Adding Flexibility to AC/DC Power Supply Design that Uses PFC+LLC Topology

Performance and cost are the main concerns of power supply designers, but how about design flexibility?

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For universal input AC/DC power supplies that fall in the range of 80-800W, the single stage boost PFC + half-bridge LLC is considered to be a very popular topology. Traditionally, such power supplies are designed with analog PFC + analog LLC as stand-alone or as combo ICs. However, this two-stage approach can be quite difficult to design, even for experienced power supply designers. Typically, these designs may involve more than a hundred components in BOM, each prototype iteration can take weeks to months to build and test, and may take up to one year or more to place into production. Oftentimes, the end customer asks for new functions during various design phases and even in production, causing the power supply vendor to redesign and re-run the entire design cycle again. In a worse case scenario, the new request cannot be delivered by the existing IC solution. For example, we learned an end customer finds auto-restart action is needed during short-circuit fault for their new generation product, but the IC is only designed for latched protection at such fault. It is possible for the power supply vendor to ask the IC vendor to create a new IC with this feature, but more than likely, this will only happen if the customer's business is worth the time and effort, and it may still take the IC vendor a few months to deliver samples with new features! This would cause a series of business hanging on a thread.

To add more obstacles for designers, various performance requirements on power supplies are being enhanced every year. For example, the European CoC Standard Tier2 will be enforced in January 2016, but many of the current power supplies cannot meet the no-load power-loss requirement yet (see Table 1). Especially for the PC power market, more end customers are demanding power supply vendors to improve efficiency and power factors to meet Gold, Platinum, and even Titanium efficiency standards (see Table 2).

Rated Output Power	No load power consumption	
	Tier1	Tier2
>0.3W and <49W	0.150W	0.075W
≥49W and <250W	0.250W	0.150W

Table 1: Code of Conduct on Energy Efficiency of External Power Supplies

	115V				230V			
Percentage of rated load	**10%**	**20%**	**50%**	**100%**	**10%**	**20%**	**50%**	**100%**
80 Plus		80%	80%	80%				
80 Plus Bronze		82%	85%	82%		81%	85%	81%
80 Plus Silver		85%	88%	85%		85%	89%	85%
80 Plus Gold		87%	90%	87%		88%	92%	88%
80 Plus Platinum		90%	92%	89%		90%	94%	91%
80 Plus Titanium	90%	92%	94%	90%	90%	94%	96%	91%

Table 2: 80 Plus Efficiency Standard for PC Power

In addition to energy efficiency, end customers also desire features such as high power factor, fast transient response, multi-level protection functions, and many more. Some of these are difficult to achieve through a strictly analog approach. In response, power supply vendors have embraced a digital approach to improve performance, achieve good resolution, and better control loop design, among other benefits. However, in AC-DC field customers may always need to use extra DSP or MCU to implement digital control, and often requires experienced digital designers, which all add to development and production cost. Digital control is oftentimes considered "high end and expensive".

To sum up, some of the challenges that the power supply designers are facing are:

- Rapid changes in end customer requirements during various design-production phases;
- High efficiency and high power factor from no-load to full load
- Expensive and difficult digital controls

To improve the situation, a solution would be to use a digital core with just enough size, speed, and memory for the AC-DC controls and to use a graphic user interface (GUI) to configure all major functions (see Figure 2). The benefits would be:

- Flexible design, many major functions can be re-configured even during production without affecting BOM at all.
- High efficiency and high power factor that no analog IC can deliver.
- Affordable digital controller at similar cost as analog controller.

This way, the power supply vendor does not need an extra programmer to enjoy the benefits of digital controls, and ultimately the vendor saves more in BOM cost by eliminating certain external components such as various RC to set time/frequency.

We designed a PFC/LLC Combo controller that utilizes such digital core, this IC's performance meets certifications for high end PC power markets, as those set by the Energy Using Product Directive (EuP) Lot 6 and the Code of Conduct Version 5 Tier 2 specifications. This is achieved by offering <150mW input power at no load and <500mW at a 250mW load. For the efficiency to meet the 80 Plus Titanium specification, the power factor must also be higher than 0.95 at 20~100% load and VIN=230VIN (see Figure 3 and Figure 4).

Besides high end PCs, this IC can also benefit other AC/DC applications to enhance system performance, such as televisions, gaming devices, laptops, LED street lights, servers, battery chargers, and more. There is also a standalone digital PFC coming up soon that shares most benefits that can work with flyback ICs.

Key features and benefits of the PFC portion of the combo controller include:

- Patented CCM/ DCM digital average current control mode to enhance overall efficiency and minimize system size
- Patented configurable input capacitor compensation to enhance PF at light load

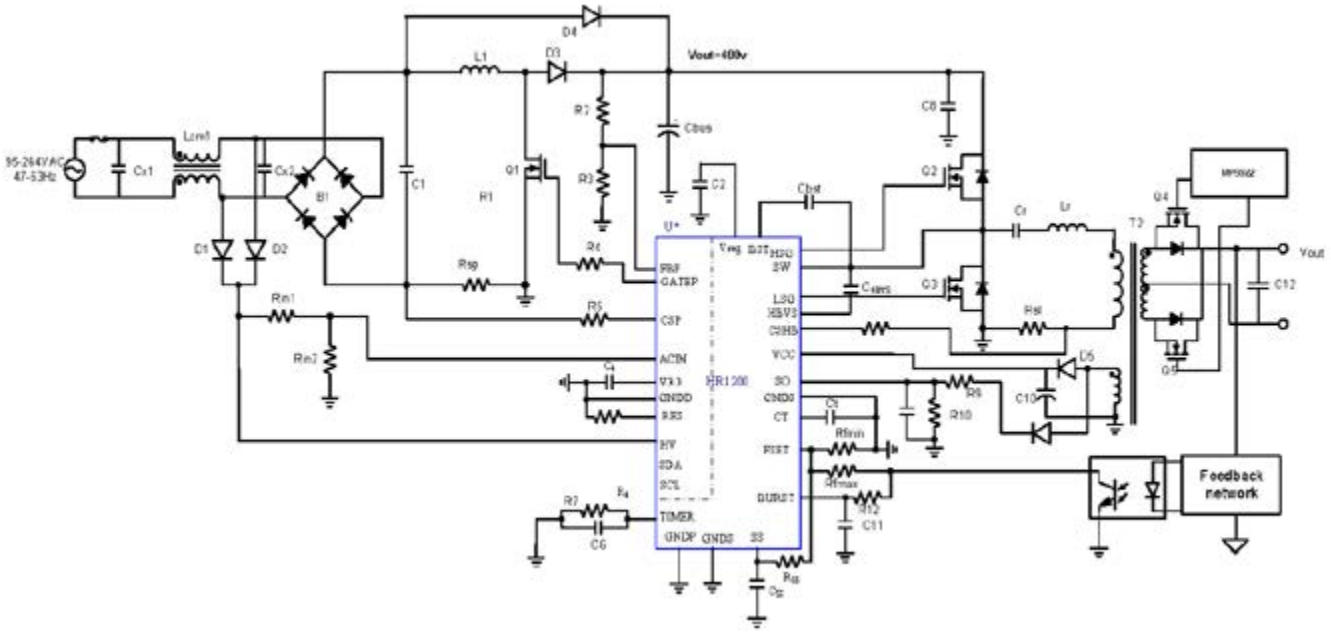

Figure 1: The Schematic for Digital PFC + LLC Combo

- Frequency jitter at CCM to improve EMI
- Patented smart X-cap discharger at AC removal to improve efficiency

Key features and benefits of the LLC portion of the combo controller include:

- 600V driver with integrated bootstrap diode and high dV/dt immunity
- Variable frequency resonant controller at 50% duty cycle
- Adaptive dead-time adjustment for best efficiency
- Automatic capacitive mode protection for safety

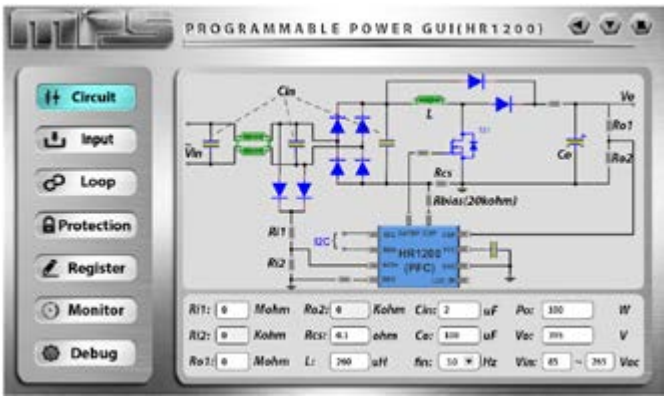

Figure 2: The Main GUI Interface to Program PFC

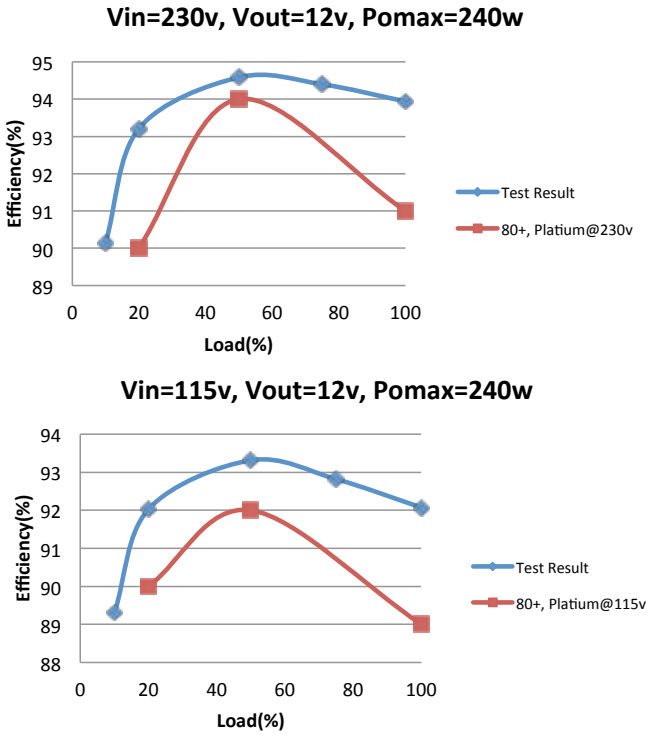

Figure 3: 240W Evaluation Board Efficiency Compared to 80 Plus Platinum Spec

Key features and benefits of the combo controller as a system include:

- High voltage current source for start-up or start-up from an external source (e.g.: a different IC)
- PIN <150mW at Po=0W, and PIN <500mW at Po=250mW
- GUI to configure system parameters with EEPROM to store configurations
- Compatibility with the MP6922 synchronous rectifier IC for best performance
- **GUI configurable functions include:**
- PFC switching frequency and frequency jitter
- Different PFC output voltages at different loads
- Patented power factor compensation at light load to improve PF
- Various configurable protection features such as OVP, OCP, brown-in, and brownout
- Visual feedback loop adjustment and fast loop gain options
- Live monitor and report of system parameters and live debug functions

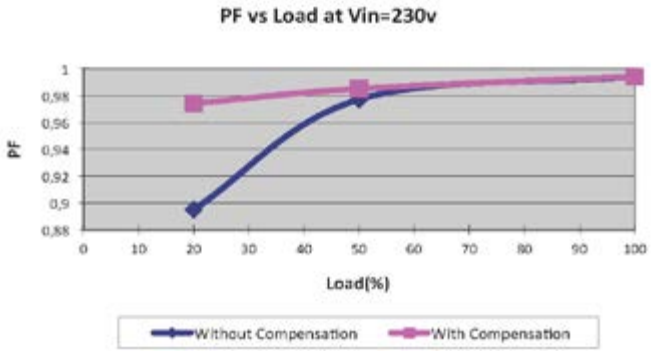

Figure 4: Power Factor Improvement at Light Load with Patented PFC Compensation

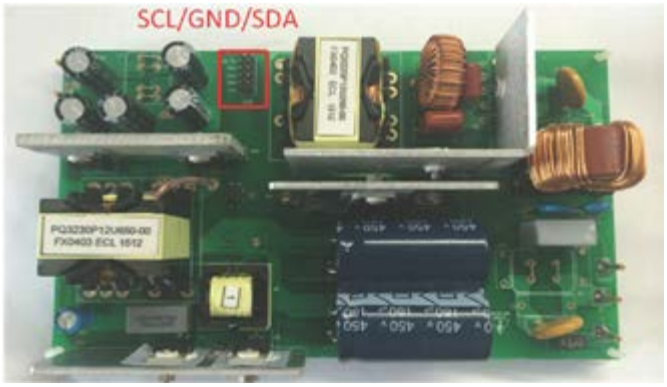

Figure 5: Digital Configurable PFC+LLC Evaluation Board

Tools and support to speed up design

EVB and various supporting documents are offered to help customers become familiar with this digital platform. The EVB is rated at 85-265VAC at input, and 12V/20A at output. The EVB is equipped with an I2C to USB adaptor, allowing customers to optimize their designs by changing all GUI settings from their computers and monitoring live performance differences. For mass production, the configuration can be done at the factory or we can help to program in house. The datasheet, application note, layout guidelines, and GUI user guideline documents will be available on the company website soon, and may require login information. The part number is HR1200.

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