Technical Article

Synchronous rectifiers improve cross-regulation in flyback power supplies

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The flyback is a logical choice when choosing a system topology that must generate multiple outputs from a single power supply. Since the voltage across each transformer winding is proportional to the number of turns in that winding, you can set each output voltage simply by providing the correct number of turns. In a perfect world, if you regulate one of the output voltages, all other outputs will scale by the number of turns and also remain regulated.

However, in the real world, parasitic elements conspire to degrade the load regulation of unregulated outputs. Back in Power Tip 72, Robert Kollman showed how to calculate the regulation error induced by the forward-voltage drop of the rectifier. In this power tip, I'll explore further to see the effects of parasitic inductance and how using synchronous rectifiers instead of diodes can greatly improve cross-regulation in flyback power supplies.

Take for example a flyback that generates two 12V outputs at 1A each from a 48V input, as shown in Figure 1 's simplified simulation model. Ideal diode models have zero forward-voltage drop and negligible resistance. The transformer winding resistances are neglected, and only parasitic inductances in series with the transformer leads are modeled. These inductances represent the leakage inductances within the transformer, as well as parasitic inductances within the printed circuit board (PCB) traces and diodes. When you set these inductances, the two outputs track each other perfectly, because when the diodes conduct during the 1-D portion of the switching cycle, the perfect coupling of the transformer forces the two outputs to be equal.

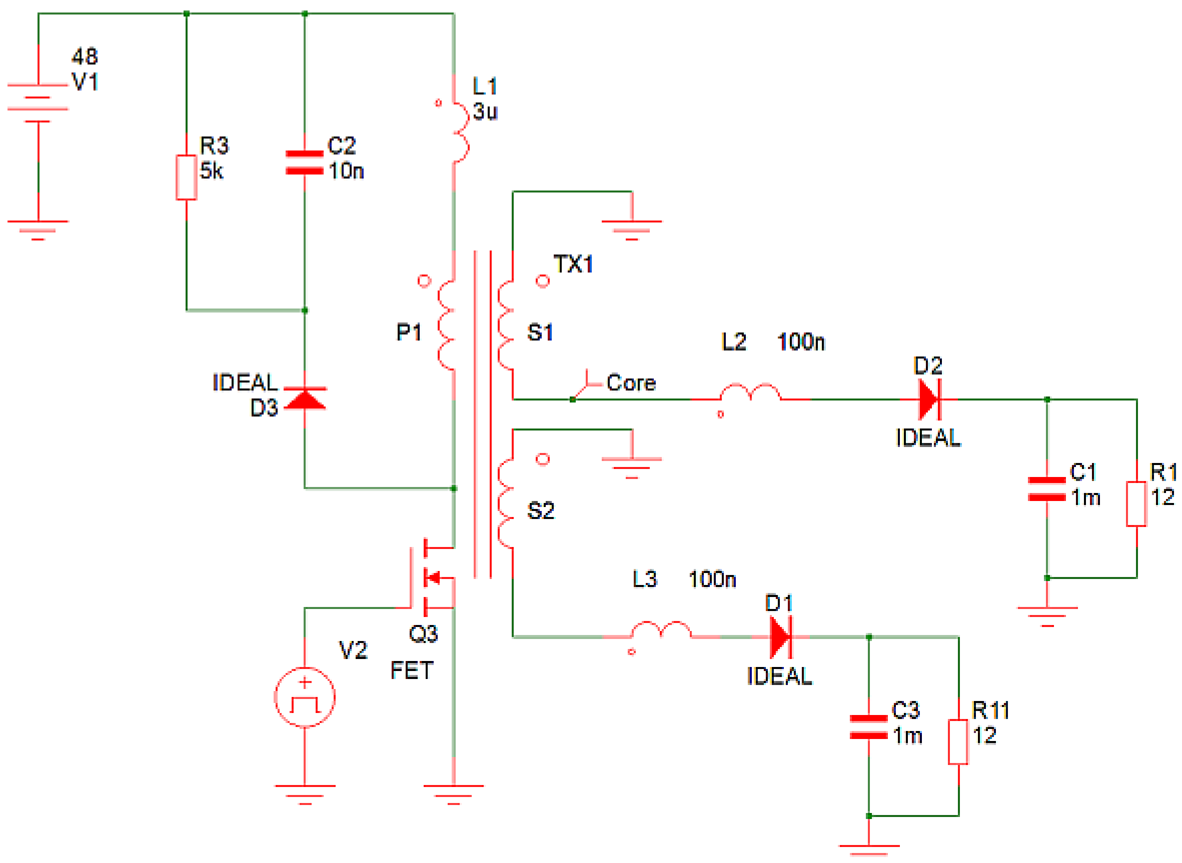

Figure 1. This simplified flyback model simulates the effects of leakage inductance on output-voltage regulation.

Now consider what happens when you introduce 100nH of leakage inductance into both secondary leads of the transformer, and 3 µH of leakage in series with the primary winding. These inductances model parasitic inductances in the current paths, which include leakage inductances internal to the transformer, as well as inductances in the PCB and other components. When the primary field-effect transistor (FET) turns off, the primary leakage inductance still has current flowing and the secondary leakage inductances begin the 1-D period with an initial condition of 0A. A pedestal voltage appears on the transformer's magnetic core, common to all windings. This pedestal voltage enables the current in the primary leakage to ramp down to 0A and the secondary leakage currents to ramp up to deliver current to the loads.

When heavily loading both outputs, current continues to flow for the entire 1-D period, and the output voltages are well balanced, as shown in Figure 2 . However, when heavily loading one output and lightly loading the other, the output capacitor on the lightly loaded output will tend to peak-charge from this pedestal voltage; its output diode will cease to conduct as the current quickly ramps back to zero. See the waveforms in Figure 3 . The cross-regulation impact of peak-charging from these parasitic inductances is typically much worse than that caused by the rectifier forward-voltage drops alone.

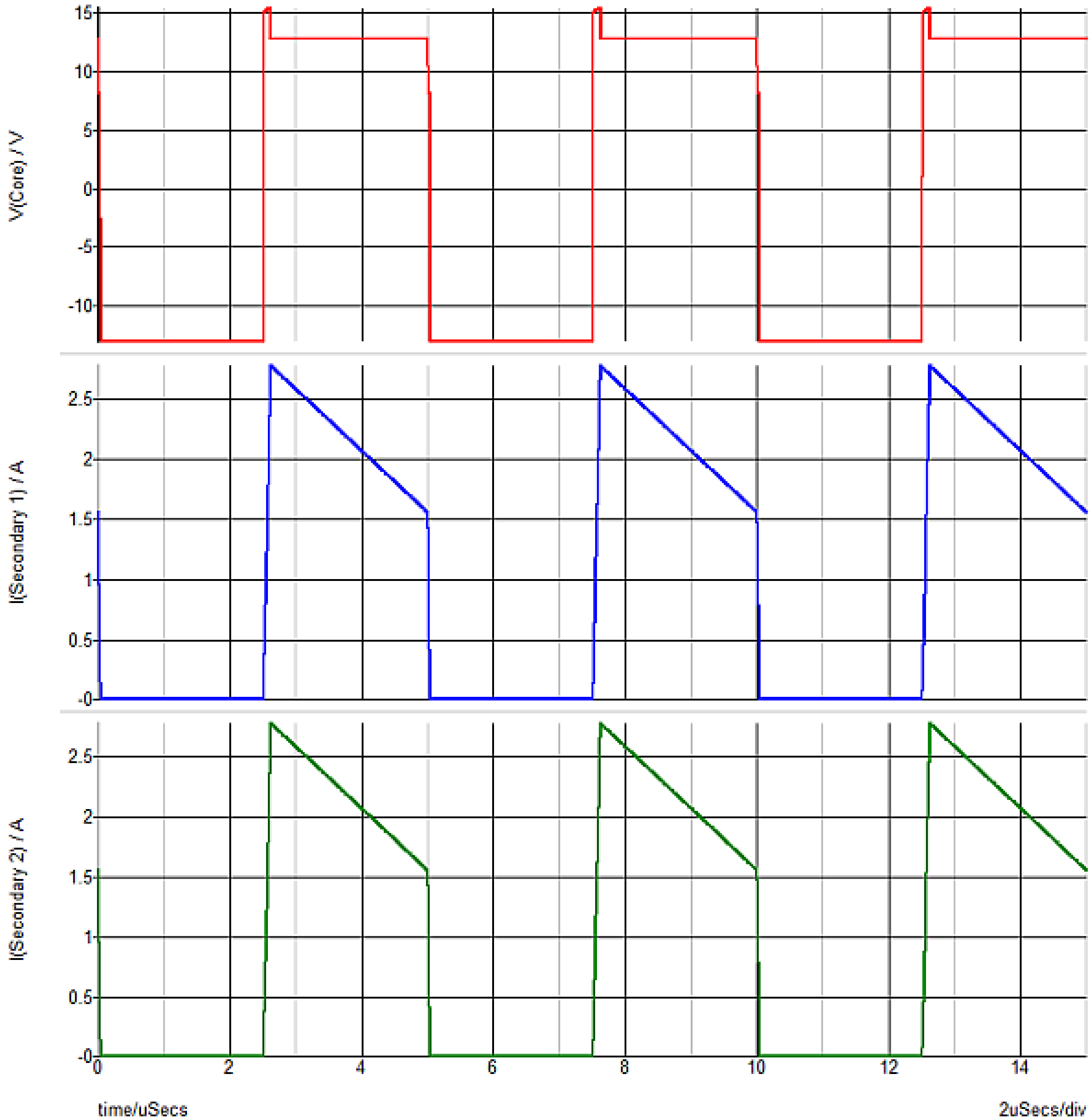

Figure 2. When applying heavy loads to both outputs, the secondary winding currents flow in both secondary windings during the entire 1-D period. You can see the pedestal voltage on the upper-red trace.

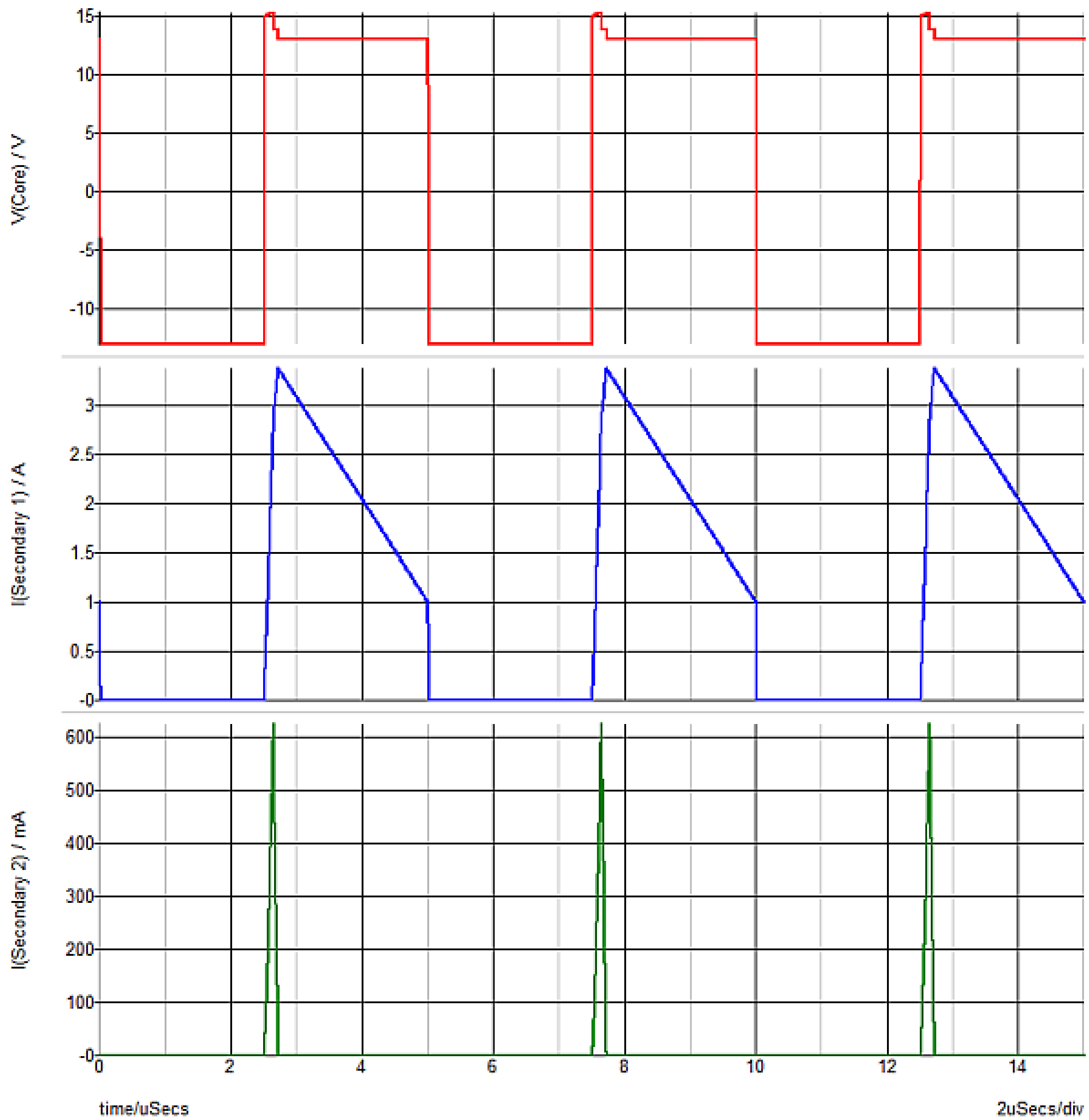

Figure 3. A heavily loaded secondary 1 and lightly loaded secondary 2. The pedestal voltage peak-charges the output capacitors of secondary 2.

Synchronous rectifiers help alleviate this issue by forcing current to flow in both windings for the entire 1-D period, regardless of loading. Figure 4 shows waveforms with the same loading conditions as Figure 3 , but replaces the ideal diodes with ideal synchronous rectifiers. Because the synchronous rectifier remains on well after the pedestal voltage diminishes, the two output voltages track each other well, even with severely imbalanced loads.

While the average current in secondary 2 is very small, the root-mean-square (RMS) content can still be quite high. That's because, unlike the ideal diode in Figure 3 , the synchronous rectifier forces continuous current flow during the entire 1-D period. Interestingly, the current must be negative for a substantial portion of this period for the average current value to be low.

Obviously, you are trading better regulation for higher circulating currents. However, this does not necessarily translate into higher overall losses. The forward drop of the synchronous rectifier is typically much lower than that of a diode, so efficiency is usually much better at higher loads with synchronous rectifiers.

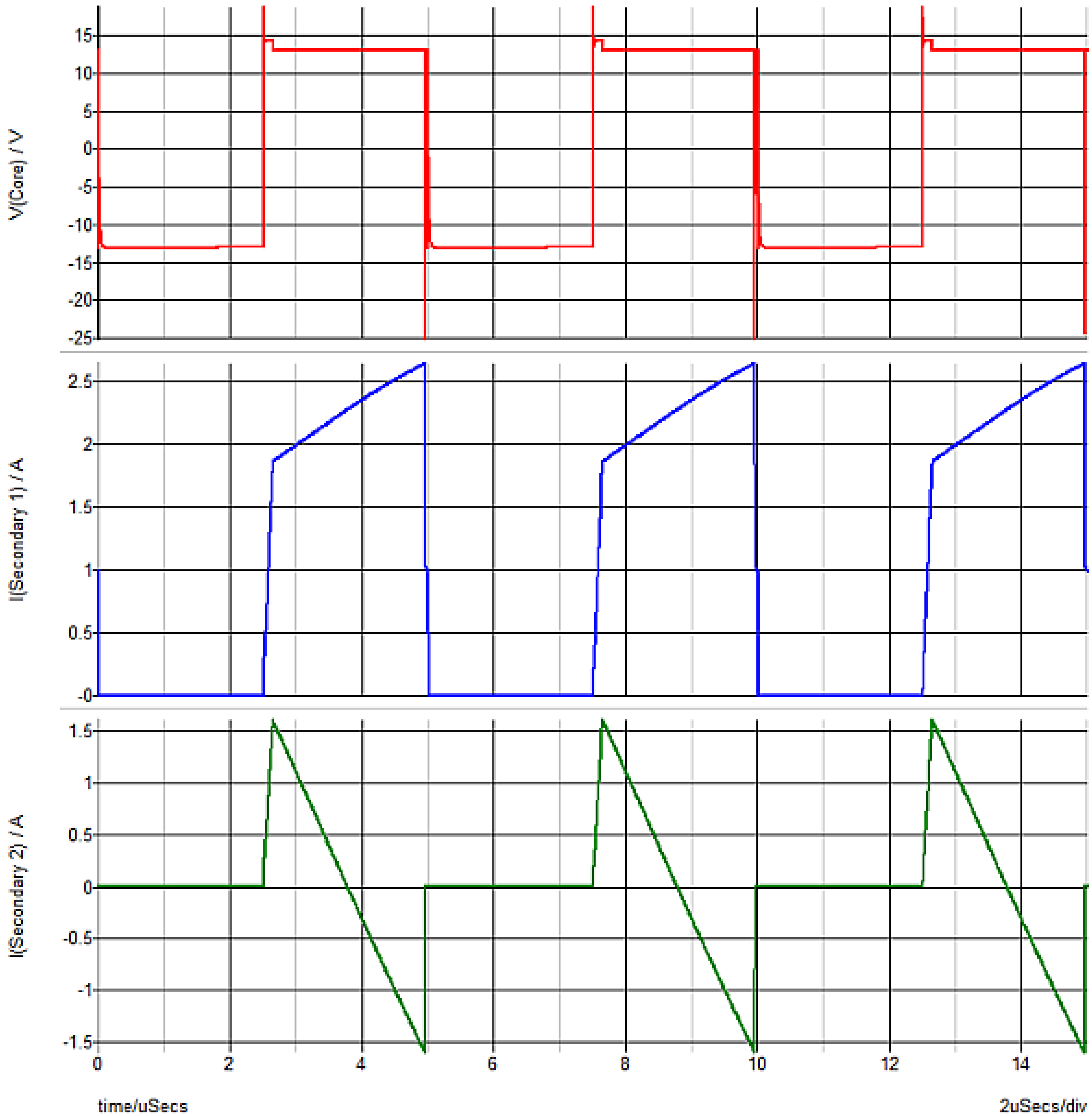

Figure 4. Replacing diodes with synchronous rectifiers forces current flow in both secondary windings and eliminates peak-charging from the pedestal voltage.

You can see the effect on cross-regulation in Figure 5 . Here, the load on output No. 1 holds steady at 1A, while the load on output No. 2 sweeps from 10 mA to 1A. At loads below 100mA, the cross-regulation is severely degraded when using diodes, due to the effect of peak-charging from the pedestal voltage.

Remember, you are looking only at the effects of leakage inductance, as these simulations use ideal diodes and ideal synchronous rectifiers. When considering the effects of the resistive and rectifier forward-voltage drops, the benefits of using synchronous rectifiers are further amplified, as summarized in Power Tip 72.

So for excellent cross-regulation in multiple output flyback supplies, consider using synchronous rectifiers. As an additional benefit, you will also likely improve the efficiency of your supply. Check out TI's 40V to 60V Input 40W Dual Output Isolated Flyback Converter (6V@4.33A) and Class 3 Dual Output Isolated Flyback Converter for PoE Applications reference designs as examples of flyback supplies using synchronous rectifiers.

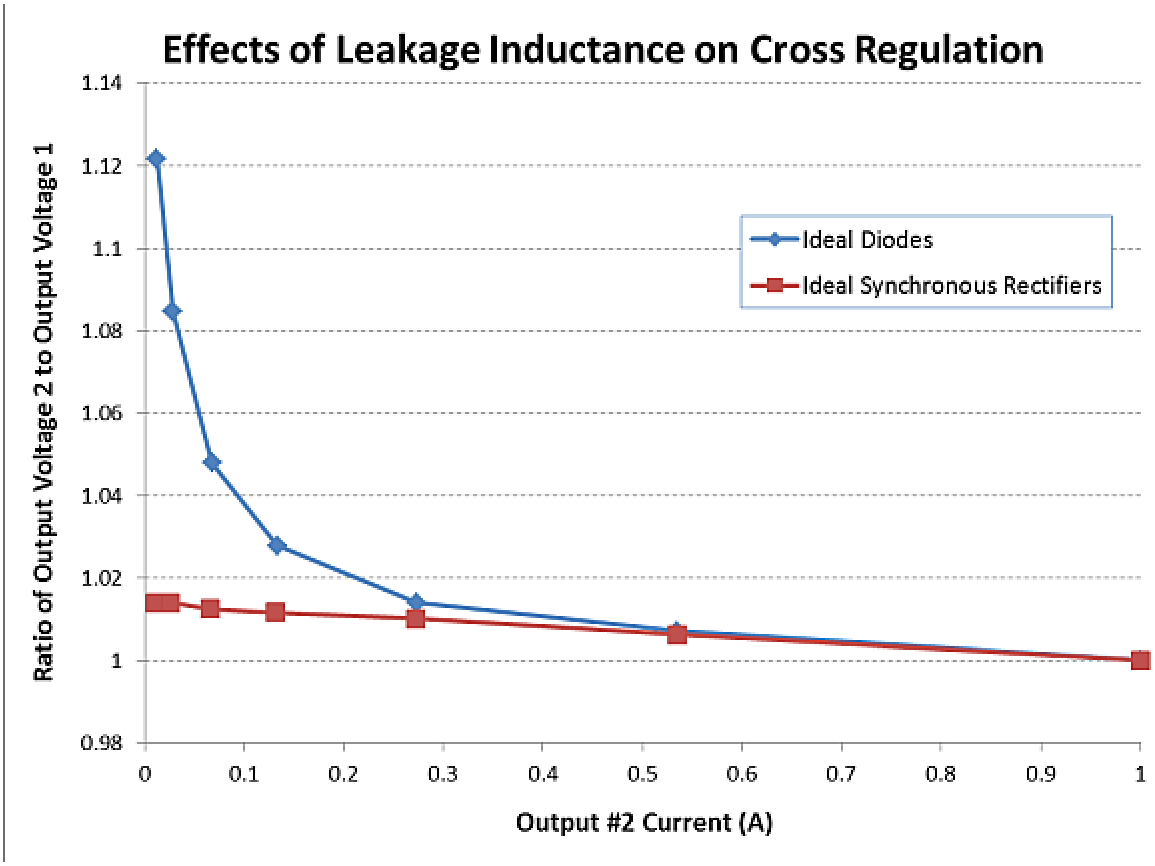

Figure 5. This plot shows the cross-regulation between the two outputs with a steady 1-A load on output No. 1 as the load on output No. 2 varies, thus highlighting how synchronous rectifiers mitigate the effects of leakage inductance.

For more Power Tips, check out TI's Power Tips blog series on Power House.

Additional resources:

- Watch the video, "Topology Tutorial: What is a Flyback?"
- Download TI's Fly-buck and Flyback Selector Tool to help select the right isolated DC-DC topology based for your specification.

Also see :

- Power Tip 72: Select the Right Rectifiers for Multiple Output Flybacks
- Method provides self-timing for synchronous rectifiers
- Synchronous rectification boosts efficiency by reducing power loss
- LLC synchronous rectification made easy, robust and more efficient

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