Low-cost flyback solutions for 10-mW standby power

By Adnaan Lokhandwala
Product Manager

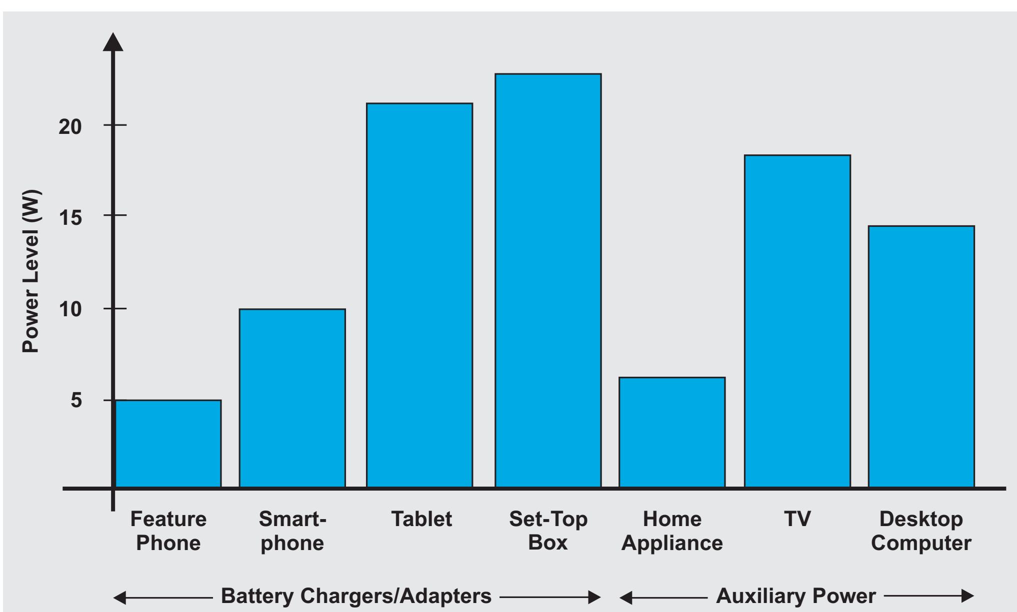
For low-power AC/DC conversion, flyback topology remains the preferred choice due to its simplicity and low cost. Using a small number of external components, this topology can provide one or more outputs for a very wide input-voltage range. It is used in isolated and non-isolated forms to cover a broad range of applications, such as battery chargers in smartphones and tablets; auxiliary power supplies in TVs, desktop computers, and home appliances; AC adapters for portable computing, set-top boxes, and networking; and many more. Figure 1 shows the typical power levels in some of these applications. The widespread applicability and use of the flyback topology in high-volume consumer markets (estimated 2012 worldwide shipments for the markets shown in Figure 1 alone exceeded a few billion units) make it a perfect candidate for optimizing every possible performance specification, such as cost, efficiency, and standby power.

In most applications, flyback converters are stand-alone external power supplies in wall chargers/adapters. In some cases they are powering either a portion of larger equipment or providing standby power to maintain system functions like the user display and remote control when the equipment is not performing its primary function. In all cases, the standby-power consumption of the flyback converter is being heavily scrutinized to minimize the overall power drain when it seems the converter is doing nothing. For example, a flyback power supply used in an AC wall charger may have a mass-production specification of less than 30 mW. If the actual supply consumes only 10 mW of standby power, the 20-mW difference can allow a higher margin for leaky circuit components such as input filters, capacitors, and bias components, reducing overall solution cost. Similarly, a flyback converter with low standby-power consumption can allow more system functions to be active in standby mode while keeping the end equipment's total power consumption to a minimum.

The push towards green power

There is an array of initiatives and directives in the power industry addressing efficiency and standby power that vary by end equipment, power level, and governing authority. In the U.S., these include the California Energy Commission and the Environmental Protection Agency's ENERGY STAR®,[1] and in Europe, the European Union's Standby Initiative, to name a few. After a quick glance at many of these energy-conservation initiatives, it is clear that they all have a common theme—driving minimal power loss at light loads and no-load/standby. Many

Figure 1. Typical power levels for AC/DC flyback-converter designs



regions in the world are also introducing mandatory and voluntary limits for standby-power consumption and light-load operating efficiency of external power supplies.

In the U.S., the California Energy Commission adopted for its own state a battery-charging efficiency standard that became effective in February 2013. Additionally, the U.S. Department of Energy is finalizing a draft that will affect current regulations for power-supply efficiency worldwide. Similarly, the Joint Research Centre of the European Commission (EC) published the final draft of Version 5 of its Code of Conduct on Energy Efficiency of External Power Supplies in October 2013. These new voluntary specifications, which propose tightening of active-mode efficiency and no-load power consumption, are tougher to meet than the mandatory specifications of the EC's current Ecodesign Directive.

To ensure that the external supply is efficient in the idle and standby modes of some applications, the EC has added an additional efficiency requirement at 10% load beyond the four-point active-mode average-efficiency requirement. The EC also has added an additional classification for mobile handheld battery-driven external supplies of less than 8 W that must limit no-load power consumption to less than 75 mW starting in 2014. Finally, the EC's Ecodesign Directive for energy-related products, Lot 6, Tier 2 took effect in January 2013. This part of the directive limits total system standby-power consumption of household and office equipment to less than 0.5 W.

Less than 10 mW of standby-power consumption

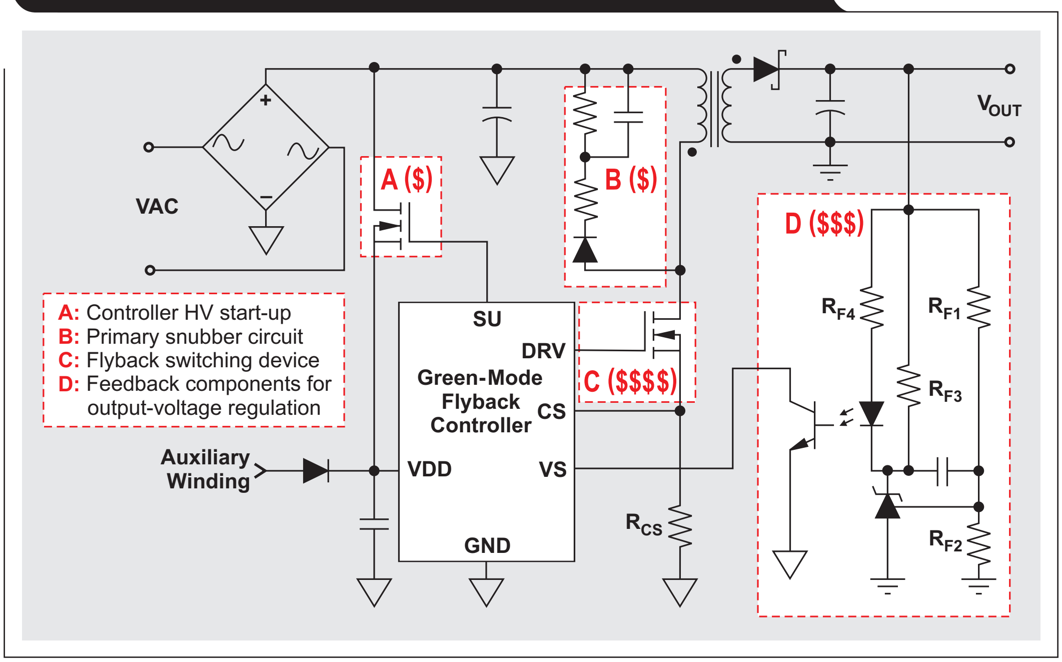
The typical architecture for an isolated flyback converter that consumes less than 10 mW of standby power is shown in Figure 2. Four key elements (labeled A through D) in a flyback that contribute most to its standby-power loss are shown along with their relative cost. Traditionally, this type of converter compares its output voltage with a secondary-side reference. An optoisolator is used to transfer an error signal across the isolation barrier.

There are two fundamental issues with this approach. First, a low-cost reference like the widely used TL431 shunt regulator from Texas Instruments (TI) needs a minimum cathode bias current (~1 mA) independent of converter loading under all conditions. Second, the standard optocoupler configuration is such that it consumes the most current under no-load conditions. Note that in order to achieve standby-power consumption of less than 10 mW, a more expensive reference such as TI's TLV431 shunt regulator with very low bias current may need to be used for feedback control.

One way to address these issues is to use a constant-voltage, constant-current (CVCC) controller with primary-side regulation, such as TI's UCC28710. This type of controller can simplify and improve performance in AC/DC designs. The UCC28710 regulates the flyback output voltage and output current within 5% accuracy without optocoupler feedback. It also processes information from the primary power switch and transformer auxiliary winding for precise output CVCC control.

To reduce its no-load consumption, the controller enters smart sleep modes as the converter load decreases and the controller reduces its average current consumption down to 95 µA. The control algorithm modulates the converter's switching frequency and the primary current's peak amplitude while maintaining MOSFET valley switching for high conversion efficiency across line and load. Finally, thanks to high-voltage IC technology, the external HV start-up

Figure 2. Conventional AC/DC flyback consumes less than 10 mW of standby power



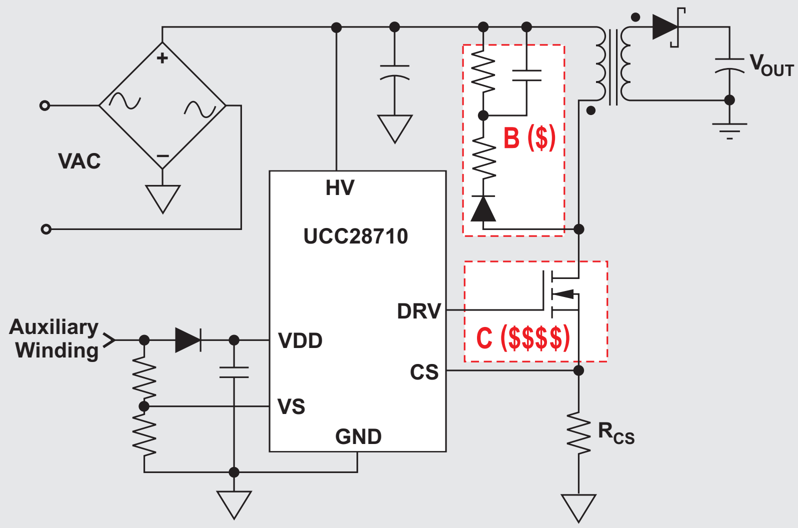
MOSFET is also integrated into the controller to further reduce component count and simplify the solution (Figure 3a).

The choice of a flyback converter switch is very application-specific and performance-driven. In some situations, a bipolar junction transistor (BJT) can be a better choice than a MOSFET. Fundamentally, BJTs cost less than power MOSFETs because their fabrication involves a simpler process with fewer layers, particularly for high-voltage (≥700-V) and low-power applications. BJTs with very high voltage (>900 V) are economical options today, making BJT-based designs attractive in off-line power supplies for the industrial market and in regions with widely varying AC utility voltages.

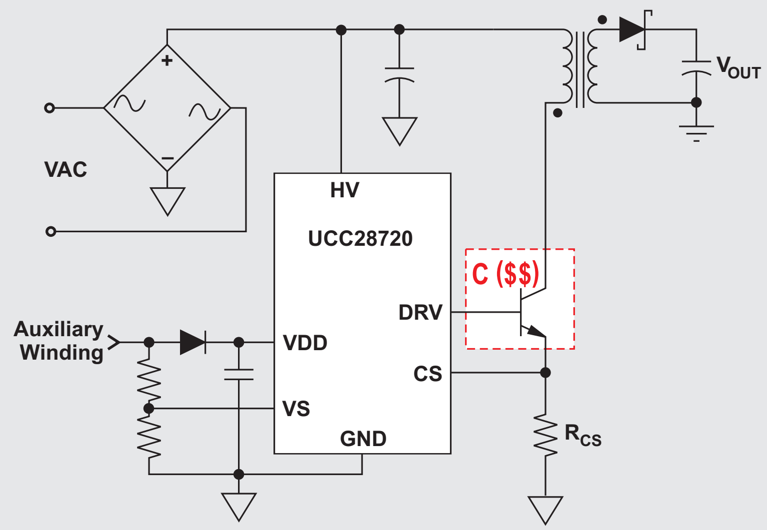
Converters with BJTs can have lower manufacturing cost because they normally have less di/dt and dV/dt switching stress, EMI compliance is easier with no Y capacitor, no common-mode choke is required, and transformer construction is simpler. Also, due to slow di/dt at turn-off, some energy in the transformer's leakage inductance can be dissipated at the BJT turn-off transition, potentially eliminating snubber circuits in some designs. On the flip side, BJTs suffer from higher switching losses, are limited to designs with lower switching frequencies, and require a complex drive scheme.

A highly integrated solution for driving a BJT is shown in Figure 3b. The UCC28720 controller incorporates a driver that dynamically adjusts the base-current amplitude based on the converter load. This ensures that the BJT always operates in optimal switching conditions with minimal switching and conduction losses even for higher-power AC/DC designs.

Figure 3. Simplified flyback schematics

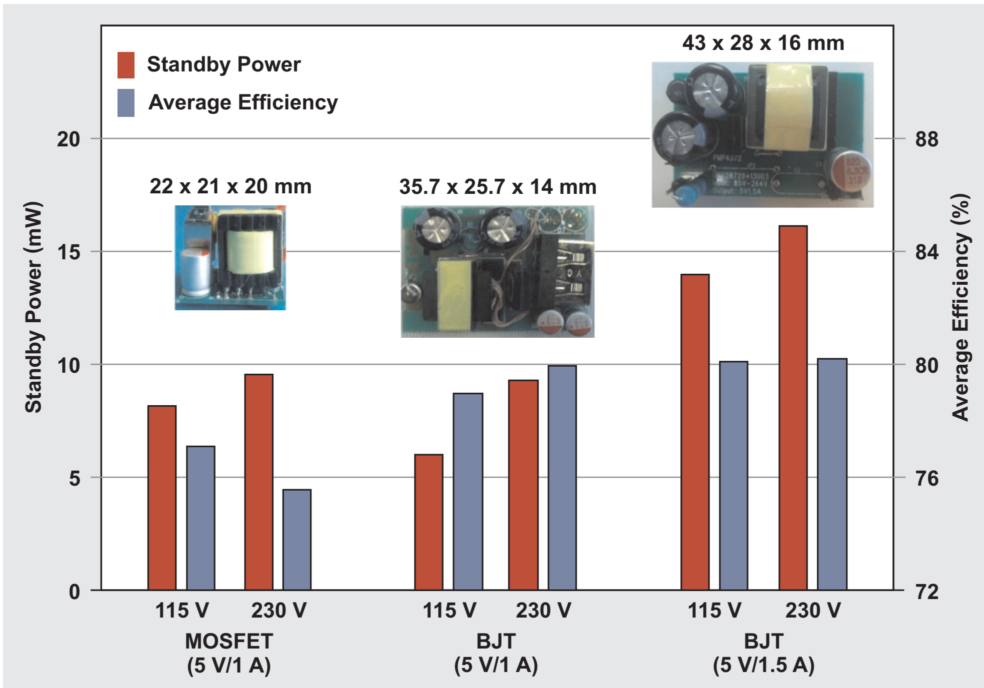


(a) With UCC28710 controller



(b) With UCC28720 controller

Figure 4. Summary of test data for AC/DC flyback designs with UCC287xx controllers



Two 5-V/1-A USB chargers were designed to illustrate some of the preceding points. Their test data are summarized in Figure 4. Note that the controllers enable ultralow standby-power consumption of less than 10 mW. Optimized modulation and drive schemes also facilitate achieving high average efficiency to meet the most stringent worldwide regulations. References 2 and 3 provide links to full test data and a bill of materials for these designs. Test data for a higher-power 5-V/1.5-A design is included in Figure 4 to illustrate that this BJT-based solution can provide an average efficiency of 80+%.[4]

Conclusion

The simplicity and cost-effectiveness of the flyback topology have made it the preferred choice for the many low-power AC/DC designs powering consumer electronics. Power-supply designers are continuously challenged to achieve the same performance at lower cost or improved performance at the same cost. This article has touched on a few of these performance aspects and how th e cost of the power-supply solution can be addressed with the smart choice of a power-efficient controller. The UCC28710 and UCC28720 members of TI's 700-V flyback-controller family enable cost-optimal designs with best-in-class standby power and efficiency for compliance with current and future industry standards.

References

1. Adnaan Lokhandwala. (May 20, 2013). "The no-load power crunch: 30 mW and beyond." *Power Systems Design* [Online]. Available: www.powersystemsdesign.com
2. "Universal AC input 5V@1.2A cube charger with <10mW no-load power," Reference Design using UCC28710. Available: www.ti.com/pmp4344-aaj
3. "5V1A low standby power AC charger with low cost BJT solution," Reference Design using UCC28720. Available: www.ti.com/pmp4373-aaj
4. "High efficiency 5V@1.5A adapter using BJT solution," Reference Design using UCC28720. Available: www.ti.com/pmp4372-aaj

Related Web sites

Power Management:
www.ti.com/power-aaj

www.ti.com/tl431-aaj
www.ti.com/tlv431-aaj
www.ti.com/ucc28710-aaj
www.ti.com/ucc28720-aaj

www.ti.com/adapterpower-aaj

Subscribe to the AAJ:
www.ti.com/subscribe-aaj

TI Worldwide Technical Support

Internet

TI Semiconductor Product Information Center Home Page
support.ti.com

TI E2E™ Community Home Page
e2e.ti.com

Product Information Centers

Americas	Phone	+1(512) 434-1560
Brazil	Phone	0800-891-2616
Mexico	Phone	0800-670-7544
	Fax	+1(972) 927-6377
	Internet/Email	support.ti.com/sc/pic/americas.htm

Europe, Middle East, and Africa

Phone

European Free Call	00800-ASK-TEXAS (00800 275 83927)
International	+49 (0) 8161 80 2121
Russian Support	+7 (4) 95 98 10 701

Note: The European Free Call (Toll Free) number is not active in all countries. If you have technical difficulty calling the free call number, please use the international number above.

Fax	+(49) (0) 8161 80 2045
Internet	www.ti.com/asktexas
Direct Email	asktexas@ti.com

Japan

Phone	Domestic (toll-free number)	0120-92-3326
Fax	International	+81-3-3344-5317
	Domestic	0120-81-0036
Internet/Email	International	support.ti.com/sc/pic/japan.htm
	Domestic	www.tij.co.jp/pic

Asia

Phone — Toll-Free Number

Note: Toll-free numbers may not support mobile and IP phones.

Australia	1-800-999-084
China	800-820-8682
Hong Kong	800-96-5941
India	000-800-100-8888
Indonesia	001-803-8861-1006
Korea	080-551-2804
Malaysia	1-800-80-3973
New Zealand	0800-446-934
Philippines	1-800-765-7404
Singapore	800-886-1028
Taiwan	0800-006800
Thailand	001-800-886-0010

International	+86-21-23073444
Fax	+86-21-23073686
Email	tiasia@ti.com or ti-china@ti.com
Internet	support.ti.com/sc/pic/asia.htm

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as "components") are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI's terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers' products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers' products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI's goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or "enhanced plastic" are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have ***not*** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

Products		**Applications**	
Audio	www.ti.com/audio	Automotive and Transportation	www.ti.com/automotive
Amplifiers	amplifier.ti.com	Communications and Telecom	www.ti.com/communications
Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Security	www.ti.com/security
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Applications Processors	www.ti.com/omap	**TI E2E Community**	e2e.ti.com
Wireless Connectivity	www.ti.com/wirelessconnectivity		

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265