Technical Article
Is PFC Possible without Input Voltage Sensing?

TEXAS INSTRUMENTS

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Power factor correction (PFC) forces the input current to follow the input voltage (V_{IN}) so that any electrical load appears like a resistor. This action requires sensing the input voltage and modulating a current reference based on that sensing. The current loop will force the input current to follow the reference. This is called average current-mode control, as shown in Figure 1.
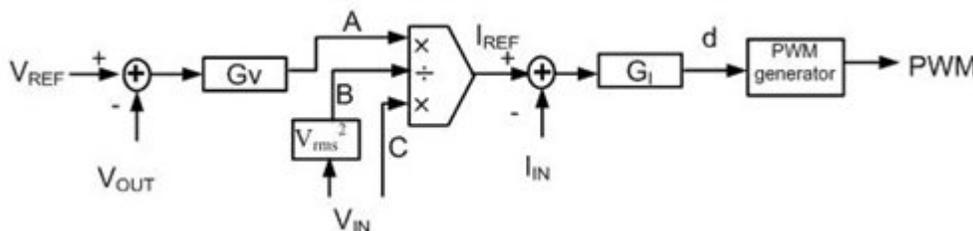

Figure 1. PFC Average Current-mode Control

You can find lots of commercial PFC controllers with low total harmonic distortion (THD) using this average current control algorithm in the market. However, these PFC controllers need a dedicated pin to sense V_{IN} and a precision analog multiplier for current-reference modulation.

Another PFC control algorithm that does not need V_{IN} sensing but can still provide average current-mode control has become very popular recently. TI's UCC28180 belongs to this family. Because it lacks a V_{IN} sense pin and the precision analog multiplier, it comes in a smaller package, enabling lower system cost, and is very easy to use.

But when we introduce the UCC28180 to designers, many times their first response is, "What? Without V_{IN} sensing? How does that work?" In this post, I will try to answer this question.

Figure 2 shows the control algorithm used in the UCC28180. A low-bandwidth voltage loop regulates the output voltage. The input current is measured as V_{lin} and compared with a saw-wave V_{ramp}. The amplitude of V_{ramp} is proportional to the voltage-loop output. Because PFC uses the boost topology, the input-voltage information is already there, but hidden. The control algorithm shown in Figure 2 employs the hidden information.
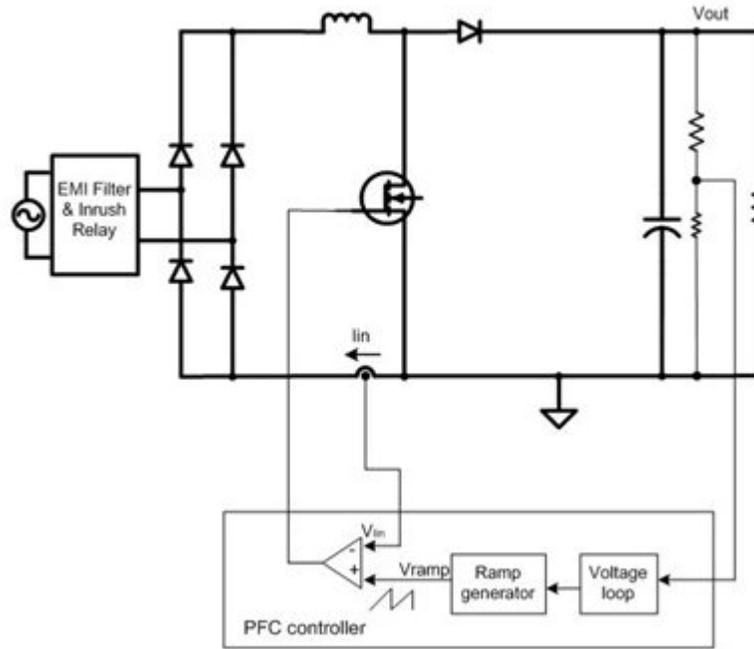
Figure 2. PFC without V_IN Sensing

The PWM output signal always starts low at the beginning of the switching cycle, triggered by the internal clock, as shown in Figure 3. The PWM output stays low until V_{ramp} rises linearly to intersect the V_{lin} voltage. The V_{ramp}/V_{lin} intersection determines switch turning off time t_{OFF}.
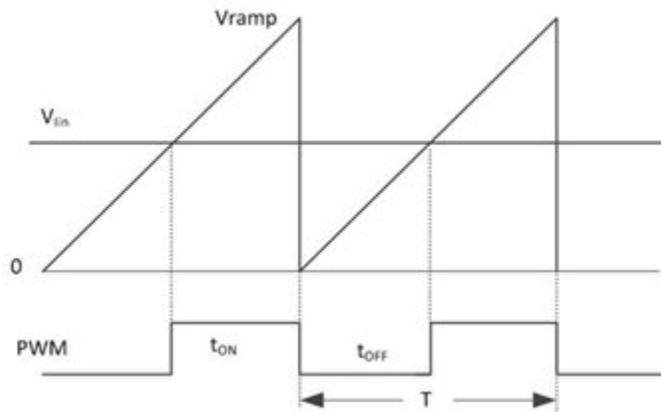

Figure 3. PWM Generation

From Figure 3:

$$\frac{V_{lin}}{V_{ramp}} = \frac{t_{OFF}}{T} \qquad (1)$$

Here T is the switching period. For boost converter operating in continuous conduction mode (CCM):

$$\frac{t_{OFF}}{T} = \frac{V_{in}}{V_{out}} \qquad (2)$$

Combining Equations 1 and 2 gives you Equation 3:

$$V_{Iin} = V_{in} * \frac{V_{ramp}}{V_{out}} \tag{3}$$

The voltage output, V_{OUT}, is a constant in steady state. Since the PFC voltage loop is very slow, V_{ramp} is also a constant in steady state. Thus, the input current is solely proportional to V_{IN}. If V_{IN} is sinusoidal, the input current must be sinusoidal, achieving good PFC. It looks like magic, doesn't it?

Learn more about TI's PFC solutions.

Additional resources:

- Get started designing with the UCC28180:
  - 230-V, 400-W, 92% Efficiency Battery Charger w/PFC and LLC for 36-V Power Tools Reference Design
  - 230-V, 3.5-kW PFC with >98% Efficiency, Optimized for BOM and Size Reference Design
  - 230V, 900W, PFC with 98% Efficiency for Inverter Fed Drives Reference Design.
- Get to know the UCC28051, UCC28063, UCC28019A and UCC28070
- Read more of Bosheng's blogs on PFC:
  - It is not just a PFC controller, it is also a power meter
  - How to reduce PFC harmonics and improve THD using harmonic injection: Part 1, Part 2
  - How To: Improve power factor and THD using DFF control

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