Surge Stopper with Ideal Diode Protects Input and Output

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Power systems in automobile and industrial applications must cope with short duration high voltage surges, maintaining regulation at the load, while protecting sensitive circuitry from dangerous transients. One common protection scheme involves a series iron core inductor and high value electrolytic bypass capacitor, augmented by a high power transient voltage suppressor (TVS) and fuse. This heavy-handed approach takes significant board real estate—the bulky inductor and capacitor are often the tallest components in the system. Even this protection scheme cannot protect against reverse input potentials or supply brownouts—possible scenarios in automotive environments. To protect against these events and maintain the output voltage, designers add a blocking diode, but the additional voltage drop in the diode increases power losses.

The LTC4364 is a complete control solution for load protection and output holdup in a small footprint, eliminating bulky components and undesirable voltage drops. Figure 1 shows a functional block diagram of the LTC4364. The part drives two back-to-back N-channel pass transistors: one protects against voltage surges and maintains a regulated voltage to the output (M1 in Figure 1), while the other acts as an ideal diode for reverse input protection and output holdup (M2 in Figure 1).

The LTC4364 also guards against overloads and short circuits, withstands output voltage reversal, holds off the MOSFETs in input undervoltage conditions and inhibits turn-on or auto-retry in input overvoltage conditions. A shutdown mode reduces the supply current to as low as 10µA.

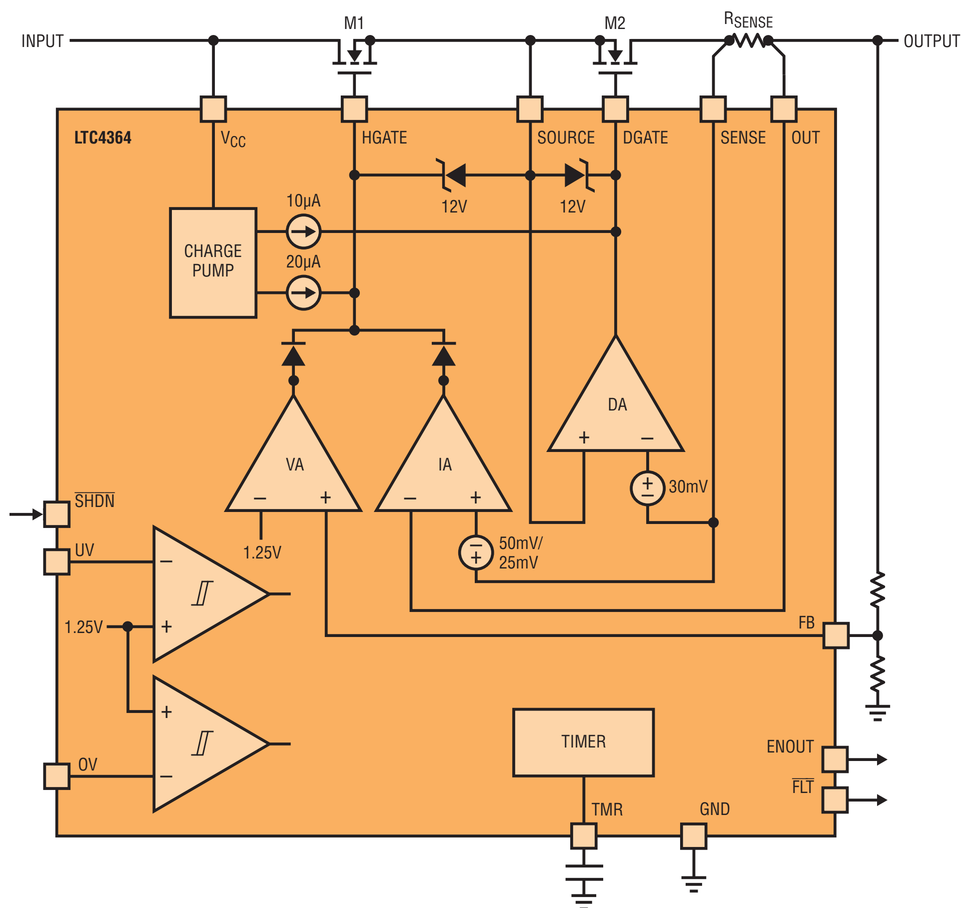

Figure 1. Simplified block diagram of the LTC4364

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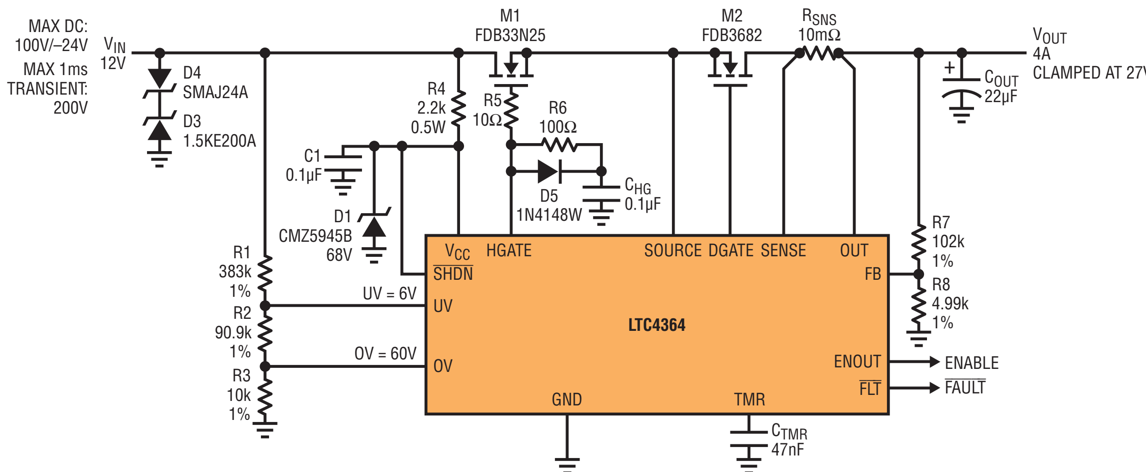


Figure 2. Surge stopper with reverse current protection withstands 200V/–24V transients at V_{IN}.

ADVANCED SURGE STOPPER WITHSTANDS HIGHER VOLTAGES AND ENSURES SAFE OPERATION

Figure 2 shows a typical application of the LTC4364. Under normal operating conditions, the LTC4364 drives the surge stopper N-channel MOSFET (M1) fully on and regulates the V_{DS} of the ideal diode N-channel MOSFET (M2) to 30mV so that the voltage drop from the input supply to the load circuitry is minimized. Once V_{OUT} rises to 0.7V below V_{IN}, the ENOUT pin goes high to activate the load circuitry.

During an input voltage surge, the LTC4364 regulates the HGATE pin, clamping the output voltage through MOSFET M1 and a resistive divider so that the FB pin voltage is maintained at 1.25V. The load circuit continues to operate, with little more than a modest increase in supply voltage as illustrated in Figure 3.

In the case of a current overload, the LTC4364 limits the output current through M1 so that the voltage across the SENSE and OUT pins is maintained at 50mV (when OUT > 2.5V). For a severe output short when OUT is below 1.5V, the current limit sense voltage folds back to 25mV for additional protection of the MOSFET (Figure 4).

The timer capacitor ramps up whenever output limiting occurs (either overvoltage as shown in Figure 5 or overcurrent). If the condition persists long enough for the TMR pin to reach 1.25V, the FAULT pin goes low to give early warning to downstream circuitry of impending power loss. At 1.35V the timer turns off the MOSFETs and waits for a cooldown interval before attempting to restart.

The LTC4364 monitors voltage across the MOSFET and shortens the turn-off timer interval in proportion to increasing $V_{CC} - V_{OUT}$. In this way a highly stressful

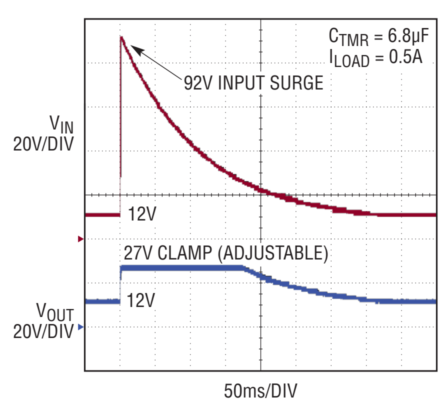


Figure 3. The LTC4364 regulates output at 27V while load circuit continues to operate in the face of a 92V input spike.

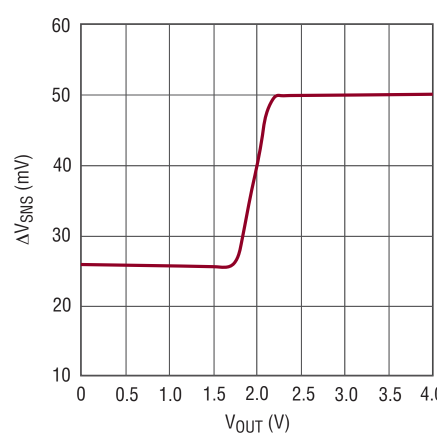


Figure 4. A 2:1 foldback of current limit reduces MOSFET stress upon severe output short.

An important feature of the LTC4364 is that a current limiting device such as a resistor can be placed between the input supply and the V_{CC} pin. Now supply transients at the V_{CC} pin can be either filtered with a capacitor or clamped by a Zener diode. If a proper MOSFET is selected, this scheme makes it possible to withstand supply transients much higher than 100V.

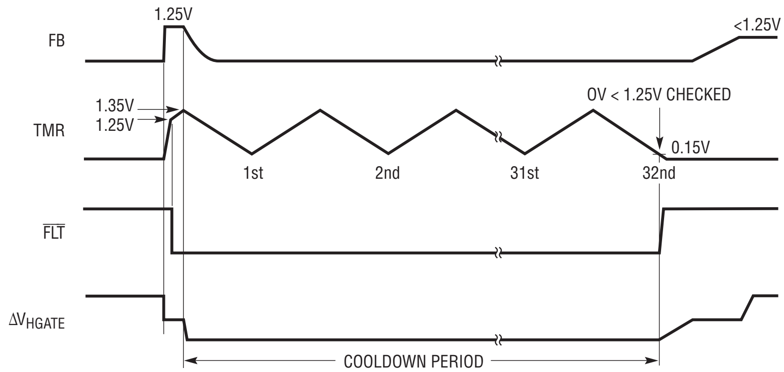


Figure 5. The LTC4364-2 auto-retry timer sequence following an overvoltage fault provides a very long cooldown period (0.1% duty cycle).

output short-circuit condition lasts for a shorter time interval than a brief, minor overload, helping ensure the MOSFET operates within its safe operating area.

The LTC4364 features a very low restart duty cycle of about 0.1% in either overvoltage or overcurrent conditions, ensuring the MOSFET cools down before restarting following a turn-off caused by fault. Figure 5 demonstrates the auto-retry timer sequence of the LTC4364-2 following an overvoltage fault.

An important feature of the LTC4364 is that a current limiting device such as a resistor (R4 in Figure 2) can be placed between the input supply and the V_{CC} pin. Now supply transients at the V_{CC} pin can be either filtered with a capacitor (C1 in Figure 2) or clamped by a Zener diode (D1 in Figure 2). If a proper MOSFET M1 is selected, this scheme makes it possible to withstand supply transients much higher than 100V. The circuit in Figure 2 can withstand supply transients up to 200V.

Figure 6. Input UV and OV monitors can be configured to block start-up into an overvoltage condition.

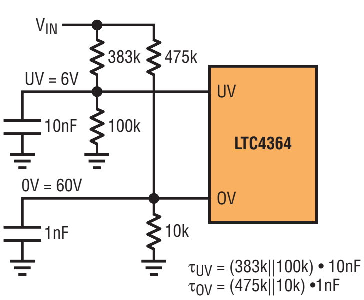
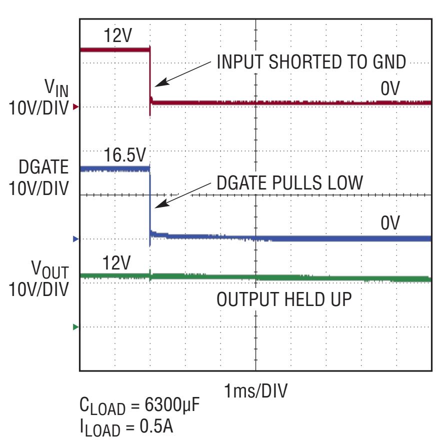
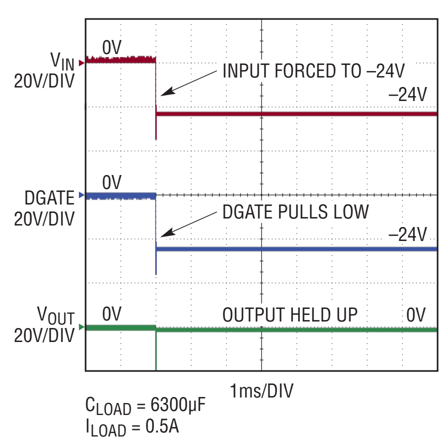


Figure 7. LTC4364 input protection:
a. Upon an input short or brownout, the DGATE pin pulls low, shutting down the ideal diode MOSFET and holding up the output voltage.



b. In reverse input conditions, the DGATE pins pulls to the SOURCE pin, keeping the ideal diode MOSFET off and cutting off back feeding.



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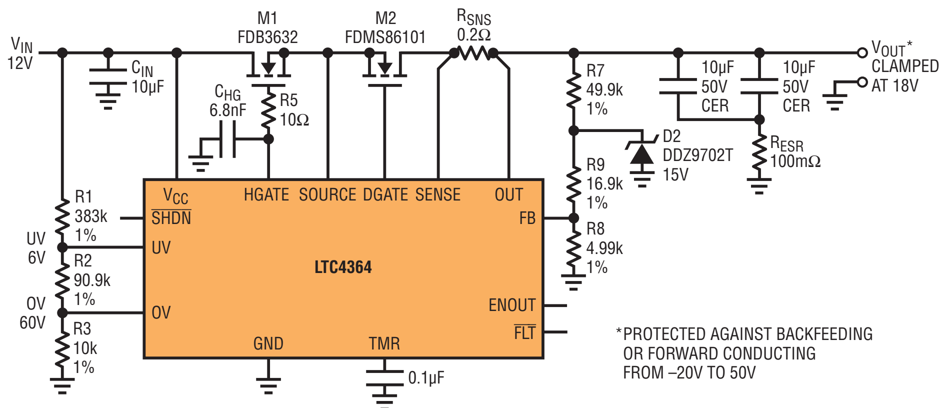


Figure 8. LTC4364 offers built-in output port protection against overvoltage, short or reverse voltage.

INPUT VOLTAGE MONITORING PREVENTS UNWANTED TURN-ON

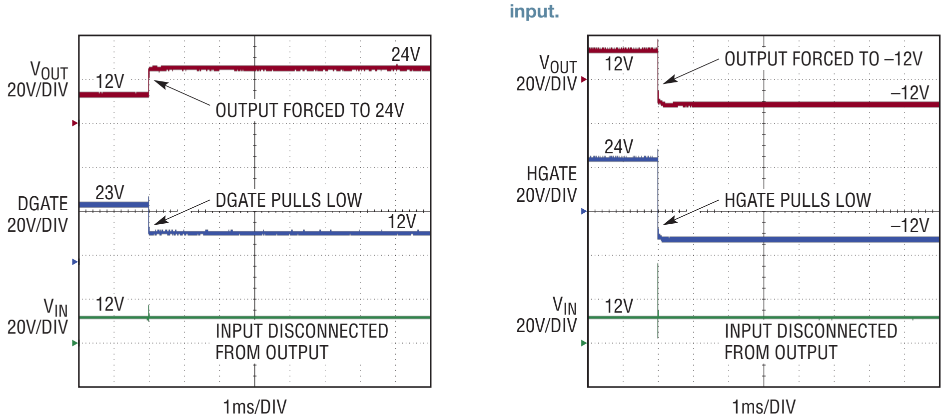
The LTC4364 detects input undervoltage conditions such as low battery using the UV pin, and keeps the MOSFETs off if the UV pin voltage is below 1.25V. The LTC4364 also monitors input overvoltage conditions and holds off the MOSFETs for start-up or restart following an output fault condition.

At power-up, if the OV pin voltage is higher than 1.25V before the 100µs power-on-reset delay expires, or before the UV pin voltage rises above 1.25V, the MOSFETs remain off until the OV pin voltage drops below 1.25V. This feature allows prevention of start-up when a board is inserted into an overvoltage supply by using two separate resistive dividers with appropriate filtering capacitors for the OV and UV pins (Figure 6).

After start-up, under normal conditions, a subsequent input overvoltage condition does not turn off the MOSFETs, but rather blocks auto-retry following an output fault. If the OV pin voltage is above 1.25V when the cooldown timer cycle ends following a fault, the MOSFETs remain off until the input overvoltage condition is cleared.

Figure 9. LTC4364 output port protection:
a. When output is forced above input, the DGATE pin pulls low to cut off back feeding.

b. When output is forced below the GND potential, the HGATE pin pulls to the SOURCE pin, cutting off forward conduction and saving battery power at input.



IDEAL DIODE PROTECTS AGAINST REVERSE INPUT AND BROWNOUT WITH MINISCULE VOLTAGE DROP

To protect against reverse inputs, a Schottky blocking diode is often included in the power path of an electronic system. This diode not only consumes power but also reduces the operating voltage available to the load circuitry, particularly significant with low input voltages, such as during an automotive cold crank condition. The LTC4364 eliminates the conventional Schottky blocking diode and its voltage and power losses by including

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the DGATE pin to drive a second, reverse-connected MOSFET (M2 in Figure 2).

In normal operating conditions, the LTC4354 regulates the forward voltage drop (V_{DS} of M2) to only 30mV. If the load current is large enough to result in more than a 30mV forward voltage drop, M2 is driven fully on and its V_{DS} is equal to $R_{DS(ON)} \bullet I_{LOAD}$.

In the event of an input short or a power supply failure, reverse current temporarily flows through M2. The LTC4364 detects the reverse voltage drop and immediately turns off M2, minimizing discharging of the output reservoir capacitor and holding up the output voltage. Figure 7a shows the result of a 12V input supply shorted to ground. The LTC4364 responds to this condition by pulling the DGATE pin low, cutting off the reverse current path so the output voltage is held up.

In a reverse battery connection, the LTC4364 shorts the DGATE pin to the SOURCE pin (that follows the input) without the need of external components, keeping M2 off and disconnecting the load circuitry from the input as shown in Figure 7b. The V_{CC}, $\overline{SHDN}$, UV, OV, HGATE, SOURCE and DGATE pins can all withstand up to 100V above and 40V below the GND potential.

BUILT-IN OUTPUT PORT PROTECTION

When the output is on a connector as shown in Figure 8, it could experience overvoltage, short-circuit or reverse voltage. The LTC4364 protects the load circuitry and input supply against those conditions with several features:

- If the output port is plugged into a supply that is higher than the input, the ideal diode MOSFET M2 turns off to cut the back feeding path open as shown in Figure 9a.
- If the output port is shorted to ground, the HGATE pin first regulates the forward current to the current limit and then turns off MOSFET M1 if the fault times out.
- If a reverse supply is applied to the output port, the LTC4364 turns off the pass MOSFET M1 once the OUT pin voltage drops below the GND potential, cutting the forward conducting current path open and avoiding battery drainage at the input.

Figure 9b shows the result when a –12V supply is applied to the output. The LTC4364 immediately shorts the HGATE pin to the SOURCE pin (that follows output), turning MOSFET M1 off so the input supply is disconnected from the faulty output.

The OUT and SENSE pins of the LTC4364 can withstand up to 100V above and 20V below the GND potential. For applications where the output port could be forced below ground, ceramic bypass capacitors with proper voltage ratings should be used at the output to stabilize the voltage and current limiting loops and to minimize capacitive feedthrough of input transients (see Figure 8). A low leakage diode (D2 in Figure 8) should be used to protect the FB pin.

CONCLUSION

The LTC4364 is a compact and complete solution to limit and regulate voltage and current to protect sensitive load circuitry against dangerous supply transients, including those over 100V. It is an easy-to-implement, high performance alternative to the traditionally bulky protection circuits in automotive and industrial systems.

The LTC4364's integrated ideal diode driver holds up output voltage during input short, supply brownout, or reverse input while cutting the voltage loss associated with blocking diodes. The built-in output port protection is useful when the output is on the connector side. Its feature set is rounded out by input UV and OV monitoring and a low current shutdown mode. ■