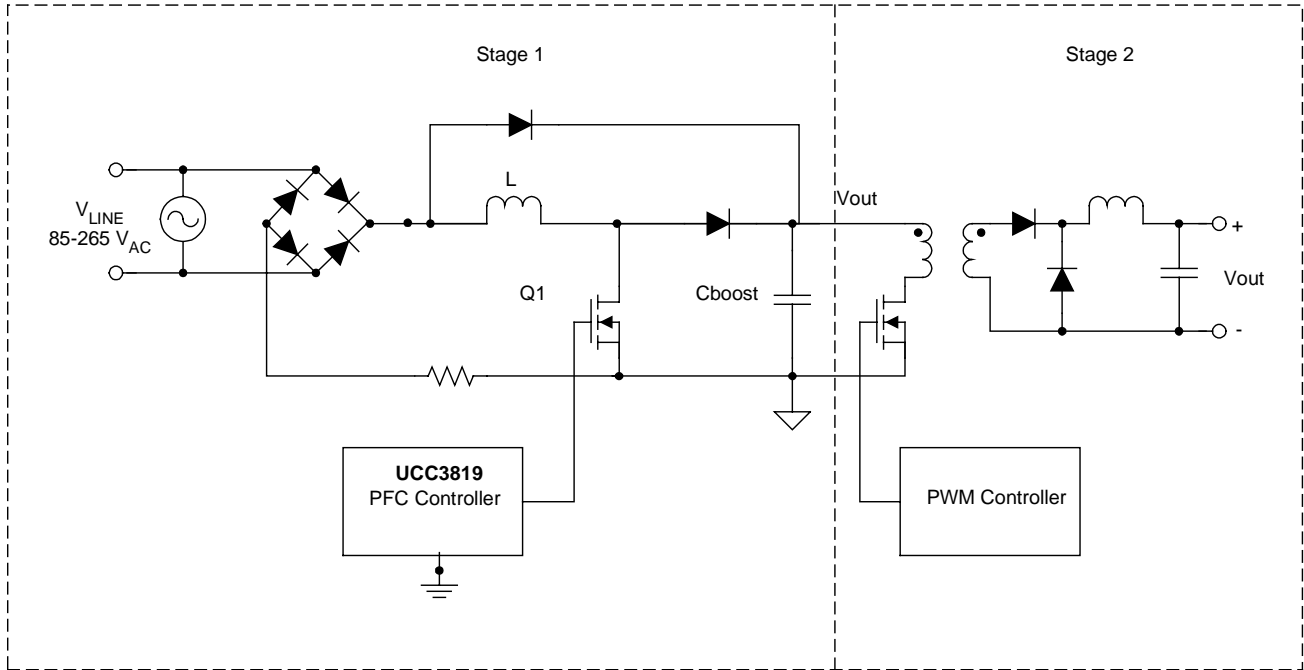


## Advantages Using A Boost-Follower In A Power Factor Corrected (PFC) Pre-Regulator

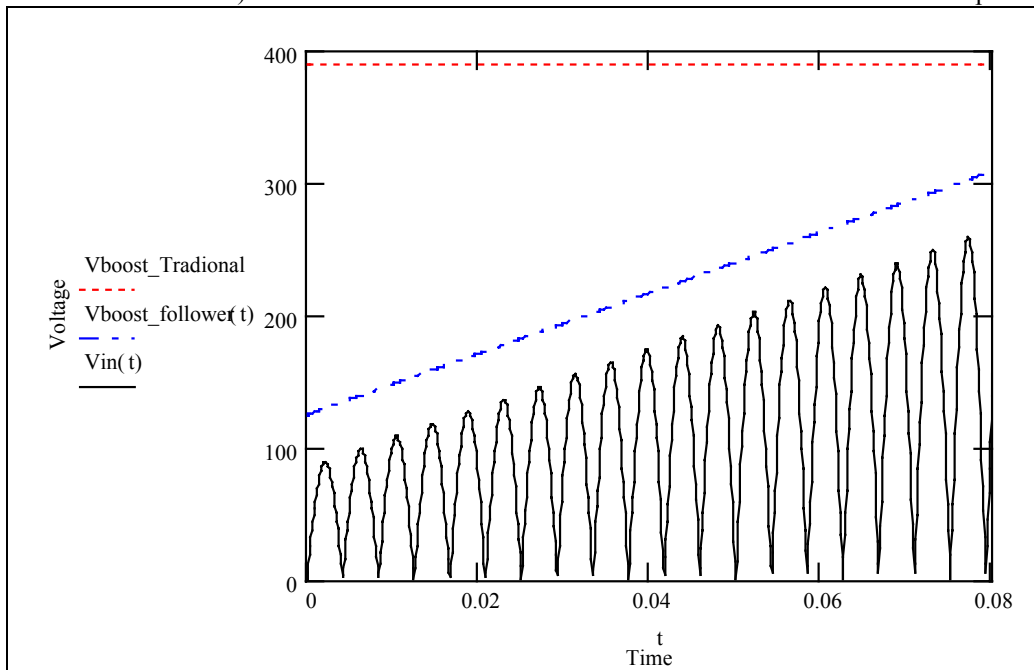
By Michael O'Loughlin,  
Member of Applications Engineering Staff  
Texas Instruments Incorporated

Conventionally, PFC (power-factor corrected) off-line power converters are designed with two power stages: The first stage is typically a boost converter because that topology has continuous input current that can be shaped through the use of a multiplier, and average current mode control, to achieve near-unity power factor (PF.) However, the boost converter requires a higher output voltage than the input and requires a second converter to step this voltage down to a usable level (see Fig. 1.)



**Fig. 1: Functional Block For Two-Stage Power Converter**

Boost converters traditionally have a fixed output voltage greater than the maximum peak line voltage, but it does not have to be well regulated because the step down converter (stage 2) is designed to handle the variations. As long as boost voltage exceeds peak input the converter will regulate properly, and there are benefits to be gained by having boost follow variations in peak line (i.e. as a boost-follower) with reduced boost inductor size and lower switch loss at low line operation.



**Fig. 2: How Boost-Follower And Traditional PFC Pre-Regulator Outputs Track  $V_{in}(t)$**

### Boost Inductor (L)

Boost inductance is selected based on the maximum allowed ripple current ( $\Delta I$ ) at maximum duty cycle (D) at the peak of minimum line voltage ( $V_{in(min)}$ ), with the following for the inductor in the power stage of either type of pre-regulator, with a  $\Delta I$  that is 20% of the peak input current [5]. Pout is maximum output power and  $V_{out(min)}$  is the minimum boost output voltage. These equations show that for wide input ranges the inductor would be much smaller for a boost-follower topology.

$$\Delta I = \frac{P_{out} * \sqrt{2} * 0.2}{V_{in(min)}} \quad D = 1 - \frac{V_{in(min)} * \sqrt{2}}{V_{out(min)}} \quad L = \frac{V_{in(min)} * \sqrt{2} * D}{\Delta I * f_s}$$

For example, using the above equations to calculate the inductor for a boost-follower topology in a 250-W application with a universal input of 85 V to 265 V and an output that tracks the input from 206 V to 390 V, an inductance of 570  $\mu H$  is required. The same conditions in a traditional topology with a 390-V fixed dc output require a 1-mH inductor.

### Boost Switch loss

The following describe the losses in the boost FET (PQ1)[3][5] and show that the parasitic FET capacitance loss (PCOSS) and the FET transition loss (PFET\_TR) would be much less for a boost-follower PFC as compared to a traditional PFC at low-line operation. This is because the output voltage ( $V_{out(min)}$ ) at low line is much lower, reducing the overall switch loss.

$$I_{RMS\_FET} = \frac{P_{out}}{V_{in(min)} * \sqrt{2}} * \sqrt{2 - \frac{16 * V_{in(min)} * \sqrt{2}}{3 * \pi * V_{out(min)}}$$

$$P_{GATE} = Q_{GATE} V_{GATE} * f_s \quad P_{COSS} = \frac{1}{2} C_{OSS} V_{out(min)}^2 * f_s \quad P_{COND\_FET} = R_{DS(on)} * I_{RMS\_FET}^2$$

$$P_{FET\_TR} = \frac{1}{2} V_{out(min)} * I_{RMS\_L} * 0.9 * (t_{on} + t_{off}) * f_s$$

$$P_{Q1} = P_{GATE} + P_{COSS} + P_{COND\_FET} + P_{FET\_TR}$$

For example, the losses of an IRFP450 HEXFET (same conditions used for boost inductor), are about 11.5 W for a boost-follower, compared to 19.5 W for a traditional regulator, i.e. the boost-follower is about 3% more efficient at low line.

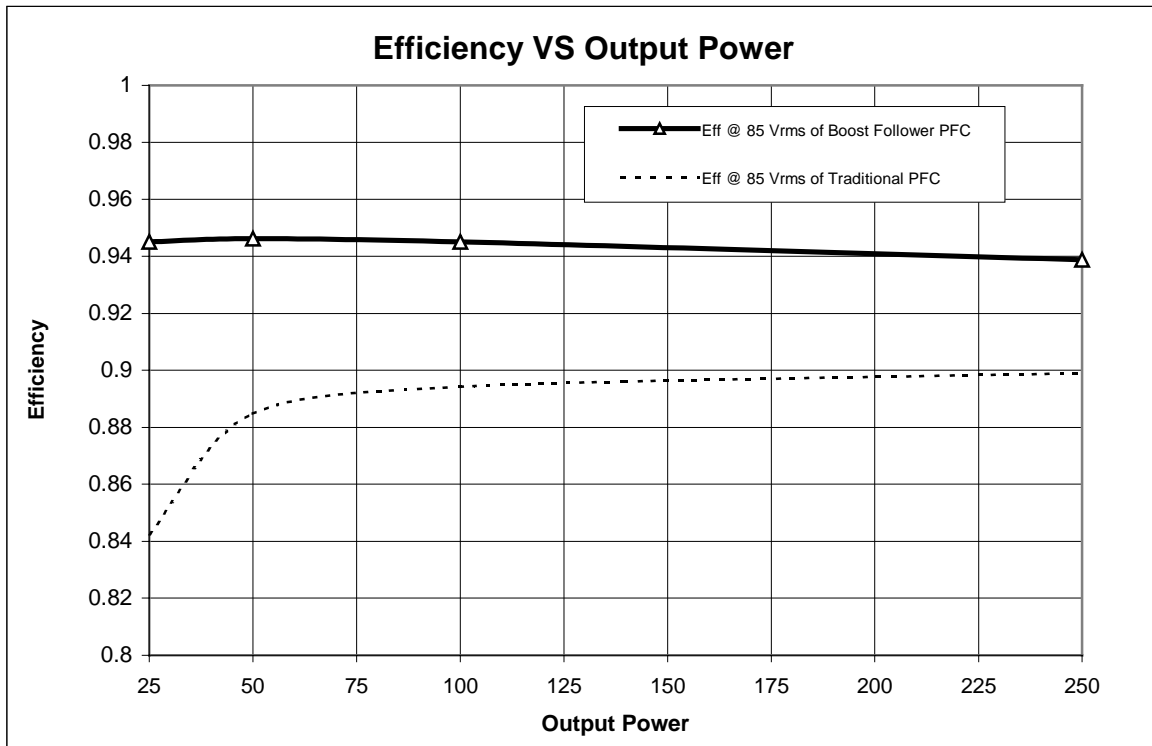


Fig. 3: Laboratory Results Of Boost-Follower Vs. Traditional PFC

### Boost FET Heat Sink Size Reduction

The heat sink for the boost FET is calculated for when the input voltage is at its lowest because – where the FET losses are at their highest. The following can be used to calculate the minimum thermal impedance of the heat sinks ( $R\theta_{sa}$ ) required for either topology, where  $T_{jmax}$  is the maximum junction temperature,  $T_{amb}$  is the maximum ambient temperature,  $R\theta_{jc}$  is the thermal impedance from the semiconductor junction to case, and  $R\theta_{sc}$  is the thermal impedance of the heat sink to case.

$$R\theta_{sa} = \frac{T_{jmax} - T_{amb} - P_{semi} * (R\theta_{sc} + R\theta_{jc})}{P_{semi}}$$

In this equation, as the loss of the FET ( $P_{semi}$ ) decreases the thermal impedance increases, and the size of the required heat sink decreases – another advantage of boost-follower over traditional. This can be further emphasized by selecting heat sinks for boost-follower and traditional PFC pre-regulators with the losses already calculated in the boost switch loss section. The design requirements for each would be that  $T_{jmax}$  would not exceed 75% of the FET's maximum rating and that  $T_{amb}$  would be maintained at 40°C by a fan capable of 150 linear ft/min. The IRFP450 used would require an AVVID heat sink part number 53002 (about 4.125 in<sup>3</sup> volume) in the traditional topology and an AVVID 531202 (about 1.38 in<sup>3</sup> volume) in a boost-follower – about 66% smaller volume.

### Holdup Capacitor Selection

Unfortunately you cannot get added performance without a cost. The cost comes with slower transient response and a larger holdup capacitor ( $C_{boost}$ ) with the following estimating the size of the capacitor required for time requirements (tholdup).  $V_{holdup}$  is the amount of holdup voltage that is required for the design.

$$C_{boost} \geq 2 * P_{out} * \frac{t_{holdup}}{V_{out(min)}^2 - [V_{out(min)} - V_{holdup}]^2}$$

Calculating the minimum required holdup capacitance for the boost-follower and the traditional pre-regulators show how much larger the capacitor could get. In the 250-W application with 16.7-ms holdup time and 85-V holdup voltage, the traditional topology had a  $V_{out(min)}$  of 390V, and the boost-follower was 206 V. The boost-follower required a hold up capacitor of about 330  $\mu$ F, while the traditional converter required only 150  $\mu$ F.

### Conclusions

The boost-follower PFC pre-regulator has some benefits over the traditional PFC pre-regulator that a power supply designer might be interested in. The added benefits are higher efficiency at low line operation, a smaller boost switch heat sink and a smaller boost inductor to meet similar power requirements. Unfortunately, to get the benefits of using a boost follower the designer has to deal with a slower transient response and a larger boost holdup capacitor.

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