

Unique Single-Chip Ballast Control IC with Integrated PFC Control Reduced Solution Cost for Electronic Ballasts

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Abstract - A new control IC, using a unique active power factor correction topology, ballast control and 600V driver output, reduces component count and improves performance of electronic ballasts. The improved power factor correction uses a modulation technique to achieve low harmonic distortion of less than 10% across the universal voltage range.

I. INTRODUCTION

As rolling blackouts sweep through parts of California, the country faces its most serious energy shortage since the 1970s. The Bush Administration warned that the crises will spread far beyond California and energy saving initiatives are being established. Approximately 20% of the primary energy used in the USA is for lighting, making it an obvious target for energy saving proposals.

The electronic ballast is the most efficient of all fluorescent ballasts thus providing a possible solution for the energy crisis. The electronic ballast offers several advantages over conventional magnetic ballasts. First, it operates at a much higher efficiency, approximately 30% more efficient than the magnetic version. Electronic ballasts also operate cooler than magnetic ballasts. This reduces the load on the cooling system, resulting in further energy savings.

The European Union has long recognized the benefits of electronic ballasts and has established mandatory legislation and directives on energy efficiency for florescent ballasts. Many ballast producers now realize the competitive advantage of energy efficient ballasts and as a result the electronic ballast market is showing signs of rapid growth.

The IR2166, 600V driver IC with ballast control IC and integrated power factor correction (PFC), addresses this growing market by offering a low cost solution for electronic ballasts which exceed the stringent CE and UL standards.

II. OVERVIEW

Most electronic ballasts for fluorescent lighting on the market today incorporate a two-stage architecture consisting of a boost converter, running in critical-conduction mode for sinusoidal input current and a regulated DC bus, and a half-bridge driven resonant output stage for lamp control. This architecture is typically controlled using a multi-chip solution that can contain up to three control ICs (Figure 1).

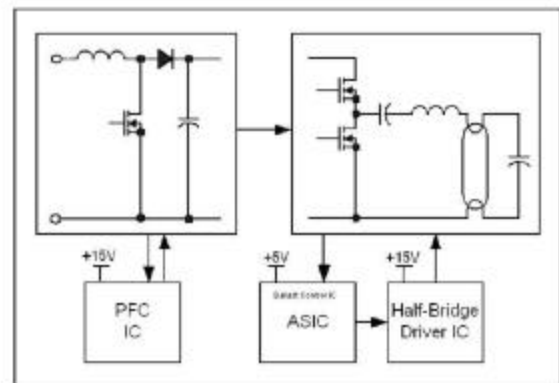


Figure 1. Typical Multi-Chip Solution

These include a PFC control IC, a ballast control IC or ASIC and a half-bridge driver IC. The new control IC is a combination of these functions into a single IC (Figure 2).

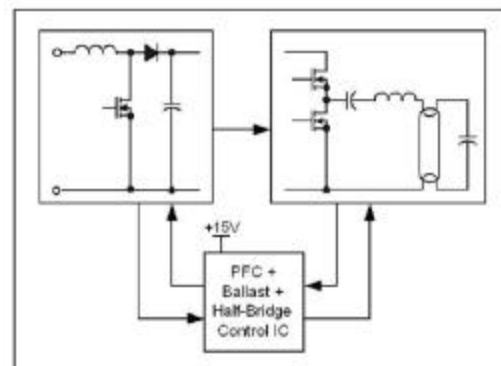


Figure 2. IR2166 Solution

This new IC contains the necessary functions for two independent control blocks including PFC control for regulating the line input current and ballast control for driving the fluorescent lamp.

Figure 3 represents the different circuit blocks within the IC and how they are integrated.

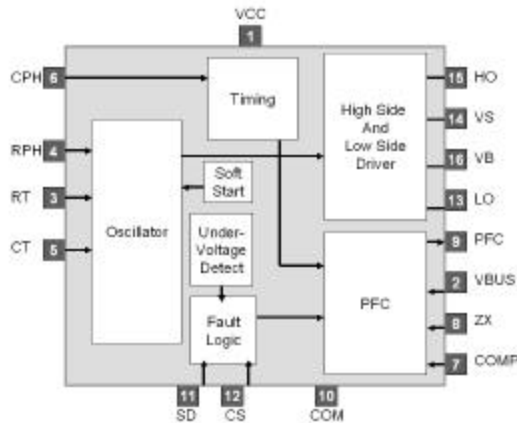


Figure 3. IR2166 Internal Block Diagram

For this new IC to be commercially attractive to the electronic ballast market, the complete system cost must be the lower than existing multi-chip solutions.

Many of the cost savings are obvious to the designer. Eliminating three packages and replacing them with one 16 lead package, replacement of three pieces of silicon IC with one IC, and the reduced manufacturing cost of placing and qualifying one IC versus separate devices.

However, the dramatic cost saving from the integrated PFC and the reduced component count is not so apparent.

III. PFC SAVES 9 COMPONENTS

Since the PFC, ballast control and high voltage driver are integrated on to a single-chip; only one VCC supply is required. Also the simplistic PFC eliminates the need for the external components normally associated with sensing the AC line voltage and current.

The PFC section alone saves the designer 9 components:

- Removes 1 expensive current sense resistor
- Removes 4 bus and protection resistors
- Removes 1 capacitor
- Removes 3 charge pump components

Figure 4 shows a comparison between a typical PFC circuit and the PFC section of the IR2166.

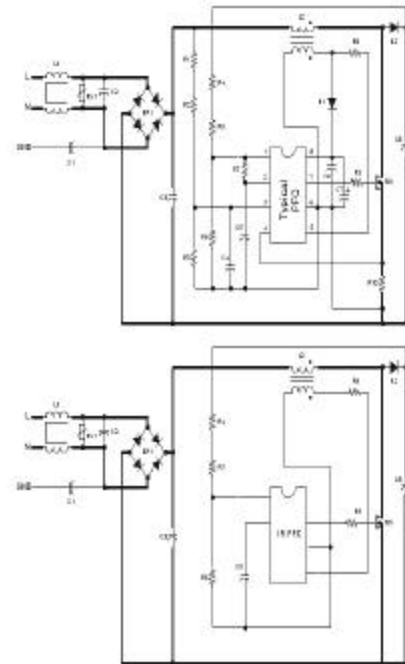


Figure 4. Typical PFC circuit vs. IR2166 PFC circuit

IV. SIMPLIFIED PFC

In most PFC circuits, the mains power source requires a sinusoidal load current that appears resistive. Therefore, an ideal power factor correction stage should appear as a resistive load to the AC line, pulling current sinusoidally and storing the power for the converter so that the regulated voltage remains stable while the line voltage varies sinusoidally. It is for this reason that the circuit act as a purely resistive load to the AC input line voltage.

To achieve this the IR2166 has an active boost-type converter. The power switch in a boost-type circuit controls the inductor charge and discharge time forcing the current to conform to a sinusoidal shape.

The boost converter operates in critical conduction mode. This means that the circuit has little or no dead time in the switch-off time. In other words, when the inductor has released all of the stored energy, the next power cycle can start.

This PFC circuitry uses only four pins: VBUS senses the output voltage from the PFC boost converter, COMP is the error amplifier compensation pin, ZX senses the inductor current and PFC is the PFC FET gate driver. This method of PFC does not require current sense input from the PFC FET as this circuit does not use a multiplier and does not need to sense the AC line.

Figure 5 shows the Power Factor control block diagram.

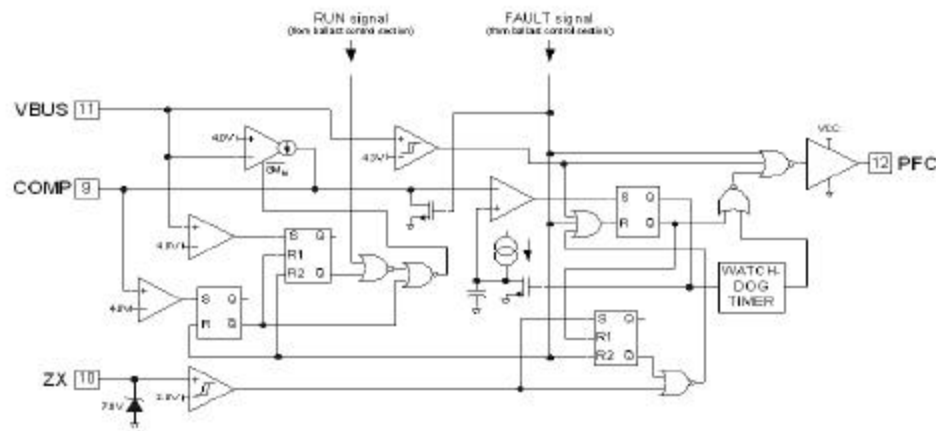
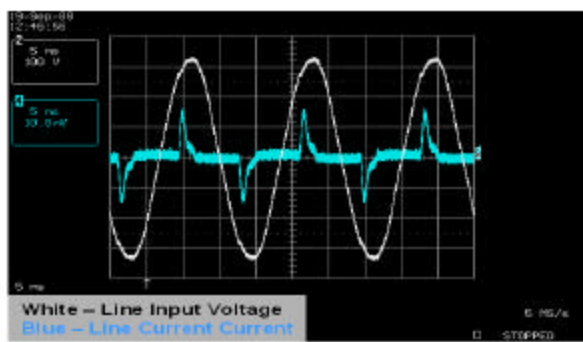


Figure 5. PFC Control Diagram

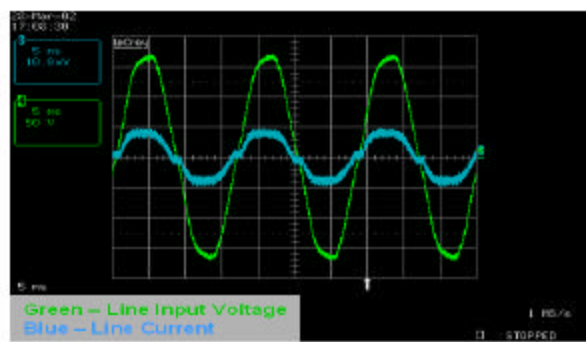
The COMP pin, error amplifier can operate either with a high gain or low gain. High gain is required when a fast response is needed for changes in line or load while a low gain is needed when the line and load are constant and the power factor needs to be optimized.

The PFC FET on-time is increased when the line voltage approaches the zero-cross point thus reducing cross-over distortion. This reduces THD to less than 10% as shown in figure 6.



Ballast with 35W load with no PFC
120VAC Input

Power Factor = 0.55
THD = 100%



IR2166 Ballast with 35W load
120VAC Input

Power Factor = 0.99
THD < 10%

Figure 6. Waveforms Comparing 35W Ballast Load Without PFC and 35W Ballast Load with IR2166

The on-time is determined from the error amplifier sensing the bus voltage (VBUS pin) and the off-time is determined from the inductor current (ZX pin). Initially the gain is high to allow the DC bus voltage to rise rapidly. The gain is also high during ignition so that the high current surge causes only a small transient in the DC bus voltage.

The off-time of the PFC FET determines the time for the PFC inductor to discharge to zero. The current is sensed by a secondary winding on the PFC inductor that is connected to the ZX pin.

The PFC FET produces a peak inductor current that follows the sinusoidal shape of the line voltage. This is due to the fixed on-time of PFC FET over a complete cycle of the line voltage. The smoothed averaged line input current is in phase with the line input voltage for higher power factor but the THD may still be too high. This is due to the distortion in line current near to the point of the zero crossing. In order to reduce these distortions, an additional modulation function was added to the PFC control. The circuit increases the on-time near the point of zero crossing which causes the PFC inductor current to rise thus reducing the amount of cross-over distortion.

V. CONCLUSION

This ballast control IC represents a significant advancement because it incorporates the PFC control, ballast control and 600V half-bridge driver, allowing a single 16-pin IC to be used.

The power factor section works in conjunction with the ballast control section. The unique variable gain can be adjusted depending on the status of the ballast controller and if the ballast is in fault mode, the PFC section will be disabled.

Since the IC requires a single VCC supply, the circuitry is considerably simplified. A further reduction in components and cost is possible because the design eliminates the need for external components to sense AC line voltage and current.

The result is a cost effective, high-performance, complete ballast solution that is easier to manufacture with higher reliability.