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A Systems Approach to Ballast IC Design

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International Rectifier's new ballast IC family delivers high-performance, ruggedness and flexibility.

INTRODUCTION

International Rectifier has recently expanded their ballast IC family to include the IR2157 Ballast Control IC and the IR2159 Dimming Ballast IC. Together with the popular IR2153, these three chips comprise International Rectifier's ballast IC family and are designed to capture a wide range of ballast applications. Ballast design tools have also been developed which include reference design kits and a new ballast design assistant (BDA) interactive software program. The emphasis with these products has been placed on high-performance, maximum flexibility and minimal component count. It is the evolution of each IC that is unique in that their specifications were carefully defined from the system side. In fact, the first of the three chips, the IR2153, was used as a development tool in the definition of the next generation ICs.

At the heart of most electronic ballasts is a traditional voltage-fed resonant output stage consisting of a half-bridge driver, a series inductor, and a parallel capacitor and lamp (Figure 1). The lamp requires a current for a specified time to preheat the filaments, a high-voltage for ignition, and running power. These requirements are satisfied by changing the frequency of the input voltage and properly selecting Vin, L and C. For preheat and ignition, the lamp is not conducting and the circuit is a series L-C. During running, the lamp is conducting, and the circuit is an L in series with a parallel R-C. Sounds simple, but a better description would be 'deceptively simple'. This circuit has hidden pitfalls which when left undetected, can surface months later after a high quantity of ballasts have been installed in the field by the end customer. Dealing with the problem at that stage can be a nightmare. By approaching the design of the IC from the system side, each of these pitfalls is first well understood and characterized before the design of the IC begins. An actual working prototype of each IC was first constructed and demonstrated to verify proper system performance and functionality.

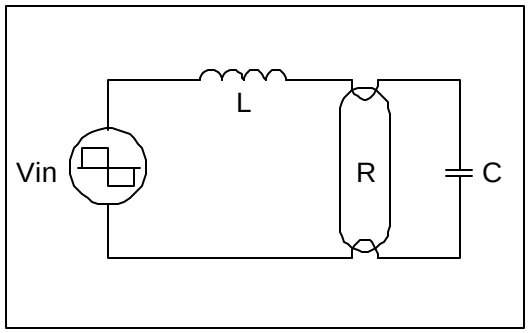

Figure 1, Simplified ballast output stage

A systems approach also allows the IR to give customers the complete solution. Reference design kits have been developed which include a near production-ready, fully-functional ballast. It is the goal of the IR Lighting Team to get the customer designed in quickly and correctly. Some customers are not aware of these hidden pitfalls and IR does not want to wait until a product is in production before finding a problem. If the customer wins, IR wins.

IR2153: KEEP IT SIMPLE

The IR2153 offers a simple solution to getting light on the table quickly. A 555-timer circuit combined with a high and low-side half-bridge driver is an idea which makes perfect sense for both IR's high voltage technology and the ballast market. Simply program the running frequency with a resistor and a capacitor (Figure 2) and turn the ballast on. The IR2153 is an improved

version of the original IR2155 and includes added features such as micro-power start-up and a shutdown option. Also attractive is the small SO8 package size which minimizes PCB area and simplifies layout. To realize a complete solution, however, external circuits are necessary for preheat, lamp fault protection and automatic restart. If the additional circuitry increases component count or takes up too much PCB area, then a more integrated solution is preferred.

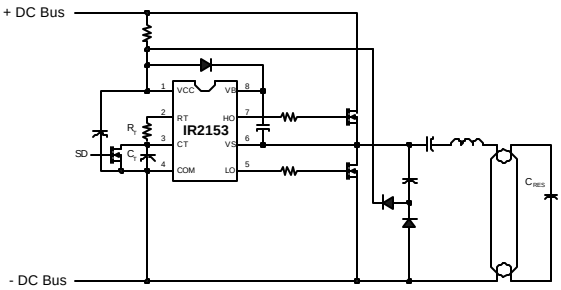

Figure 2, IR2153 ballast control IC

IR2157: RUGGED YET FLEXIBLE

The IR2157 ballast control IC offers an elegant and simple solution with minimal external components. The system homework was done before the actual IC design to ensure that the end solution was robust. In the area of lamp fault protection, the approach was all or nothing. If any of the abnormal lamp fault conditions are left undetected, this can spell disaster for a ballast manufacturer. Also, new lamp types are continuously emerging on the market. For this reason, it is important to have a solution which is easily adaptable to a wide range of lamp types. To achieve this, the IR2157 allows for independent programmability of each ballast operating frequency (Figure 3).

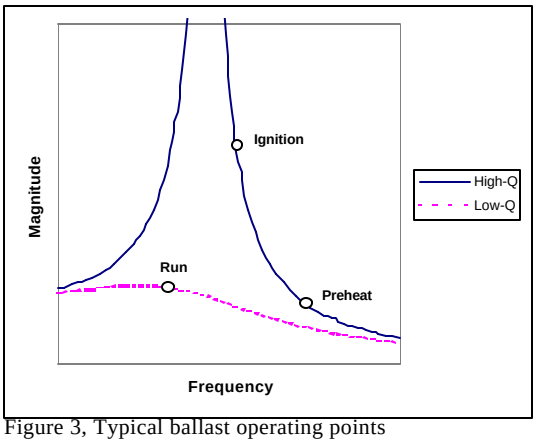

Figure 3, Typical ballast operating points

The IC starts oscillating at a high-frequency before sweeping smoothly to a lower preheat frequency (Figure 4) where it remains for the duration of the preheat period. After the preheat period has ended, the IR2157 ramps the frequency down through the ignition frequency to the final run frequency. If the lamp fails to ignite, the over-current threshold is reached and the half-bridge is shutdown.

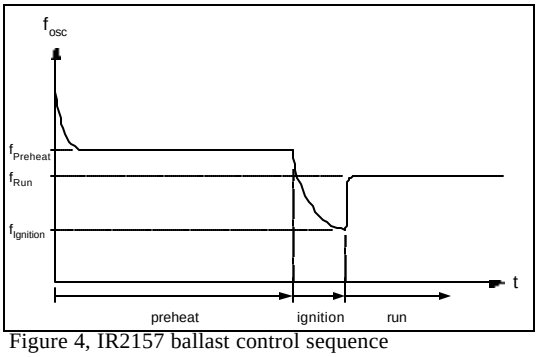

Figure 4, IR2157 ballast control sequence

The location of the operating frequencies depend on the lamp voltage, lamp power, L, C, and the DC bus voltage. Once the frequencies are known, the IR2157 is then programmed with a few external resistors and capacitors (Figure 5). The IR2157 also includes end of lamp life protection, capacitive mode protection, brown-out protection, over-temperature protection, and automatic restart.

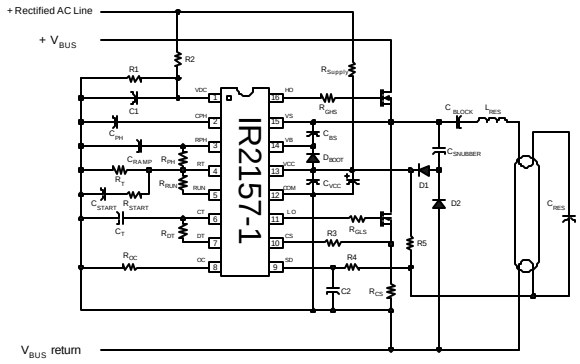

Figure 5, IR2157 Ballast controller IC

IR2159: TRANSFORMER-LESS DIMMING

At the heart of the IR2159 Dimming ballast IC is a new control method for controlling lamp power without separating lamp current with an additional transformer. By controlling the phase of the half-bridge current, a linear relationship to lamp power is obtained (Figure 6).

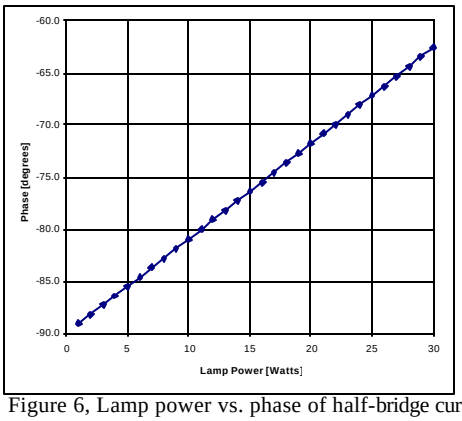

Figure 6, Lamp power vs. phase of half-bridge current

The system is closed-loop, so the approach with this IC is slightly different. Closing the loop actually relaxes the specifications of certain blocks within the IC and reduces both the die size and pin count. The IR2159 is based on a single-pin architecture in which one pin is used to measure all feedback information necessary for preheat, ignition, dimming, and lamp fault protection. The control sequence is simple: regulate the preheat current for a preheat time, ignite the lamp, then close the dimming feedback loop. The IR2159 includes a 0.5 to 5VDC dimming control input (Figure 7) and a MIN and MAX pin for programming the minimum and maximum brightness boundaries. The IR2159 also includes end of lamp life protection, capacitive mode protection, brown-out protection, over-temperature protection, and automatic restart.

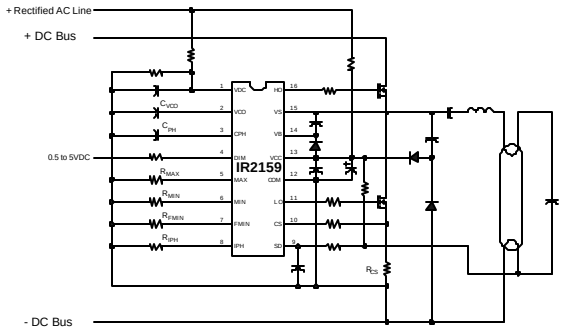

Figure 7, IR2159 Dimming ballast IC

REFERENCE DESIGN KITS

To help speed up design-in time, reference design kits have been developed for the IR2157 and IR2159. These are near production-ready, fully functional ballasts. The functions performed by the reference design kits include (Figure 8) electromagnetic interference (EMI) filtering to block ballast generated noise, power factor correction (PFC) for sinusoidal input current, undervoltage lockout (UVLO) and fault protection, half-bridge switches with driver and timing for high-frequency operation, and final output stage to power the lamp.

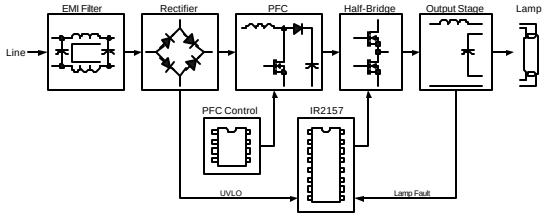

Figure 8, Ballast functional block diagram (non-dimming).

Temperature, lifetime, performance margins, packaging, layout, manufacturability and cost were all considered during the design process.

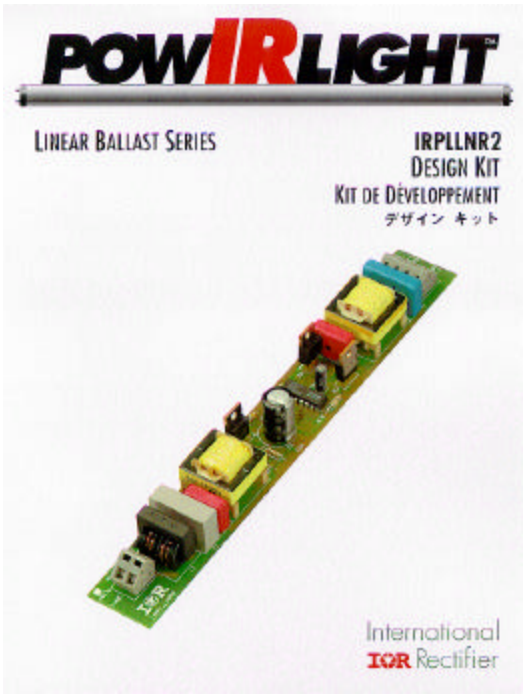

Figure 9, PowIRlight ballast reference design kit

BALLAST DESIGN ASSISTANT (BDA)

Ballast design software has been developed to assist in selecting ballast component values for different lamp types. The software is based on a set of equations and a design procedure [1] which model the ballast output stage and calculate component values. Some of the components include the L and C of the output stage, the PFC inductor, and the programmable components of the IR2157 and IR2159. The BDA software will generate a complete schematic and bill of materials based on a simple 3-step procedure (Figure 10).

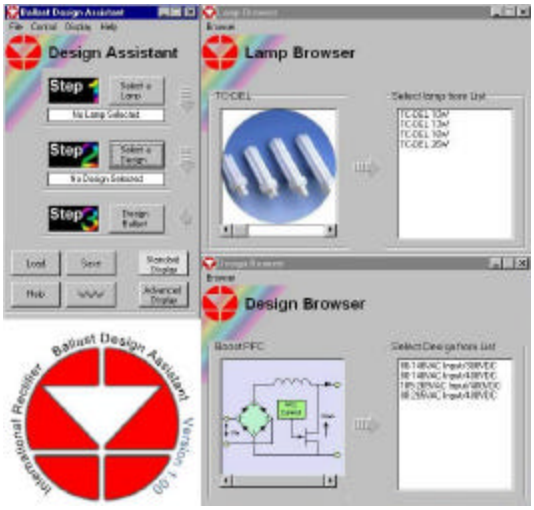

Figure 10, Ballast Design Assistant Software (BDA)

Select a lamp type, select an input line voltage, then click on ballast design. An advanced options screen is also available for customization or a detailed look at the ballast operating frequencies, currents and voltages. The program also includes a magnetics designer and PCB gerber files to speed up design time even further.

CONCLUSION

The new family of IR ballast ICs are very easy to use. Simply adjust the programmable inputs of the IC for each different lamp type. Together with the design kits and BDA software, the entire system is now available to the designer. By using a systems approach to design each IC, the end solution is one which is greatly simplified for both the IC and the ballast. A good sign of an IC that has been designed with the entire system in mind is an IC that requires very few external components.

For more information please visit International Rectifier's web site at: www.irf.com

REFERENCES

[1] T. Ribarich, J. Ribarich, *A New Model for High-Frequency Ballast Design*, in IEEE-IAS *Conf. Rec.*, 1997, pp. 2334-2339.