International Rectifier

APPLICATION NOTE

Application Note AN-1147

Filaments Detection Circuit

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INTRODUCTION

One of the requirements of electronic ballasts is the filament failure / lamp removal protection. When either filaments fails or the lamp is removed, the ballast has to shut down to prevent a non-desirable condition, such as non-ZVS or inductor saturation, from occurring extensively. These conditions may damage some components in the ballast and may cause safety issues.

An electronic ballast designed using IR2520D has the filament failure / lamp removal protection; however, it does not have an auto-restart feature where the lamp is automatically restarted after the lamp exchange. There are other ICs in the market that come with an auto-restart feature, but they are limited to lower filament failure only, and for some cases, this is not adequate. This Application Note suggests a circuit to detect and auto-restart either filament failures. The proposed circuit is designed around the IR2520D to show that both, upper and lower, filaments failure can be successfully detected, and the lamp is auto-restarted.

First, this note will describe in detail the filament failure / lamp removal protection in the IR2520D electronic ballast. Next, it will describe how some ICs in the

market utilize auto-restart feature for lower filament only, and why it is not adequate in some cases. Finally, the proposed filament detections with auto-restart will be described in full detail. An additional section on how to detect all filaments in the dual lamp series configuration will be given at the end.

ELECTRONIC BALLAST USING IR2520D

Below is the typical application schematic of IR2520D:

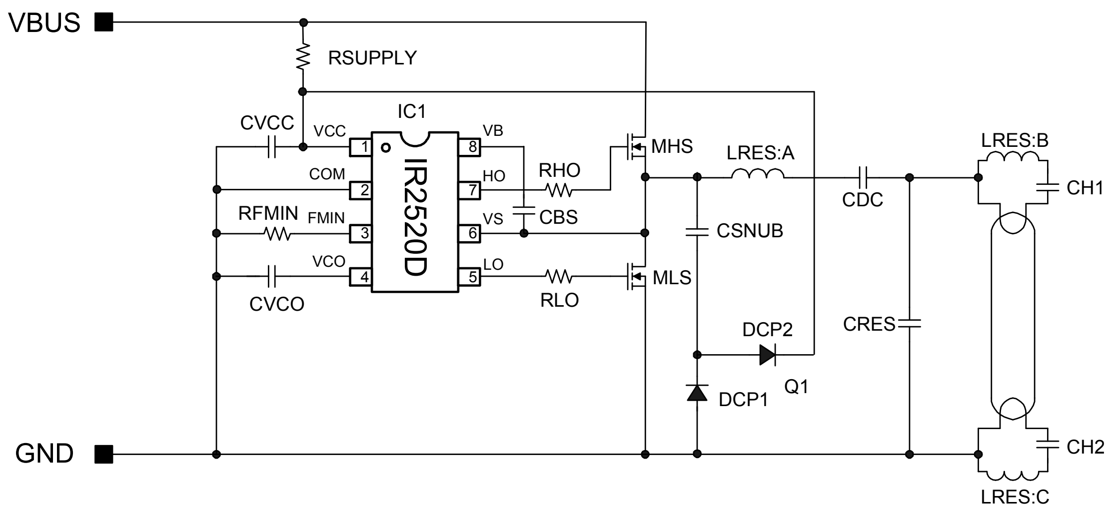

Figure 1: ***Typical Application Schematic for IR2520D ballast***

The schematic does not include the EMI filter and the rectifier stage since they are not important in the discussion about the protection. The supply voltage VCC for the IR2520D is mainly derived from the current supplied from the VBUS through the resistor RSUPPLY. The charge pump, containing CSNUB, DCP1 and DCP2, provides auxiliary supply to VCC.

The open filament protection relies on the non-ZVS circuit of the IR2520D, enabled in the RUN mode when pin VCO reaches 4.8V (See State Diagram, page 3). When one of the filaments failed, hard-switching will occur at the half-bridge and the non-ZVS circuit inside the IR2520D will detect this condition, increase the frequency each cycle and go into Fault Mode when VCO decreases below 0.82V.

The IR2520D, however, does not have an auto-restart feature that will allow the lamp to restart automatically after the lamp exchange. After VCO decreases below 0.82V, the IC is latched in the Fault mode since VCC is still kept above VCCUV- by the current supplied from RSUPPLY. In order to restart the lamp, VCC must be recycled below and back above the UVLO threshold by turning off the power to the ballast and turning it back on.

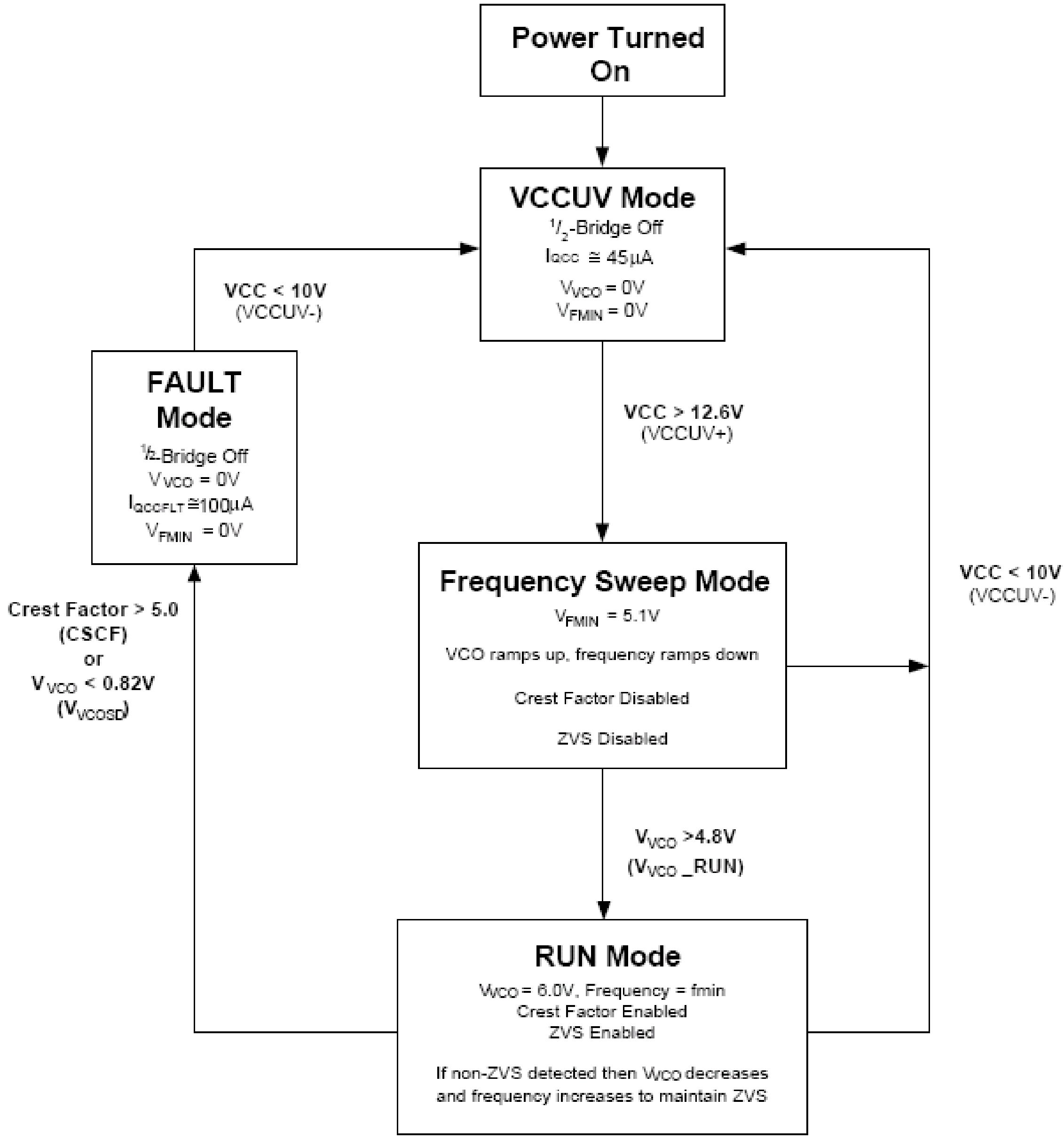

Figure 2: ***IR2520D State Diagram***

BALLASTS WITH AUTO-RESTART FEATURE

There exist electronic ballast ICs in the market that have the auto-restart feature. These ICs use the lower filament of the lamp to detect lamp removal. The lower filament, when intact, will pull down one pin of the IC. When the filament fails or the lamp is removed, this pin will be pulled-up by a resistor, signaling the IC to shut down and go into the UVLO mode.

In some cases, however, detecting through lower filament only is not adequate to guarantee lamp restart. For example, when the lamp exchange takes place, it is possible to insert one end of the lamp first into the fixture. Without knowing which end has an auto-restart feature, it is possible to insert the lower filament first. When the lower filament is inserted, the IC will turn-on and the half bridge will start to oscillate. However, since the upper filament has not been inserted, the IC will detect this open filament condition and go into the Fault mode. After the upper filament is inserted, the IC will still be latched in the Fault mode, and the lamp will not restart.

PROPOSED BOTH FILAMENTS DETECTION CIRCUIT WITH AUTO-RESTART

An additional circuit that detects either filaments failure and allows auto-restart is shown below:

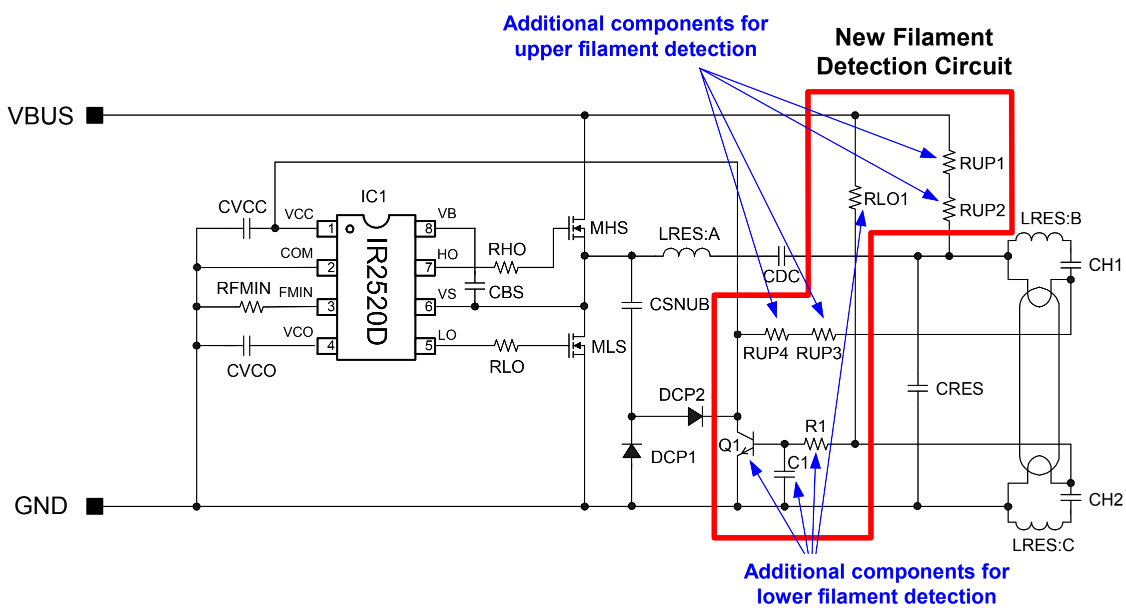

Figure 3: ***New Filaments Detection Circuit***

The circuit uses eight additional components (RUP1, RUP2, RUP3, RUP4, RLO1, R1, C1 and Q1) and detects each filament failure separately. The following sections will explain how each detection circuit works and how to calculate the additional component values.

Upper Filament Detection Circuit

The upper filament detection circuit is shown below:

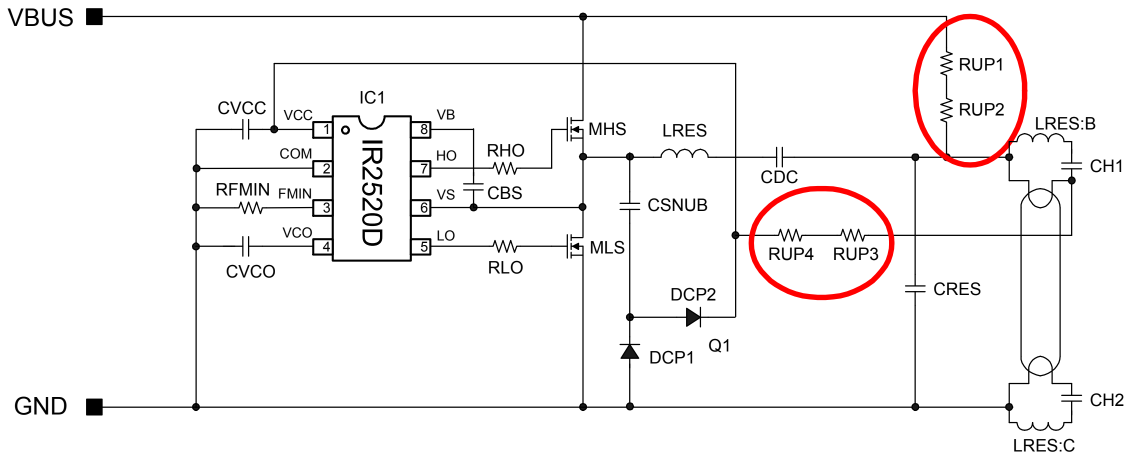

Figure 4: ***Upper Filament Detection Circuit***

The upper filament detection circuit replaces RSUPPLY with RUP1, RUP2, RUP3 and RUP4 to supply current to CVCC. When the lamp is removed or the upper filament fails, hard switching will occur at the half-bridge and the IR2520D will enter the Fault mode as explained above. In the Fault mode, the half-bridge is off and therefore, the charge pump circuit stops supplying current to VCC. There is no current flowing from VBUS to VCC to maintain charges at CVCC since the supply current path through RUP1, RUP2, RUP3 and RUP4 is broken. The voltage at VCC pin will drop as the IR2520D keeps drawing micro-power current IQCCFLT (100µA) from CVCC in the Fault mode. After VCC drop below VCCUV- (10V), the IR2520D enters VCCUV mode (See State Diagram, page 3).

When the filament is back intact, the current path from the VBUS voltage to the VCC pin is restored, and the VBUS will recharge CVCC through RUP1, RUP2, RUP3 and RUP4. After the VCC reaches VCCUV+ (12.6V), the IR2520D will enter Frequency Sweep Mode and restart the lamp.

Figure 5 shows the VCC voltage, the VS voltage and the voltage across the lamp when the upper filament of the lamp is removed, and then reinserted. When the upper filament is removed, VCC discharge, half bridge is off and the ballast shut down. When the upper filament is back intact, the IR2520D goes back to Frequency Sweep Mode, and the half bridge starts to oscillate again.

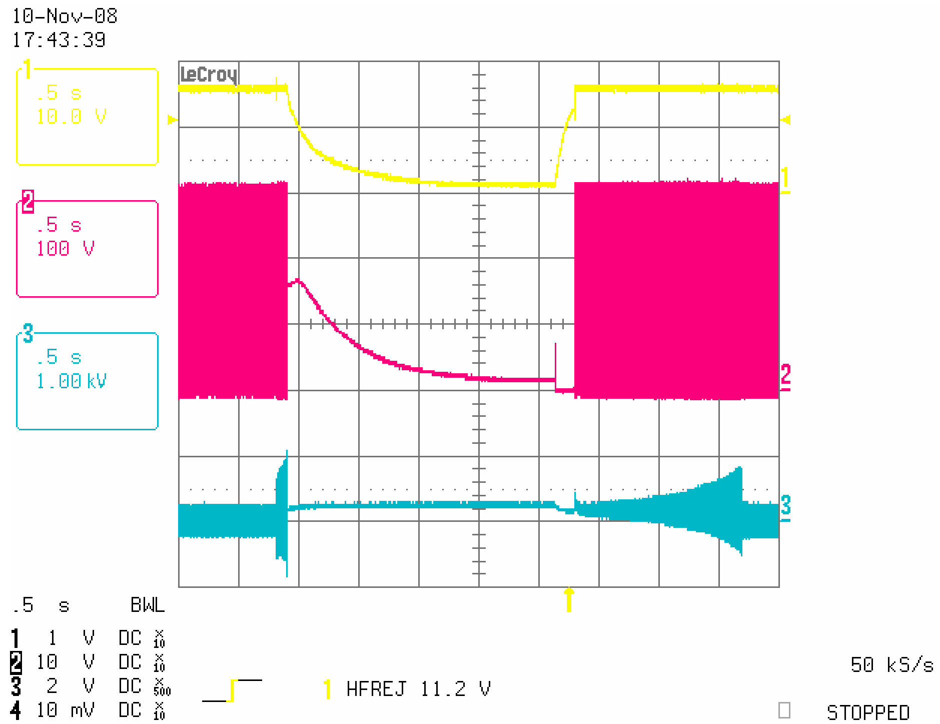

Figure 5: ***Upper Filament Removed and Reinserted: CH1 is VCC pin voltage, CH2 is VS voltage, CH3 is the voltage across the lamp***

Figure 6 shows the VCC and the VS voltage in close-up when the lamp restarts. After the VCC reaches the VCCUV+ (12.6V), the VCC voltage starts to decrease as the LO-pin is switching and the high-side supply CBS is charging. After the VBS reaches VBSUV+, the HO-pin begins to switch and so does the VS-pin.

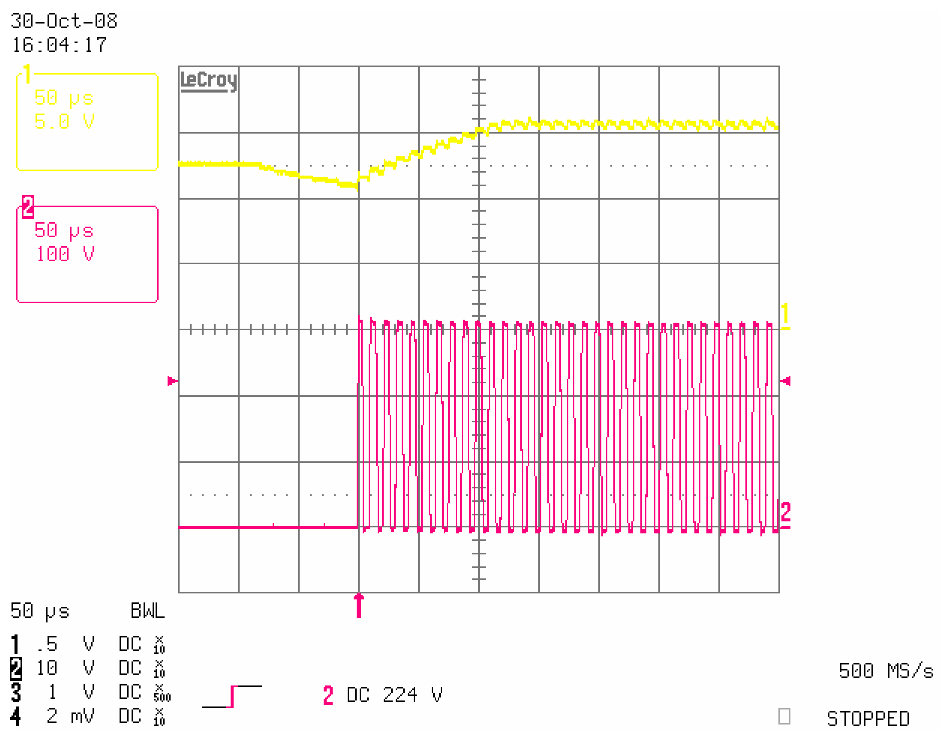

Figure 6: ***Upper Filament Reinserted: CH1 is VCC pin voltage, CH2 is VS voltage***

Lower Filament Detection Circuit

The lower filament detection circuit is shown below:

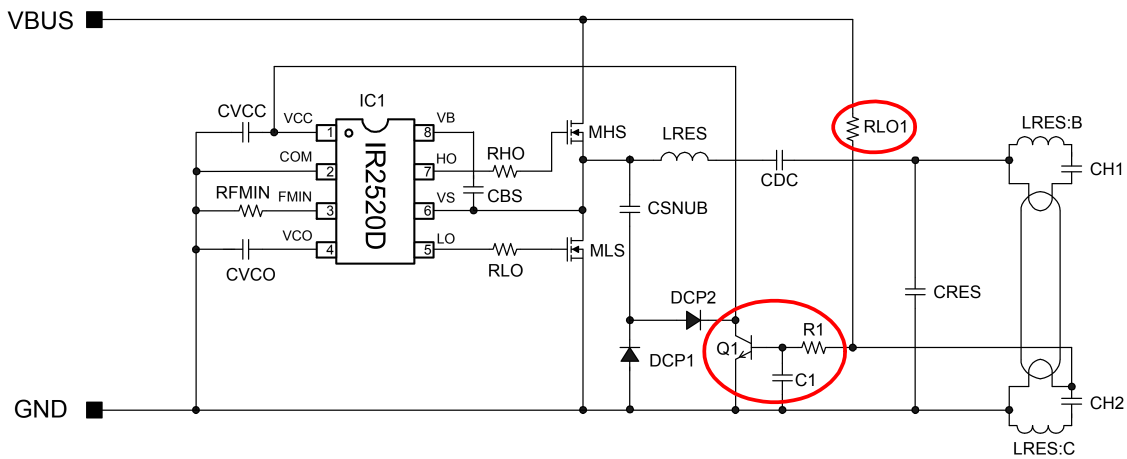

Figure 7: ***Lower Filament Detection Circuit***

The lower filament detection circuit uses transistor Q1 to detect filament failure. When the lower filament of the lamp is intact, transistor Q1 is off since the base terminal of Q1 is pulled down by the filament. R1 and C1 act as a filter to noise that may occur at the filament of the lamp.

When the lower filament fails, resistor RLO1 pulls the base of Q1 high and Q1 will turn-on to draw current from CVCC. Once VCC drops below VCCUV- (See State Diagram, page 3), the IR2520D enters the VCCUV mode. The half-bridge is off, and VS pin is pulled to ground.

When the lower filament is back intact, the base terminal of Q1 will be pulled low by the filament, and the CVCC will be recharged by VBUS through supply resistors RUP1, RUP2, RUP3 and RUP4, assuming the upper filament is intact. After VCC reaches VCCUV+ (12.6V), the IR2520D will enter the Frequency Sweep Mode and restart the lamp.

Figure 8 shows the VCC voltage, the VS voltage and the voltage across the lamp when the lower filament of the lamp is removed, and then reinserted. When the lower filament is removed, VCC discharge, half bridge is off and the ballast shut down. When the lower filament is back intact, the IR2520D goes back to Frequency Sweep Mode, and the half bridge starts to oscillate again.

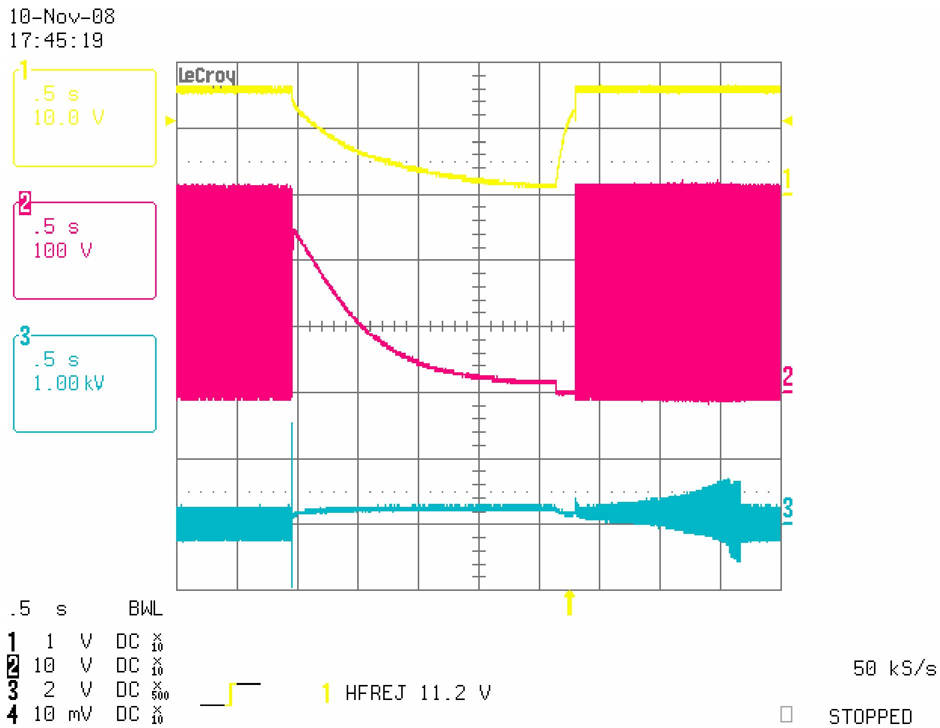

Figure 8: ***Lower Filament Removed and Reinserted: CH1 is VCC pin voltage, CH2 is VS voltage, CH3 is the voltage across the lamp***

Figure 9 shows the VCC and the VS voltage in close-up when the lamp restarts. After the VCC reaches the VCCUV+ (12.6V), the VCC voltage starts to decrease as the LO-pin is switching and the high-side supply CBS is charging. After the VBS reaches VBSUV+, the HO-pin begins to switch and so does the VS-pin.

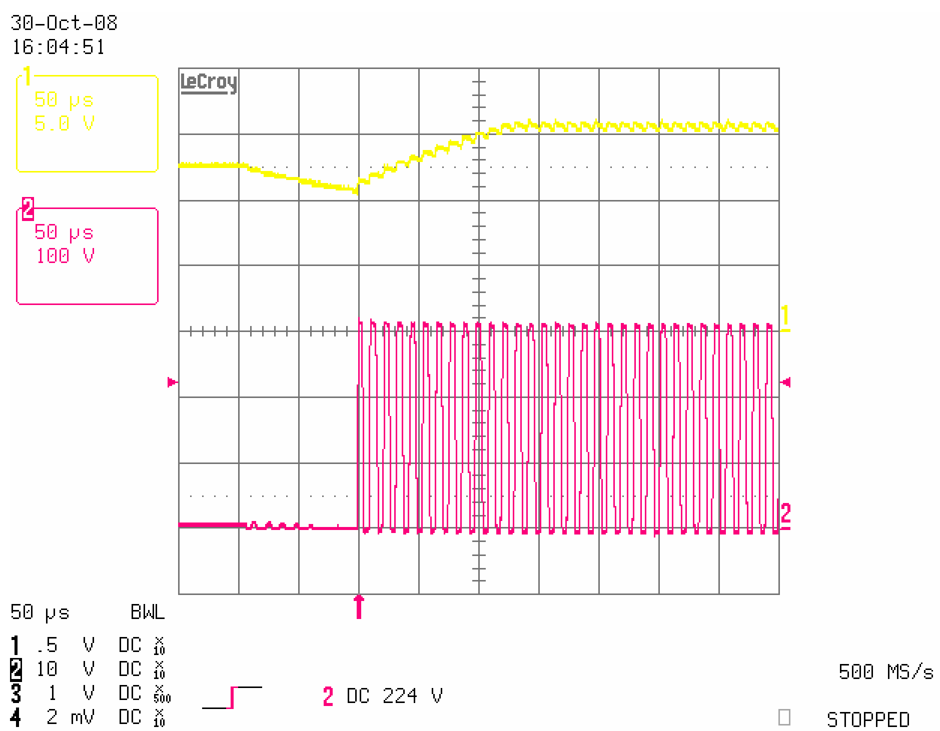

Figure 9: ***Lower Filament Reinserted: CH1 is VCC pin voltage, CH2 is VS voltage***

Additional Components' Value

Please consult the datasheet of IR2520D (http://www.irf.com/product-info/datasheets/data/ir2520d.pdf) for parameter's value used in this section.

1) RUP1, RUP2, RUP3 and RUP4 will determine the turn-on voltage (VAC_{ON}) of the ballast, and can be calculated using:

$$RUP1 + RUP2 + RUP3 + RUP4 = \frac{\sqrt{2} \times VAC_{ON} - VCCUV^{+}}{100\mu A^{*}}$$

* IQCCUV ≅ 100µA at VCC slightly lower than VCCUV+ (before IR2520D turn on at VCC = VCCUV+).

RUP1, RUP2, RUP3 and RUP4 have to be rated at 750V and 3W to be able to withstand high-voltage that occurs during normal ignition and during failure to strike condition.

2) During the Run mode, the IR2520D draws ICCLF (2mA) current from VCC. When the lower filament fails, Q1 has to draw at least this amount of current from VCC to drive the IR2520D into the UVLO mode.

$$I_{C,Q1} \geq ICCLF$$

The base current of Q1 can be determined using:

$$I_{B,Q1} = \frac{I_{C,Q1}}{(I_C / I_B)_{sat}}$$

RLO can then be calculated using:

$$RLO = \frac{VBUS - V_{BE(sat)}}{I_{B,Q1}}$$

$(I_C / I_B)_{sat}$ is the DC current gain at saturation and $V_{BE(sat)}$ is the base-emitter saturation voltage of Q1.

3) For our evaluation circuit, we use the NPN transistor P2N2222A from On Semiconductor for Q1 transistor.

4) R1 and C1 should be selected to adequately filter high frequency switching noise

Using the above formula, we arrived at the following values for the additional components:

Item #	Reference	Value	Filament
1	RUP1	470 kΩ	Upper
2	RUP2	470 kΩ	Upper
3	RUP3	470 kΩ	Upper
4	RUP4	470 kΩ	Upper
5	RLO	1 MΩ	Lower
6	R1	100 kΩ	Lower
7	C1	100 nF	Lower
8	Q1	P2N2222A	Lower

Table 1: ***Components Value for Filaments Detection Circuit***

FILAMENTS DETECTION CIRCUIT FOR DUAL LAMP SERIES CONFIGURATION

There are four filaments in the dual lamp series configuration: the upper filament, the two middle filaments, and the lower filament. The detection circuit for these filaments is shown below:

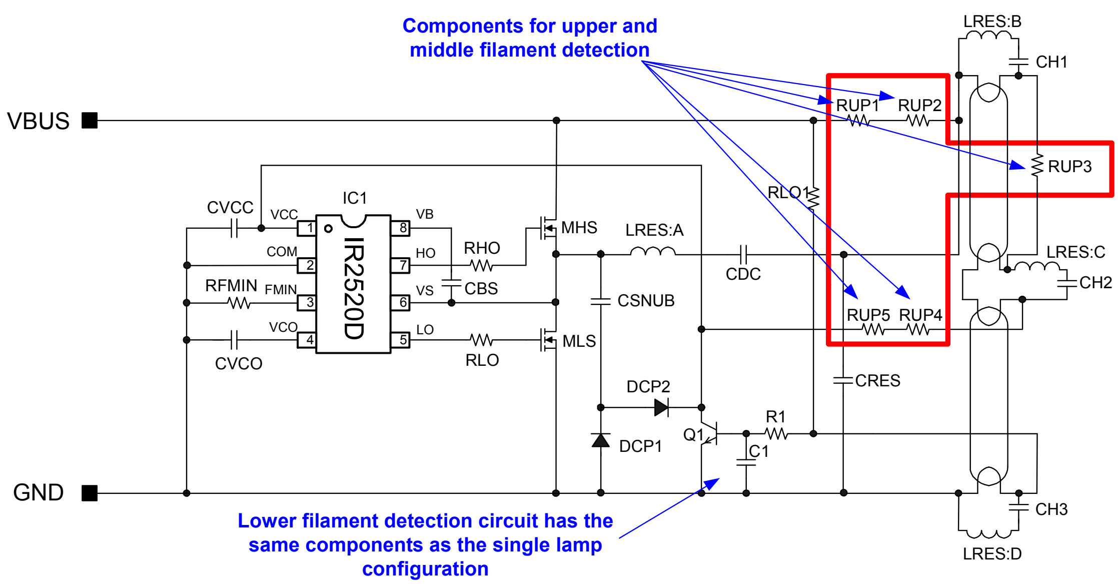

Figure 10: ***Filaments Detection Circuit for Dual Lamp Series Configuration***

The lower filament detection circuit in the dual lamp series configuration is the same as the one in the single lamp configuration. The upper and the middle filaments detection circuit in the dual lamp series configuration operates the same way as the upper filament detection circuit in the single lamp configuration.

In the dual lamp series configuration, resistors RUP1, RUP2, RUP3, RUP4 and RUP5 are used to supply startup current to CVCC. When either lamp is removed, or the upper filament or either middle filament fails, hard switching will occur at the half-bridge and the IR2520D will enter the Fault mode as explained above. In the Fault mode, the half-bridge is off and therefore, the charge pump circuit stops supplying current to VCC. There is no current flowing from VBUS to VCC to maintain charges at CVCC since the supply current path through RUP1, RUP2, RUP3, RUP4 and RUP5 is broken. The voltage at VCC pin will drop as the IR2520D keeps drawing micro-power current IQCCFLT (100µA) from CVCC in the Fault mode. After VCC drop below VCCUV- (10V), the IR2520D enters VCCUV mode (See State Diagram, page 3).

When the filament is back intact, the current path from the VBUS voltage to the VCC pin is restored, and the VBUS will recharge CVCC through RUP1, RUP2, RUP3, RUP4 and RUP5. After the VCC reaches VCCUV+ (12.6V), the IR2520D will enter Frequency Sweep Mode and restart the lamp.

RUP1, RUP2, RUP3, RUP4 and RUP5 will determine the turn-on voltage (VAC_{ON}) of the ballast, and can be calculated using:

$$RUP1 + RUP2 + RUP3 + RUP4 + RUP5 = \frac{\sqrt{2} \times VAC_{ON} - VCCUV^{+}}{100\mu A}$$

RUP1, RUP2, RUP3, RUP4 and RUP5 have to be rated at 750V and 3W to be able to withstand high-voltage that occurs during normal ignition and during failure to strike condition.

Figure 11 shows the VCC voltage, the VS voltage and the voltage across the lamp when one of the middle filaments of the lamp is removed, and then reinserted. When one of the middle filaments is removed, VCC discharge, half bridge is off and the ballast shut down. When the middle filament is back intact, the IR2520D goes back to Frequency Sweep Mode, and the half bridge starts to oscillate again.

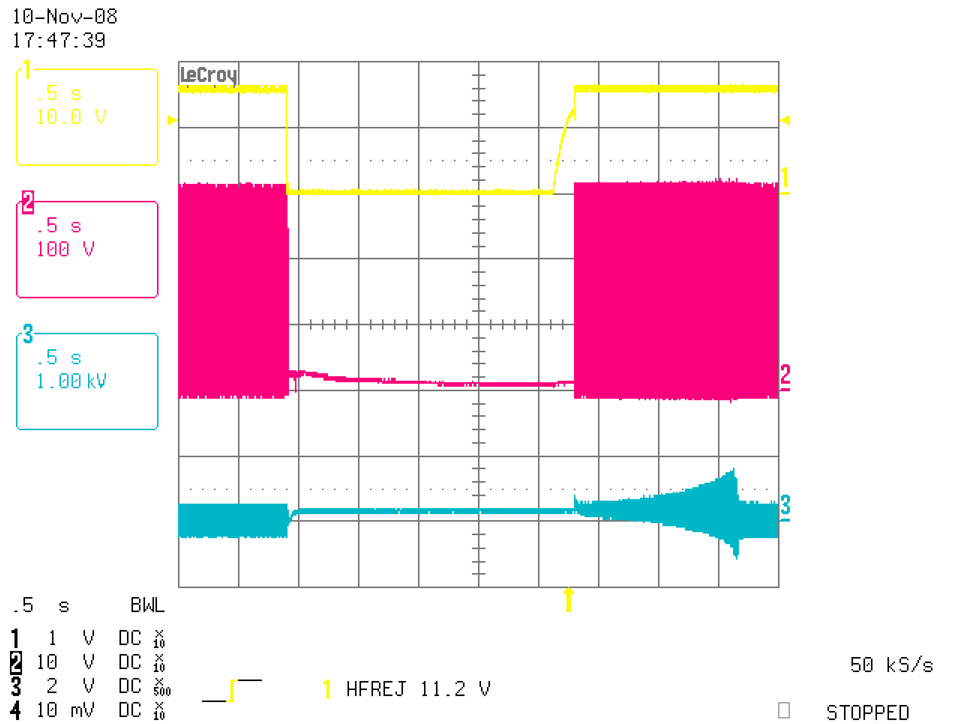

Figure 11: ***Middle Filament Removed and Reinserted: CH1 is VCC pin voltage, CH2 is VS voltage, CH3 is the voltage across the lamp***

Figure 12 shows the VCC and the VS voltage in close-up when the lamp restarts. After the VCC reaches the VCCUV+ (12.6V), the VCC voltage starts to decrease as the LO-pin is switching and the high-side supply CBS is charging. After the VBS reaches VBSUV+, the HO-pin begins switching and so does the VS-pin.

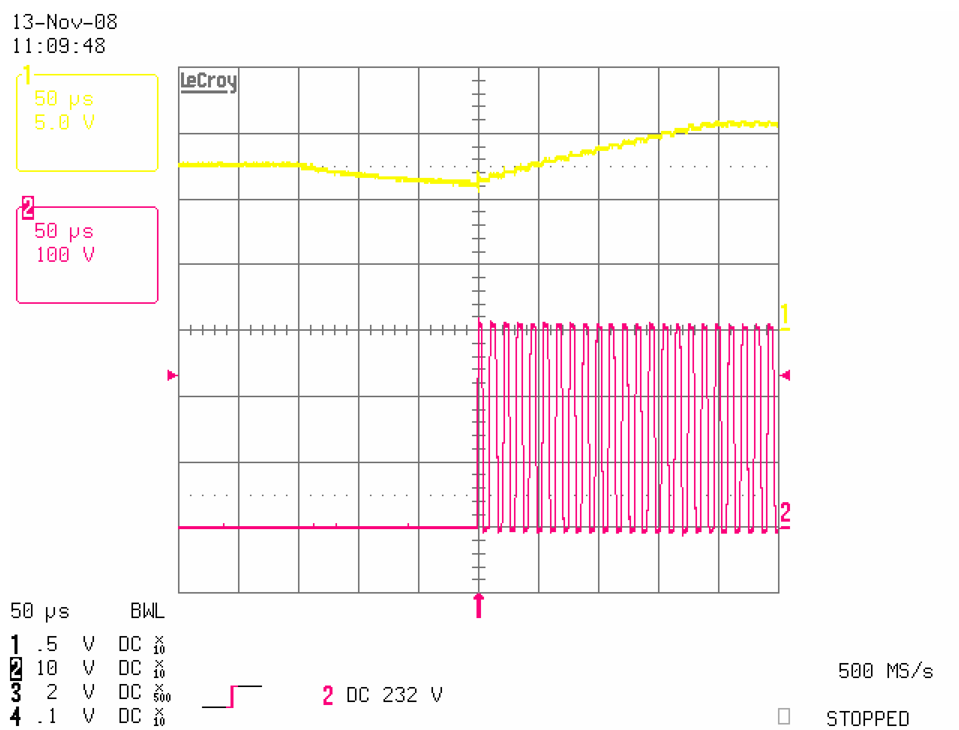

Figure 12: ***Middle Filament Reinserted: CH1 is VCC pin voltage, CH2 is VS voltage***

CONCLUSIONS

One of the requirements of the electronic ballast is the filament failure / lamp removal protection. An electronic ballast designed using IR2520D has the filament failure / lamp removal protection; however, it does not have an auto-restart feature where the lamp is automatically restarted after the lamp exchange. Other ICs in the market are able to detect either filament failure, but only auto-restart when the lower filament is back intact. In this Application Note, a circuit to detect either filament failures and to auto-restart after either filament back intact is proposed and is successfully evaluated. An additional section that describes how to detect all filaments in the dual lamp series configuration is also given.