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DESIGN TIPS

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CHOOSING THE CORRECT DROPPING RESISTOR VALUE FOR THE IR2151/IR2152/IR2155 CONTROL IC'S

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INTRODUCTION

The IR2155/51/52 are high voltage integrated circuits (IC) designed specifically for controlling electronic lamp ballasts. These devices include a front-end oscillator similar to the popular CMOS 555 timer circuit, and a high voltage half-bridge MOS gate driver.

Additional circuits control the startup of the IC and the lamp, and provide a nominal 1.2 µs cross-conduction dead-time between the high-side and low-side gate driver outputs.

Figure 1 illustrates a typical electronic lamp ballast circuit using the IR2151 Control IC as the central ballast controller. The output of the half bridge oscillates at a frequency determined by the timing components R_T and C_T (with a 50% duty cycle), and self starts when the high voltage dropping resistor R1 charges the IC supply voltage filter capacitor C1 above the chip's rising undervoltage lockout (UVLO) threshold ($UV_{CC}+$).

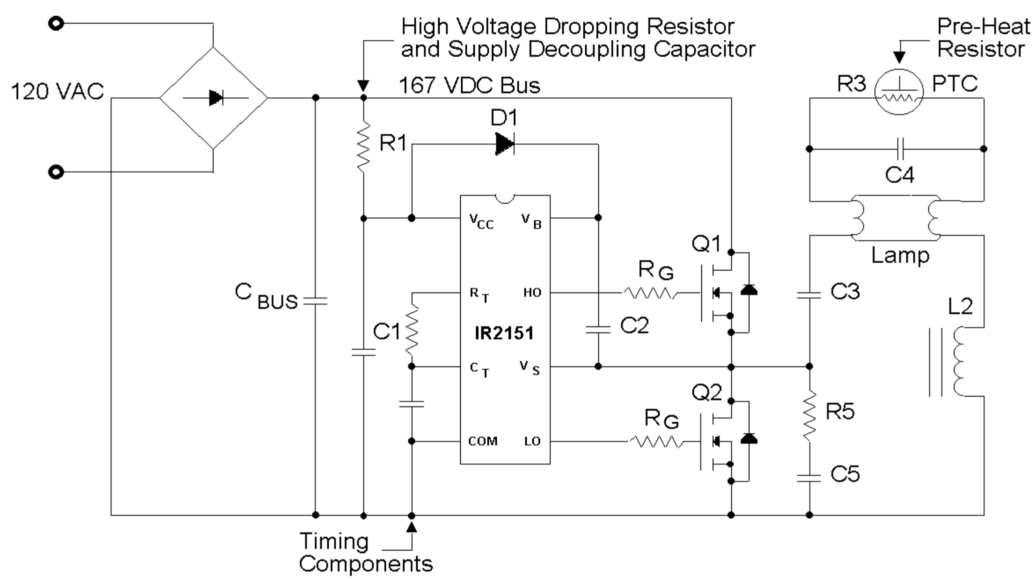

Figure 1
Electronic Fluorscent Lamp Ballast Utilizing the IR2151

TheLamp filament pre-heating is accomplished by means of the positive temperature coefficient (PTC) resistor R3, which initially has a low value. As this resistor heats up, the voltage across the start capacitor C4 rises, until the lamp has sufficient voltage across it to strike. Once the lamp has struck, its beam current is controlled by the half-bridge output frequency, the dc bus voltage, and the value of the series resonant load filter components C3 and L2.

In order to choose the proper value and rating of the high voltage dropping resistor R1 it is important to understand all the IC and surrounding component currents which contribute to the total current flowing through R1. These contributions include:

1. The quiescent current (I_{QCC}) of the IR2155 IC itself,
2. The current required to switch the gates of the power MOSFETs (dQ_G/dt),
3. The current sourced into the RT resistor by the chip V_{CC},
4. The high voltage level-shifting currents within the IC, and
5. The additional current required to properly regulate the voltage on the IC's internal supply-to-ground zener clamp diode.

The first of these considerations is the quiescent current of the IC, which is typically 400mA at room temperature. This current has a low temperature coefficient (less than -1000 ppm/°C), so the I_{QCC} drops by less than 10% as the junction temperature rises from 25°C to 125°C. In addition to its temperature coefficient, the production variation of this current needs to be considered (these two sources of variation are included in the Electrical Characteristics within the data sheet). The IC quiescent current is also relatively independent of the supply voltage, for UVCC+ < V_{CC} < V_{CLAMP}, where V_{CLAMP} is the internal supply-to-ground zener clamp voltage (typically 15.4V at room temperature).

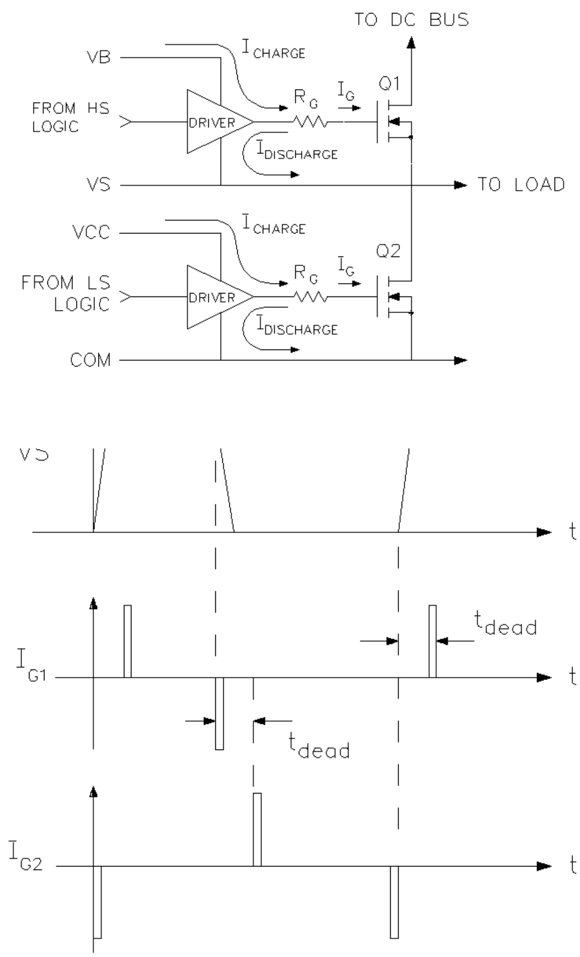

Figure 2
Power MOSFET/IGBT Gate Switching Currents

The second current contribution comes from the gate charge of the power MOSFETs (or IGBTs). If we look at one cycle of the output of the half-bridge (see Figure 2), it is evident that each power MOSFET/IGBT gate is charged and discharged once. This implies that the total current consumed by the power transistor gates which flows through the high voltage dropping resistor R1 is

$$I_G = 2Q_G(f_{OUT}) \qquad (1)$$

where f_{OUT} is the output frequency. It is interesting to note that even though current flows into the IC when the gate of a power MOSFET/IGBT is being discharged, this current does not flow through the supply lead (it is a local loop current which flows from the gate capacitance of the power transistor through the IC gate driver output stage, and back to the power transistor source), and therefore does not contribute to the total current which flows through R1.

The third component of current flows from the IC supply through the timing resistor R_T when R_T is high and C_T is charging from its 1/3 V_{CC} threshold to its 2/3 V_{CC} threshold. Since the average voltage on C_T is 1/2 V_{CC}, and since the duty cycle at R_T is 50%, this current contribution is:

$$I_{RT} = 0.25(V_{CC})/R_T \qquad (2)$$

In the same way that the power MOSFET/IGBT gate discharge current does not contribute to the total current flowing in R1, when R_T is low and C_T is being discharged, the current flowing back into the IC through the R_T terminal is local loop current, and does not contribute to the chip I_{QCC}.

The fourth component of current consists of the pulsed currents which flow in the high voltage level-shifting transistors in order to translate set (on) and reset (off) signals from the ground-referenced logic circuitry to the floating high-side driver (see Figure 3). When the logic circuitry commands the high-side driver to turn on, a low voltage drop is seen across the corresponding level-shift transistor (V_S is low). The current pulse amplitude is approximately 10 mA and the duration is typically 200 ns, and this current flows from the IC low voltage supply bypass capacitor, through the bootstrap diode, and into the V_B lead.

Conversely, when the logic circuit commands the high-side driver to turn off, a high voltage drop is seen across this level-shift transistor (V_S is approximately equal to the dc bus voltage, and the high-side power transistor is on). In this case the current pulse amplitude is approximately 20 mA, the duration is typically 200 ns, and this current flows from the floating supply bootstrap capacitor into the V_B lead.

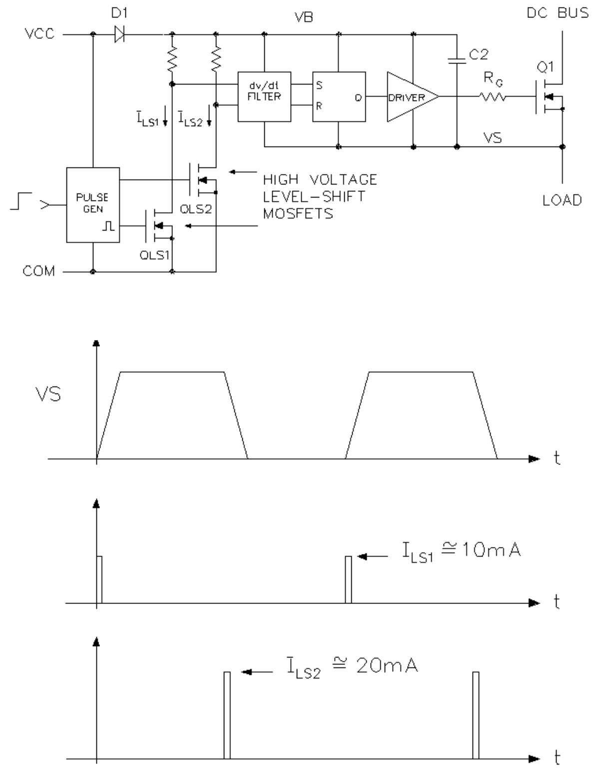

Figure 3

Level-Shifting Currents Within the IR2155

The average value of these current pulses must be supplied by the high voltage dropping resistor R1, and depends upon the operating frequency according to the following equation:

$$I_{AVE} = (10\text{ mA} + 20\text{ mA})(200\text{ ns})f_{OUT} \qquad (3)$$

It is interesting to note that as the operating frequency goes up, the duty cycle of the current pulses goes up (because the period goes down and the current pulse width is constant), and the average current value rises.

The final component of the current supplied by the high voltage dropping resistor flows into the internal 15.4V clamp zener within the IC. It is important to maintain some minimum level of current flowing in this zener, in order to avoid too low a gate voltage on the power MOSFETs/ IGBTs, and in order to avoid falsely resetting the undervoltage lockout circuit (which would prematurely halt switching at the output of the half-bridge and cause low, poorly regulated lamp luminosity). This minimum zener clamp current level need not be high (the zener diode alone will bias to 15.4V reliably at as low as 100 mA and as high as 5 mA), and really only represents some level of guardband above the sum of all of the other supply current components.

The total current which flows through the high voltage dropping resistor, then, is:

$$I_{TOT} = I_{QCC} + 2Q_G(f_{OUT}) + 0.25(V_{CC})/R_T + (10\text{ mA} + 20\text{ mA})(200\text{ ns})f_{OUT} + I_{CLAMP} \quad (4)$$

Example: Consider a 20W compact fluorescent lamp ballast which operates at 30 kHz (R_T = 24 kW, C_T = 1 nF) from a rectified 120 VAC line and which utilizes IRF624 power MOSFETs. This ballast must operate over a 0°C < T_A < 100°C ambient temperature range.

a) From the IR2155 datasheet, I_{QCCMAX} = 1.0 mA at 12V and 25°C. Since the temperature coefficient of this current is slightly negative, assume a 1.10 mA maximum value at $T_A = T_j$ = 0°C.

b) From the IRF624 datasheet, Q_{GMAX} = 14 nC, so the 2nd term in Eq. (4) is 0.840 mA.

c) From the IR2155 datasheet, V_{GMAX} = 16.8V, so the 3rd term in Eq. (4) is 0.175 mA

d) At a switching frequency of 30 kHz, the current due to the internal level-shifting current pulses is 0.180 mA.

e) Finally, a value of I_{CLAMP} = 500 mA is chosen because it represents:

1) a sufficient guardband on the sum of the other current components in Eq. (4), and

2) sufficient current to reliably bias the internal 15.4V supply-to-ground zener clamp diode.

The total current which must flow through the high voltage dropping resistor R1 is therefore:

$$I_{TOT} = 1.10\text{ mA} + 0.840\text{ mA} + 0.175\text{ mA} + 0.180\text{ mA} + 0.500\text{ mA} = 2.795\text{ mA}.$$

With a line voltage of 120 VAC, and therefore a rectified DC bus of 167V, the maximum value of R1 required to satisfy all of the IC and its surrounding component current demands is:

$$R1 = (167V - 15.4V)/2.795\text{ mA} = 54\text{ kW}.$$

With a continuous operating power dissipation of 0.516W [$(V_{BUS})^2$/R1], a 1W rating for R1 is suggested (this power rating is typically specified at T = 70°C, and derated with a thermal resistance of approximately 75°C/W for 70°C < $T_{RESISTOR}$ < 150°C).

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