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COURSE NOTES

Fixing a Flyback Supply Where the Output Fails to Reach Regulation

Introduction

These course notes are to be read in association with the PI University video course, *Fixing a Flyback Supply where the Output Fails to Reach Regulation*. In this course, you will learn how to diagnose why your Power Integrations design may consistently enter auto-restart and, as a result, fail to achieve regulation.

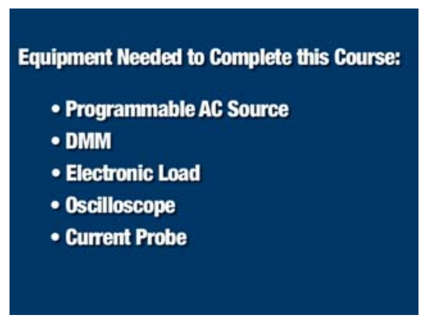
Before starting this course, you should have built a flyback power supply and identified through the bring-up procedure that the output is not reaching regulation and/or is hiccupping (i.e., entering auto-restart protection mode). This could be happening immediately upon startup, or when the output load is applied.

Auto-restart is a function of Power Integrations' ICs that protects the circuit under fault conditions or when the maximum loading for a circuit is exceeded.

Equipment Required

To complete the testing in this course, you will need the following equipment:

- A Programmable AC source or a Variac
- Several digital multimeters
- An electronic load
- An oscilloscope with one high-voltage probe and a current probe



Equipment required

Common Problems

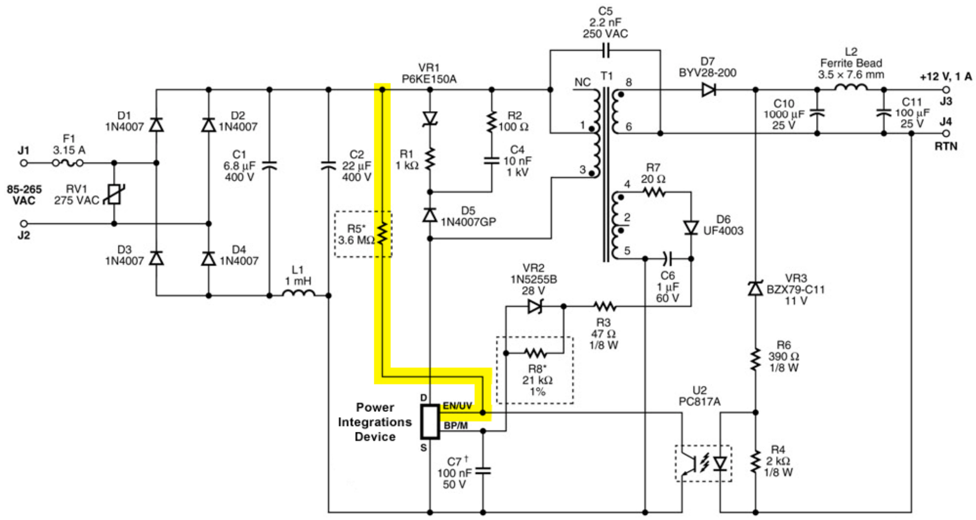
Common causes for a power supply to fail to start up or to enter auto-restart are:

1. A poor layout around the undervoltage pin
2. The AC source is undersized
3. Load characteristics
4. The output diode is reversed
5. There is a failed or incorrectly designed clamp circuit
6. The feedback path is open
7. Incorrect feedback component values were used
8. An output and/or bias winding diode has a long reverse recovery time
9. There is excessive capacitance on the drain node
10. The transformer bias winding is disconnected (specific to designs based on the *TOPSwitch* device family)
11. The polarity of a transformer winding has been reversed

Each of these potential causes will be examined in turn.

1. A poor layout around the undervoltage pin

Some Power Integrations devices include an undervoltage lockout (UVLO) feature which prevents output glitches upon startup. This operates by sensing the voltage on the DC bus and delaying startup until the input reaches a user-defined voltage. The Power Integrations device may fail to start properly if there is noise on the undervoltage pin or the value of undervoltage resistor is too large.

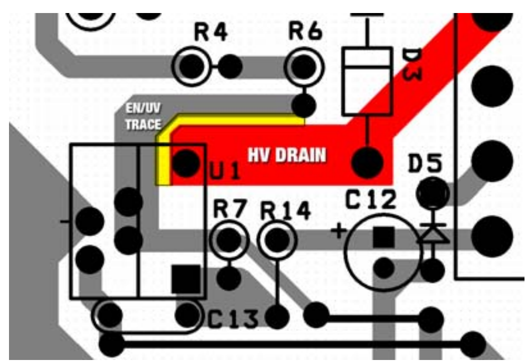


Undervoltage lockout resistor

First, make sure that the value of undervoltage resistor installed on the board matches with *PI Expert* . If it does, or if your design does not include an undervoltage resistor, then verify if leakage current into the undervoltage pin is causing the problem by connecting a 100 kΩ resistor between the bypass pin and the undervoltage pin on the underside of the board. Then test again. If this solves the problem, then verify that your board is clean of flux and that no high-voltage traces are in close vicinity to the undervoltage trace.

For example, in the layout illustrated to the right, the EN/UV trace is extremely close to the high-voltage drain trace. This allows noise coupling and leakage currents between the drain trace and the EN/UV pin. To solve this problem, you will need to re-layout your board, or alternatively, keep the 100 kΩ resistor in your design.

For layout guidelines, see the applicable Power Integrations device datasheet.



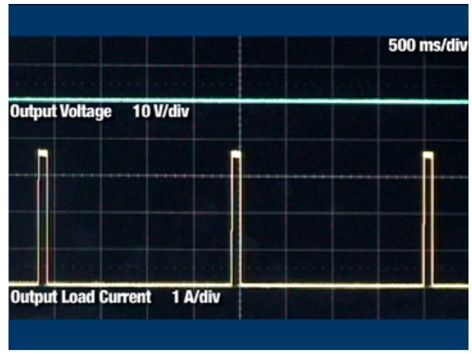
EN/UV trace extremely close to the high voltage drain trace

2. The AC source is undersized

Check that the AC source is rated to handle the expected input power of your supply. If it is not, the AC source will limit the power provided to the converter and prevent proper start-up and regulation. As a rule, your AC source Volt-Amp rating should be greater than twice the maximum output power of your supply. An undersized AC source is typically an issue with high-power designs.

3. Load characteristics

Next, examine the load on the power supply. Any power supply should be designed to deliver at least the maximum output power required by the load. If at startup the output voltage fails to reach regulation within a specified auto-restart on-time, the Power Integrations device will enter auto-restart protection mode. The auto-restart function is designed to prevent components from being damaged by limiting the average power delivered by the supply in a fault condition. The specific auto-restart on-time can be found in the relevant Power Integrations device datasheet.



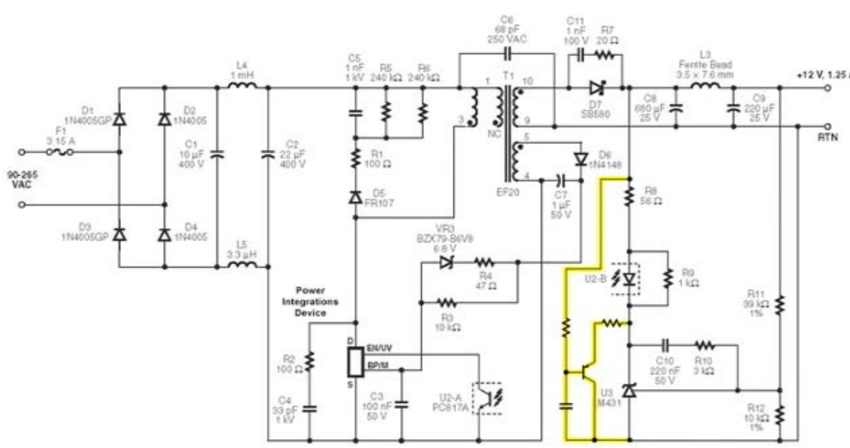
Output voltage and current indicative of auto-restart

Non-linear loads that can cause an auto-restart condition at start-up include motors which draw large currents until they reach full speed, or filament lamps. Filament lamps have an effective resistance at startup of close to zero ohms which then increases gradually as they heat up. In both cases, the output voltage may not reach regulation within the auto-restart on time.

For example, when 10 W halogen lamp is connected to a 12 V, 1 A power supply (e.g., Reference Design RD-91) the power supply won't start-up and the lamp will flicker while the supply is in auto-restart mode.

To verify if the load is causing the problem, first replace it with an electronic load, set to draw the maximum current specified by your design. If the power supply correctly starts with the electronic load, then the issue is that the actual load is drawing a higher power than the supply is designed to deliver. Characterize your load again to confirm that your power supply specification is correct.

If your load is non-linear at startup, then adding a soft-finish circuit as shown below can give the output voltage sufficient time to reach regulation.



A soft finish circuit can help a supply start-up with a non-linear load

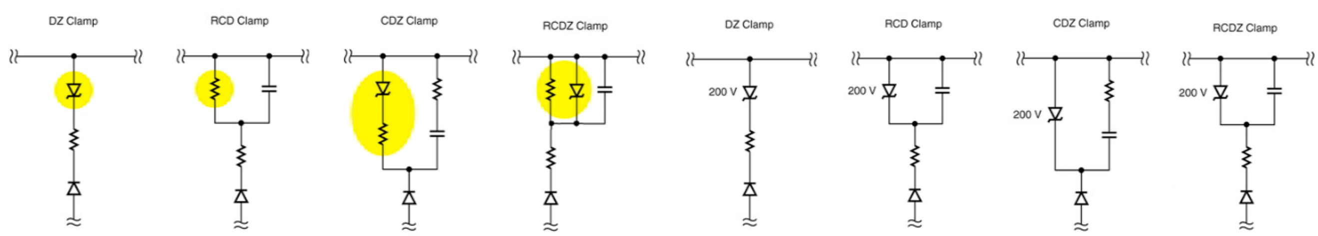
4. The output diode is reversed

If your power supply still fails to startup with an electronic load, then the next action is to check if the output diode has been inserted backwards. If it has been reversed, replace the diode with a new one and retest your board.

5. There is a failed or incorrectly designed clamp circuit

If the output diode is not causing the problem, next check that the diodes in the clamp circuit are in the correct orientation. If the diodes are not correctly inserted, replace them with new components installed properly.

To identify if the hiccupping condition is caused by an improperly designed clamp circuit, replace the dissipative portion of your clamp, highlighted in the diagram below, with a 200 V Zener diode.

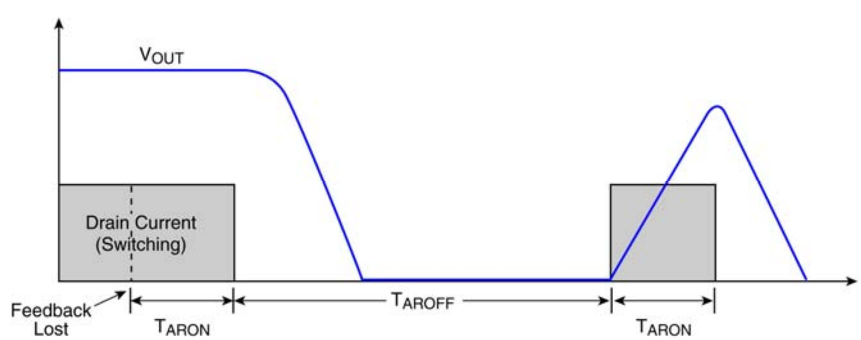


Dissipative elements *Zener diode replacement*

Now retest your board. If the hiccupping output problem is resolved, then the issue is being caused by the clamp.

6. The feedback path is open

The next area of your board to check is the feedback circuit. If, for any reason, the Power Integrations device does not receive feedback for longer than the auto-restart on-time, the device will enter auto-restart protection mode. This will always happen when the feedback loop is open.

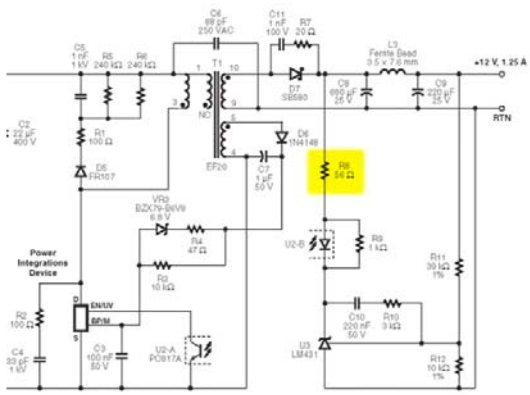


Loss of feedback triggers auto-restart mode

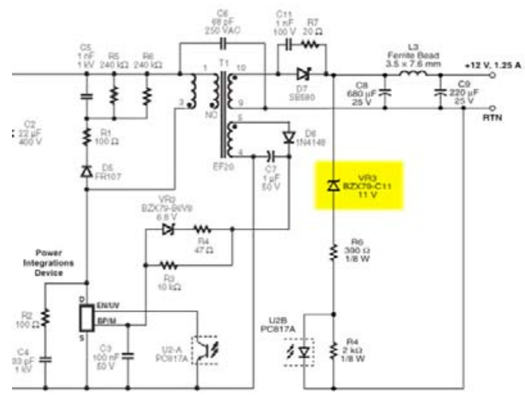
First, check that there is no debris on the back of the board that may be shorting out a feedback component, such as the optocoupler LED. Also, check that there are no cold solder joints in your feedback circuit by touching up each connection with a little extra solder. Cold solder joints often appear as normal connections, but provide intermittent connectivity at best.

7. Incorrect feedback component values were used

If your design uses a secondary side feedback circuit, then verify that the feedback components installed are as specified by *PI Expert*. Feeding back too little current to the Power Integrations device will cause the device to enter auto-restart mode. This can happen when the opto series resistor value is too high or, in Zener-based feedback circuits, if the Zener voltage is too high.



Feedback resistor value too high



Feedback Zener voltage too high

Finally, if using an LM-431 reference IC, a disconnected upper sense resistor can also cause the device to enter auto-restart.

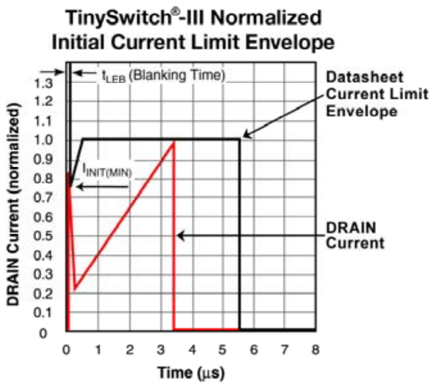
If your design uses a primary side feedback circuit instead of a secondary side circuit, then verify that the values of the resistors in the voltage divider match those specified by *PI Expert*.

8. An output and/or bias winding diode has a long reverse recovery time

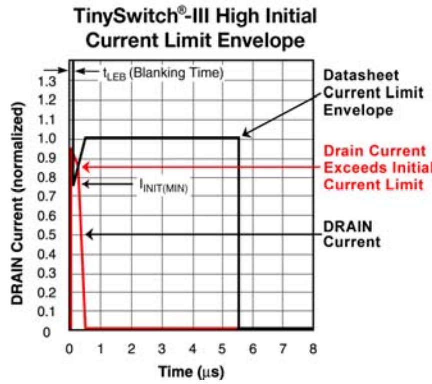
Next, verify that all output diodes are either ultrafast or Schottky types.

Power Integrations devices implement a leading edge blanking feature which disables the current limit for a fixed period immediately following MOSFET turn on. This prevents the initial current spike from triggering the current limit and prematurely terminating the switching cycle. However, if the turn-on spike is larger than normal, it can still trigger the initial current limit of the device and cause it to limit power transfer to the output.

Using slow recovery diodes on the output windings will increase reverse recovery current. This current flows backwards into the secondary winding, is transformed through the turns ratio back to the primary, and increases the initial turn-on spike seen by the MOSFET. The turn on spike may be sufficient to trigger initial current limit, decreasing power delivery and preventing the supply from reaching regulation.



Leading edge blanking



Large turn-on spike triggers initial current limit

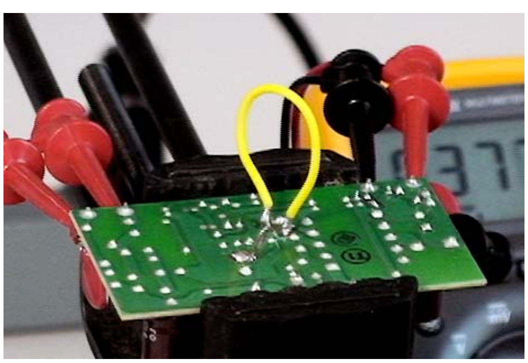
Visually inspect all output diodes to ensure that a fast or standard recovery diode has not been used. If an improper type has been fitted, replace it with an ultrafast recovery or Schottky diode, and retest.

A bias winding diode with a long reverse recovery time can cause a similar problem, though this is less common when a series resistor is used in the circuit. If a slow recovery diode is used in your design, try replacing it with a 1N4937 rectifier. If this solves the problem, then refer to *PI Expert* to verify that the bias winding diode you have used matches the specifications given. If the diode does not match the specification, then replace your bias winding diode with the one recommended by *PI Expert*.

9. There is excessive capacitance on the drain node

Excessive capacitance on the drain node can also cause large turn-on current spikes. This capacitance can come from transformer winding capacitance, large RC snubbers across the device MOSFET, or the transformer primary winding. To verify if capacitance is causing a problem, you will need to monitor the drain switching voltage and current.

First, turn off and disconnect the AC input and discharge the input capacitor. Break the MOSFET drain trace on your board and insert a wire current loop to monitor drain current. Be sure to make this break between the Drain pin of the Power Integrations device and any clamp components in your design. Measuring from other points along this trace will not allow you to properly diagnose all issues with your design.

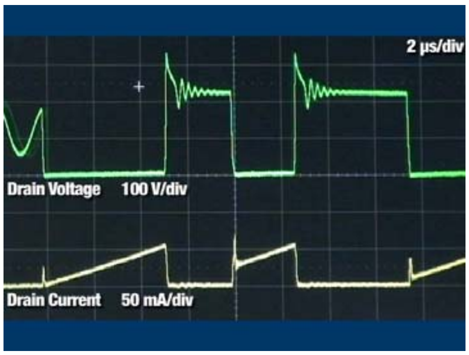


Current loop added to board

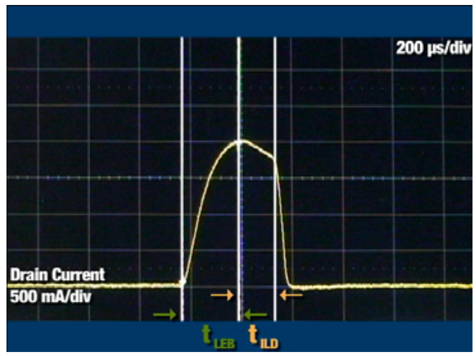
Connection of voltage and current probes

Connect a high voltage oscilloscope probe from the Drain node to the Source pins to measure the switching voltage across the MOSFET. Also connect the current probe on the current loop you just made. Now reconnect the AC input, and set the input voltage to the maximum for your design. Configure your oscilloscope to view both the MOSFET voltage and current, and set it to normal trigger mode. Trigger on the rising edge of the MOSFET voltage to ensure stable readings.

Study the datasheet for your Power Integrations device to determine the leading edge blanking time in your design, as well as the initial current limit at the end of leading edge blanking. Then, measure the current level you see through the MOSFET after the leading edge blanking time. Compare this value with the initial current limit in the datasheet. If the value you measure is greater than the initial current limit, then you will see an extremely brief current pulse terminated at the end of leading edge blanking time. This can cause power delivery problems.



Drain voltage and current



Current pulse terminates at end of leading edge blanking time

Disconnect all primary side snubbers from your circuit and re-measure the initial current after leading-edge blanking. If disconnecting the primary side snubbers solves the problem and the initial current spike decreases to acceptable levels, you will need to decrease the capacitance of your primary snubber circuits. If the problem remains, then verify that the transformer winding capacitance is not too large.

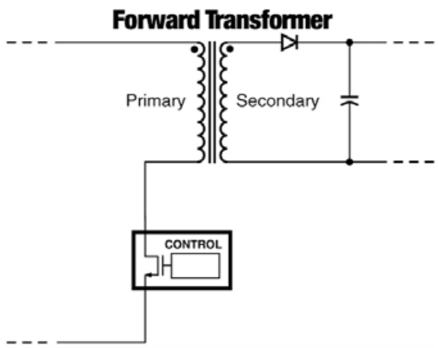
10. The transformer bias winding is disconnected (specific to designs based on the TOPSwitch device family)

If you are using a TOPSwitch device, verify that the return, the 0-volt end, of the transformer bias winding is connected to primary side return. This is the negative terminal of the input capacitor. If the transformer bias winding is left floating, the optocoupler has no supply voltage and therefore no feedback signal can be provided to the Power Integrations device. This will cause the device to enter auto-restart mode.

11. The polarity of a transformer winding has been reversed

If your board is still not reaching regulation, the last thing to check is the polarity of your transformer windings. If a winding has been reversed, this winding will appear as a forward winding. Reversal of a transformer winding prevents the power supply from operating as a flyback converter, limiting power transferred to the output.

Illustrated below are the voltage and current waveforms from the drain pin of an RD-91 board. On the left side are the waveforms of a correctly operating flyback supply and on the right are the waveforms seen when the secondary winding is reversed on that same supply. With the timebase of both waveforms set to 20 µs/division, it is clear that the reversed winding current pulses are much shorter than with the normal transformer.



Transformer primary winding reversed

RD-91 drain current and voltage waveforms – with and without reversed winding

In the diagram to the right, the timebase has been expanded to measure the pulse duration. The MOSFET on-time of the normal pulse is approximately 4 microseconds while the reversed winding transformer pulse on-time is only 400 nanoseconds. If you see a similarly shortened on-time in your design, then it is likely one of your transformer windings has been reversed.

Shortened drain current pulse with reversed transformer winding

For More Information

If you have any questions or comments about the information presented in this course, please email PIUniversity@powerint.com.