ISSUE: January 2019

Two-Switch Flybacks Outperform LLC Resonant Converters On Most Parameters

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While price usually comes first, the other main criteria when designing a power supply are high efficiency, low standby power and high power factor. Some of these goals are hard to meet with the widely used flyback converter. A significant portion of its losses are incurred by the leakage power of the main transformer, wasted in the snubber circuit, or due to switching losses in the MOSFET and losses on the secondary-side diode rectifier. In terms of efficiency and switching losses, the LLC resonant converter is now preferred over the flyback because it offers the advantage of zero-voltage switching (ZVS).

But because of its high circulating current in the resonant circuit, the LLC shows worse efficiency at low load. However, an alternative is emerging thanks to some new design options discussed here. Specifically, the two-switch flyback implemented with a quasi-resonant (QR) PWM controller brings significant improvement in all of the key power supply parameters. In this article, we demonstrate how new QR resonant PWM controllers and SiC MOSFET-compatible gate drivers are making the two-switch flyback converter a lower-cost, higher performance alternative to the LLC resonant converter, especially in cases with high-voltage input.

In particular, the aim was to reach the possibility of using ST QR PWM controllers for a high efficiency, high power factor LED driver at output power up to 150 W or a high-voltage input, high efficiency power supply with output power up to 300 W at parameters comparable or better than an LLC resonant converter.

Four options were developed and tested, two based on the HVLED001 HPF QR PWM controller and two on the STCH02/03 low standby QR PWM controller, with usage of the L6385E standard HV MOSFET driver and with an innovative ac-coupled transformer-based MOSFET driver, finally optimized and tested for use with SiC MOSFETs. This transformer gate driver version is also applicable for high input voltage above 1 kV.

Benefits Of The Two-Switch Flyback And Component Choices

The two-switch flyback comes with a number of advantages. It offers high efficiency from low to high load. The energy that would otherwise be wasted in discharging the leakage inductance is returned to the bulk capacitor. The voltage stress on the MOSFETs is limited to Vin, and there's also lower voltage stress on the secondary side. In addition, the two-switch flyback based on QR FB controllers achieves close to zero (voltage) switching of the main MOSFET. On top of all this, it's easier to design than the LLC converter.

ST's QR flyback controllers have some advantages that can be exploited in two-switch flyback designs. They make it possible to use primary sensing of output voltage and current. They also permit valley skipping, which reduces use of burst switching and lowers output ripple.

The different controller ICs have their own specific advantages. For example, the HVLED001A HPF QR FB controller enables design of a high power factor QR FB, while providing primary sensing of the output voltage. The STCH02/STCH03 QR FB controllers are notable for their extra low standby power and primary sensing of output current.

There are additional benefits stemming from the use of an ac-coupled transformer-based MOSFET driver. These include zero standby power, the possibility of using a working voltage over 650 V and compatibility with common PWM controllers with single gate-drive output (i.e., complementary outputs are not necessary). Also important, this type of driver is usable for driving SiC MOSFETs.

In the first design option, we used the L6385E standard HV gate driver. It had the following limitations. When used commonly with current controlled PWMs, which generally aren't equipped with on-time cycle limiting, the first high-side gate pulse isn't passed. This problem was solved by adding Q1 which completes the first cycle. However, the standard MOSFET gate driver also has a narrower working voltage range than the PWM controller, which can cause limitations when used in a dimmable LED driver. Most applicable MOSFET gate drivers can be used only below 600-Vdc input voltage and are not suitable when low standby power is requested.

To remove these restrictions, the ac-coupled transformer-based MOSFET driver was developed (Fig. 1). With this driver, the voltage limitation is removed and there is zero standby power. The principle driver schematic is shown in Fig. 1. It consists of a push-pull driver working to virtual ground at half supply voltage. Virtual ground also creates a reference signal for the push-pull driver.

Current through the primary can flow in both directions, depending on input edge polarity. The result is a symmetrically excited core, zero standby current, effective use of core volume and less risk of saturation. Schematics and measurements for both the STCH02/03 controllers (200-W FB schematic, Fig. 2; efficiency and standby power, Fig. 4) and for the HVLED001A controller (100-W HPF FB schematic, Fig. 5; efficiency and power factor Fig. 6).

Fig. 3 confirms the predicted improvement in efficiency of a dual-switch FB (200-W version using the STCH02) from that of a single-switch flyback (with the same transformer) and a 150-W LLC half-bridge resonant converter (with a synchronous rectifier).

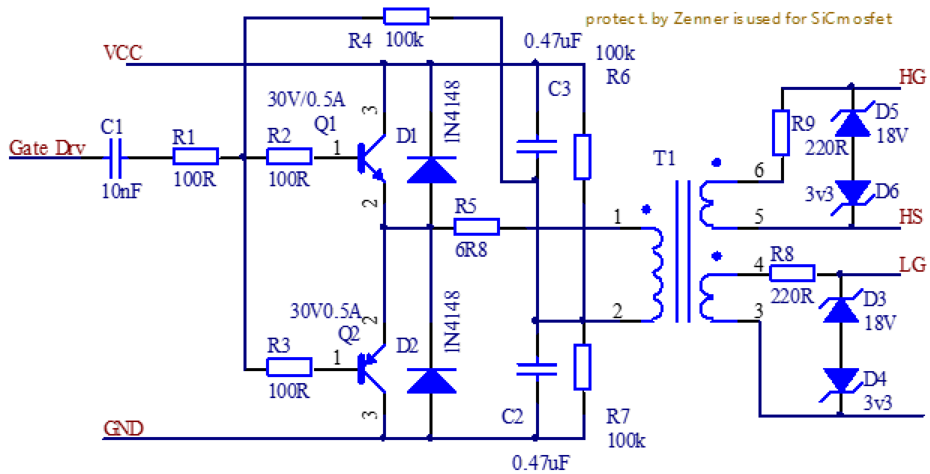

Fig.1. AC-coupled HB MOSFET driver including SiC MOSFETs.

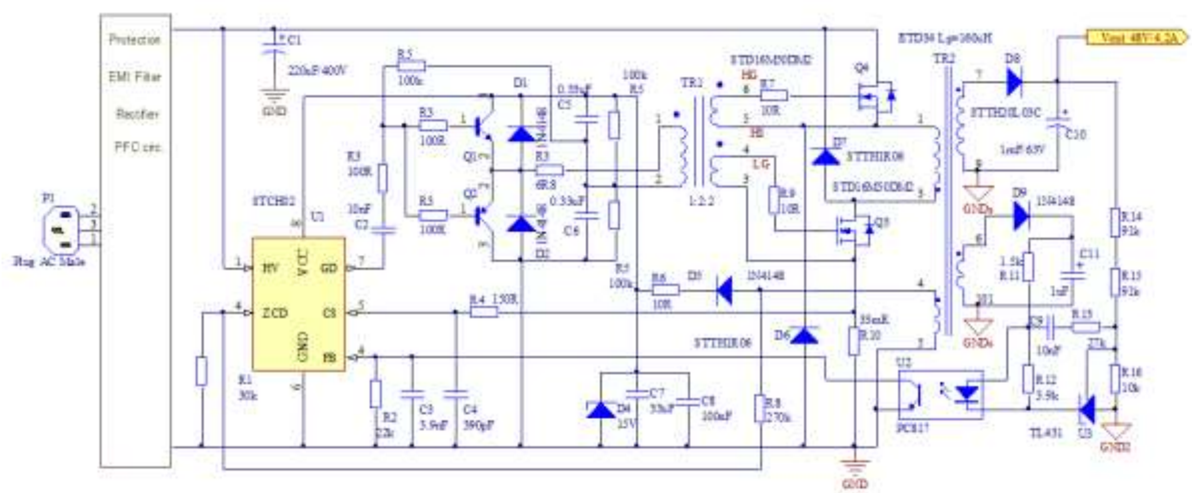

Fig. 2. Schematic of 200-W dual-switch QR flyback.

Fig. 3. Efficiency comparison of a two-switch flyback with an LLC resonant and a single-switch flyback.

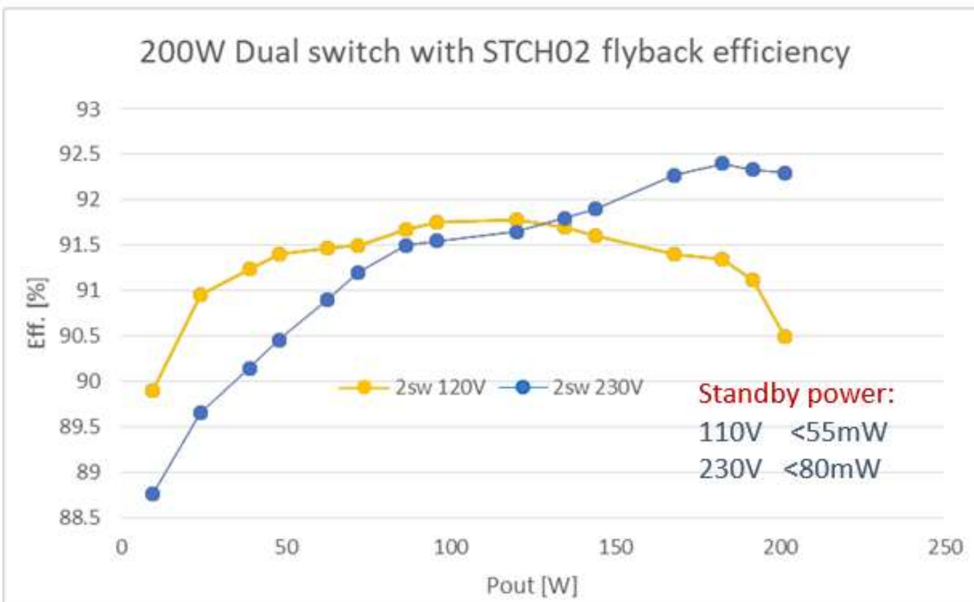

Fig. 4. Efficiency of 200-W dual-switch QR flyback.

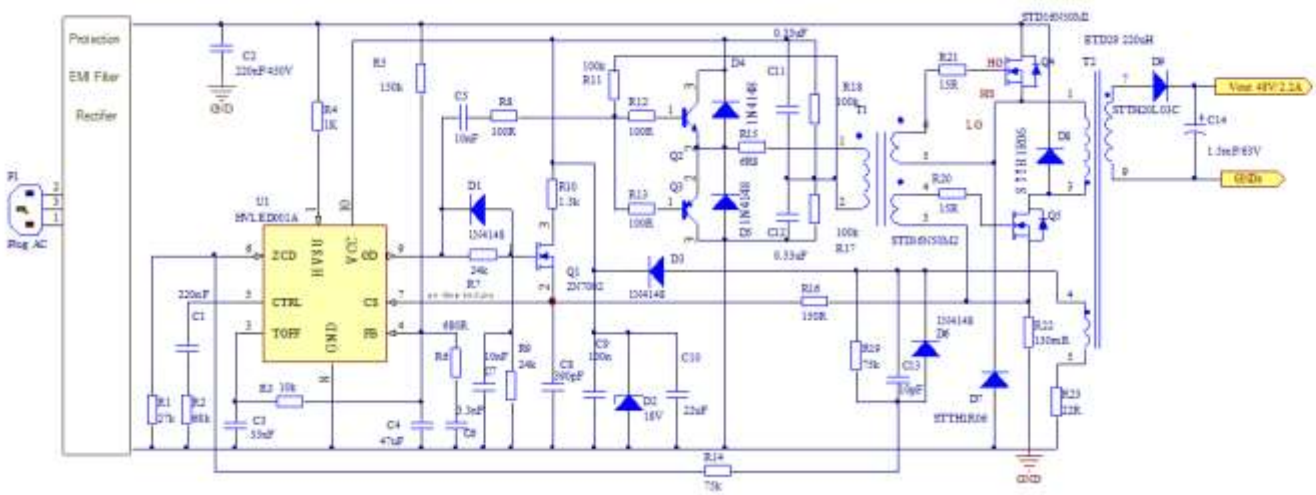

Fig. 5. Schematic of 100-W HPF QR flyback.

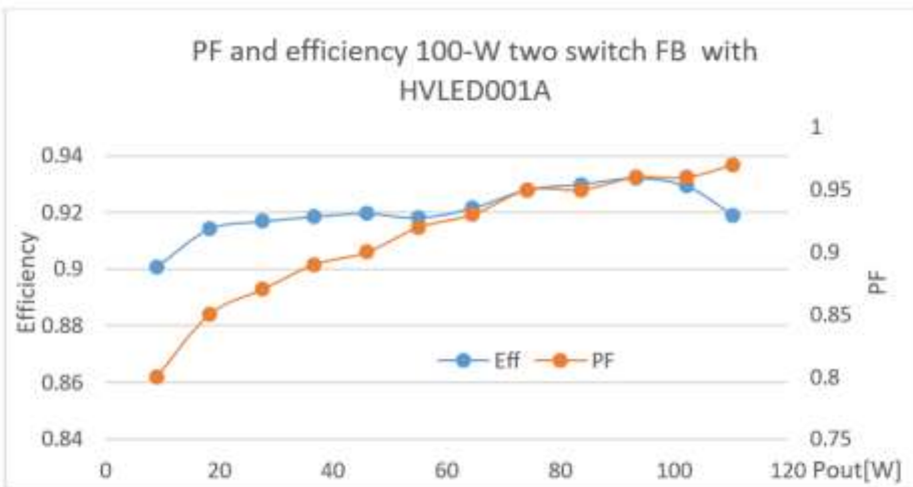

Fig. 6. Efficiency and power factor of 100-W HPF QR flyback.

Conclusion

This project showed that expanding the use of flybacks to the applications now using mostly LLC offers the advantages of lower cost, easier design, lower development effort, higher power per volume and easier control. The use of the transformer gate driver expands the applicability of dual-switch flybacks to applications with high-voltage input and permits use of SiC MOSFETs without special controllers or isolated gate drivers with the need for an isolated auxiliary supply.

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About The Author

Jiri Jirutka has worked for more than 40 years in the development of electronic devices, including the development of audio and music synthesis equipment, and 15 years in industrial automation and development of x86 and PowerPC industrial computers with support for BIOS and RT systems. Jiri's experience also includes five years working as an ASIC designer. For the past six years, he has been an application engineer supporting power management circuits at STMicroelectronics. Jiri has completed two master studies at CVUT Prag (Technology and Operating Systems). In his spare time, he enjoys downhill skiing, travel to exotic countries and keeping and renovating a cottage in the mountains.

For more information on flybacks and other topologies, see How2Power's Design Guide, locate the Topology category and see the various topology links.