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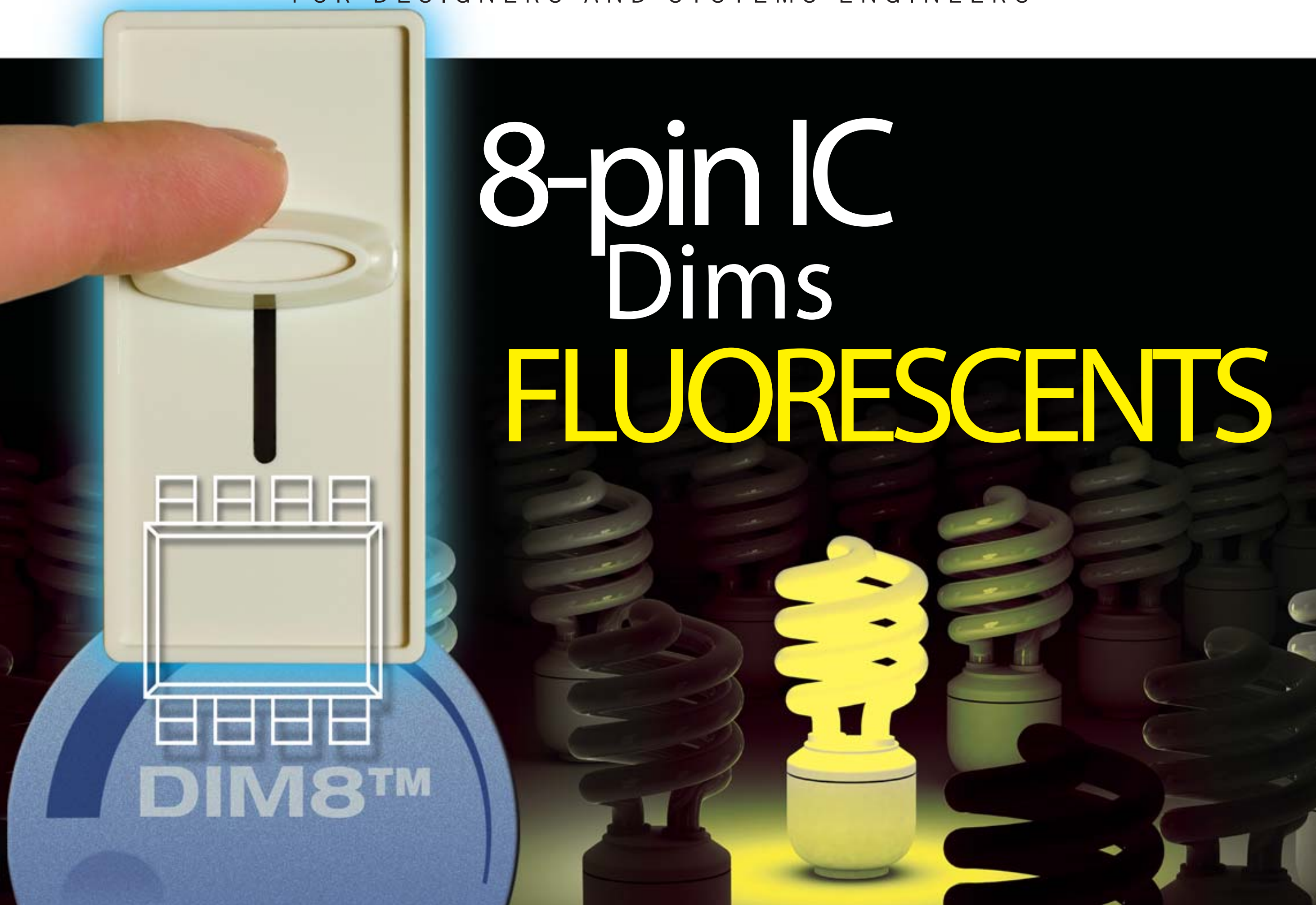
FOR DESIGNERS AND SYSTEMS ENGINEERS

8-pin IC Dims FLUORESCENTS



ALSO IN THIS ISSUE:

A PENTON PUBLICATION

Fluorescent Lamp Control IC
Does Dimming with Only 8 Pins

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With dimming levels down to 10%, a new IC minimizes component count to improve dimming-circuit speed, simplify design, and open up new dimming applications.

DESIGNING DIMMING CIRCUITS FOR FLUORESCENT LAMPS is a challenging task typically realized using a complex, high-pin-count control IC. Compared with non-dimming designs, dimming circuit ICs:

- **Are more difficult to design so they meet the required performance**
- **Require more components**
- **Require more PC board area and layers**
- **Cost more**

There are several challenges associated with adding dimming functionality to this IC without increasing pin count. A novel control method overcomes this challenge with a new "DIM8™" control IC for the general fluorescent lighting market. The result is an 8-pin dimming IC that is simple and has a wide variety of applications.

To understand the details behind the new dimming IC, we should first look at the IR2520D, an existing 8-pin, non-dimming ballast-control IC used in a vari-

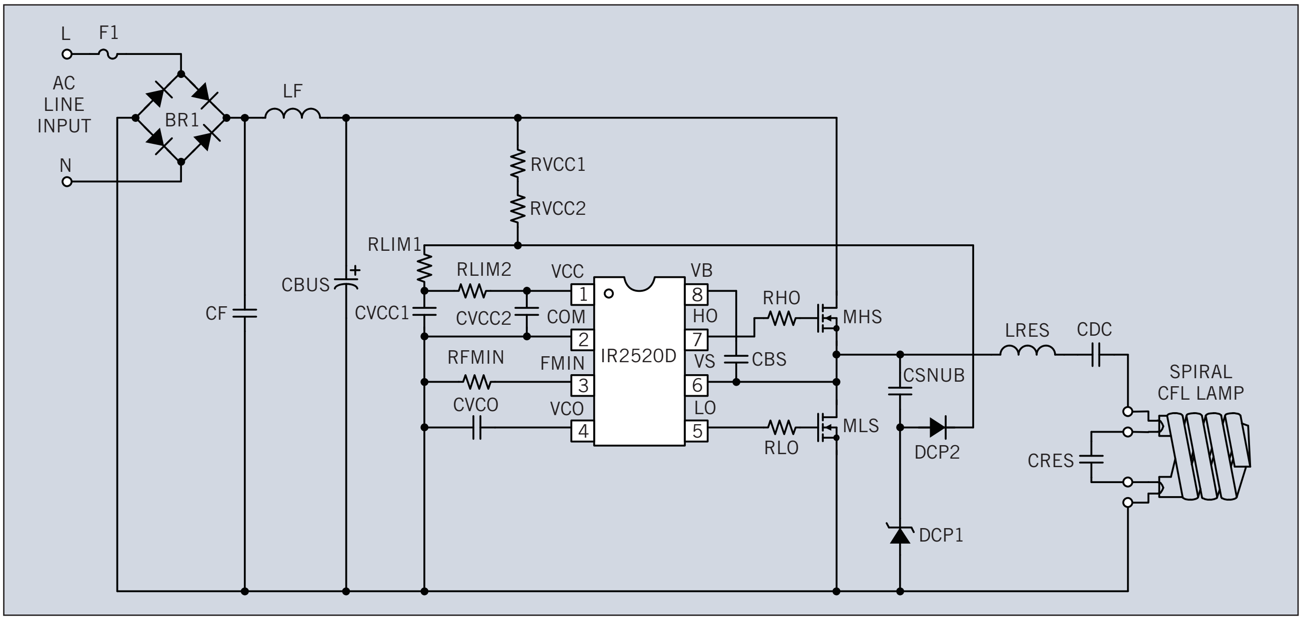


Fig 1. Fluorescent lamp ballast circuit using the non-dimming IR2520D control IC.

ety of fluorescent lighting applications (*Fig. 1*). This IC only requires two pins—FMIN and VCO—to control preheat, ignition and running requirements of the lamp.

The remaining pins perform standard functions such as IC supply and ground (pins VCC and COM), and high- and low-side gate drive for the half-bridge (pins LO, VS, HO and VB).

When the ac line voltage is first applied to the circuit, the voltage across capacitor CBUS charges up. Resistors RVCC1 and RVCC2 supply VCC with the necessary micro-power current to charge VCC up to the internal UVLO+ threshold. When VCC exceeds the UVLO+ threshold, the IR2520D enters the frequency-sweep mode.

The gate driver outputs (LO and HO) and the half-bridge circuit (MHS and MLS) oscillate at the maximum frequency. The charge-pump circuit (CSNUB, DCP1 and DCP2) takes over as the main supply circuit for the IC and keeps VCC maintained at the internal clamp voltage of 15.6 V.

A small internal current source at the VCO pin slowly charges up the external capacitor (CVCO) causing the voltage on pin VCO to ramp up linearly (*Fig. 2*). This causes the frequency of the gate-driver outputs and the half-bridge switching circuit to ramp down from the maximum starting frequency. As the frequency ramps down toward the resonance frequency of the high-Q, under-damped output stage (LRES, CRES), the lamp voltage increases (*Fig. 3*).

The voltage on pin VCO continues to increase while the frequency keeps decreasing until the lamp ignites. The output circuit then becomes an over-damped, low-Q circuit. The voltage on pin VCO continues to increase until it exceeds 4.6 V and the IC enters run mode.

The frequency stops decreasing when the VCO pin exceeds 5 V and stays at the minimum frequency as programmed by an external resistor, RFMIN, on pin FMIN. Capacitor CVCO sets the time for preheating the lamp filaments and sweep-

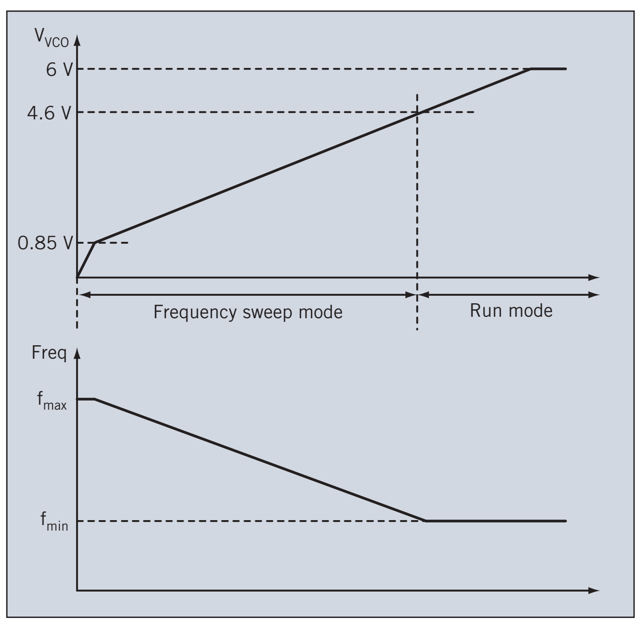


Fig. 2. Frequency sweep mode timing diagram for the non-dimming IR2520D fluorescent lamp control IC.

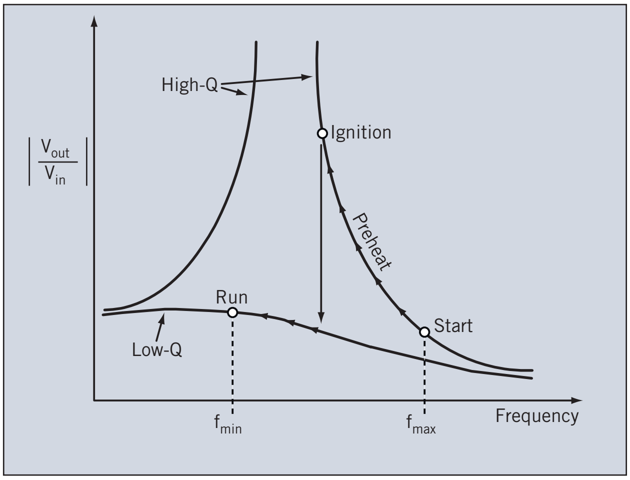


Fig. 3. Resonant-tank Bode plot with lamp operating points (start, ignition, run) for the non-dimming IR2520D control IC.

ing the frequency for ignition, and resistor RFMIN sets the running frequency, which sets the correct lamp power during running. All the remaining fault-protection circuits guard against ac line brown-out, lamp non-strike and filament failures, which are integrated into the IC and require no additional external components.

This IC is simple to use and requires minimal time to design the complete electronic ballast. With dimming now becoming more and more popular due to the increased energy savings, the challenge is to add the dimming function to the IC without increasing pin count and maintaining the simplicity of the IR2520D.

We always need a VCO pin to perform the necessary frequency sweep for preheat and ignition, so this leaves only the FMIN pin to be used for dimming control.

SINGLE-PIN DIMMING CONTROL

To dim the fluorescent lamp, the frequency is used to control the lamp current. As the frequency of the half-bridge is increased, the gain of the resonant-tank circuit decreases and the lamp current also decreases. A closed-loop feedback circuit is used to regulate the lamp current to a dimming reference level by continuously adjusting the half-bridge operating frequency. The new dimming function is realized by combining the ac lamp current measurement (*Fig. 4*) with a dc reference voltage at a single node. The ac lamp current is measured across a sensing resistor, RCS, and coupled onto the dc dimming reference through feedback capacitor CFB and resistor RFB.

The feedback circuit regulates the valley of the ac+dc signal to COM as the dc dimming level is increased or decreased by continuously adjusting the half-bridge frequency. This causes the amplitude of the lamp current to increase or decrease for dimming. If the dc reference is increased, the valley of the ac+dc signal will increase above COM and the feedback circuit will decrease the frequency to increase the gain of the resonant tank. This will increase the lamp current, as well as the amplitude of the ac+dc signal at the DIM pin, until the valley reaches COM again. If the dc reference is decreased, the valley will decrease below COM. The feedback circuit will then increase the frequency to decrease the gain of the resonant tank until the valley reaches COM again. The FMIN pin of the IR2520D used to program a single running frequency has now been replaced with the new DIM pin, which is used to measure the ac+dc signal for dimming.

The new IRS2530D dimming-control IC is a complete 8-pin solution that includes all dimming ballast functionality and protects the circuit against lamp fault conditions. The IC already uses six pins for very basic but necessary functions: IC supply and ground (VCC, COM), and half-bridge high- and low-side gate drive (VB, HO, VS, LO). The VCO pin includes the frequency-sweep timing control for preheat and ignition, and also programs the loop speed for the dimming feedback circuit during dim mode.

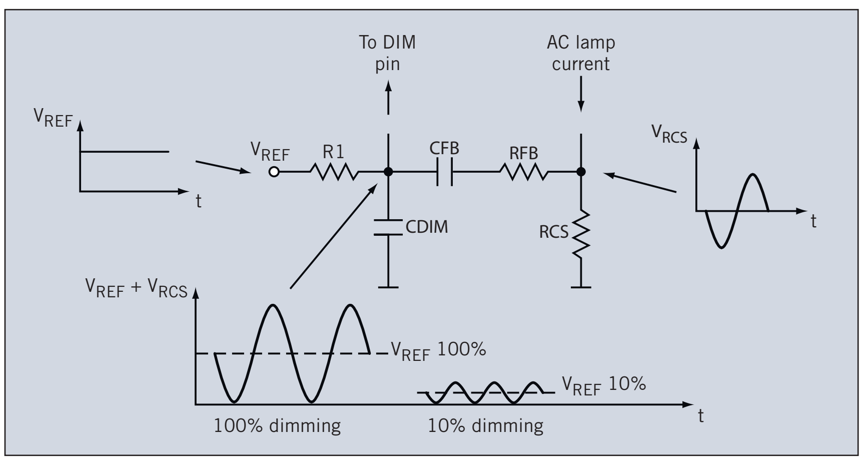


Fig. 4. Single-node ac+dc dimming-control method employed in the new IR2530D control IC.

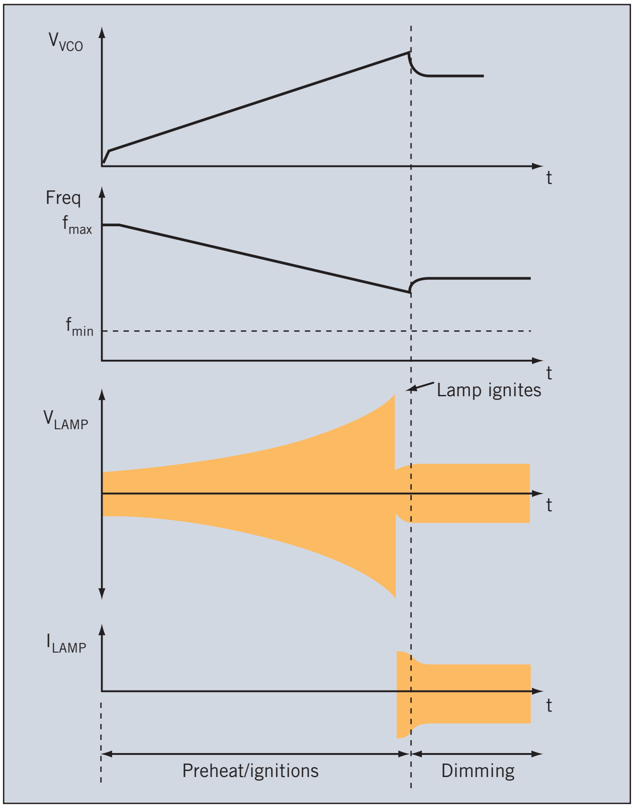


Fig. 5. Preheat, ignition and dimming timing diagram for the new IR2530D control IC.

When a voltage is first applied to VCC (14 V typical) the IC exits UVLO mode and enters Preheat/Ignition mode. The half-bridge begins oscillating at the maximum frequency and the internal current source at the VCO pin begins charging up an external capacitor (CVCO) linearly from COM (*Fig. 4*). The output frequency decreases as the VCO voltage increases and the lamp filaments are preheated by secondary windings from the resonant tank inductor. As the VCO voltage charges up, the frequency decreases toward the resonant frequency of the resonant-tank circuit and the output voltage across the lamp increases. The lamp ignites when the output voltage exceeds the lamp ignition threshold voltage, lamp current begins to flow, and the IC enters dim mode. *Fig. 5* is the preheat, ignition and dimming timing diagram for the IR2530D.

DIMMING MINI-BALLAST DESIGN

A complete dimming mini-ballast circuit (*Fig. 6*) was built and tested to demonstrate performance. The circuit runs from a 220-Vac line and drives a 25-W compact fluorescent lamp. The 220-Vac/50-Hz line-input-voltage is full-wave rectified (BR1) and goes through an EMI filter (CF and LF) before being smoothed by the dc bus capacitor (CBUS). The half-bridge switches (MHS and MLS) are controlled by the new IRS2530D for preheating, igniting and dimming the lamp. RVCC1 and RVCC2 provide the micro-power start-up current for the VCC supply

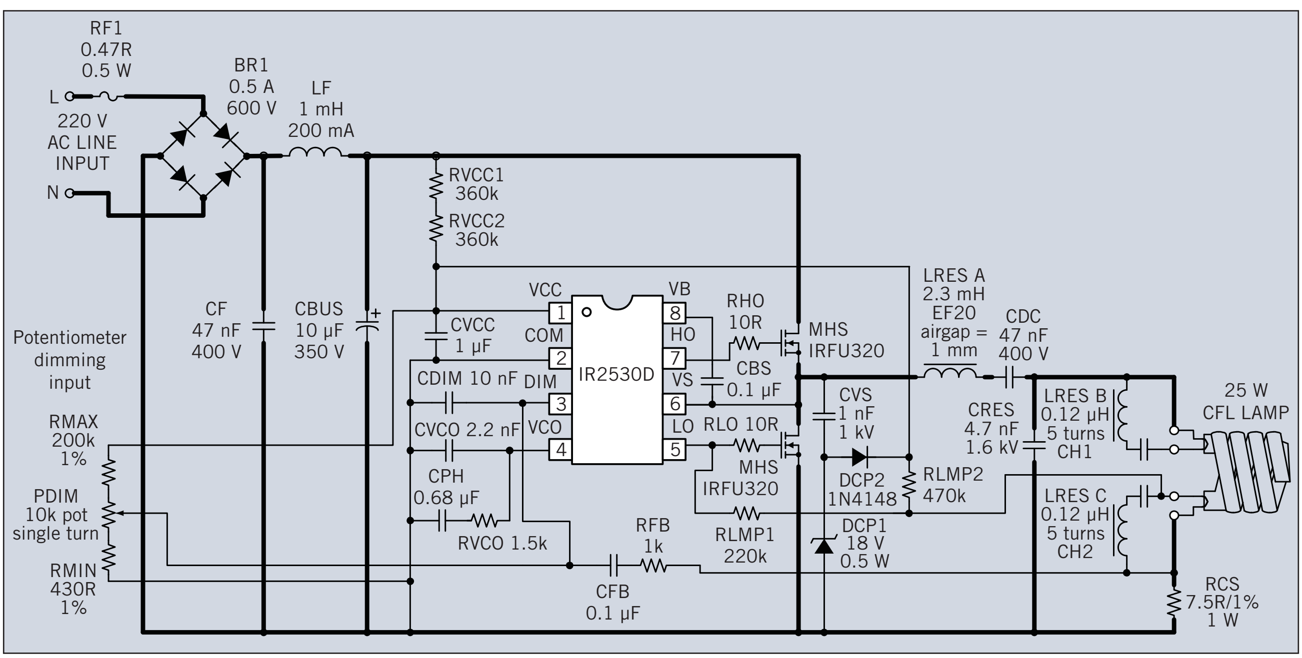
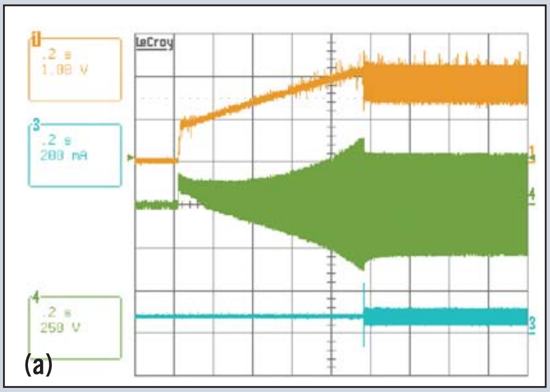
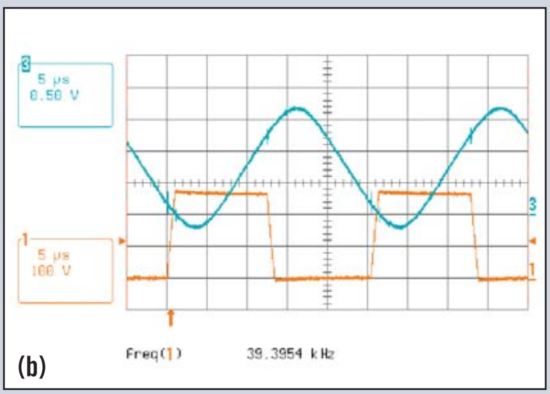


Fig. 6. Dimming fluorescent lamp mini-ballast circuit for the IR2530D control IC.

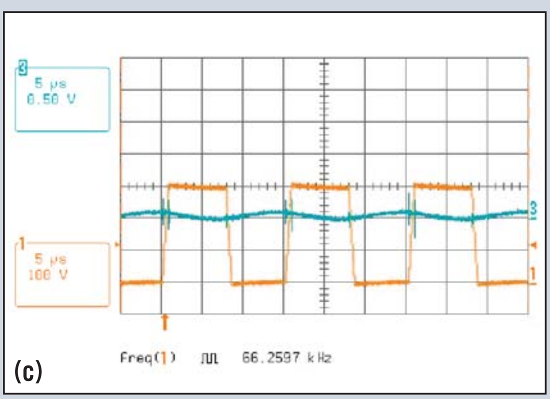
Fig. 7. Mini-ballast measured waveforms.



(a) VCO pin voltage (upper trace), lamp voltage (middle trace) and lamp current (lower trace) during normal preheat, ignition and dimming modes.



(b) Half-bridge output voltage (VS pin, lower trace) and DIM pin voltage (upper trace) during 100% dimming.



(c) Half-bridge output voltage (VS pin, lower trace) and DIM pin voltage (upper trace) during 10% dimming.

of the IC, and the charge pump (CSNUB, DCP1 and DCP2) takes over as the IC supply once the half-bridge begins to oscillate.

The resonant-tank circuit (LRES and CRES) provides the necessary transfer function for generating high voltages for lamp ignition and low-pass filtering for dimming. A dc blocking capacitor (CDC) ensures that the lamp current is always ac to prevent mercury migration, which can cause lamp-end blackening and a shortened lamp life. Secondary windings from the resonant inductor (LRES:A,B) are used to heat the lamp filaments during preheat and dimming, and also separate the lamp current from the filament current allowing for a single current-sensing resistor (RCS) to be used to sense the lamp current.

The ac lamp current measurement across RCS is coupled to the DIM pin through a feedback capacitor and resistor (CFB and RFB). A potentiometer dimming input circuit is used (PDIM, RMIN, RMAX) to convert the potentiometer resistance to the necessary dimming reference voltage for the IC that is connected to the DIM pin. Finally, resistors RLMP1 and RLMP2 are used to detect if the lamp has been removed and to automatically restart the ballast when the lamp is re-inserted. Protection against all other ballast fault conditions such as failure to strike, open filament, and low ac line/brown-out are included internally to the IRS2530D to further reduce component count and increase reliability.

The measured ballast waveforms are shown in *Fig. 7*. *Fig. 7a* shows the VCO pin voltage (upper trace), lamp voltage (middle trace) and lamp current (lower trace) during normal preheat, ignition and dimming modes. The VCO pin and lamp voltage ramp up during preheat and ignition to preheat the lamp filaments and then to ignite the lamp when the lamp ignition voltage threshold is reached. Lamp current starts to flow immediately after ignition at the start of dimming. Fig. *7b and 7c* show the half-bridge output voltage (VS pin, lower trace) together with the DIM pin voltage (upper trace) during 100% and 10% dimming conditions. The DIM pin voltage amplitude decreases (together with the lamp current) from 100% down to 10% and the operating frequency is continuously adjusted to keep the valley of the sinusoid regulated at COM.

The new IC delivers excellent dimming performance down to 10% dimming levels while minimizing component count.