By Tom Ribarich, *International Rectifier*

DUAL-MODE BUCK AND FULL-BRIDGE IC CONTROLS HID LAMPS

High-intensity discharge (HID) lamps boast high efficacy, good color rendering, and a long lifetime. Electronic ballasts are used to control HID lamps, but typically they're complex due to the extensive lamp requirements they must fulfill.

Designers, however, can take advantage of a novel dual-mode buck and full-bridge control IC to control HID lamps, which have unique electrical characteristics and require a careful and specific control solution. A fundamental understanding of these components will help the designer gain further insight to the nature of HID lamps and the circuits used to control them.

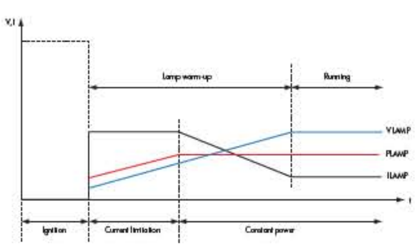
Available in the form of metal halide, mercury, or sodium vapor, HID lamps are popular because they are efficient and have a high brightness output. HID metal-halide lamps are generally five times more efficient than incandescent lamps and last 20 times longer.

HID lamps produce light using a technique similar to that used in fluorescent lamps, where a low-pressure mercury vapor produces ultraviolet light that excites a phosphor coating on the tube. In the case of HID lamps, it's a high-pressure gas, the distance between the electrodes is very short, and the light is produced directly without the need for the phosphor.

HID lamps require a high voltage for ignition (3 to 4 kV typical, greater than 20 kV if the lamp is hot), current limitation during warm-up, and constant power control during running. Tight regulation of lamp power is important for minimizing lamp-to-lamp color and brightness variations. Also, HID lamps are driven with a low-frequency ac voltage (less than 200 Hz typical) to avoid mercury migration and to prevent lamp damage due to acoustic resonance.

A typical metal halide 70-W HID lamp features a nominal wattage (W) of 70 W, a warm-up time of 1 to 2 minutes, and a cold-start ignition voltage (Vpk) of 4 kV. Before ignition, the lamp is open-circuit *(Fig. 1)*. After the lamp ignites, the lamp voltage drops quickly from the open-circuit voltage to a very low value (20 V typical) due to the low resistance of the lamp.

This drop causes the lamp current to increase to a very high value, so it should be limited to a safe maximum level. As the lamp warms up, the current decreases as the voltage and power increase. The lamp



1. During a typical HID lamp startup, the lamp is open-circuit before ignition. After the lamp ignites, voltage drops quickly but eventually reaches its nominal value.

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voltage eventually reaches its nominal value (100 V typical), and the power is regulated to the correct level.

To satisfy the lamp requirements and different operating modes, the electronic ballast topology must efficiently convert the ac mains voltage to the desired ac lamp voltage, ignite the lamp, and regulate lamp power.

HID Ballast Topology

A typical HID ballast includes electromagnetic interference (EMI) filtering to block ballast-generated noise, a bridge rectifier to convert the ac mains voltage to a full-wave rectified voltage, a boost power-factor correction (PFC) stage for PFC and a constant dc bus voltage, a step-down buck converter for controlling the lamp current, a full-bridge output stage for ac operation of the lamp, and an ignition circuit for striking the lamp *(Fig. 2)*. This is one of the standard approaches for powering HID lamps with a low-frequency ac voltage.

The boost PFC stage typically runs in critical-conduction mode, but can be controlled with a continuous-conduction mode for higher powers (greater than 200 W) when the peak boost inductor currents using critical-conduction mode become too high. During critical-conduction mode, the boost stage operates with a constant on-time and variable off-time, resulting in a free-running frequency across each half-wave of the ac line cycle.

The frequency range is typically from 200 kHz near the ac line zero-crossings to 50 kHz at the peak of the ac line. The on-time is used to regulate the dc bus to a constant level. The off-time is the time it takes for the inductor current to reach zero each switching cycle. The EMI filter then

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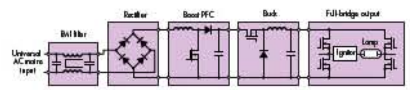

2. A typical HID ballast includes EMI filtering, a bridge rectifier, a boost PFC stage, a step-down buck converter, a full-bridge output stage, and an ignition circuit.

filters the triangular inductor current to produce a sinusoidal input current at the ac mains input for high power factor and low harmonic distortion.

The buck control circuit is the main control circuit of the ballast, as it is used to control the lamp current *(Fig. 3)*. The buck stage is needed to step-down the constant dc bus voltage from the boost stage to the lower lamp voltage at the full-bridge stage. This particular circuit can run in continuous or critical-conduction operating modes, based on the condition of the load.

The lamp output current is measured in the full-bridge stage and fed back to the buck circuit to control the buck on-time. The lamp voltage and current are multiplied together to produce a lamp power measurement, which is also fed back to control the buck on-time.

During the lamp warm-up period (after ignition) when the lamp voltage is very low and the lamp current is very high, the lamp current feedback will determine the buck on-time to limit the maximum lamp current. During lamp steady-state running, the power feedback will then determine the buck on-time to control the lamp power.

The off-time is determined by the zero-crossing of the buck inductor current during critical-conduction mode or by a maximum off-time limit during continuous-conduction mode. The continuous-conduction mode

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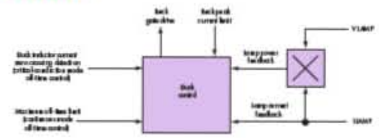

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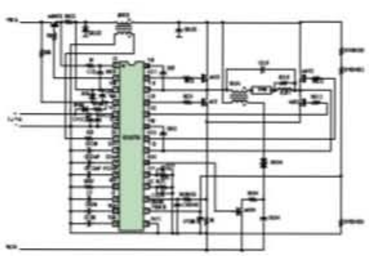

4. The International Rectifier IRS2573D can serve as the heart of a complete buck and full-bridge control circuit.

lets the buck circuit supply more current to the lamp during the warm-up without saturating the buck inductor.

The full-bridge stage is necessary to produce an ac lamp current and voltage during running. Typically, the full-bridge operates at 200 Hz with a 50% duty cycle. It also features a pulse transformer circuit for producing 4-kV pulses across the lamp necessary for ignition.

The IRS2573D from International Rectifier features control for the buck stage, the full-bridge, lamp current and voltage sensing, and feedback loops for controlling lamp current and lamp power *(Fig. 4)*. It includes an integrated high-side driver for the buck gate drive (BUCK) and high-side buck cycle-by-cycle over-current protection (CS).

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The lamp power control loop (PCOMP pin) or lamp current limitation loop (ICOMP pin) controls the buck-switch on-time. The inductor current zero-crossing detection input (ZX pin) controls the buck-switch off-time during critical-conduction mode, and the off-time timing input (TOFF pin) controls it during continuous-conduction mode.

The IC also includes a fully integrated high-side and low-side full-bridge driver. The operating frequency of the full-bridge is controlled with an external timing pin (CT pin). The IC provides lamp power control by sensing the lamp voltage and current (VSENSE and ISENSE pins) and then multiplying them together internally to generate the lamp power measurement.

The ignition control is performed using an ignition timing output (IGN pin) that turns an external ignition MOSFET (MIGN) on and off to enable the ignition circuit of the lamp (DIGN, CIGN, TIGN). The ignition timer is programmed externally (TIGN pin) to set the ignition circuit on and off times.

Finally, the IC includes a programmable fault timer (TCLK pin) for programming the allowable fault duration times before shutting the IC off safely. Such fault conditions include failure of the lamp to ignite, failure of the lamp to warm up, lamp end-of-life, and output open/short circuit. ■

TOM RIBARICH, director of the Lighting Design Center at IR, holds a BSEE from California State University, Northridge, and a master's degree in ASIC design from the University of Rapperswil, Switzerland.

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