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Simple, Versatile Control IC Dims Fluorescent Ballasts

The IRS2530D is simple to use with any analog and digital control method available for dimming fluorescent lamps. In addition, it can implement dimming control for LEDs.

Fluorescent dimming systems can satisfy visual comfort, and reduce utility costs through daylight harvesting, demand reduction, scheduled dimming, and other strategies. A dimming electronic ballast is an essential part of this system.

To perform dimming functions, the ballast must be configured to understand an input signal from the control device, and act upon the current flowing through the lamp. Typically, this is a challenging task for the ballast designer and is usually achieved using a complex, high-pin-count control IC.

The IRS2530D is a new dimming ballast control IC in a compact 8-pin form-factor (*Fig. 1*). This DIM8™ is a 600-V half-bridge driver IC that includes all the necessary functions for preheat, ignition, and dimming control of the lamp, and protects the circuit against line and lamp fault conditions. With only eight pins to accomplish all dimming ballast functions, the IC can minimize component count and simplify design, and is flexible enough to be used with various dimming control methods.

Several reference-design kits have been created to help with the evaluation of the IRS2530D. Each of these kits uses a different dimming control method, and they cover various input voltages and lamp types. A complete description of each kit is available at International Rectifier's lighting website (www.irf.com/product-info/lighting/).

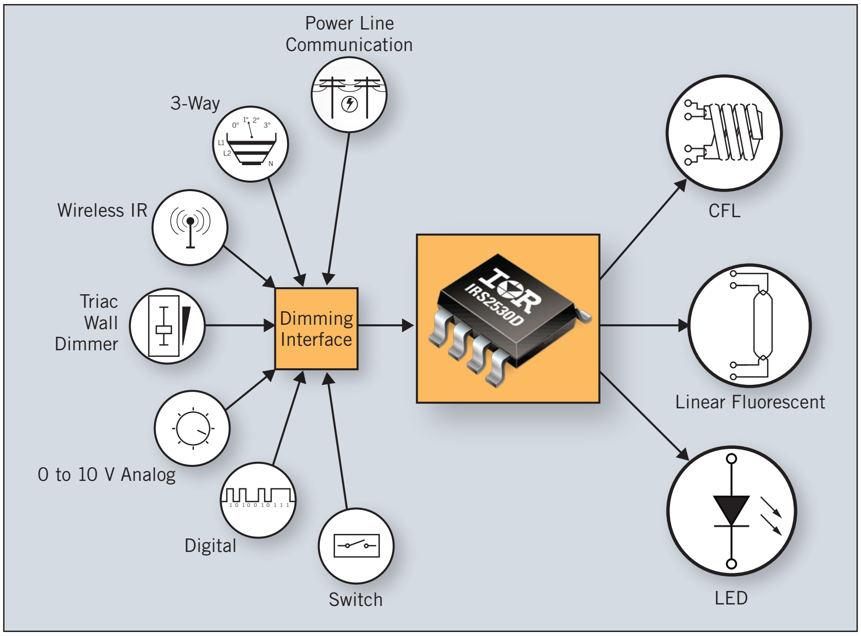

Fig. 1. The IRS2530D is a 600-V half-bridge driver IC with all the necessary functions for preheat, ignition, and dimming control of the lamp. Plus, it protects the circuit against line and lamp fault conditions.

ANALOG DIMMING

Fig. 2 shows the schematic of a dimmable electronic ballast for driving a 26-W quad-pin CFL from a 220-Vac line with an isolated 1- to 10-Vdc dimming input. The ballast comprises an EMI filter to block ballast-generated noise, a rectifier and bus capacitor to convert ac line input into a dc bus voltage, a control IC and half-bridge to produce high-frequency square-wave voltage, and a resonant output stage for preheating, igniting, and running

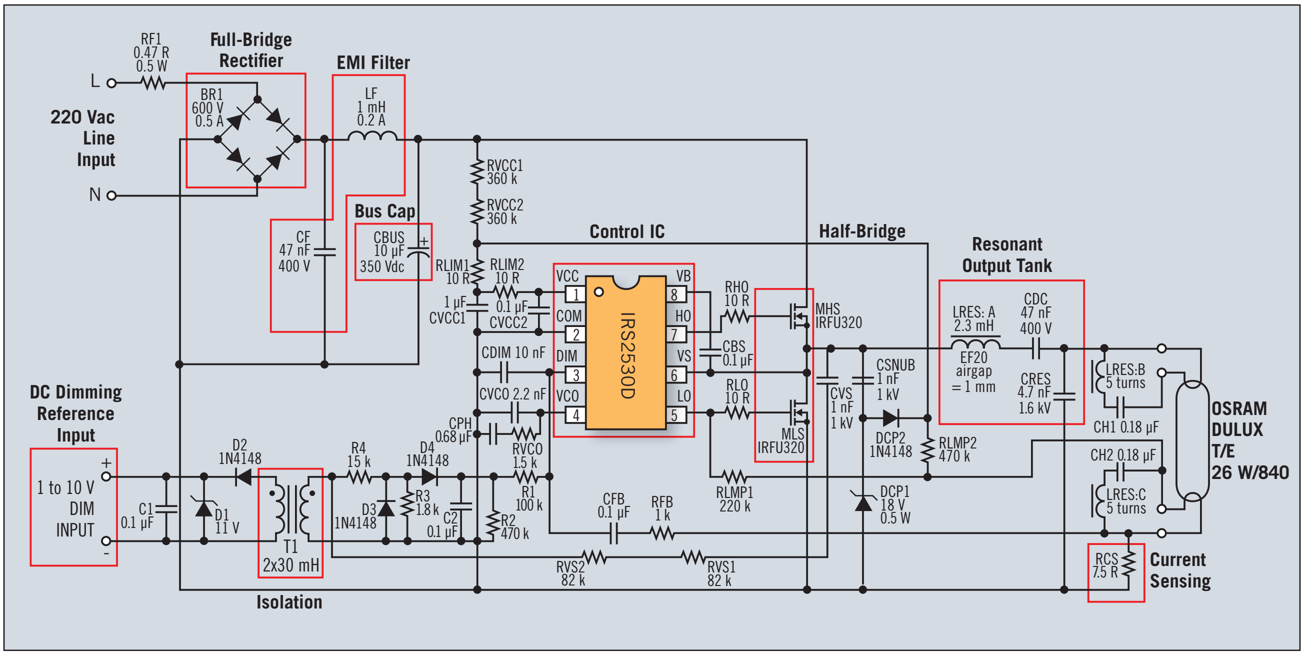

Fig. 2. The ballast contains an EMI filter, rectifier, bus capacitor, control IC, and half-bridge to produce high-frequency square wave voltage, and a resonant output stage for preheating, igniting, and running the lamp.

the lamp. The current-sensing resistor and the isolated dimming reference input are additional components needed for dimming application. The IRPLDIM4E reference design kit does not include the isolation section of the circuit.

When power is initially turned on, the bus capacitor (CBUS) charges up, and resistors RVCC1 and RVCC2 supply the micro-power current to the IRS2530D. After the VCC voltage reaches above UVLO threshold, the half-

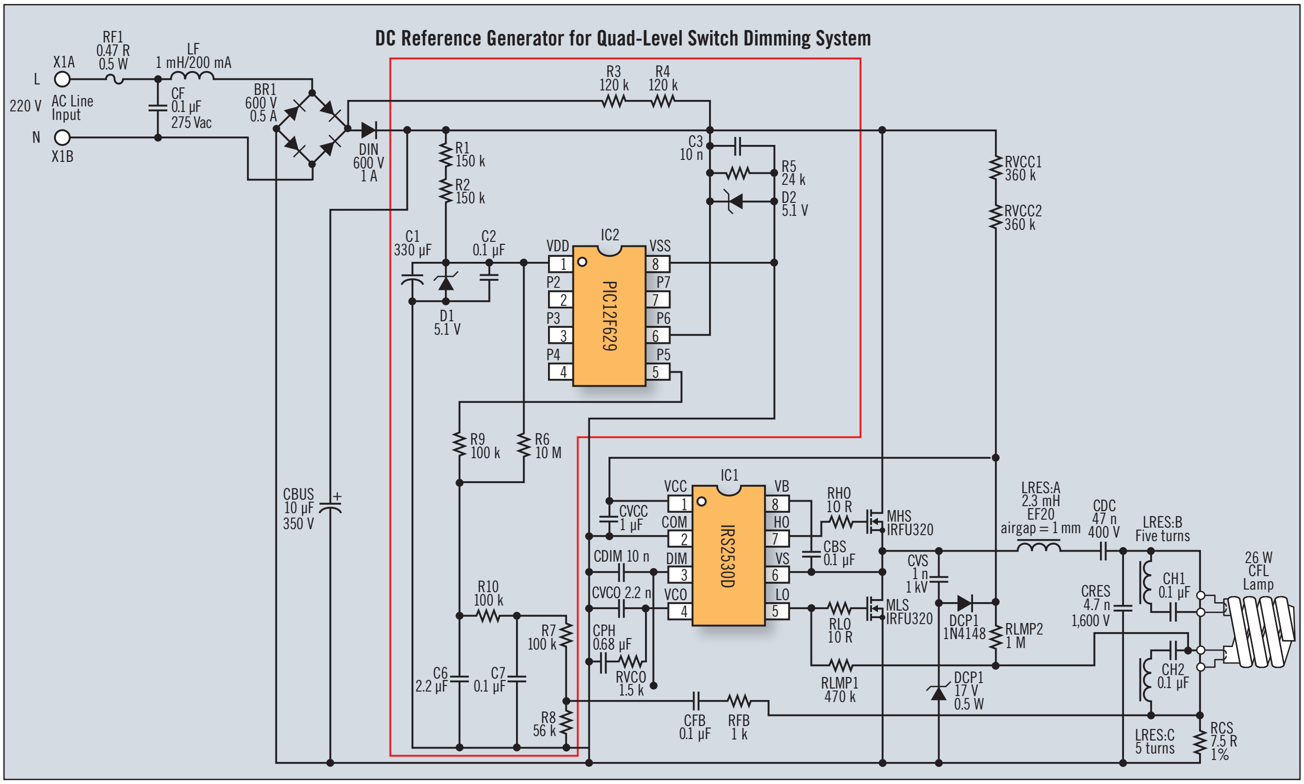

Fig. 3. The IRPLDIM5E is a quad-level switch-dimming fluorescent ballast that operates from a 220-Vac line and drives a 26-W quad-pin CFL.

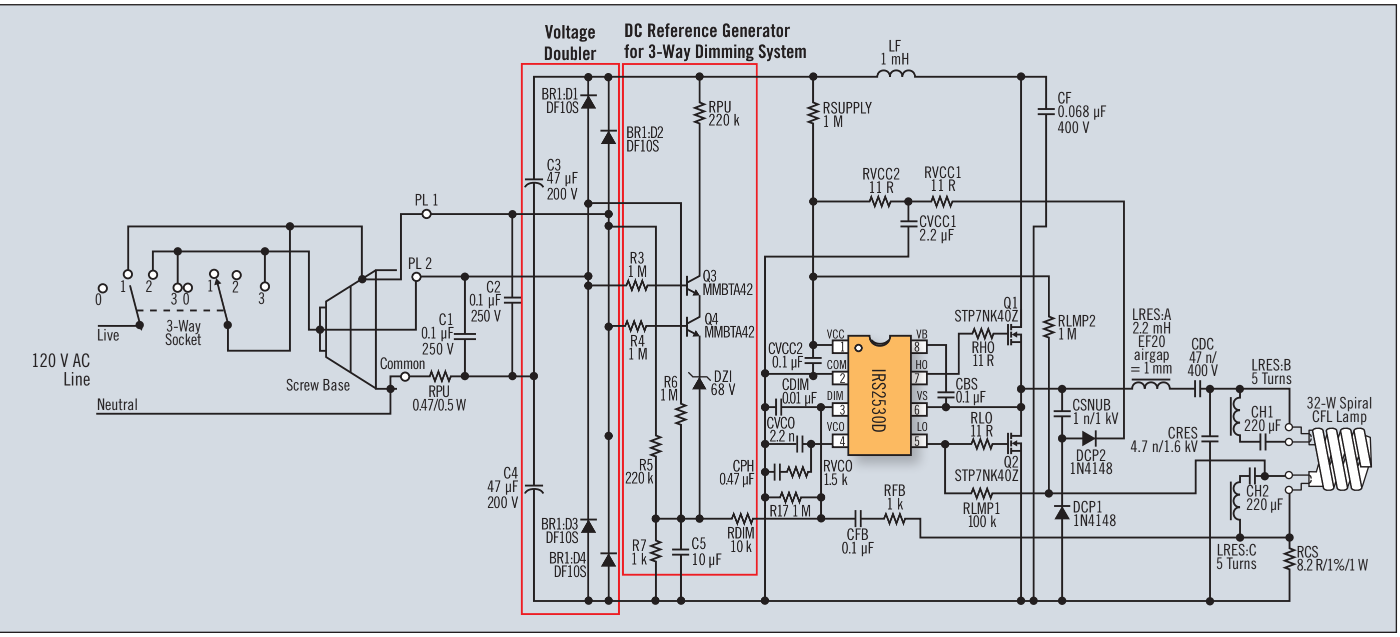

Fig. 4. The IRPLCFL8U is a three-way switch-dimming electronic ballast driving a 32-W spiral CFL from a 120-Vac line.

bridge starts to oscillate at the maximum frequency. The charge-pump circuit (CVS, DCP1, and DCP2) takes over as the main supply circuit for the IC and keeps the VCC at the internally clamped 15.6 V.

An internal current source at the VCO pin charges up the external capacitor (CPH). Output frequency decreases as the CPH charges and, at the same time, the lamp filaments are preheated using the secondary winding from the resonant inductor. As the frequency decreases toward the resonant frequency of the output stage, the voltage across the lamp increases. After it reaches a high enough voltage to ignite the lamp, lamp current begins to flow. The resonant output stage transitions to a series-L, parallel RC circuit with the Q-value and operating point determined by the user's dim level.

Ac lamp current is sensed by the resistor RCS, and the resulting ac voltage is coupled with the dc dimming reference voltage from isolation through feedback resistor (RFB) and feedback capacitor (CFB). This dc + ac signal is then fed into the DIM pin of the IRS2530D and is regulated by the control loop, such that the valley of the ac voltage always stays at COM.

When the dc reference voltage at the DIM pin is decreased for dimming, the valleys of the ac voltage are pushed below COM. The dimming control circuit increases the frequency to decrease the gain of the resonant tank circuit, and thus the ac lamp current, until the ac valleys at the DIM pin are at COM again.

The opposite happens when the dc reference is increased to increase the brightness level. In this way, the dimming control circuit keeps the ac lamp current peak-to-peak amplitude regulated to the desired value at all dc dim level settings.

QUAD-LEVEL SWITCH DIMMING

Another dimming control method is quad-level switch dimming, which uses the on/off switch to control the dimming level. When the switch is turned off and then turned back on in less than one second, the dimming level is reduced by one level.

If the dimming level is already at the minimum, this action will cycle the dimming level back to the maximum. If the switch is turned off for more than one second, dimming will stay at the last level.

The IRPLDIM5E is a quad-level switch-dimming fluorescent ballast which drives a 26-W quad-pin CFL from a 220-Vac line. *Fig. 3* shows the schematic of the IRPLDIM5E.

The circuit in *Fig. 3* is similar to the IRPLDIM4E, except for the circuitry to generate the dc dimming reference voltage. A microcontroller is used to provide the reference voltage and to determine whether to switch to the next dimming level.

The micro-controller used here is the PIC12F629, which contains some EEPROM non-volatile memory that allows the microcontroller to store the last dim level setting before shutting down after power is switched off. This enables the ballast to start up at that same setting when power is restored, no matter how long the ballast has been off.

Pin 5 of the microcontroller generates a fixed-frequency square wave signal with four different duty cycles, which correspond to four dimming levels. The square wave signal then goes through the low-pass filter to produce the dc reference voltage.

Pin 6 of the microcontroller is connected to the bridge rectifier through a filter circuit with a very short delay. This allows the microcontroller to detect when ac power has been removed and restored quickly.

The VDD supply capacitor, C1, is large enough to allow the microcontroller to continue to run for more than one second after ac power has been removed from the ballast. The microcontroller starts a timer as soon as it detects that the power is switched off. If power is restored within one second, the microcontroller will reduce the duty cycle one level, and thus reduce the dc reference by one step. If the level is already at the minimum, it will cycle back to the maximum duty cycle.

THREE-WAY SWITCH DIMMING

The three-way dimming system is widely adopted in the U.S. The system consists of a special lamp socket that has a four-position switch and a bulb with a modified screw base. For incandescent lamps, the bulb has two filaments and two connections on the lamp screw base.

The IRPLCFL8U is a three-way switch-dimming electronic ballast driving a 32-W spiral CFL from a 120-Vac line. *Fig. 4* shows the ballast, together with the three-way socket and the modified lamp base. The interface circuit includes a voltage doubler (D1, D2, D3, D4, C1, and C2) in place of a rectifier and a circuit to generate the dc dimming reference voltage (R3, R4, R5, R6, R7, RPU, Q3, Q4, DZ1, and C5).

The first socket switch position is "off," in which no filaments are connected. In the second position, the first filament (PL1) is connected across the ac line for the lowest brightness setting. Resistor R5 pulls up the dc dimming reference across resistor R7 and capacitor C5 to set the minimum brightness.

The third position, which corresponds to the medium brightness setting, uses R6 to pull up the dc dimming reference. In the fourth position, parallel resistors R5 and R6 set the dc dimming reference for the high brightness setting. The level of brightness can be modified as needed by changing the value of R5, R6, and R7. Transistor Q3 and Q4 ensure that the dc reference voltage is high enough at the high brightness, setting since both of these transistors will be switched on in this case.

PHASE-CUT (TRIAC) DIMMER

Virtually all domestic and professional dimming systems are based on triacs, also known as phase-cut dimmers. These devices conduct once they have been fired, only while the current flows in excess of the holding current of the device. These dimmers work very well with a resistive load—such as an incandescent light bulb—as the triac continues to conduct after it is fired, until very close to the end of the half-cycle.

A traditional CFL ballast, in which there is no power factor correction, only draws current from the mains near the peak of the mains voltage where the storage capacitor charges—and not during the remainder of the mains half-cycle. The inability of traditional CFL ballasts to sustain conduction of the triac will cause severe flickering when used with such a dimmer.

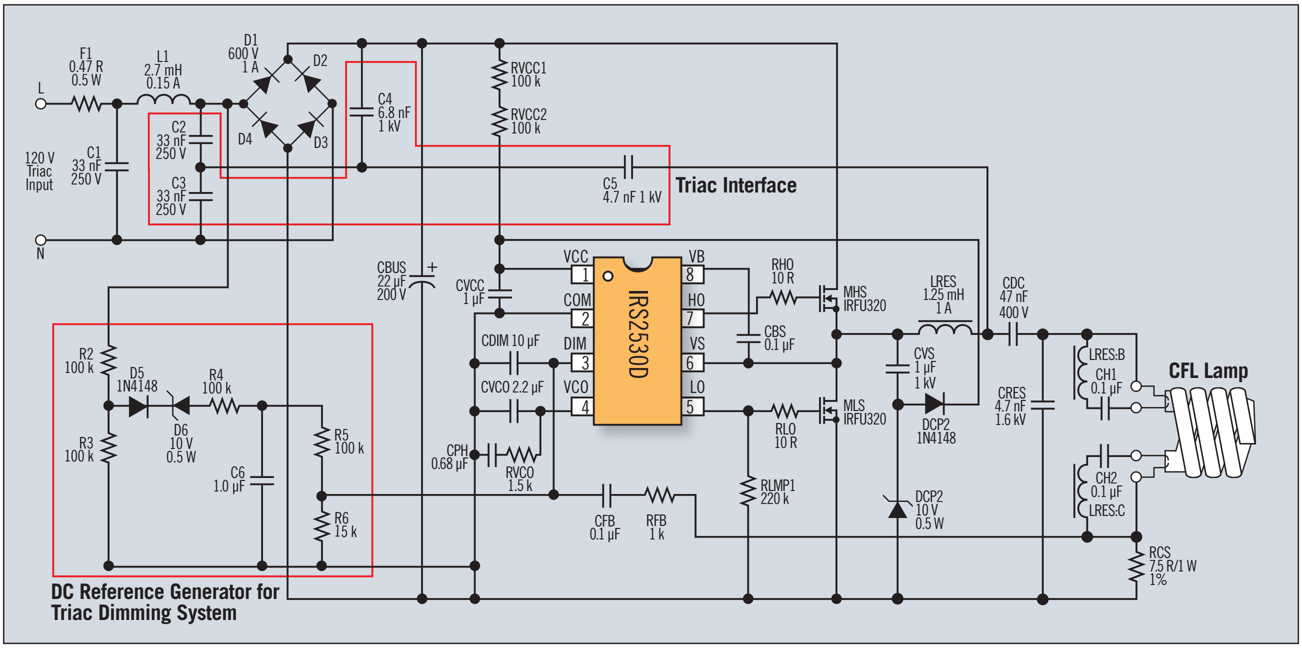

Fig. 5. A triac-dimmable CFL ballast driving a single 15-W spiral CFL from a 120-Vac input.

Application note AN-1153 describes a triac-dimmable CFL ballast driving a single 15-W spiral CFL from a 120-Vac input. *Fig. 5* shows the schematic of the ballast.

Capacitors C2, C3, C4, and C5 are used to interface with the triac in the dimmer so that the ballast can maintain triac conduction until almost the end of the mains half-cycle. There is also circuitry that detects the firing angle of the triac and adjusts dc reference voltage to set the lamp current.

The voltage waveform at the junction of D1 and D4 is equivalent to the output voltage of the dimmer. This will be a phase-cut approximated sine wave with a dc offset, such that the negative peak is at ground. This is reduced by the voltage divider network of R2 and R3, which is then fed into D5 and D6.

Only the signal representing the positive half-cycle of the mains is left at the anode of D6, which is then converted to a dc level via the filter of R4 and C6. Because the minimum dimming level occurs at a point where the dimmer is still capable of providing enough output for the ballast to operate, this voltage will never actually be zero. The dc level is further reduced with the voltage divider network of R5 and R6, and used as the dc dimming reference voltage.

OTHER DIMMING SYSTEMS

There are various dimming control methods available for fluorescent applications. In general, dimming control can be categorized into two methods: analog and digital. While analog dimming systems are well-established and common, digital dimming systems are relatively new.

> Digital dimming offers a number of advantages compared to analog methods, including simplified wiring, a higher degree of control accuracy, and two-way communication

Because of the simplicity of its dimming control method, the IRS2530D can be easily utilized for both methods. The ballast designer needs to determine how to generate the proper dc voltage reference from the dimming control method being used.

Analog dimming methods include 0- to 10-Vdc, phase-cut dimmers, and three-wire phase controls, as well as photo-sensor, motion-sensor, and wireless infrared. The dc voltage reference can be generated by a voltage divider using a combination of resistors, photoresistors, potentiometers, or rheostats.

The dc voltage reference should be properly set, as it should not be too high to limit power loss in the current-sense resistor, and not too low to avoid noise problems at the minimum dimming level. The IRS2530D datasheet (www.irf.com/product-info/datasheets/data/irs2530d.pdf) explains how to properly set the dc reference and the current sense resistor.

Digital dimming offers a number of advantages compared to analog: simplified wiring, a high degree of granularity for control accuracy, and two-way communication. Another advantage of this system is its capability to perform logarithmic dimming level. Since the human eye is much more sensitive to lower rather than higher light levels, the logarithmic light output appears to be linear.

The most prominent of digital dimming methods is the open-standard two-wire interface digital addressable lighting interface (DALI). To work with digital dimming methods,

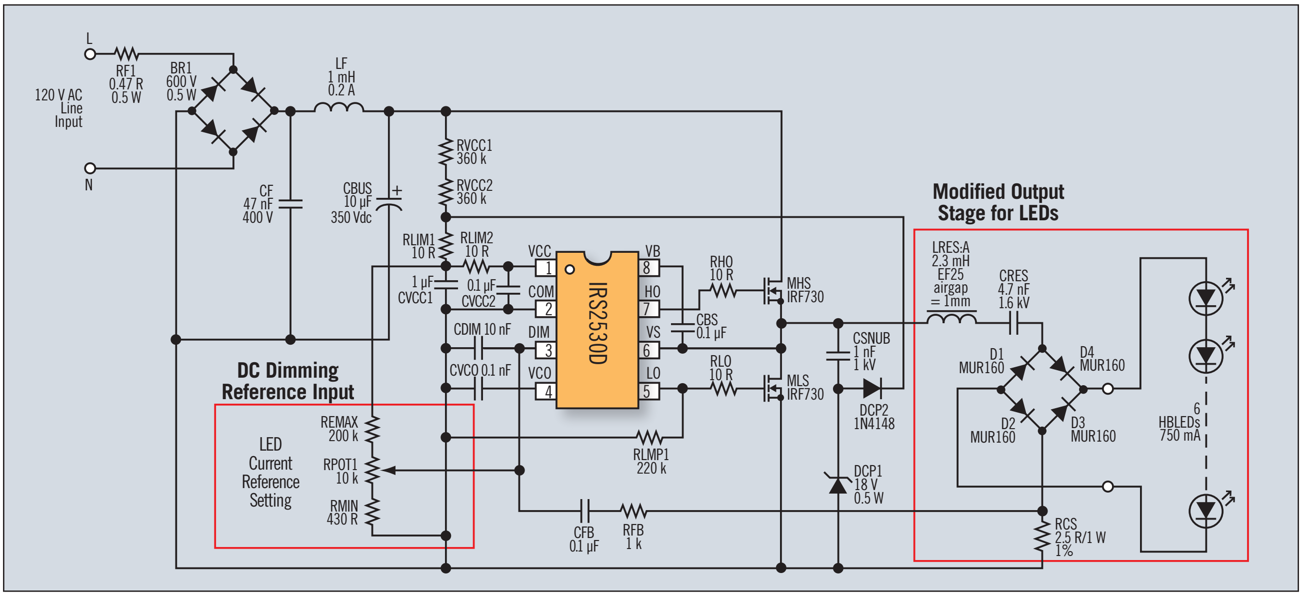

Fig. 6. The IRS2530D ballast can be used to control and dim the current of an offline LED.

a dimming ballast designed around the IRS2530D requires a microcontroller to communicate with digital protocols. The microcontroller interprets data from the digital control, and generates the square wave signal with fixed frequency but varying duty-cycle, which corresponds to the desired dimming level.

> The dimming control loop of the IRS2530D keeps the amplitude of the LED current regulated by adjusting the frequency of the half-bridge switching circuit

DIMMABLE LED DRIVERS

Unlike a fluorescent lamp, an LED requires constant current control and does not need to be preheated or ignited. The IRS2530D can also be used to control and dim LED current. *Fig. 6* shows the schematic of an offline LED driver using the IRS2530D.

The circuit is a resonant-mode circuit that has been slightly modified from the IRPLDIM4E circuit. Since it is no longer necessary to preheat and ignite the load, the output stage has been modified to become a series L-C-LED configuration. The resulting square-wave ac voltage at the output is converted to positive full wave rectified voltage using an additional full-bridge rectifier.

Ac current sensing is still performed by the current-sensing resistor (RCS). This provides a direct ac measurement of the full wave rectified LED current amplitude. This ac signal is then coupled with the dc voltage from the current reference setting onto the DIM pin of the IRS2530D. The dimming control loop of the IRS2530D keeps the amplitude of the LED current regulated by continuously adjusting the frequency of the half-bridge switching circuit, such that the nominal rms LED current is maintained within the manufacturer's specifications.

When the dc reference voltage is decreased for dimming, the IRS2530D increases the frequency to decrease the gain of the resonant tank circuit and thus decrease LED current. This control scheme keeps LED current constant over line, load, and temperature variations for any given dimming reference input, and will work for any number of LEDs in series.

The above LED control circuit is almost similar to the IRPLDIM4E dimming fluorescent ballast circuit. Any of the dimming fluorescent ballast methods described above can be easily translated to an LED control circuit. The dimming control loop of IRS2530D allows the circuit to be scaled to any number of LED in series. To work with LEDs with different current ratings, the current-sense resistor and dc reference settings need to be adjusted accordingly.