Protect Mobile Devices from Hot Plug Transients (to 85V) and from Users Who Use the Wrong Power Adapter

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Battery powered mobile gadgets like smart phones, tablets and digital cameras have become integral parts of the modern lifestyle. More and more functionality is squeezed into increasingly small form factors in the endless quest for more mobility. The proliferation of mobile devices has spawned a corresponding number of power adapters to charge batteries and power the devices: from AC wall outlets, car battery adapters, USB ports and even mobile solar panels. Although many adapters use similar plugs, their electrical specifications can be very different. Product designers are thus forced to employ protection circuitry to protect the low voltage rated electronics from transient and steady state overvoltages.

Failures or faults in the power adapters can cause an overvoltage event. So can hot-plugging an adapter into the power input of the mobile device (see Linear Technology Application Note 88). With the prevalence of universal connectors, a user can also unknowingly plug in the wrong adapter, damaging the device with a high or even negative power supply voltage. The LTC4360, LTC4361 and LTC4362 can protect against the above mentioned fault situations with minimal components. See Table 1 for a comparison of these devices.

The LTC4360 and LTC4361 protect low voltage electronics from overvoltage conditions by controlling a low cost external N-channel MOSFET configured as a pass transistor. The LTC4362 achieves an even smaller PCB footprint by incorporating an internal 28V, 7mΩ $R_{DSON}$ MOSFET and a 31mΩ sense resistor.

The LTC4360 and LTC4361 can withstand up to 85V at IN, SENSE and GATEP. For all three parts, there is no requirement for a high voltage bypass capacitor at IN, eliminating a potential point of failure. The low voltage capacitor required at OUT is also the bypass capacitor to the downstream circuits. It helps to slow down the $dV/dt$ at OUT during a fast overvoltage, allowing time for the protection part to shut off the MOSFET before $V_{OUT}$ overshoots to a dangerous voltage. These features make the parts versatile building blocks for some very robust yet simple overvoltage protection circuits.

**OPERATION**

When power is first applied or the part is activated by pulling ON low, a 130ms delay cycle starts. Any undervoltage or overvoltage event at IN ($V_{IN} < 2.1V$ or $V_{IN} >$...
With the prevalence of universal connectors for mobile devices, users can easily plug in the wrong adapter, damaging the device with a high or even negative power supply voltage. The LTC4360, LTC4361 and LTC4362, along with a few components, protect valuable downstream devices against this and other fault situations.

5.7V) restarts the delay cycle. This allows the MOSFET to isolate the output from any input transients that occur at start-up. When the delay cycle completes, the MOSFET is turned on by a controlled 3V/ms gate ramp. The voltage ramp of the output capacitor follows the slope of the gate ramp and sets the supply inrush current at:

\[ I_{\text{INRUSH}} = C_{\text{OUT}} \times 3 \text{ [mA/µF]} \]

As gate ramps higher, it trips an internal gate high threshold (7.2V for \( V_{\text{IN}} = 5V \)) to start a 65ms delay cycle. After the delay, \( \text{PWRGD} \) asserts low to signal that the MOSFET has fully enhanced. An internal circuit clamps GATE at 6V above OUT to protect the MOSFET gate.

When \( V_{\text{IN}} \) rises above the 2% accurate overvoltage threshold of 5.8V, a 30mA fast pull-down on the GATE pin is activated within 1µs and the \( \text{PWRGD} \) pull-down is released. After an overvoltage condition, the MOSFET is held off until \( V_{\text{IN}} \) once again remains below 5.7V for 130ms.

In addition to overvoltage protection, the LTC4361 and LTC4362 have overcurrent protection to protect the pass MOSFET from excessive current. The LTC4361 implements a 10% accurate 50mV electronic circuit breaker threshold with a 10µs glitch filter. A 50mΩ \( R_{\text{SENSE}} \) connected between IN and SENSE implements a 1.5A overcurrent threshold as shown in Figure 1. The LTC4362 implements internal current sensing and has a 20% accurate 1.5A overcurrent threshold with a 10µs glitch filter. As in an overvoltage, an overcurrent activates a 30mA fast pull-down on GATE and releases the \( \text{PWRGD} \) pull-down. After an overcurrent fault, the LTC4361-1 and LTC4362-1 latch off while the LTC4361-2 and LTC4362-2 automatically restart after a 130ms delay.

An optional P-channel MOSFET driven by the GATEP pin as shown in Figure 1 provides low loss negative input voltage protection down to the \( B_{\text{VDS}} \) of the MOSFET. An internal IN to GATEP Zener protects the MOSFET gate by clamping its \( V_{\text{GS}} \) to 5.8V when \( V_{\text{IN}} \) goes high.

Another feature is the CMOS-compatible, active low enable input \( \text{ON} \). With
The LTC4360 and LTC4361 overvoltage protection controllers use small footprint and low cost external N-channel MOSFETs while the LTC4362 incorporates the MOSFET into a 2mm × 3mm DFN package. Although these overvoltage protection circuits occupy very little PCB space, they are rich in features like an 85V rating at the input side and fast response in the event of overvoltage or overcurrent.

![Figure 4. Overvoltage protection waveforms when 20V adapter is plugged into 5V system](image)

\[\text{RIN actively pulled to ground or left open to pull low with its internal 5µA pull-down, the device operates normally. If RIN is driven high while the MOSFET is turned on, GATE is pulled low with a weak pull-down current (40µA) to turn off the MOSFET gradually, minimizing input voltage transients. The part then goes into a low current sleep mode and draws only 1.5µA at IN.}

INPUT TRANSIENTS
Figure 2 shows the circuit of a LTC4361 protecting the power input of a mobile device. L\text{IN} and R\text{IN} model the accumulated parasitic inductance and resistance in the wall adapter, adapter cable and the connector. A 20V wall adapter’s output is hot-plugged into the device to simulate an accidental plug-in with the wrong adapter. To do a before and after comparison, the LTC4361, R\text{SENSE} and MOSFET are removed and the same hot-plug is repeated with IN shorted to OUT. Figure 3 compares the two hot-plug waveforms. Due to the low capacitance at the IN pin, there is little overshoot and inrush current for the case with the LTC4361 circuit. A higher voltage rated MOSFET can be used to protect the system against even higher transient or DC voltages up to the BV\text{DSS} of the MOSFET. For example, a MOSFET with a 60V BV\text{DSS} used with the LTC4361 is able to withstand transient and DC voltages up to 60V at IN.

The circuit in Figure 4 illustrates a worst case overvoltage situation that can occur at a mobile device power input. In a device with dual power inputs, a 20V wall adapter is mistakenly hot-plugged into the 5V adapter input with the 5V USB input already live. The LTC4360 detects the overvoltage at IN quickly and cuts off the MOSFET. But the large current built up in L\text{IN} causes an inductive spike at IN. The body diode of the avalanche breakdown rated MOSFET breaks down to discharge this energy into C\text{OUT}, clamping IN at about 40V, well below the 8V that IN can withstand. If the avalanche capability of the MOSFET is exceeded or the voltage rise at V\text{OUT} due to the discharge of the energy in L\text{IN} into C\text{OUT} is not acceptable, an additional external clamp like the SMAJ24A can be placed between IN and GND.

CONCLUSION
The LTC4360 and LTC4361 overvoltage protection controllers use small footprint and low cost external N-channel MOSFETs while the LTC4362 incorporates this MOSFET into a 2mm × 3mm DFN package. Although these overvoltage protection circuits occupy very little PCB space, they are rich in features like an 85V rating at the input side and fast response in the event of overvoltage or overcurrent. In addition, there is a PWRGD status flag for the downstream circuits and a low power mode enabled by a CMOS compatible input to save battery power when necessary. The LTC4360, LTC4361 and LTC4362 form a simple yet effective and rugged barrier between the sensitive electronics inside a mobile device and real life accidents like faulty, substandard power adapters or a user’s absent-mindedness in plugging in the wrong adapter. ■