Digital PFC + LLC Combo Controller Helps Fast-Charge Adapters Enter the New Age

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Fast-charge technology has developed rapidly in the last few years due to the exponential increase in power demand for mobile devices. In late 2020, cell phone market leaders (such as Apple, Xiaomi, and Samsung) started to abandon in-box adapters for cell phones. This change stimulated another boom for the demand of aftermarket adapters, and also confirmed two trends for the fast-charging adapter market.

The first trend was the demand for multiple-port adapters. Conventional cell phone in-box adapters were designed with a single USB port, regardless of how much power the adapter could deliver. The traditional “one phone, one adapter” concept became less relevant once there was no longer an in-box adapter, as customers started to prefer adapters designed with multiple USB ports. Day-to-day life requires numerous electrical devices (e.g. cell phones, tablets, and notebooks), and whether a consumer is at home or traveling, a single adapter that can simultaneously power multiple devices is the preferred charging method (see Figure 1).

Figure 1: 100W Adapter with 3C1A USB Ports

The second trend was adapters suited for higher power levels that often exceed 100W. The power levels of most adapters have already increased due to the development of fast-charge technology. USB PD protocol allows up to 20V of charging voltage and 5A of charging current.

So far, the majority of in-box adapters in the market are still below 65W due to considerations such as the cost for high-volume products and the practical charging requirements for single portable devices.

However, many aftermarket multiple-port adapters exceed traditional limitations, because higher power is necessary to charge multiple devices. For multiple-port adapters, a higher cost is accepted because it can charge multiple devices. As a result, high-power adapters with rated power exceeding 100W are becoming mainstream products.

The single-stage flyback has been the most popular solution for adapters up to 65W. Especially for single-port fast-charge adapters with a wide input and output voltage range, flyback solutions can adapt to these voltage combinations without requiring an additional DC/DC power stage. However, based on the trends discussed above, the market is demanding an evolution in fast-charge adapter solutions.

First, there are mandatory power factor regulations on power supplies in most regions, so power factor correction (PFC) is necessary on the front end as the rated power exceeds a certain level. Second, it is very difficult for flyback solutions to meet the high efficiency and power density requirements for applications exceeding 100W.

Because multiple-port adapters require each port to be able to adjust the output voltage independently, each port must have its own DC/DC stage. This means that the primary power supply only needs to provide a fixed output voltage instead of an adjustable voltage. All of these differences make a two-stage PFC + LLC combo controller a more suitable solution for high-power adapters with multiple ports. LLC is a resonant converter that can achieve zero-voltage switching (ZVS) across a wide load range. With PFC on the input and DC/DC at the output, an LLC solution can achieve much better efficiency and power density than a flyback solution. Figure 2 shows a PFC + LLC solution.

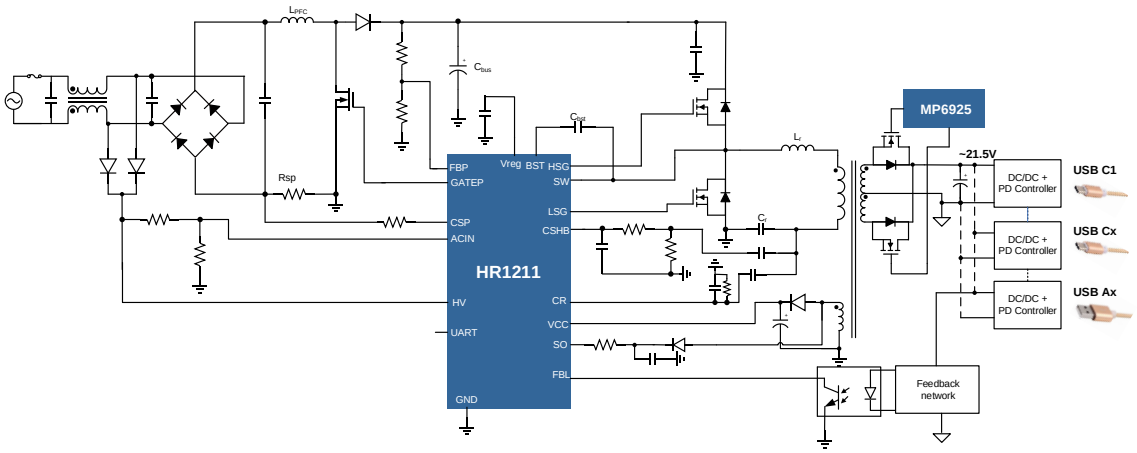

Figure 2: Typical PFC + LLC Controller Solution Based on the HR1211

As an example, we'll look at the HR1211 from MPS, a digital PFC + LLC combo controller that is suitable for high-power multi-port PD adapter designs.

This PFC + LLC combo controller is an ideal solution for multi-port adapters. A hybrid control scheme such as that in the HR1211 allows for continuous conduction mode (CCM) and discontinuous conduction mode (DCM) in the PFC stage. Under full loads, CCM reduces conduction loss (especially at the low-line input) and the inductor size requirement. At the same time, the LLC stage implements current mode control with adaptive dead time tracking technology to guarantee ZVS operation with minimal dead time under any conditions. This minimizes the LLC converter's switching and conduction loss. These features are essential to achieve high efficiency and high power density. In an actual 100W PD adapter with 3C1A USB ports, the full load efficiency from AC to the LLC output can be close to 95% (see Figure 3).

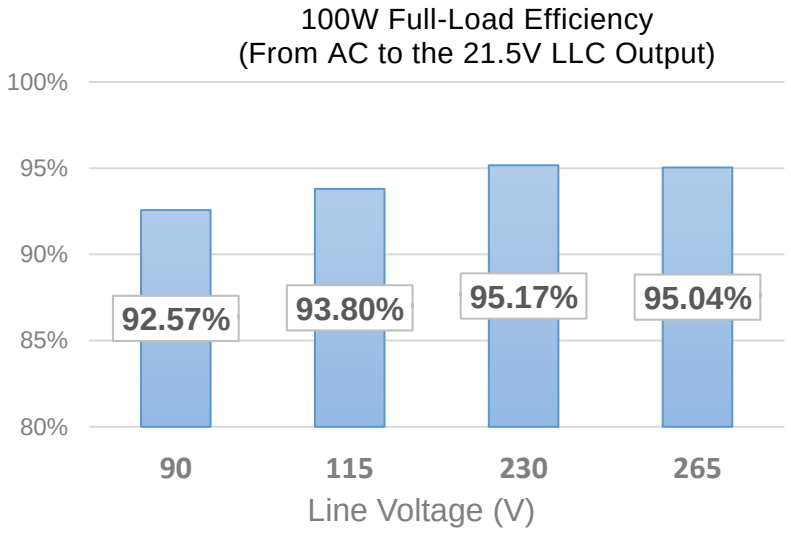

Figure 3: Full-Load Efficiency in the HR1211 Based on a 100W Design

As a result, a 100W high-power adapter can be implemented in a very small form factor (76mmx61mmx29mm). At the same time, the temperature rise can be easily controlled. Figure 4 shows that this solution's maximum temperature is 77°C at the continuous full-load operating condition of 20V/5A.

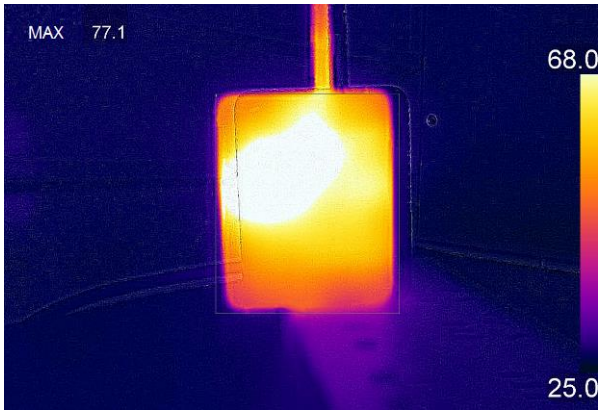

Figure 4: Thermal Performance at a Continuous 20V/5A Output

The HR1211's proprietary control scheme can also achieve superior light-load performance. As the load decreases, the solution gradually changes its PFC operation from CCM to DCM with a reduced switching frequency. LLC control implements skip mode and burst mode to reduce the equivalent switching frequency of the LLC converter under light loads, which then reduces the switching loss.

Figure 5 shows the efficiency from a 10% load to a full load at one of the USB Type-C outputs when the output voltage is 20V. A PFC + LLC combo can achieve average efficiencies at 88.3% and 89% for high lines and low lines, respectively, which easily meets worldwide efficiency regulations.

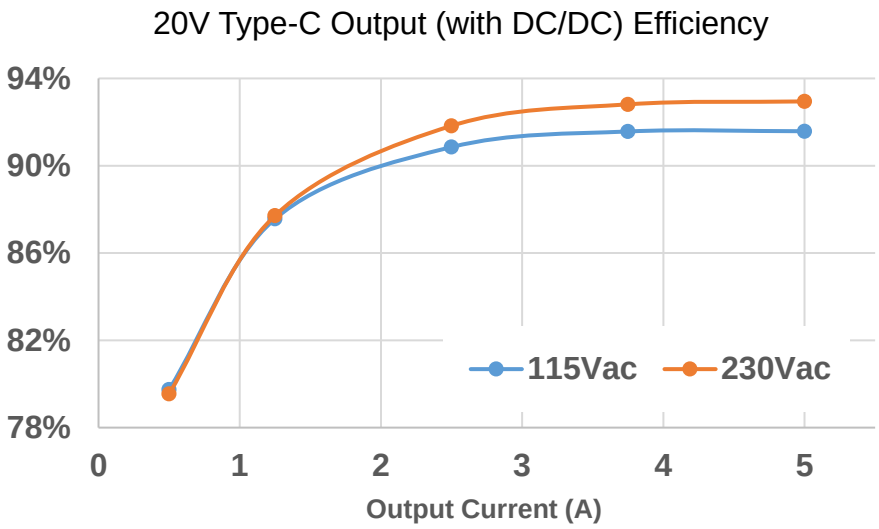

Figure 5: USB Type-C Output Efficiency

An additional benefit of this solution is the design flexibility achieved through digital implementation. Although the external circuits are quite simple, the HR1211 has rich programmability due to the chip's digital core and the multiple-time programmable (MTP) memory. All of the key parameters, switching characteristics, regulation and production levels, and transition thresholds are among the different operation modes that can be programmed through a UART-based communication interface and a graphic user interface (GUI).

With this digital flexibility, any kind of performance, such as efficiency, ripple, noise, protection behaviors, can be easily optimized for a given design (see Figure 6). This is particularly important for a fast-evolving market like that of high-power fast-charge adapters. Whenever there is demand on the market of a new power specification, form factor, or performance regulation, PFC + LLC combo controllers can quickly adapt.

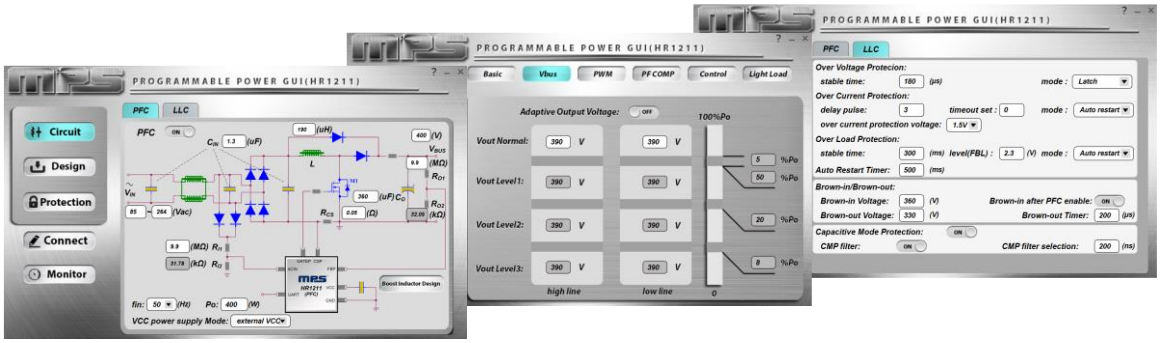

Figure 6: HR1211 GUI

Fast-charge adapters are constantly evolving, and the market is seeing in influx in demands for high-power adapters exceeding 100W, as well as new adapter models with multiple USB PD ports. Digital PFC + LLC controller solutions like the HR1211 are vital to meeting this demand. Their excellent efficiency, performance, power density, and flexibility will help the adapter market enter a new age.