VIII. SWITCHING TRANSIENTS

When current in the Schottky is rapidly switched, a voltage transient is generated, due to interaction between circuit inductance and the Schottky's self-capacitance. This happens, for example, in a Forward or Bridge Converter, whenever the output transformer voltage changes polarity. The transformer's leakage inductance, as well as "stray" circuit inductance, forms a resonant circuit with the Schottky's self-capacitance. Figure 48 shows an equivalent circuit and idealized current and voltage waveforms during commutation.

With no snubber, the reverse voltage across the outgoing Schottky overshoots, to about twice the transformer voltage; this is followed by an underdamped oscillation, at the resonant frequency of the circuit inductance with the Schottky's capacitance.[7]

A snubber serves the dual purpose of reducing the Schottky's peak reverse voltage and of damping the high frequency oscillation.

IR's Schottkys are rated to absorb avalanche energy, at voltage above the normal working voltage. This will not stop oscillation from occuring below the Schottky's avalanche voltage, which will typically be about 1.5x the Schottky's rated working voltage. The switching oscillations typically have a frequency in the range of 1 to 15 MHz and may be undesirable, because of the electrical interference they create. A snubber will usually be needed, if only to dampen the oscillation.

Thus the Schottky avalanche property will generally not eliminate the need for a snubber. What is does do is provide a valuable "insurance" against abnormal voltage transients; it also eliminates the need for a generous operating voltage margin, which allows the size and losses of the damping snubber to be minimized.

A. Snubber Circuit Design

The R-C snubber circuit requires careful dimensioning. Energy equal to $1/2\ C_{SNUBBER}\ V^2$ is dissipated each time the snubber capacitor is charged or discharged.[8] Thus total energy equal to $C_{SNUBBER}\ V^2$ is lost in each snubber during each switching cycle. ($1/2\ C_{SNUBBER}\ V^2$ when the Schottky turns ON, and $1/2\ C_{SNUBBER}\ V^2$ when it turns OFF). The snubber capacitance must be kept as small as possible, consistent with achieving the required damping of the switching oscillation, in order to minimize the snubber losses.

Though, for a given capacitance, the value of the snubber resistance has no effect upon the net energy dissipation, it does have a major effect upon the amplitude of the voltage oscillation.

If the snubber resistance is too small, then the snubber capacitance, in effect, is connected almost directly in parallel with the Schottky capacitance. The circuit will be underdamped and resonate at a frequency of $1/[2\pi \bullet \sqrt{L \bullet (C_{SCHOTTKY} + C_{SNUBBER})}]$.

If the snubber resistance is too large, it will not damp the oscillations caused by the Schottky capacitance. The circuit will now have an underdamped oscillation at a frequency of $1/[2\pi \bullet \sqrt{(L \bullet C_{SCHOTTKY}})]$.

Figures 49 through 53 show switching voltage and current waveforms, based on a linear approximation of the Schottky self-capacitance. A value of 1nF is assumed; this would be representative, for example, of a 50HQ Schottky.

Figure 49 illustrates the effect of the choice of snubber resistance, with a fixed snubber capacitance, equal to 6x the Schottky capacitance. (N = 6, where N is the ratio of snubber to Schottky capacitance). These waveforms confirm that a snubber resistance that is either too large or too small results in an oscillation that is underdamped and has substantial voltage overshoot. With the "correct" value of snubber resistance, effective damping of the oscillation is achieved; the peak voltage is kept to about 45V, for a 34V transformer voltage.

Figure 50 illustrates the effect of increasing the snubber capacitance, to 10x Schottky capacitance. The peak Schottky voltage is now just over 40V, for a 34V transformer voltage. These waveforms show virtually "perfect" damping.

Figures 51 and 52 show the effect of higher circuit inductance — 300nH and 1μH respectively-compared with 100nH in Figures 49 and 50. These waveforms demonstrate that with proper choice of the snubber resistance, the size of the snubber capacitance, for a given voltage overshoot, stays about the same with increasing circuit inductance. Of course, a larger inductance means a slower voltage rise time, and a lower amplitude snubber current.

The waveforms in Figure 53 are for a reduced transformer voltage, of 28V. The snubber capacitance values range from 6 to 2x the Schottky capacitance. The value of snubber resistance in each case is chosen to maximize the damping.

These waveforms demonstrate the trade-off between voltage overshoot and snubber capacitance. A snubber capacitance of 6x the Schottky's capacitance is needed to limit the peak Schottky voltage to 36V. The snubber capacitance can be reduced to just 2x the Schottky's capacitance, if the voltage is allowed to rise to 43V.

Thus, by taking advantage of the ruggedness of IR's Schottkys and paring down the operating voltage margin, the size and losses of the snubber can be significantly reduced.

---

[7] The Schottky's capacitance is non-linear and is a function of the applied voltage. The circuit operation can be approximated by assuming a linear capacitance of about the value obtained at the full circuit operating voltage.

[8] This is fundamental, and independent of the value of circuit inductance or snubber resistance. V is the level to which the capacitor voltage settles when the oscillation is completed, i.e. it is the operating voltage delivered by the output transformer, not the peak voltage to which the capacitor voltage may overshoot.

click here to go to next section

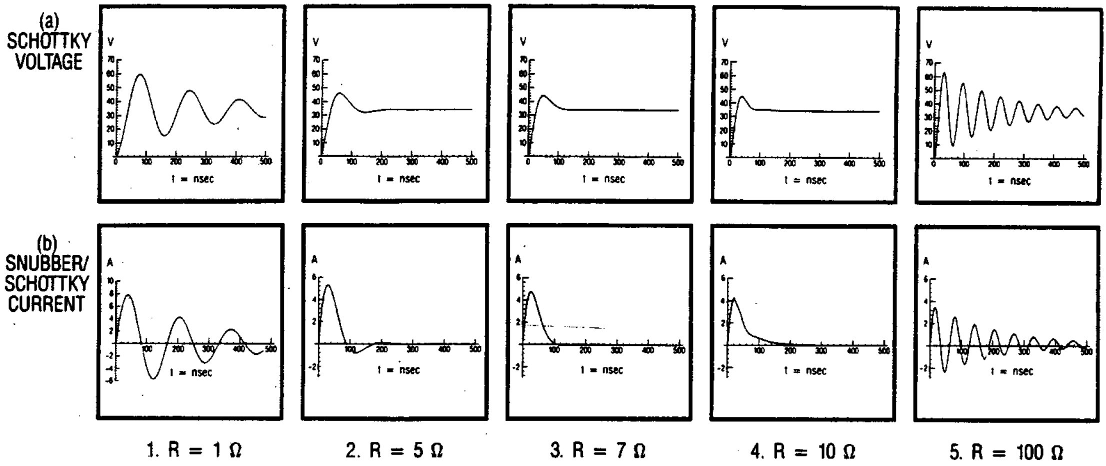


Figure 49. Waveforms of (a) commutating voltage across Schottky and (b) combined current in snubber and self-capacitance of Schottky, for various values of snubber resistance. N = $C_{Snubber}/C_{Schottky}$ = 6.

$C_{Schottky}$ = 1nF $C_{Snubber}$ = 6nF L = 100nH V_T = 34V

(Reference Figure 48)

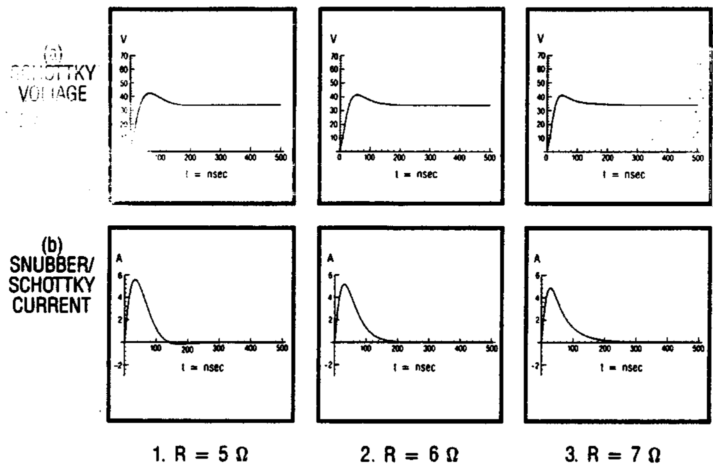


Figure 50. Waveforms of (a) commutating voltage across Schottky and (b) combined current in snubber and self-capacitance of Schottky, for various values of snubber resistance. N = $C_{Snubber}/C_{Schottky}$ = 10.

$C_{Schottky}$ = 1nF $C_{Snubber}$ = 10nF L = 100nH V_T = 34V

(Reference Figure 48)

click here to go to next section

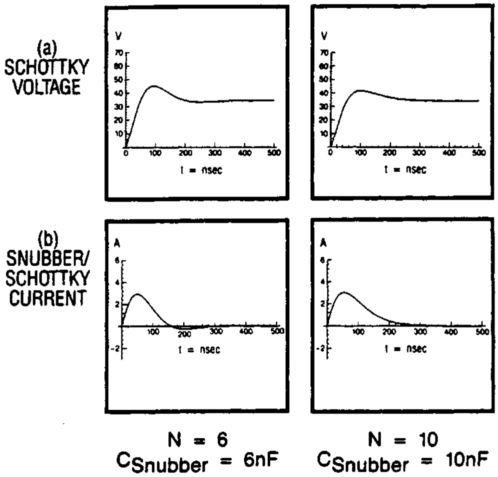


Figure 51. Waveforms of (a) commutating voltage across Schottky and (b) combined current in snubber and self-capacitance of Schottky, for different values of snubber capacitance. (= N x Schottky Capacitance).

$C_{Schottky}$ = 1nF $R_{Snubber}$ = 10 Ohms L = 300nH V_T = 34V

(Reference Figure 48)

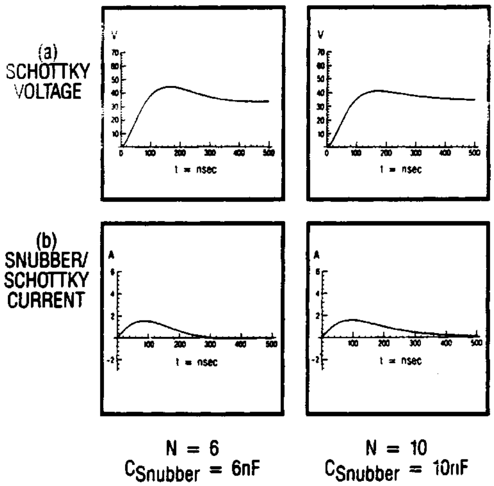
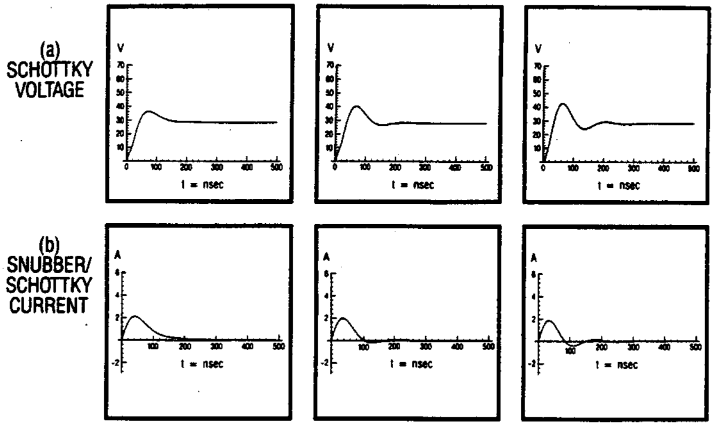


Figure 52. Waveforms of (a) commutating voltage across Schottky and (b) combined current in snubber and self-capacitance of Schottky, for different values of snubber capacitance. (= N x Schottky Capacitance).

$C_{Schottky}$ = 1nF $R_{Snubber}$ = 20 Ohms L = 1μH V_T = 34V

(Reference Figure 48)

click here to go to next section



N = 6	N = 3	N = 2
$C_{Snubber}$ = 6nF	$C_{Snubber}$ = 3nF	$C_{Snubber}$ = 2nF
$R_{Snubber}$ = 15Ω	$R_{Snubber}$ = 18Ω	$R_{Snubber}$ = 23Ω

Figure 53. Waveforms of (a) commutating voltage across Schottky and (b) combined current in snubber and self-capacitance of Schottky, for various values of snubber resistance.

$C_{Schottky}$ = 1nF L = 300nH V_T = 34V

(Reference Figure 48)

click here to go to next section