} and V_{OUT} pins can be driven by two different power supplies at different voltages. The LTC4365 automatically drives the GATE pin below the lower of the two supplies, thus preventing current from flowing in either direction through the external MOSFET. The application of Figure 7 uses two LTC4365s to select between two power supplies. Care should be taken to ensure that only one of the two LTC4365s is enabled at any given time.

REVERSE V_{IN} HOT SWAP WHEN V_{OUT} IS POWERED

LTC4365 protects against negative V_{IN} connections even when V_{OUT} is driven by a separate supply. With the LTC4365 in shutdown and V_{OUT} powered to 20V, Figure 8 shows the waveforms when V_{IN} is hot swapped to −20V. As long as the breakdown voltage of the external MOSFET is not exceeded (60V), the 20V supply at V_{OUT} is not affected by the reverse polarity connection at V_{IN}.

CONCLUSION

The LTC4365 controller protects sensitive circuits from overvoltage, undervoltage and reverse supply connections. The supply voltage is passed to the output only if it is qualified by the user adjustable UV and OV trip thresholds. Any voltage outside this window is blocked, up to 60V and down to −40V.

The LTC4365's novel architecture results in a rugged, small solution size with minimal external components, and it is available in tiny 8-pin 3mm × 2mm DFN and TSOT-23 packages. No reverse voltage blocking diode in series with the supply is needed; the LTC4365 performs this function automatically with back-to-back external MOSFETS. The LTC4365 has a wide 2.5V to 34V operating range and consumes only 10μA during shutdown. ■

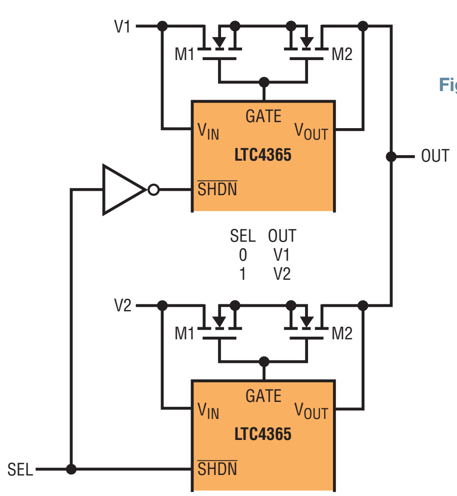


Figure 7. Selecting between one of two supplies

Figure 8. Negative V_{IN} hot swap with V_{OUT} powered