

# Crafty Idea: Create a 150V Non Synchronous Buck Solution with a Lower VIN Rated Controller



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Many applications today require an input-voltage rating beyond the  $V_{IN}$  max ratings of many DC-to-DC controllers. Traditional options include using expensive front-end protection or implementing a low-side gate-drive device, which means employing an isolated topology such as a flyback converter. Isolated topologies often require custom magnetics and increase design complexity and cost compared to a nonisolated approach.

But another alternative exists that enables you to resolve the issue by using a simple buck controller with a  $V_{IN}$  max less than the system input voltage. How is this possible?

Buck controllers typically derive a bias supply referenced from ground potential (0V) (Figure 1a). The bias supply is derived from the input; therefore, the device needs to withstand the full  $V_{IN}$  potential. However, P-channel buck controllers have the gate-drive supply referenced to  $V_{IN}$  (Figure 1b), because the gate-drive voltage required to turn on the P-channel metal-oxide semiconductor field-effect transistor (MOSFET) is at  $V_{GS}$  below  $V_{IN}$ . To turn off the P-channel MOSFET, the gate voltage simply goes to  $V_{IN}$  (0V  $V_{GS}$ ) (Figure 2).

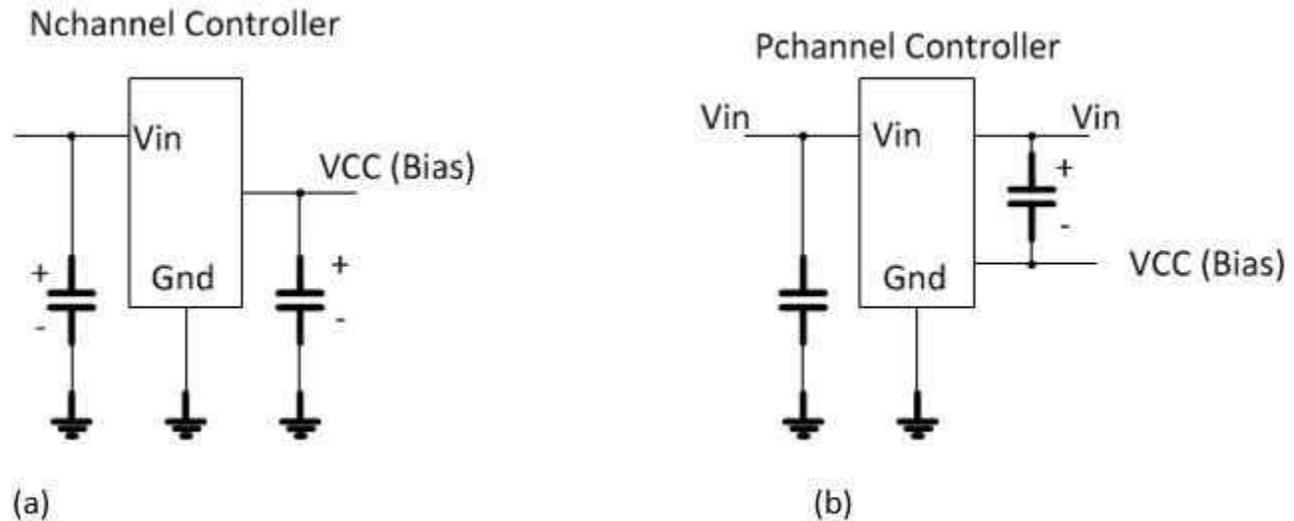
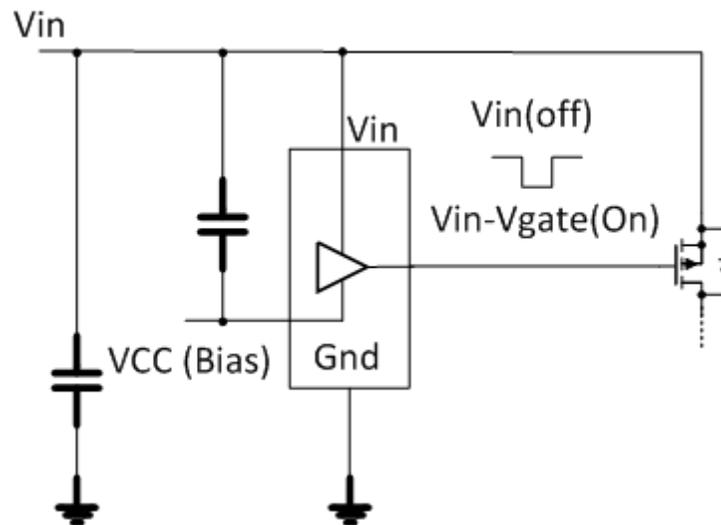


Figure 1. VCC Bias Generation for N-channel (a); and P-channel Controllers (b)



**Figure 2. Gate Drive for a P-Channel Controller**

The fact that the nonsynchronous P-channel controller derives its bias supply to drive the P-channel gate in this way is a huge benefit and makes it possible to supply a virtual ground that floats above a 0V potential. For an N-channel high side MOSFET the voltage is derived from a supply that is referenced to ground. This is charge pumped using a boot capacitor and diode to supply a gate voltage higher than its source potential of  $V_{IN}$ . With a P-channel high side MOSFET, things are a lot simpler. To turn on the P-channel MOSFET, the gate potential needs to be lower than its source potential of  $V_{IN}$ . Therefore the supply is referenced to  $V_{IN}$  only and not  $V_{IN}$  and ground as described above.

### Floating Ground

How can you create a floating ground for the controller? It's quite simple: by using an emitter follower. [Figure 3](#) shows a basic implementation of such a scheme. The emitter of the P-channel N-channel P-channel (PNP) will sit at a potential that is  $V_{be}$  ( $\sim 0.7V$ ) below the Zener diode voltage potential ( $V_z$ ). In essence, you're floating the controller to  $V_{IN}$  and regulating the reference of the controller to limit the voltage between  $V_{IN}$  and the device ground.

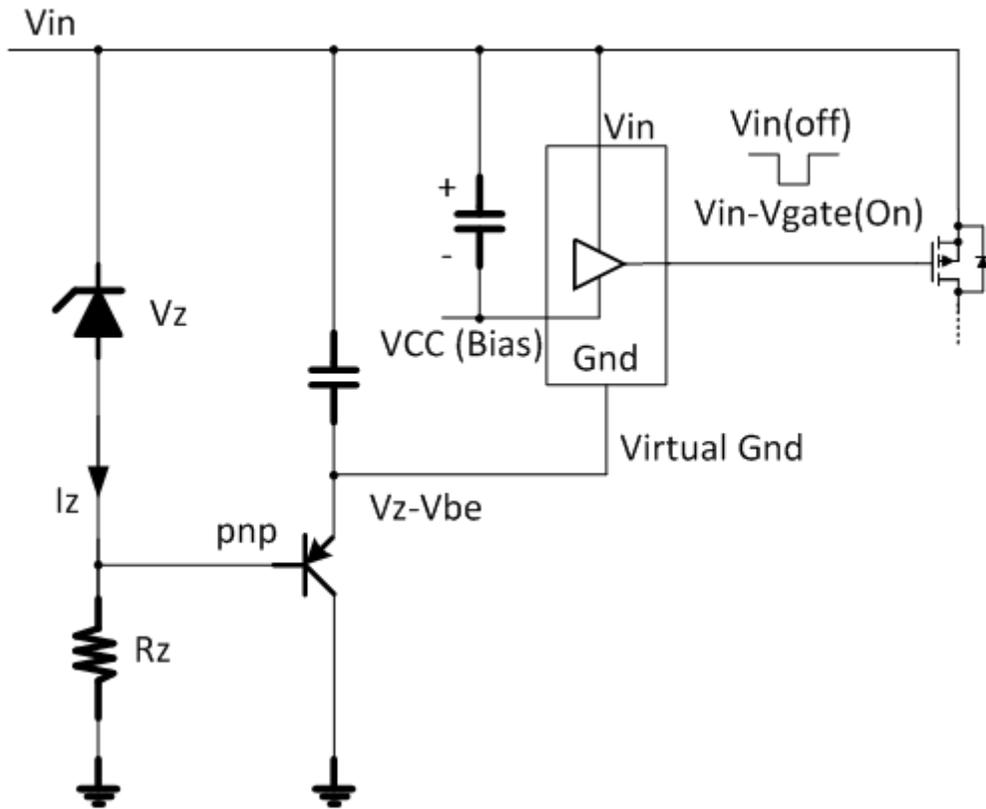


Figure 3. Creating a Virtual Ground Using a Simple Emitter Follower Scheme

### Output-voltage Translation

There is one challenge to overcome. Because the controller is sitting on a virtual ground ( $V_z - V_{be}$ ) and generating a step-down output voltage that is referenced to ground (0V) potential, how are you going to translate the output-voltage signal to a feedback voltage (typically between 0.8V and 1.25V) sitting above a virtual ground? Figure 4 illustrates the challenge.

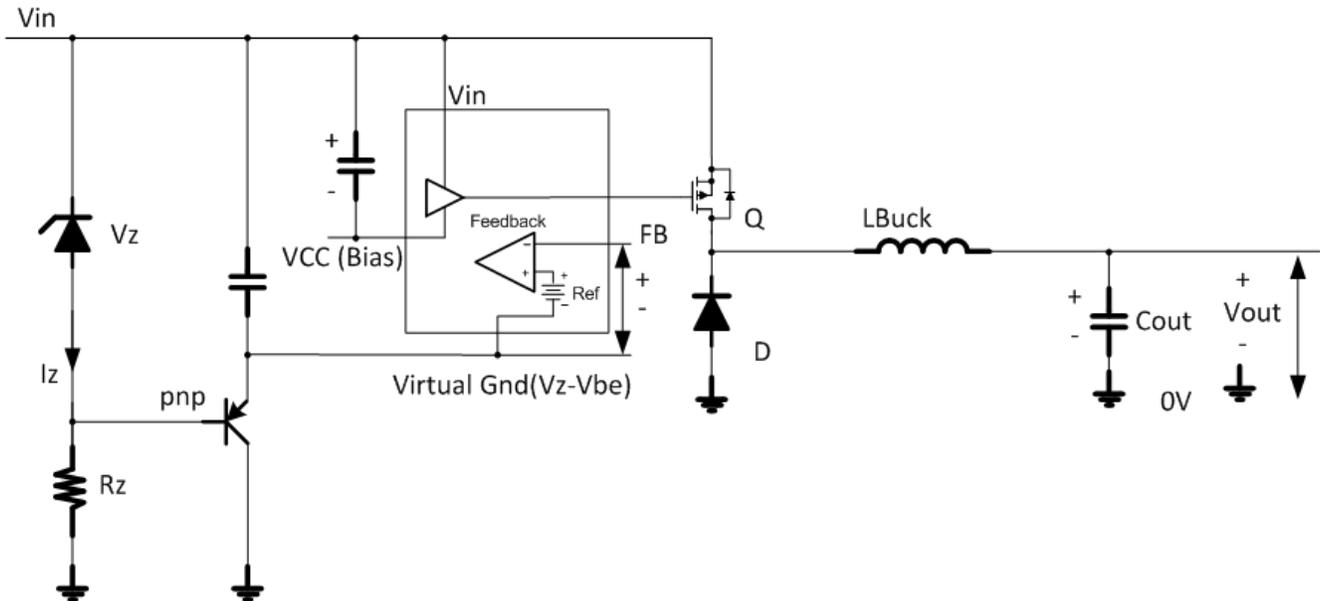
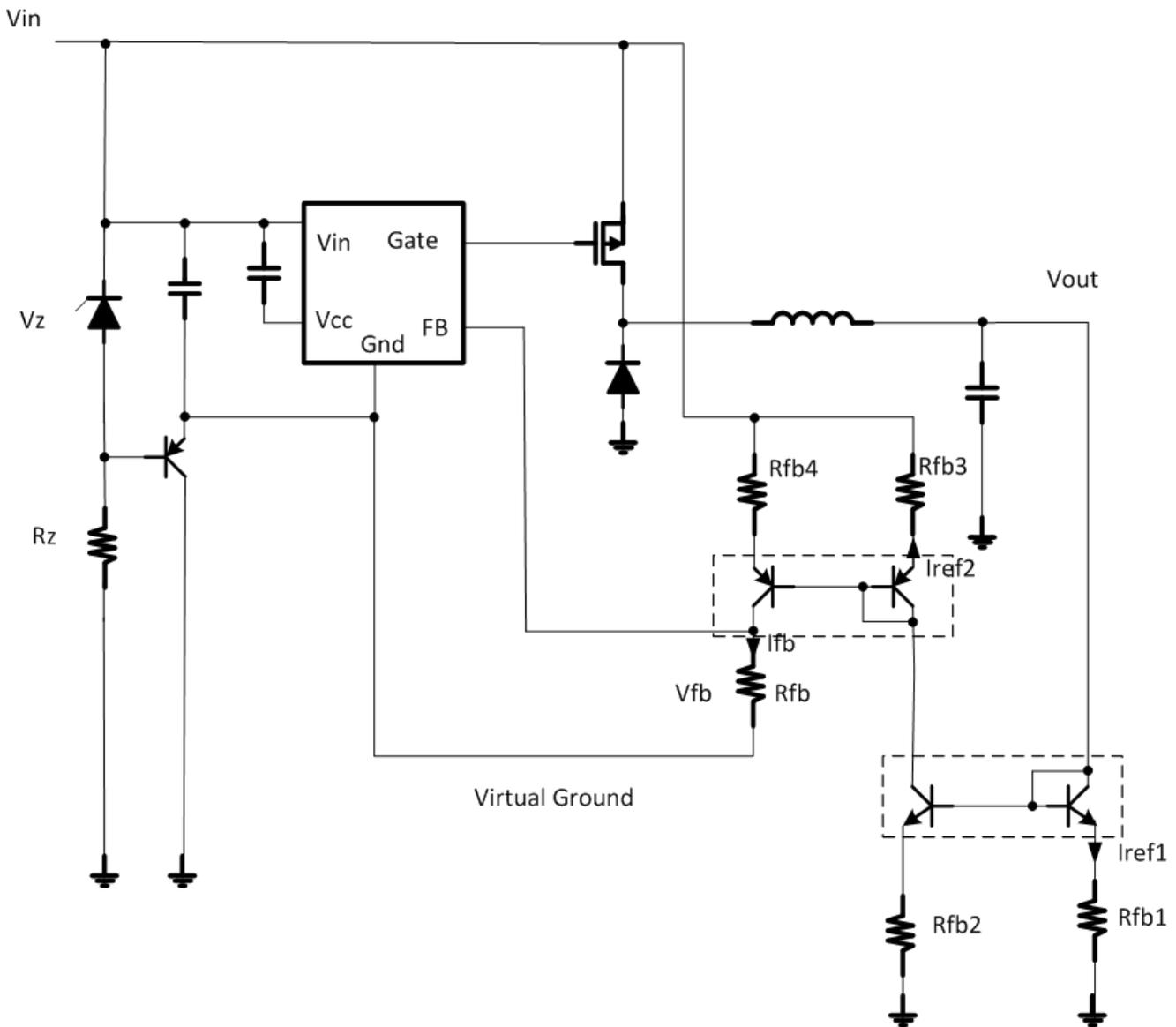


Figure 4. Schematic Showing the Difference in Voltage Potential between  $v_{OUT}$  (Referenced to 0V Ground) and the Feedback Voltage of a Controller (Referenced to Virtual Ground)

To close the loop, you can implement [Figure 5](#) by using a couple of matched-pair transistors. One pair sends the feedback signal to  $V_{IN}$ ; the other matched pair generates a current from  $V_{IN}$  to a potential above the virtual ground.



**Figure 5. High-level Schematic of a Nonsynchronous Controller and Feedback Implementation Using Matched-pair Transistors**

### Putting It All Together

The LM5085 is ideal for the application I've described because it is a P-channel nonsynchronous controller whose VCC bias supply is referenced to  $V_{IN}$ . The LM5085 can withstand input voltages up to  $75V_{IN}$  in traditional applications. For applications with input transient voltages much higher than  $75V$ , consider the solution presented here, specified for an output of 12V.

Starting from the controller feedback voltage of 1.25V and using a current to generate the feedback ( $I_{fb}$ ) set to 1mA, calculate the  $R_{fb}$  value using [Equation 1](#):

$$R_{fb} = \frac{V_{fb}}{I_{fb}} \quad (1)$$

(1)

where  $R_{fb} = 1.25k$ .

$R_{fb1}$  sets the reference current for the current mirrors. Once again, with 1mA as the reference current and using Equation 2, calculate  $R_{fb1}$  to set the output voltage:

$$R_{fb1} = \frac{V_{out} - V_{be}}{I_{fb1}} \quad (2)$$

where  $V_{OUT} = 12V$ ,  $R_{fb1} = 11.3k$  and  $V_{be}$  is  $\sim 0.7V$ .

With 1mA flowing into  $R_{fb2}$  and the emitter current being approximately equal to the collect current ( $I_e \sim I_c$ ), this sets the reference current  $I_{ref2}$ . The loop is closed and the voltage will regulate to the set voltage described.

### Output Voltage Regulation

One possible application this idea is suitable for is when voltage transients are significantly higher than the absolute maximum of the LM5085. The LM5085 is a constant on-time (COT) controller; as such, its on-time ( $T_{on}$ ) is inversely proportional to  $V_{IN}$ . However, when clamping the  $V_{IN}$  to the LM5085,  $T_{on}$  will no longer adjust with increasing  $V_{IN}$  (to the power stage) because the device will have a fixed voltage set by the Zener diode while the  $V_{in}$  to the power stage is increasing. This will cause the frequency to drop as the input voltage to the power stage increases beyond the clamping voltage to the LM5085; the regulation voltage may begin to increase slightly as a result. Therefore, take care to size the ripple-injection voltage using a Type 1 ripple-injection scheme, thus ensuring that the ripple is set within acceptable limits to maintain stability and minimize error on the output from increasing ripple.

### Example Schematic

Figure 6 shows an example schematic of a 48V supply with an absolute maximum  $V_{IN}$  rating of 150V. The example board can deliver 12V<sub>OUT</sub> at 3A.

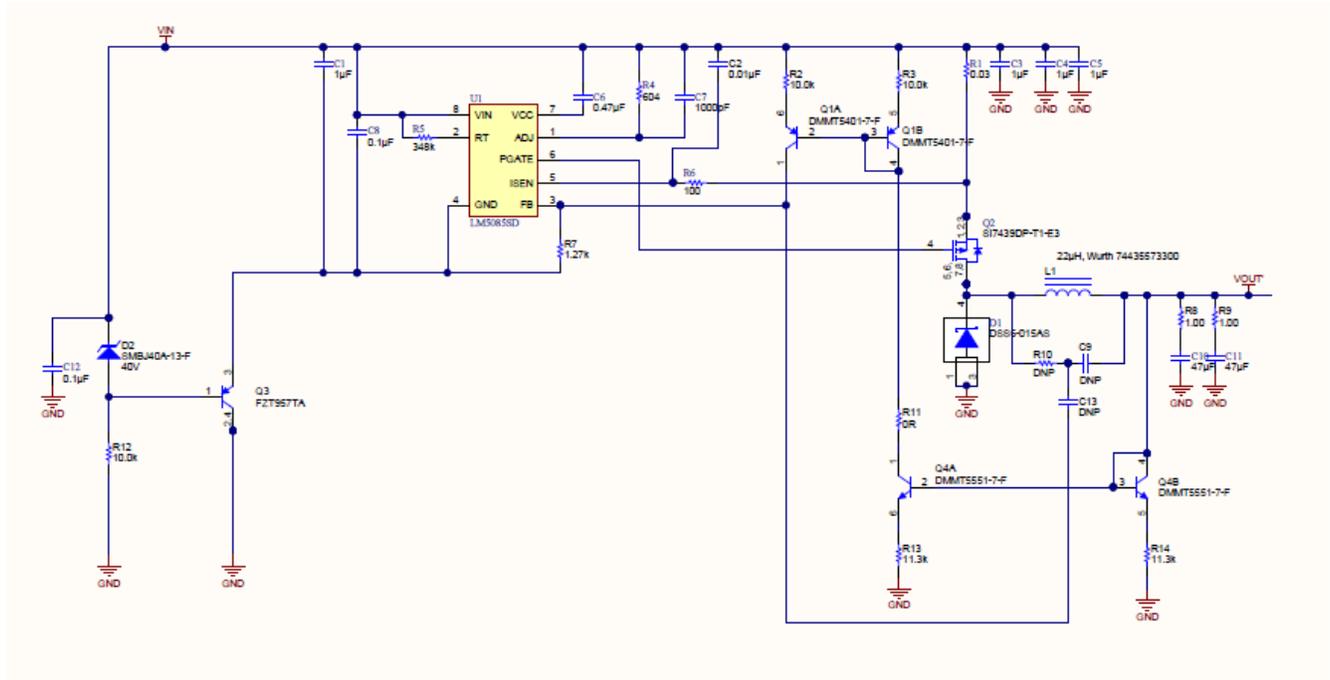


Figure 6. A 24V to 150V<sub>IN</sub> (Max)/12V<sub>OUT</sub> At 3A Design Using the LM5085

Figure 7 shows an efficiency plot taken from a prototype board, with efficiency (%) vs. load current (A).

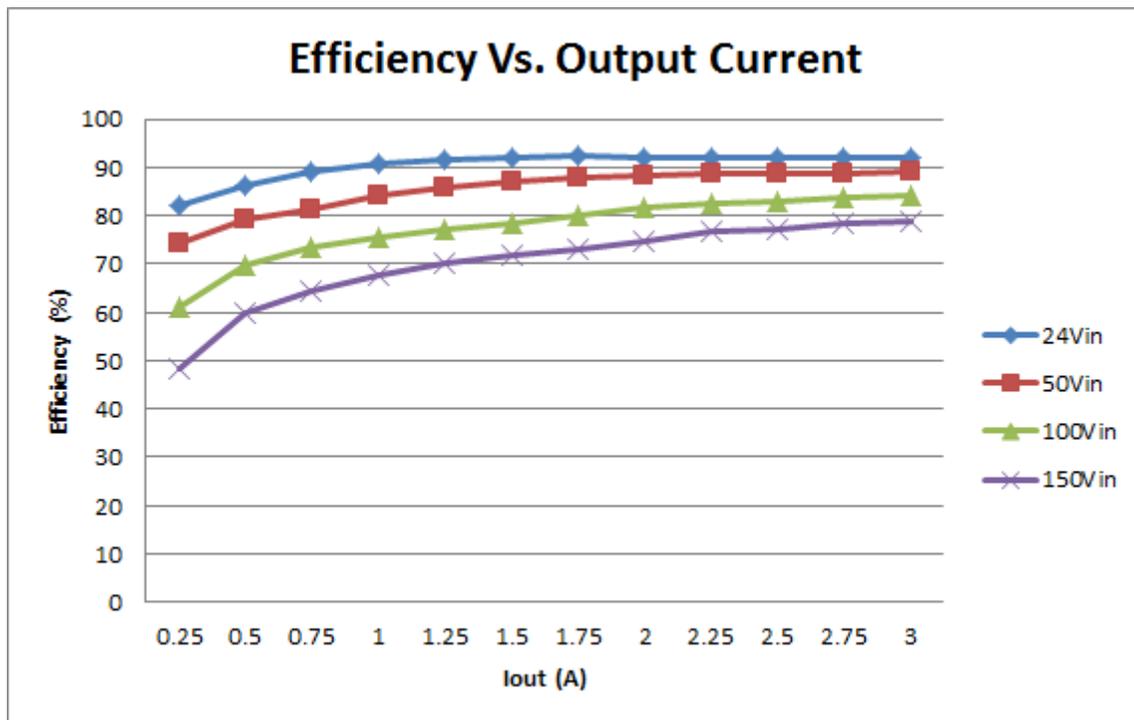


Figure 7. Efficiency (%) vs. Load Current (a) at Various Input Voltages

Figure 8 shows the switch-node voltage and inductor ripple current at 150V<sub>IN</sub>.

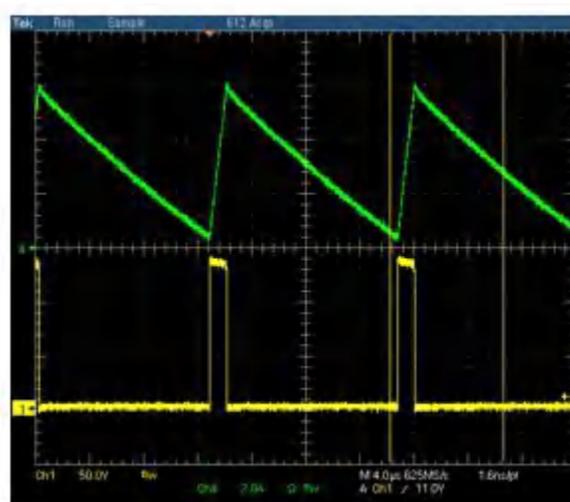


Figure 8. Channel 1 Switch-node Voltage, Channel 4 Inductor Ripple Current

### Conclusion

You can use a P-channel nonsynchronous buck controller in applications where the input voltage of the system exceeds the maximum input-voltage rating of the device. This application has the benefit of using a lower-cost controller with minimal component count. For design guidance on the power stage of the buck converter, please see the application information in the [LM5085 data sheet](#).

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