

Lower EMI and Quiet Switching with the Fly-Buck™ Topology



Eric Lee

My colleagues have written extensively about the [Fly-Buck topology](#), but the details of the Fly-Buck’s soft/quiet switching characteristic haven’t been shared, which helps achieve higher efficiency, lower electromagnetic interference (EMI) and a smaller solution size in isolated DC/DC bias applications.

Why Flyback/buck Switching Is Noisy

In a flyback topology, the DC voltage stress across the switch is $V_{IN} + V_{OUT}/N$. On top of this DC voltage stress, high-frequency ringing caused by the transformer leakage inductance adds more stress at the moment the switch turns off; ([Figure 1\[a\]](#)). A resistor-capacitor-diode (RCD) snubber is usually required on the primary side to clamp and dampen ringing at the switching node ([Figure 1\[b\]](#)).

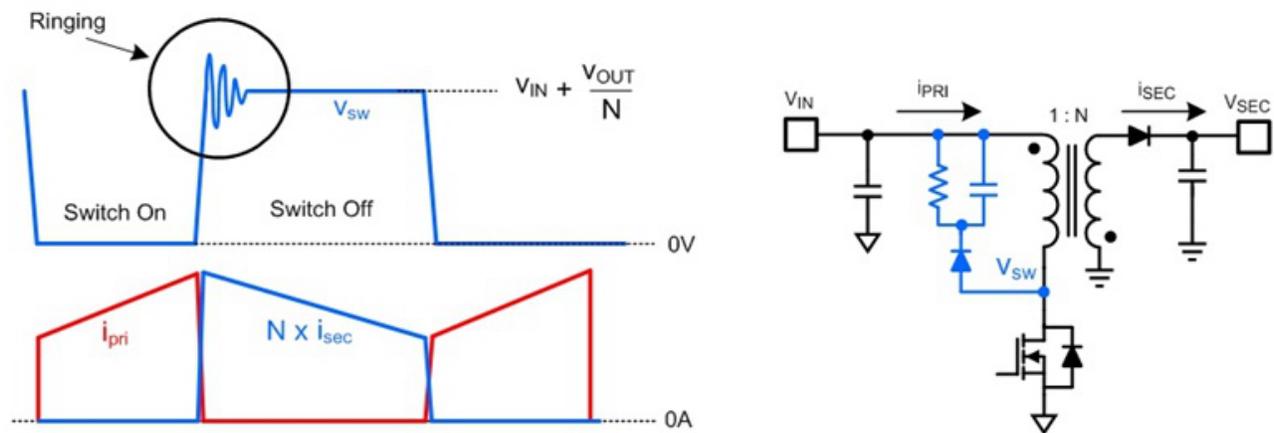


Figure 1. Flyback Topology: Simplified Waveforms (a) and a Typical Flyback Circuit (b)

It is also very common to minimize the high-frequency ringing at the switching node when designing a buck converter by using an RC snubber in parallel with the low-side switch, as shown in [Figure 2\(a\)](#). In a buck topology, the ringing happens at the moment when the high-side switch turns on, as shown in [Figure 2\(b\)](#). The printed circuit board (PCB) trace inductance and reverse-recovery characteristic of the low-side body diode both affect the amount of ringing.

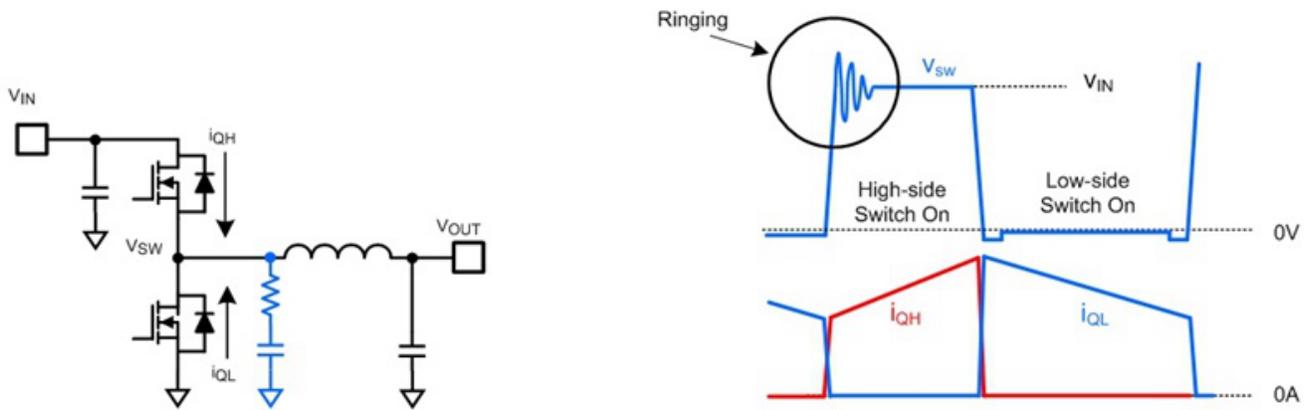


Figure 2. Buck Topology: a Typical Synchronous Buck Circuit (a) and Simplified Waveforms (b)

Soft/quiet Fly-Buck Switching

In a Fly-Buck topology, the low-side switch turns on softly because the low-side body diode conducts before the switch turns on. The energy stored in the transformer leakage inductance always has a path to flow out. The high-side switch switches quietly because the low-side body diode is reverse-biased before the high-side switch turns on. Because the low-side body diode is reverse-biased, there is no reverse-recovery current flow when the high-side switch turns on.

The DC voltage stress across the switch is V_{IN} ; see Figure 3(b). Because the Fly-Buck switching is soft/quiet, just a small margin is required on top of V_{IN} . Figure 3 shows a typical Fly-Buck circuit and switching waveforms. In Figure 3, i_m is the magnetizing current, which is the combination of the primary current and secondary current reflected to the primary side.

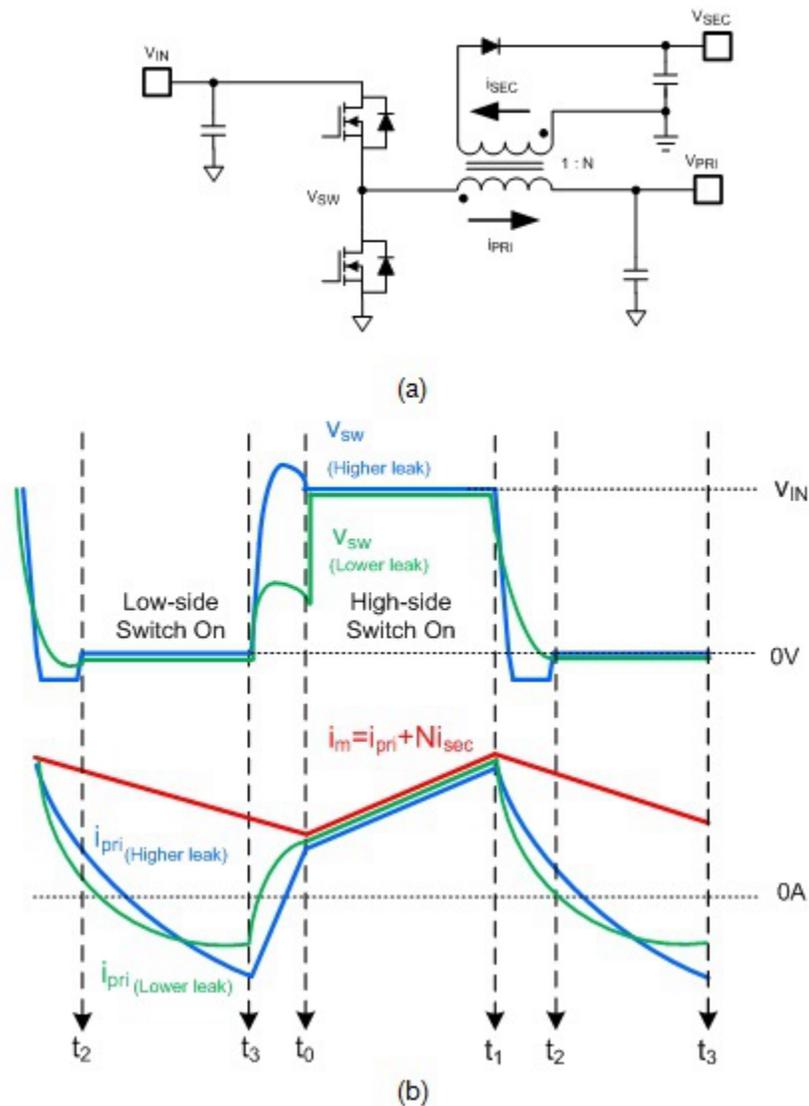


Figure 3. Typical Fly-Buck Circuit (a) and Switching Waveforms (b)

Figure 4 shows the equivalent circuits of four switching modes. The four modes are:

- **MODE0: t_0 - t_1 (energy store).** The converter stores energy in the transformer when the high-side switch turns on. The primary-side current rises linearly during this period, similar to how the inductor current rises linearly in a buck.
- **MODE1: t_1 - t_2 (high-side off to low-side on dead time).** When the high-side switch turns off, the primary-side current keeps flowing through the low-side body diode after fully discharging/charging the low- and high-side parasitic capacitors. The secondary-side current starts flowing since the secondary-side diode is forward-biased. The switch-node voltage becomes almost zero before t_2 , which allows the low-side switch to turn on softly.
- **MODE2: t_2 - t_3 (energy transfer).** In this period, the low-side switch turns on and the converter transfers the stored energy to the secondary side, similar to how the flyback transfers energy to the secondary side when its low-side switch turns off. Assuming no/light load at the primary-side output, the primary-side current flows in a positive direction initially, but changes its direction to negative at the end of this period.
- **MODE3: t_3 - t_0 (low-side off to high-side on dead time).** The primary-side current flows in a negative direction in this period. This current discharges/charges the high- and low-side parasitic capacitors and reverse-biases the low-side body diode. Since the low-side body diode is reverse-biased before the high-side switch turns on, the high-side switch can turn on quietly at t_0 , without any excessive high-frequency ringing caused by the reverse-recovery effect. The secondary-side current stops flowing in this period since the secondary-side diode is reverse-biased.

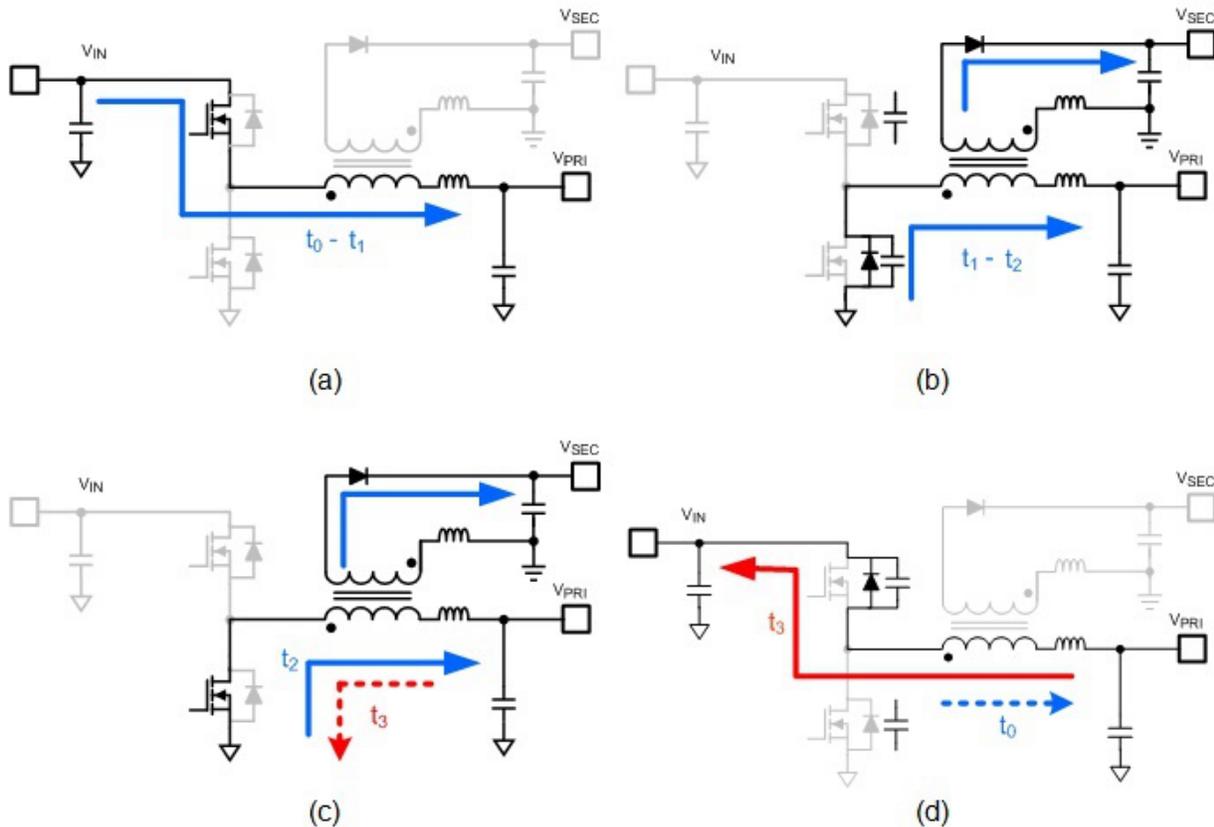


Figure 4. Equivalent Circuit of Each Mode and Current Flows: MODE0, T_0 - T_1 (a); MODE1, T_1 - T_2 (Dead Time) (b); MODE2, T_2 - T_3 (c); and MODE3, T_3 - T_0 (Dead Time) (d)

Conclusion

The Fly-Buck converter switches more quietly than the flyback or the buck. This quiet switching characteristic can bring some benefits beyond the Fly-Buck's simplicity and good cross-regulation performance, including lower EMI; smaller board size, since the snubber circuit at the primary switch node is no longer necessary; and higher efficiency, by saving snubber loss on the primary side.

Additional Resources

- Download the application report, "[Designing an Isolated Buck \(Fly-Buck\) Converter.](#)"
- Check out the product page for the [LM5160](#).
- Watch Robert Kollman's video, "Power Tip 34: [Design a simple, isolated bias supply.](#)"
- Use WEBENCH Power Designer to create LM5160 [Buck](#) and [Fly-Buck](#) designs, run [electrical](#) and [thermal](#) simulations and [export](#) your customized schematic and board to popular CAD formats.
- Simulate LM5160 designs using standalone [Spice Models](#).

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to [TI's Terms of Sale](#) or other applicable terms available either on [ti.com](https://www.ti.com) or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2023, Texas Instruments Incorporated