AC-DC Power Supply Considerations for Home Appliances

Zahid Rahim, Vice President and General Manager of the AC/DC Business Unit at iWatt, Inc.

Home appliances are generally grouped into two categories:

1. Major electrical appliances, often referred to as white goods, which include refrigerators, microwave ovens, dishwashers, dryers, washing machines, etc.

2. Small appliances, which include electric blenders, coffee makers, food processors, slow cookers, etc.

Most modern-day home appliances include electronic circuits such as micro-controllers, LCD displays, et al, which need an AC/DC power supply to provide clean and regulated DC power. The challenges when designing a power supply are to provide safe and reliable power, while also delivering high performance with low power consumption and low bill-of-material (BOM) cost.

Generally for low-power applications, the power switch is often integrated or co-packaged with the PWM IC. An example universal offline isolated power supply, which uses the iWatt iW1810 digital PWM IC, is shown in Figure1. It operates from universal AC input and delivers 12V/0.3A output power with better than +/-3 percent output voltage regulation over the entire operating line (85 VAC to 265 VAC), load (0 mA to 300 mA) and temperature (-20degC to +85degC) range.

Key requirements for power supplies must be maintained as described below.

Safety and Reliability
In a flyback power supply, the collector or drain of the power switch can fly up to very high voltages well above the input voltage. Figure1 shows a snubber circuit (R1, R4, C8 and D2) that clamps the collector of the example iW1810 IC’s internal bipolar junction transistor (BJT) power switch to a safe level.

As seen in Figure 2, the collector voltage is as high as 532 V when input voltage is 265 VAC. Over the course of high-volume production, the variation of leakage inductance (higher is worse) will adversely affect the collector voltage. A good rule of thumb suggests that collector voltage (drain voltage for a MOSFET) must be de-rated to 80 percent of its collector-to-emitter (drain to Source for a MOSFET) breakdown voltage rating to ensure that the power supply does not experience unacceptable failure rates during volume production.

Home appliances using electric motors may have inductive kick-back-induced high voltage at the input of the power supply. In such cases, designers must be especially careful in selecting the appropriate de-rating for the power switch under worst case input voltage. In the Figure 1 circuit, the power supply IC includes a BJT with breakdown voltage rating of 800 V to provide sufficient margin in most applications. Many integrated AC/DC PWM ICs include a 700 V-rated power switch as designers must take special care and perform worst case analysis when designing power supplies for electric motor-based appliances. In the Figure 1 circuit, the IC shuts down and auto-restarts if there is a short circuit at the output. This results in very low power consumption on the order of hundreds of milliwatts to protect the system. However, in case of a short circuit at the primary side of the transformer, the wire wound fusible resistor F1 becomes an open circuit to protect the system from safety hazards. Moreover; in normal operation, resistor F1 reduces inrush current to preserve the long life time of the components on the printed circuit board (PCB).

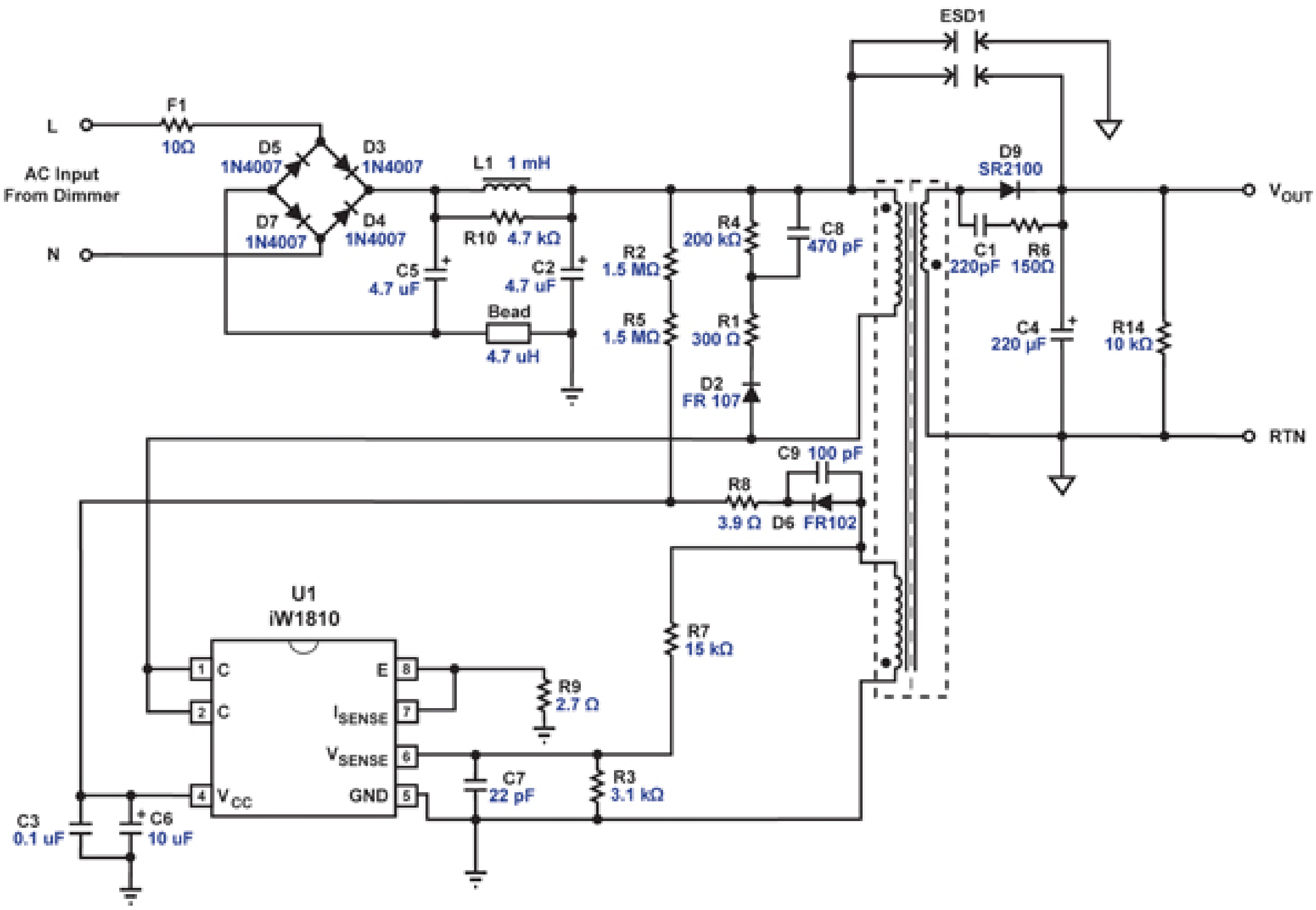

Figure 1. Universal offline 12-V/0.3-A isolated power supply using iWatt iW1810 sigital AC/DC PWM IC

Meet Power Supply Specifications With Sufficient Margin

Given the nature of high-volume manufacturing associated with home appliances and their high repair costs, the power supply design must not only be robust, it should also be insensitive to manufacturing processes and component tolerances. Worst case design techniques should ensure that each power supply parameter tolerance is tight and well within the specification limits; good design practice mandates six sigma limits. Key specifications are usually tight output voltage regulation, fast load transient response, and low output voltage undershoot over the entire operating line, load and temperature range. For high-power applications, efficiency may also be critical because low efficiency results in high thermal losses. In addition, if appliances must meet EMI standards such as CISPR22B or EN55022B, the power supply must have low conducted and radiated EMI with sufficient margin to ensure that a randomly sampled appliance does not fail EMI.

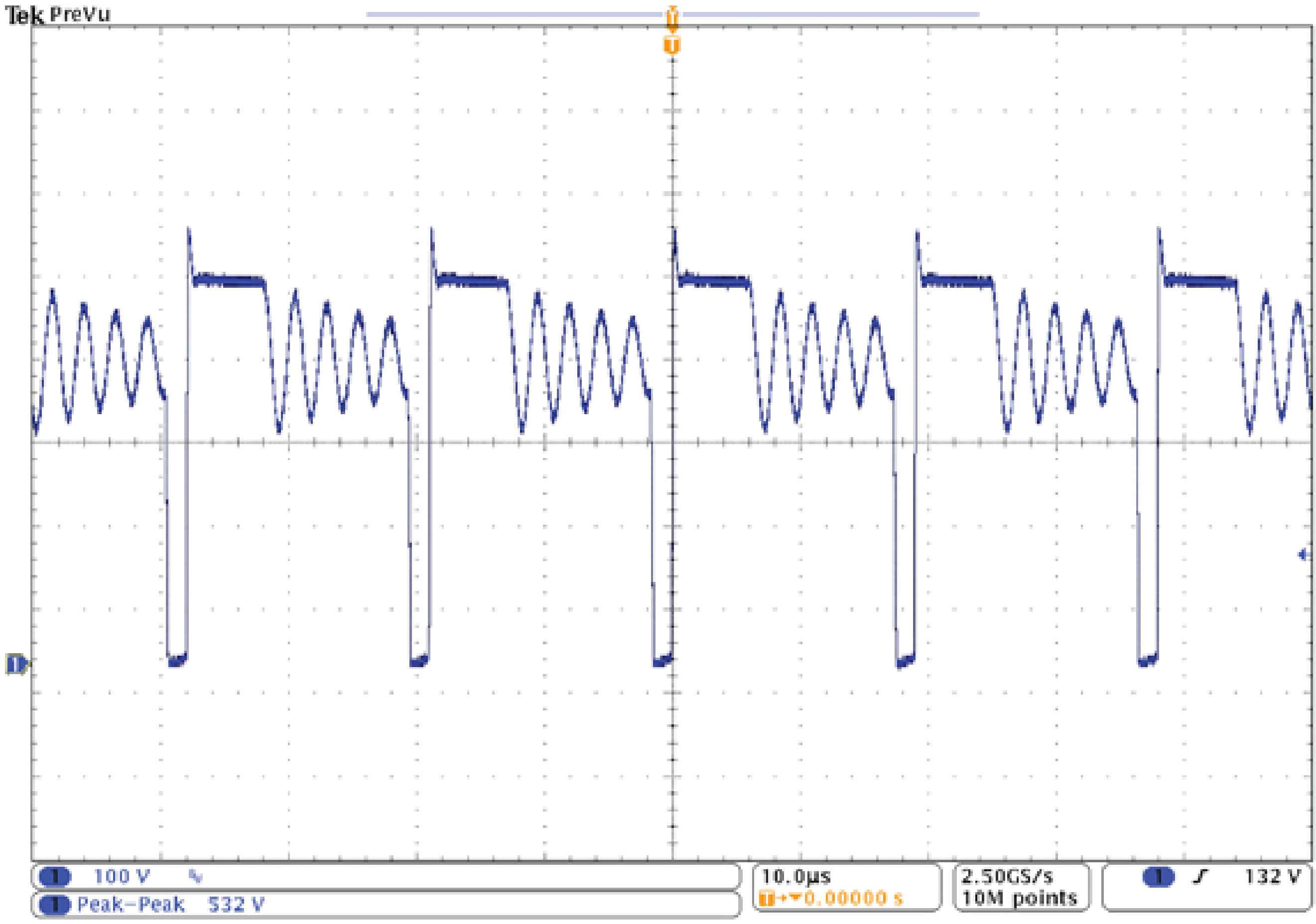

Figure 2. Collector voltage at transformer primary side is as high as 532 V (265 VAC/0.3 A input)

Digital control techniques can be used to achieve high performance and low costs for the end user. For example, the iW1810 employs iWatt's patented adaptive digital PWM control technology in which a digital feedback and control loop adjusts the IC's internal parameters on a cycle-by-cycle basis to optimize performance over varying line and load conditions. The circuit of Figure1 can achieve better than +/-3 percent output voltage regulation over the entire operating range. Moreover the output voltage undershoot is 10.9 V minimum and recovers in under 2 ms when the load transitions from no-load (0 mA) to full load (300 mA). Peak efficiency is over 80 percent. Quasi-resonant (or valley mode) switching techniques can also be used to reduce EMI. As shown in Figure 3, the circuit achieves over 10dB conducted EMI margin when compared with the CISPR22B or EN55022B limits.

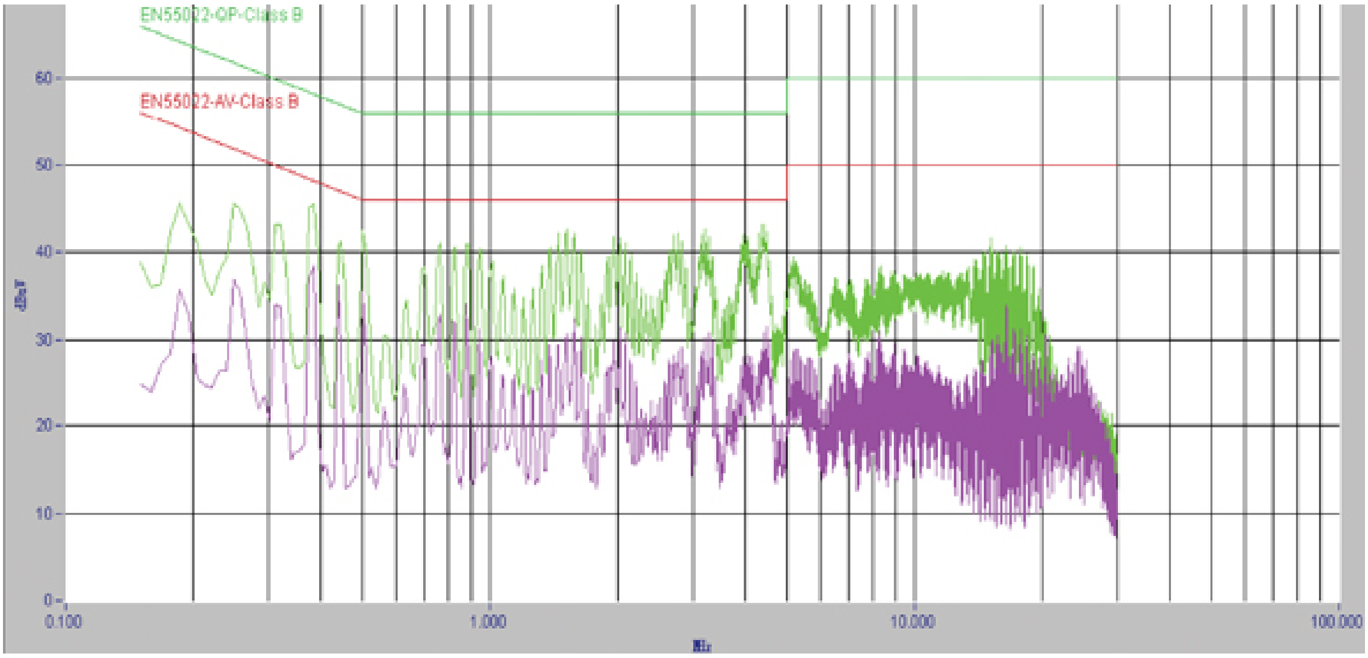

Figure 3. Measured conducted EMI at 230 VAC/50 Hz line.

Low BOM Cost

In a cost-sensitive consumer market, low BOM cost is mandatory. A simple circuit with fewer components drives down the cost. Primary side regulation can be used to eliminate an opto-coupler, a shunt reference and associated resistors and capacitors from an isolated offline power supply. Moreover; if the output power requirement is under 3 W, then the snubber circuits on the primary side (R1, R4, C8 and D2) and secondary side (C1 and R6) may be eliminated.

The total manufacturing cost for an electronic PCB not only includes the cost of the components and the PCB, it also includes the insertion cost associated with each component. The fewer the components, the lower the insertion cost and higher the throughput; i.e. number of PCBs manufactured per hour. A 12 V/0.3 A offline power supply based on the circuit of Figure 1 can be manufactured for well under $1.00 in high volumes.

REFERENCES

[1] J. Zheng, Y. Li and Z. Rahim “Real Time Waveform Analysis Helps Optimize Charger Performance,” Power Electronics Technology, March 2011, pp 8 – 13.

[2] “What Is Digital Power,” http://www.iwatt.com/pdf/What_is_Digital_Power.pdf [1]