Microcontroller Simplifies PFC Design

In Europe, all equipment connected to the public utility grid needs to comply with European Standard EN 61000-3-2. This standard sets the maximum permissible harmonic current that is injected by equipment back onto the public utility grid. The standard affects any electronic and electrical equipment with a power rating greater than 75 W. A microcontroller based active PFC operating in Critical Conduction Mode is a suitable solution for cost sensitive application. This PFC can be easily integrated into a XMC1300 design without incurring much effort or extra cost. **Eugene Yuen, Senior Application Engineer, Infineon Technologies, Singapore**

The main contributor of the harmonic current is the equipment rectification circuit that converts the input alternating current (AC) to direct current (DC). A typical circuit consists of standard full bridge rectifier feeding a bulk capacitor. Current is drawn from the mains when the input voltage exceeds that of the bulk capacitor. The current is limited by the resistance of the diode and capacitor; as a consequence the input current waveform is non-sinusoidal and contains many harmonics.

One technique to comply with the standard is by shaping the input current of an equipment to be proportional to the applied line voltage thus giving an input current that is in phase with the line voltage. The purpose is to make the load circuitry appear purely resistive to the utility grid thus generating less current harmonic. This is known as active Power Factor Correction (PFC).

This also means additional cost as extra circuitry is needed to implement the active PFC. This is unavoidable but for microcontroller (MCU) based design, the MCU can be used to implement the PFC function in addition of the main application e.g. driving a motor. This will save the cost of purchasing an additional PFC controller chip at the price of complexity.

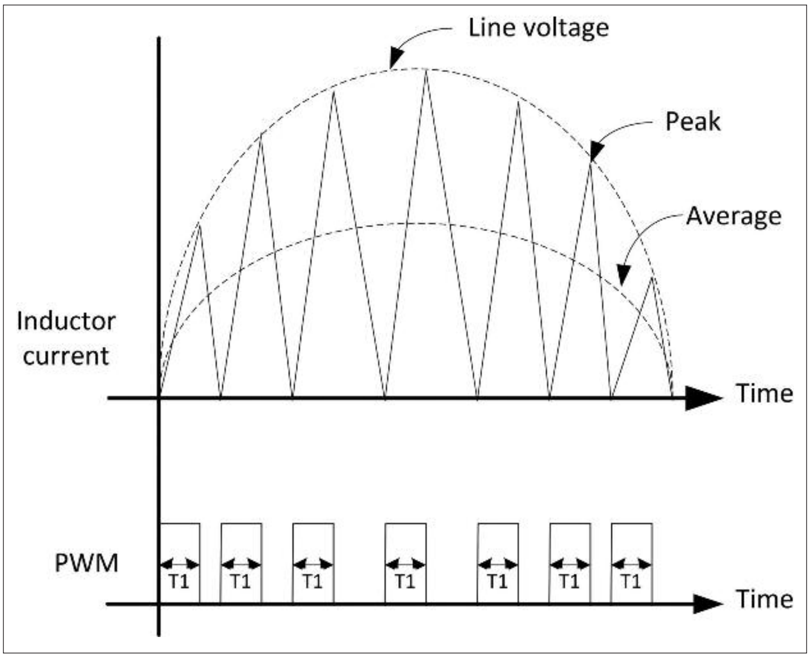

Figure 2: PFC in Critical Conduction Mode

But the addition of a PFC to a motor control application increases the complexity of the design. The XMC1300 from Infineon Technologies is a microcontroller capable of handling this level of complexity at a low cost.

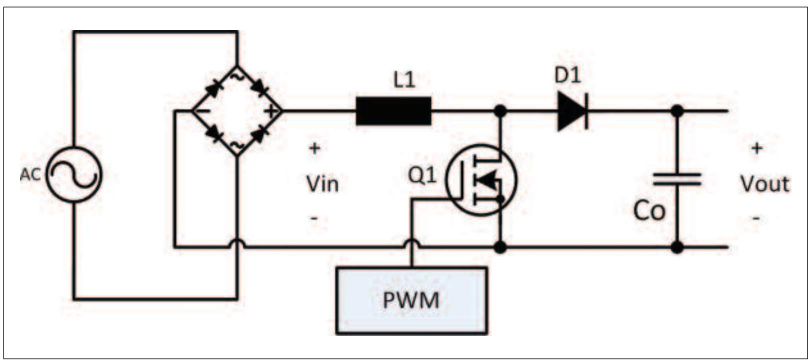

Figure 1: Boost PFC schematic

Boost PFC in Critical Conduction Mode

There are several ways to implement an active PFC. The most popular method is to use a boost converter (Figure 1). The boost converter input current is "shaped" to be proportional to the input voltage by modulating boost MOSFET. The rectified source voltage wave shape is used as a reference, the inductor current which is the input current will be "shaped" to be sinusoidal and in phase with the source voltage.

For low output power level (<300W) a boost circuit operating in Critical Conduction Mode (CrCM) is a simple solution for active PFC (Figure 2). In CrCM the inductor current is operating in the "critical" section between Continuous Conduction Mode and Discontinuous Conduction Mode.

In each switching cycle, the boost inductor is charged from zero current. The PWM on-time is held constant for each switching cycle during the whole line cycle. A new switching cycle is only started when inductor current falls to zero. As a result the inductor current is triangular in each switching cycle.

For a single switching cycle, the voltage across the inductor is given

$$Vin = L\frac{di}{dt}$$

Given inductor, L is fixed and constant "on" time, T1

$$Ipeak = \frac{T1}{L}Vin$$

Based on the inductor current shape, the average current is half of the peak current

$$Iaverage = \frac{1}{2}Ipeak = \frac{1}{2}\frac{T1}{L}Vin$$

With a fixed inductance and constant on-time, the peak switch current is automatically forced to track the input voltage. This also mean that the input current ($I_{average}$) will track the input voltage (V_{in}). This PFC can be realized automatically without current sensing. However, for load regulation there is still a need for a compensation loop.

PFC with XMC1300

The boost PFC operating in CrCM can easily implemented using Infineon XMC1300 MCU. The MCU only needs to run the voltage compensation loop. A Proportional-Integral (PI) control loop can be used for the voltage compensation. Additionally the control loop need not be run on every switching cycle. Infineon XMC1300 standard ARM Cortex M0 central processing unit(CPU) running at 32MHz is more than capable to run the PFC

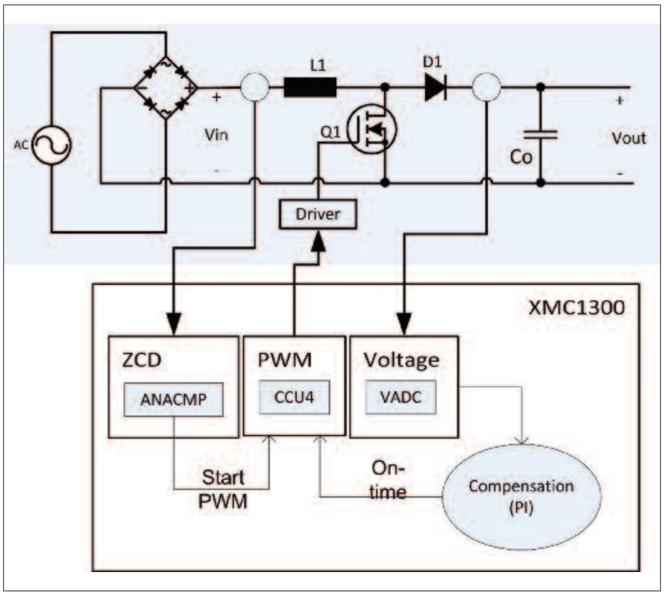

Figure 3: XMC1300 PFC implementation

compensation loop with enough CPU time left for other task.

The XMC1300 powerful capture and compare timers (CCU4) can be configured to generate complex PWM output with minimal CPU load. Once configured the PWM are automatically generated without further CPU intervention.

The CCU4 shadow transfer mechanism, allows the PWM duty cycle to be updated without introducing any glitch in the PWM. This also allows the voltage compensation loop to update the PWM on-time independently from the generation of PWM.

The CCU4 also support external event to trigger the start of PWM generation. This can be used by the zero crossing detection (ZCD) circuit to start the PWM upon detecting inductor current has reached zero. A typical ZCD circuit will consists of a comparator that compares the inductor current with a reference zero. The on-chip comparator (ANACMP) can be used as part of the ZCD circuit to trigger the CCU4. This will save the cost of an external comparator.

The PFC output voltage can be measured with the 12-bit versatile analog to digital converter (VADC). If desired the voltage measurement can also be synchronized with the PWM output by using the CCU4 output to trigger the VADC conversion.

Other considerations

The XMC1300 is designed to be able to handle a wide variety of applications, e.g. motor control and power supply with ease. A good example is the design of a field oriented control of a 3-phase motor which can make use of another advanced PWM peripheral, the CCU8 and the MATH co processor. Communication is usually a major reason that a microcontroller is considered for a design. The communication peripheral of the XMC1300, the USIC, is configurable to be able to handle a variety of protocols.

Digital systems are not just about hardware as software plays a very crucial part. Software performance can make or break a project. Software design is aided with the free CMSIS library from ARM and the completely free software tool set DAVE that includes IDE, compiler, debugger and code generator.