Cascode MOSFET increases boost regulator's input- and output-voltage ranges

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Targeting use in portable-system applications that require raising a battery's voltage to a higher level, IC boost regulators often include output transistors that can drive storage inductors. However, most boost regulators' absolute-maximum input-voltage rating typically doesn't exceed 6V, an adequate level for battery operation. In addition, breakdown voltage of the regulator's output transistor limits the regulator's absolute-maximum output voltage to 25 to 30V, which may be too low for some applications.

You can extend a boost regulator's output-voltage range by adding an external transistor that has a higher breakdown voltage than the regulator. However, the internal design of a typical boost regulator's control circuitry often prevents direct drive of an external transistor's base or gate. As an alternative, you can add an external higher voltage transistor by connecting it in a cascode configuration.

Most boost regulators feature a peak-current-control method that reduces the number of external components and thus shrinks the overall pc-board area of the converter circuit. Figure 1 shows a boost regulator based on a TPS61040 boost controller, IC1, which uses peak-current control.
**Figure 1** Based on the “barefoot” TPS61040, this dc/dc boost converter delivers output voltages only within IC₁’s ratings.

Applying input voltage \( V_{\text{IN}} \) to IC₁’s \( V_{\text{CC}} \) pin and to one leg of inductor \( L₁ \), turns on IC₁’s internal MOSFET switch, \( Q₁ \), allowing a gradually increasing amount of current to flow from \( V_{\text{IN}} \) through \( L₁ \), \( Q₁ \), and internal current-sense resistor \( R₁ \). The circuit’s internal controller monitors the voltage across sense resistor \( R₁ \) and, upon reaching a predetermined current limit, turns off \( Q₁ \).

Interrupting the current through \( L₁ \) raises the voltage across the inductor and applies forward bias to diode \( D₁ \), which conducts and charges output capacitor \( C₁ \) to a higher voltage than would be available from the input voltage alone. The input voltage, \( L₁ \)’s inductance, and the preset peak current through \( R₁ \) all affect \( Q₁ \)’s on-time, and the output voltage sensed by IC₁’s FB (feedback) pin and its external components determines \( Q₁ \)’s off-time. To maintain operation and set \( Q₁ \)’s off-time, IC₁’s internal controller must monitor current through \( L₁ \) using \( Q₁ \) and \( R₁ \).

You can add a higher voltage MOSFET transistor, \( Q₂ \) (**Figure 2**), for applications that require an output voltage higher than the internal transistor’s breakdown voltage. To maintain the circuit’s current-flow path through \( L₁ \) and IC₁’s SW pin, you connect the external transistor in a cascode, or common-gate, configuration.

**Figure 2** Adding an external cascode-connected MOSFET transistor, \( Q₂ \), with higher breakdown-voltage ratings, enables the circuit to produce higher output voltages.

\( Q₂ \) comprises a low-on-resistance, low-gate-voltage-threshold MOSFET with the addition of diode \( D₂ \) between \( Q₂ \)’s gate and source. To ensure the circuit’s proper operation, \( V_{\text{CC}} = 5 \text{V} \) in this example—must exceed \( Q₂ \)’s gate-threshold turn-on voltage. In operation, IC₁’s internal control circuit turns on \( Q₁ \), which pulls \( Q₂ \)’s source close to ground level and turns on \( Q₂ \) with almost 5V of gate-to-source potential.

Current flows through inductor \( L₁ \), external transistor \( Q₂ \), internal transistor \( Q₁ \), and sense resistor \( R₁ \), and IC₁’s control circuit “sees” no difference with the installation of \( Q₂ \). Once the inductor current reaches its preset limit, \( Q₁ \) turns off, leaving \( Q₂ \) with no path for current to flow from its source. The voltage on \( Q₂ \)’s drain rises rapidly to the desired output voltage plus the voltage drop across \( D₁ \). As
the drain voltage rises, Q₂’s drain-to-source capacitance attempts to pull the MOSFET’s floating source above 5V, which forward-biases D₂, connects IC₁’s SW pin voltage to 5V plus one diode drop, and clamps Q₂’s source to the same voltage.

A boost converter delivers a 180V output at 4 mA (V_{out}) to bias a laser circuit from a 9V power supply (V+). In this application, the 5V input supply need provide only enough current—typically, a few milliamperes—to drive IC₁’s internal logic and the gate of cascode MOSFET Q₂. You can use a dropping resistor and zener-diode voltage regulator (not shown) to supply the 5V requirement from the 9V supply. You can drive the inductor and IC₁ from a common power supply or from a separate source that’s within Q₂’s breakdown-voltage rating. The cascode circuit also can produce any output voltage that’s within Q₂’s drain-to-source breakdown-voltage rating. Specify other components with an appropriate voltage rating—for example, breakdown-voltage ratings of inductor L₁ and capacitor C₁ should safely exceed the desired output voltage.