Power Loss Analysis of Push-Pull Snubber Circuit

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The push-pull circuit is widely used in isolated power supply. Due to the power transistors in isolated topology operating in hard-switching mode, snubber circuits are generally required to suppress the voltage spike of the switching point. The paper addresses the power loss of RC snubber.

1. Equivalent Circuit

A typical push-pull circuit is illustrated in Figure1-1. The primary switch Q1 and Q2 are conducted interleaved with switching frequency fs at duty 50%. After full-wave rectification, the isolated output can be achieved.

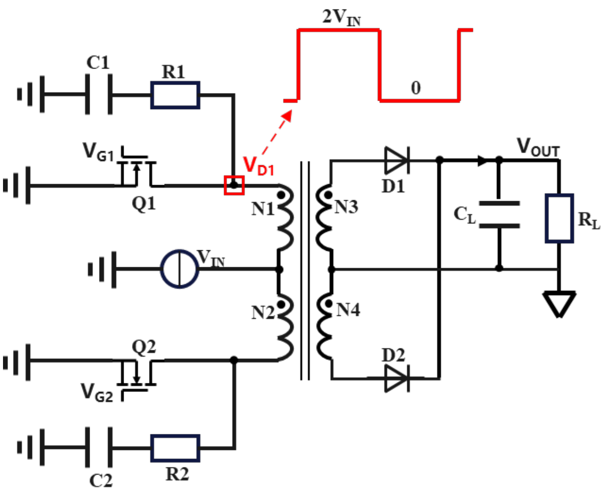

Figure 1-1 Push-pull Topology

The switching point V_{D1} can be considered as a rectangle wave with peak-to-peak voltage $2V_{IN}$ and switching frequency fs.

$$\begin{cases} V_{D1} = 2V_{IN}, & D \\ V_{D1} = 0, & 1 - D \end{cases}$$

To analyze the power loss, an equivalent circuit can be generated with switching frequency fs and magnitude $2V_{IN}$, as Figure 1-2 shows.

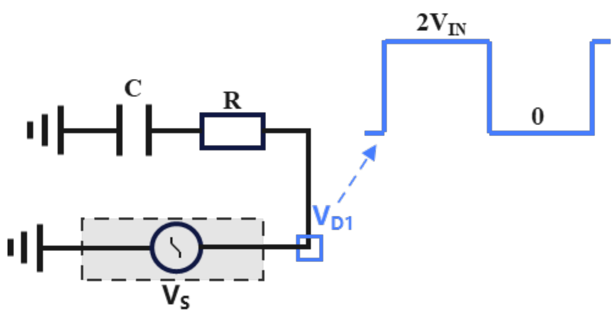

Figure 1-2 Equivalent Circuit

2. Snubber Resistor Power Loss

The circuit equations can be summarized in the following table, per switching on/off stage.

	Response Characteristics	Capacitor Voltage	Current	Power Loss at Snubber Resistor
ON	Zero-stage Response	$V_C = 2V_{IN} \times (1 - e^{-\frac{t}{RC}})$	$I_C = C \times \frac{dV_C}{dt} = \frac{2V_{IN}}{R} \times e^{-\frac{t}{RC}}$	$P_{ON} = \int_0^{\infty} I_C^2 R dt = \frac{4V_{IN}^2}{R} \times [-\frac{RC}{2} e^{-\frac{2t}{RC}}]\|_0^{\infty} = 2CV_{IN}^2$
OFF	Zero-excitation Response	$V_C = 2V_{IN} \times e^{-\frac{t}{RC}}$	$I_C = C \times \frac{dV_C}{dt} = -\frac{2V_{IN}}{R} \times e^{-\frac{t}{RC}}$	$P_{OFF} = \int_0^{\infty} I_C^2 R dt = \frac{4V_{IN}^2}{R} \times [-\frac{RC}{2} e^{-\frac{2t}{RC}}]\|_0^{\infty} = 2CV_{IN}^2$

The total power loss is the sum of the on/off stage as the following formula shows. It is apparent that the power loss is only related to the capacitor, input voltage, and switching frequency.

$$P_{loss} = (P_{ON} + P_{OFF}) = 4CV_{IN}^2 f_s$$

3. Simulation Validation

A simulation under LTspice is conducted to validate the analysis.

Resistor	Capacitor	Supply Voltage	Switching Frequency	Resistor Power Loss
100R	1 nF	5 V	400 kHz	Calculation: 4.00 mW Simulation: 3.94 mW

4. Conclusion

The paper gives a quantitative solution to evaluate the power loss of a snubber resistor. The analysis method can be extended to analyze gate driver loss and Buck snubber loss.