To: PI-Taiwan FAE Staff

From: PI-San Jose Applications Engineering

Date: 30-Dec-15

Revision: A

Re: RCD snubber - Reducing snubber resistor dissipation and output rectifier diode peak inverse voltage stress in a fly-back power supply

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## Introduction:

Voltage waveform across output rectifier diode in a flyback converter shows a voltage ring at the instant of turn-ON of the primary side MOSFET. This ringing is caused by resonant interaction between the leakage reactance of the secondary winding, trace inductance of the secondary side circuit interconnections, output rectifier diode reverse recovery and diode junction capacitance. The resulting reverse voltage can exceed the PIV (Peak Inverse voltage) rating of the output rectifier diode and the ringing results in increased EMI.

A reduction in the peak voltage and damping of the resonant ring can be achieved by connecting an RC circuit across the output rectifier diode. The addition of this RC snubber circuit results in a slight drop in efficiency due to power dissipation in the resistor. This RC circuit can also lead to increase in the initial peak current at the instant of turn-ON of the primary side MOSFET.

Choice of components used for the RC circuit is a tradeoff between losses, EMI performance improvement and voltage stress on the output rectifier diode.

Reduction in diode peak inverse voltage is typically achieved by increasing the capacitance in the RC snubber however increase in capacitance results in increased loss in the snubber resistor.

Adding a diode in parallel with the snubber resistor reduces loss in the resistor. This allows for an increase in snubber capacitance while simultaneously keeping the loss in the snubber resistor low.

Use of a diode in parallel with the resistor is therefore recommended for designs where the peak voltage across the output rectifier diode is to be reduced by increasing the snubber capacitance and the loss in the snubber resistor is to be reduced.

**Explanation:**

Figure.1 shows the equivalent circuit of the flyback converter power stage. Lm is the magnetizing inductance of the primary and NP and NS represent the ideal transformer. Whenever the primary side MOSFET turns ON while the secondary side diode is still conducting, the voltage across the secondary side diode is rapidly reversed. The diode goes from a conducting state to a reverse biased state and the magnitude of the reverse current depends on the diode reverse recovery characteristics. Energy is stored in the leakage reactance Llk2. Following the reversal of voltage across the secondary winding, a resonant ring is seen at the anode of the reverse biased output diode. Llk2 and junction capacitance Cj determine the frequency of the resonant ring seen across the diode. This ringing can generate conducted and radiated EMI. The ring can exist for a prolonged period of time due to low inherent damping in the circuit and the overshoot in voltage across the output diode that is caused by this ring can exceed diode rating in some designs and lead to diode damage.

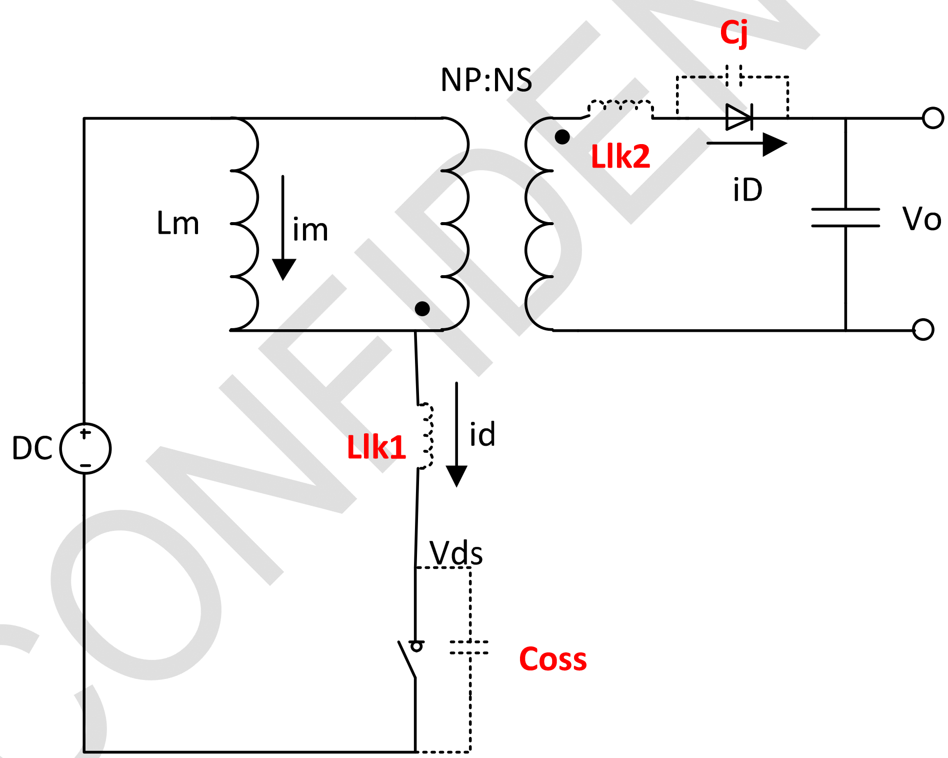



**Figure 1** Equivalent circuit of the flyback converter

Figure.2 shows one example of the voltage at the anode of the rectifier diode without any RC snubber connected across the diode for a 19V output power supply.

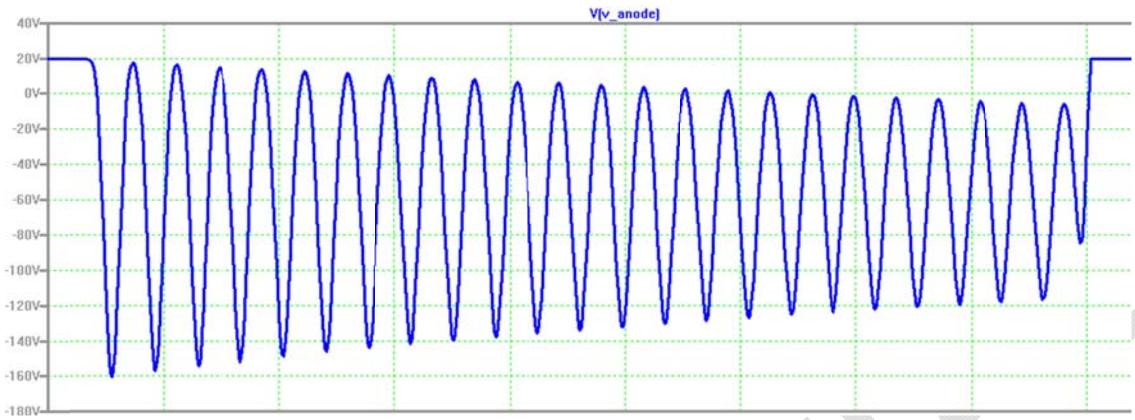



**Figure 2** Undamped ringing at the anode of the output rectifier diode

Damping of the resonant ring is achieved using a RC circuit connected across the diode as shown in Figure.3. The capacitance used in the RC circuit is considerably higher than the junction capacitance of the output rectifier diode.

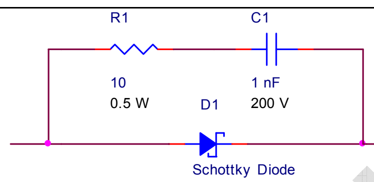



**Figure 3** RC snubber connected

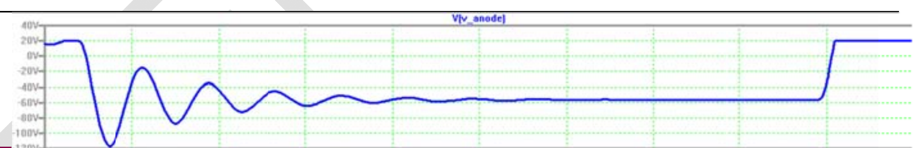



**Figure 4** Damping of resonant ring with the addition of the RC snubber

As shown in Figure.4, the peak amplitude of the first resonant ring is dramatically reduced with the addition of the RC snubber across the diode. For the example shown, the first peak reduced from 160V to 120V with a 10Ω resistor and 1nF capacitor in the RC snubber circuit. Further reduction in the magnitude of the resonant ring can be achieved with increase in the capacitance used in the snubber as shown in Fig.5 and Fig.6

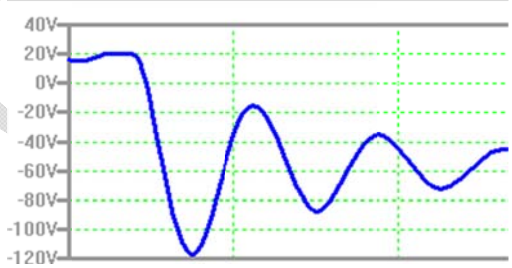



**Figure 5** 10Ω + 1nF RC snubber

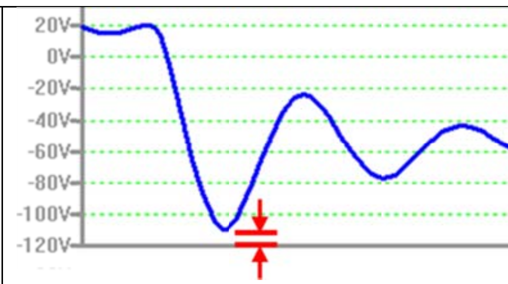



**Figure** 6 10Ω + 1.5nF RC Snubber

The values of the resistor and capacitance used in the RC snubber circuit are adjusted until the peak reverse voltage across the output rectifier diode is sufficiently below the PIV rating of the diode and conducted and radiated emissions are below the applicable limits.

In each switching cycle, the snubber capacitor is charged and discharged through the snubber resistor which results in loss in the resistor. Increase in the value of the capacitance results in increase in RMS current through the resistor thus resulting in increased loss.

If a diode is connected across the resistor in the RC snubber, part of the current flow in the snubber circuit is through the diode which results in a net reduction in current through the snubber resistor and hence a reduction is the loss in the snubber resistor. The addition of the diode changes the resistance in the RC circuit depending on the direction of current flow in the circuit and hence has the effect of changing the damping offered by the circuit however without significantly altering the magnitude of the peak ring voltage for the first ring which happens to have the highest amplitude.

Figure.7 shows the location and connections of the additional diode in the proposed RCD snubber circuit.

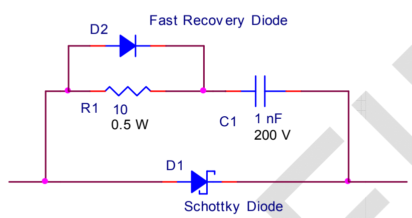



**Figure 7** RCD Snubber for output rectifier

Figure.8 and Figure.9 show one example of change in current flowing through the resistor with and without the diode added across the resistor.

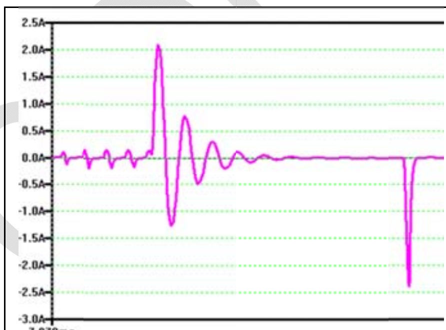



**Figure 8** Current through snubber resistor without parallel diode

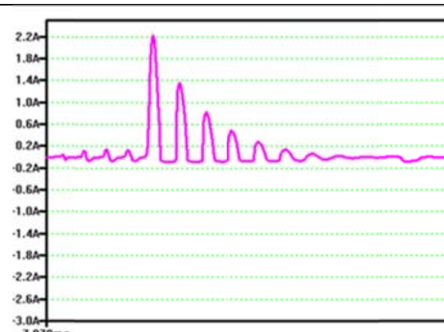
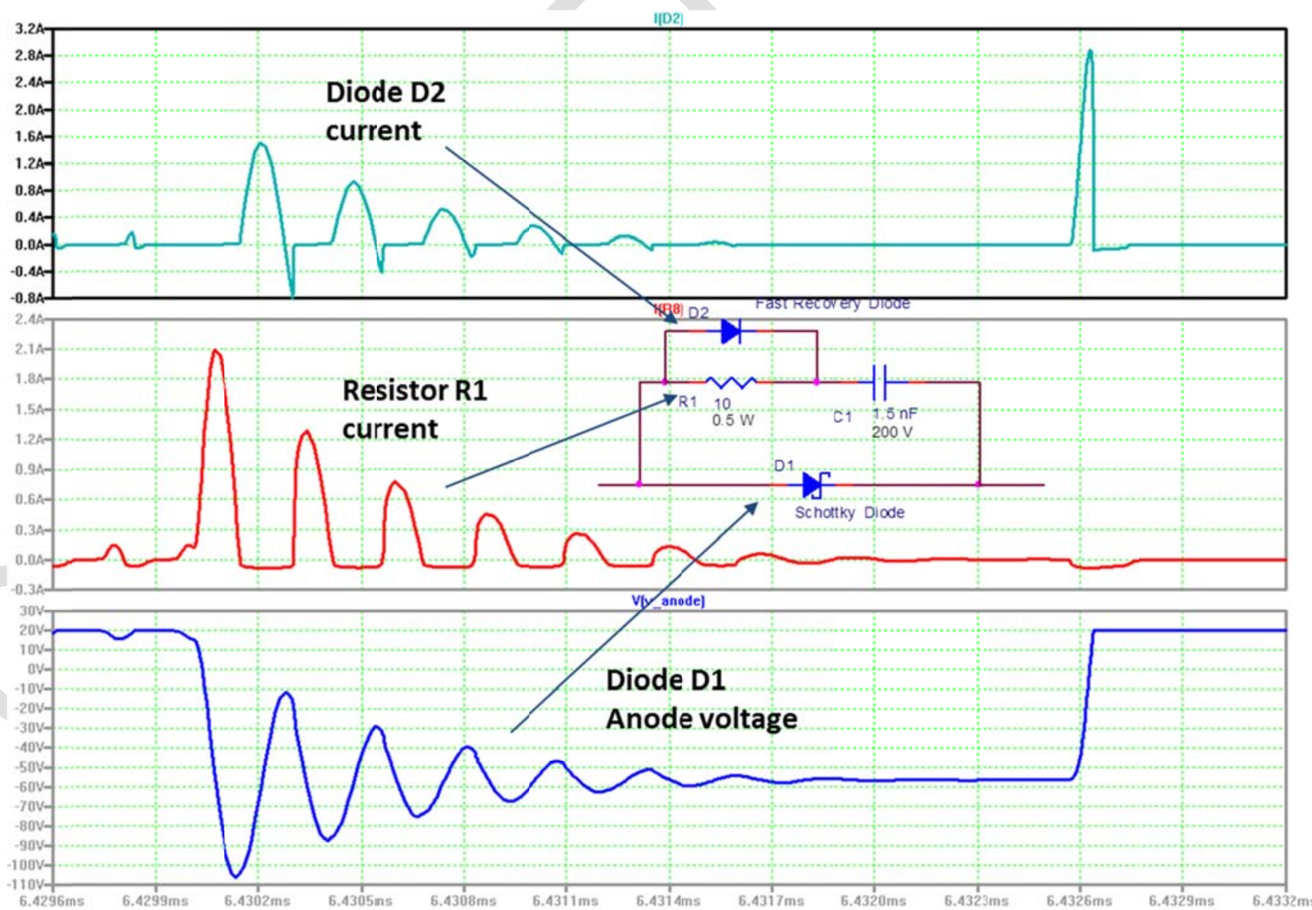



**Figure 9** Current through snubber resistor with diode in parallel with resistor

Table.1 compares current through the snubber resistor for three different combinations of the snubber circuit under the same operating condition. Addition of the diode across the resistor has the effect of reducing the RMS current through the resistor without affecting the improvement in peak inverse voltage achieved through the increase in capacitance

| Resistor | Capacitor | Diode in parallel with snubber Resistor | Negative peak Anode voltage | RMS current through resistor |
|---|---|---|---|---|
| 10Ω | 1nF | No | -114V | 224.7mA |
| 10Ω | 1.5nF | No | -106V | 268.4mA |
| 10Ω | 1.5nF | Yes | -109V | 214.2mA |

Figure.10 shows the diode anode voltage, current through the snubber resistor and current through the snubber diode under one operating condition for the example used for this note.



## Conclusion

For some of the high power switching power supplies, loss in the snubber resistor may be considerable and may require high power resistors to handle the power dissipation. In such designs use of the RCD snubber can effectively keep the loss in the snubber resistor low.

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## Feedback

Please send feedback or comments to E. Hwang, D. Chen, or R. Joshi

## Revision History:

(Rev A. 12302015) First release