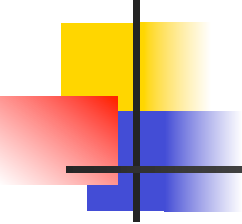


Losses Reduction

Increasing Efficiency
with Snubbers

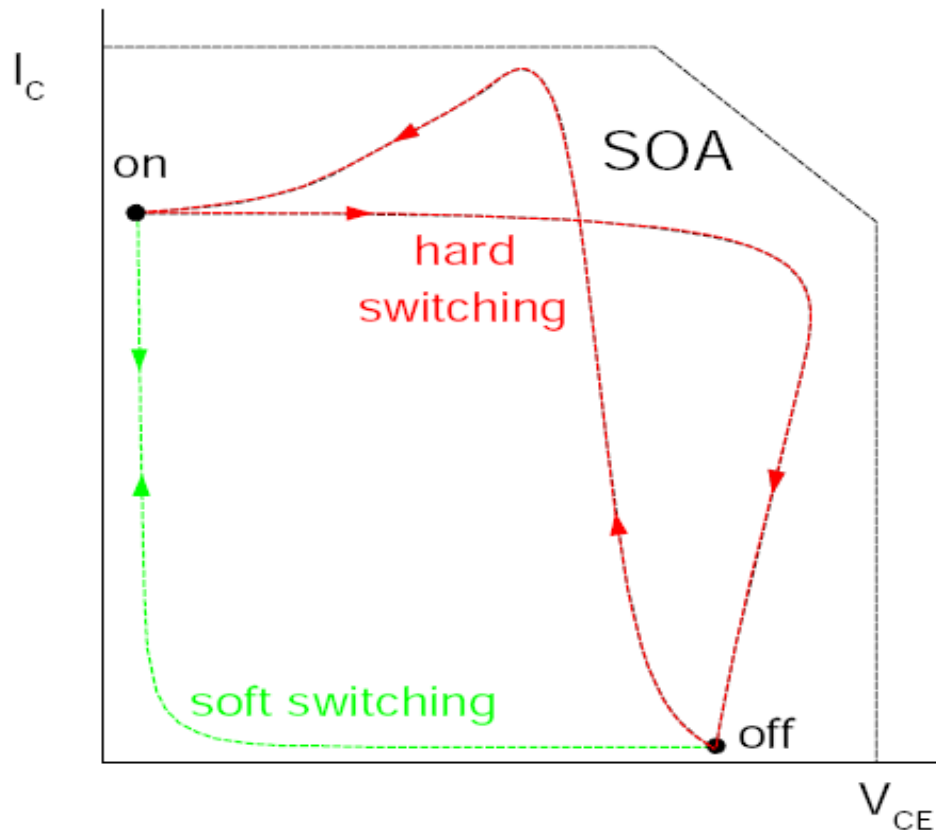


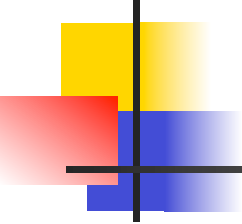
Snubber Added Values

- Reduce Voltage or Current Spikes
- Limit dV/dt (EMI) & dI/dt (Sw Loss)
- Shift Current or Voltage Phase while Switching to meet SOA
- Transfer losses from Switch to Source or Resistor
- Reduce EMI by damping V & I ringing.

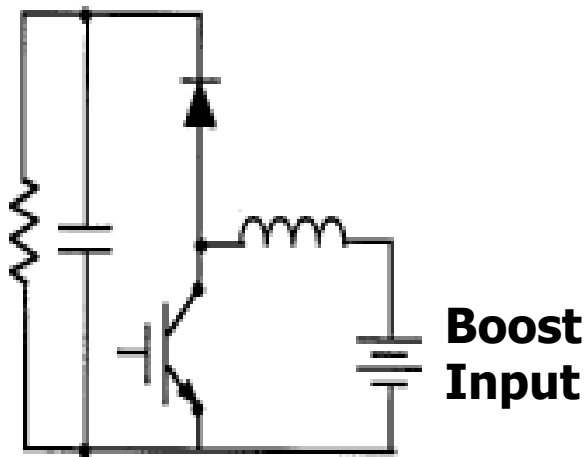
Shape I-U to meet SOA

- $P_{sw} = U \times I \text{ Area} = \text{IGBT losses}$

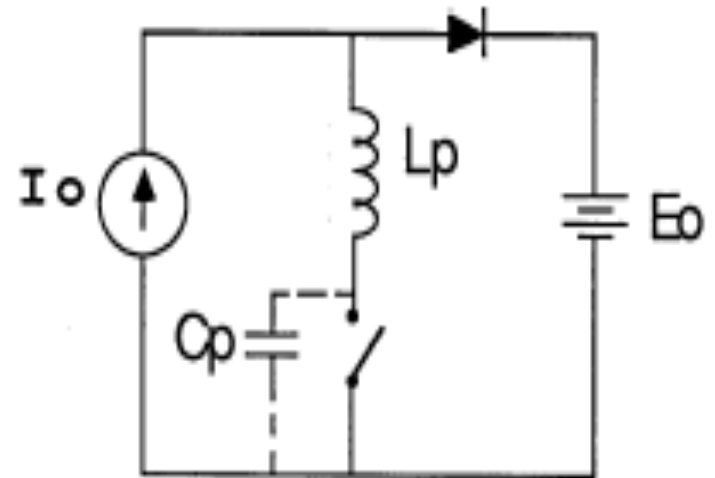




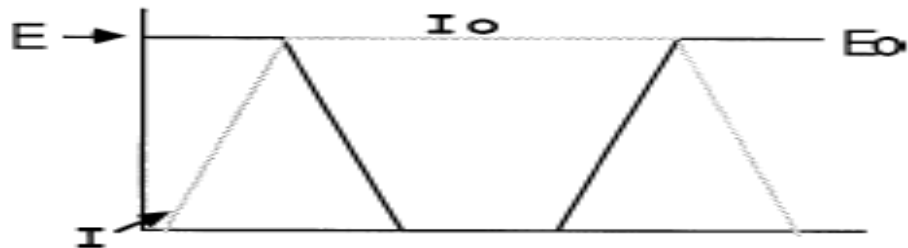
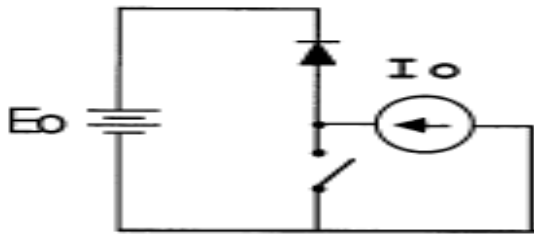
Boost Model



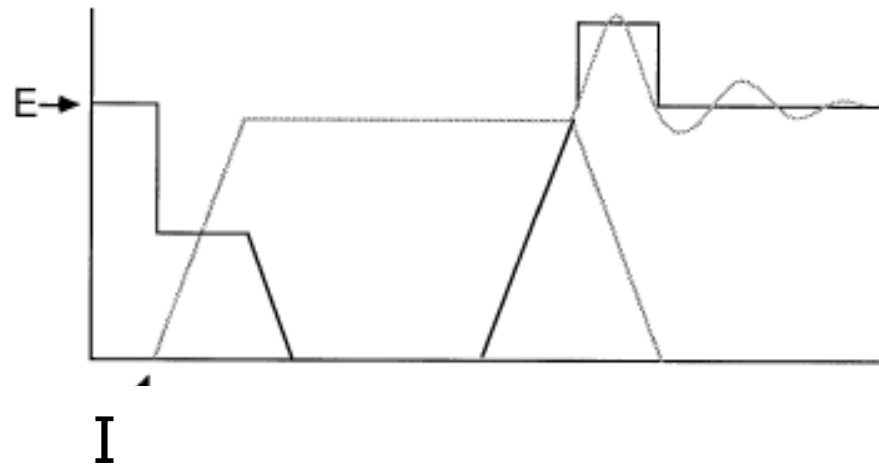
$\Rightarrow$



Boost Switching



W/ parasitical
Elements C_p , L_p

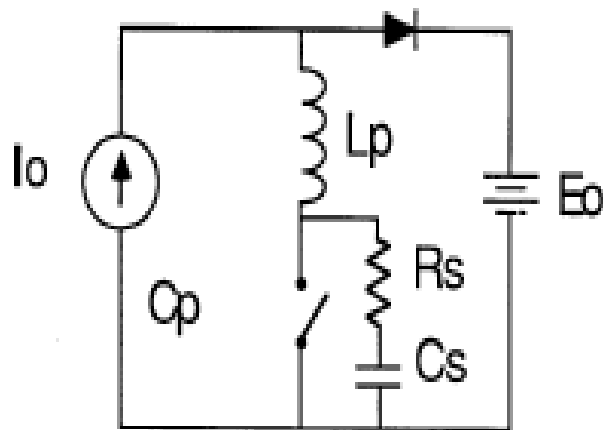


Rs & Cs Estimation

Add $C_{ad} // C_p$ to get $T_2 = 2 \times T_1 \Rightarrow C_{test} = C_p + C_{ad} \Rightarrow \underline{C_p = C_{ad} / 3}$

$$f_n = \frac{1}{2\pi\sqrt{LC}}$$

$$L_p = (T_2^2 - T_1^2) \left(\frac{1}{4\pi^2 C_{test}} \right)$$

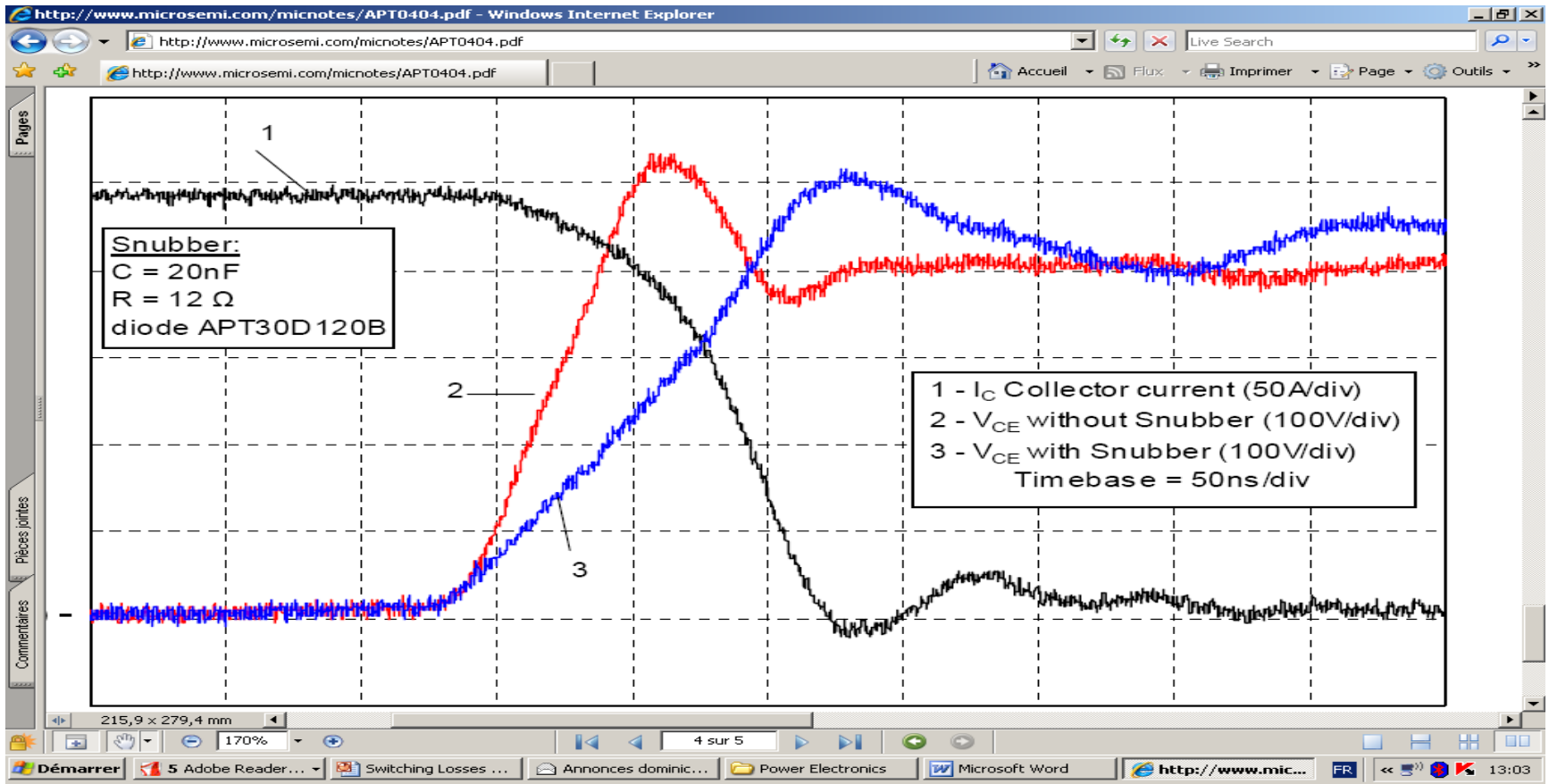


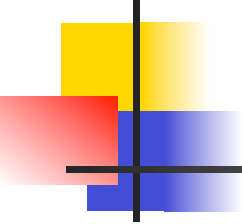
$$R_s = \sqrt{\frac{L}{C}}$$

$$C_s \approx \frac{1}{R_s f_o} = \frac{2\pi\sqrt{LC}}{R_s}$$

Boost Switching (50 ns/Div)

I_c (50A/div) $V_{ce}-S_b$ $V_{ce}+S_b$ (100V/Div)





Parasitic Elements L_p , C_p

- Wiring Inductance: 10nH / cm on:
Capacitors, Resistors, Switches
- Leakage Inductor on Transformer
- Loop (next pg)

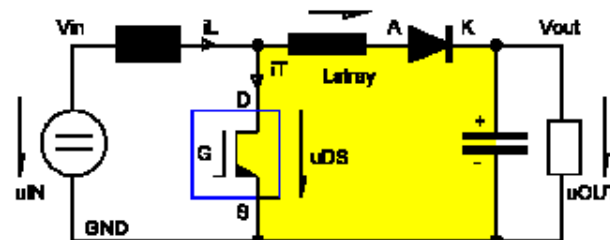
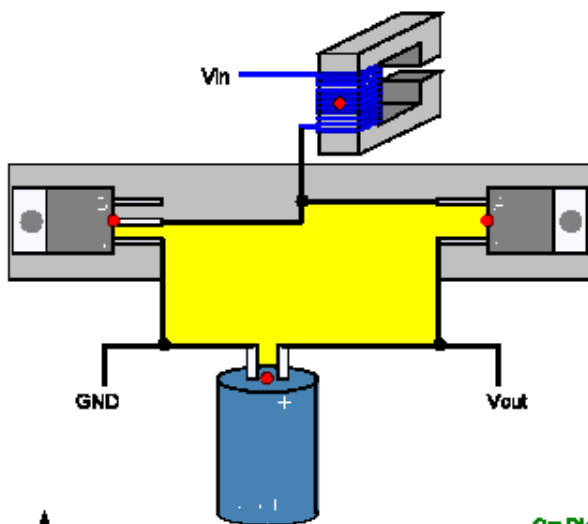
- Capacity: on winding W/ a lot of turns
- MOS Cds, IGBT Cce, Diode,
- PCB Plane

Resonant Converters

Influence of Wiring Inductance on Switching Losses

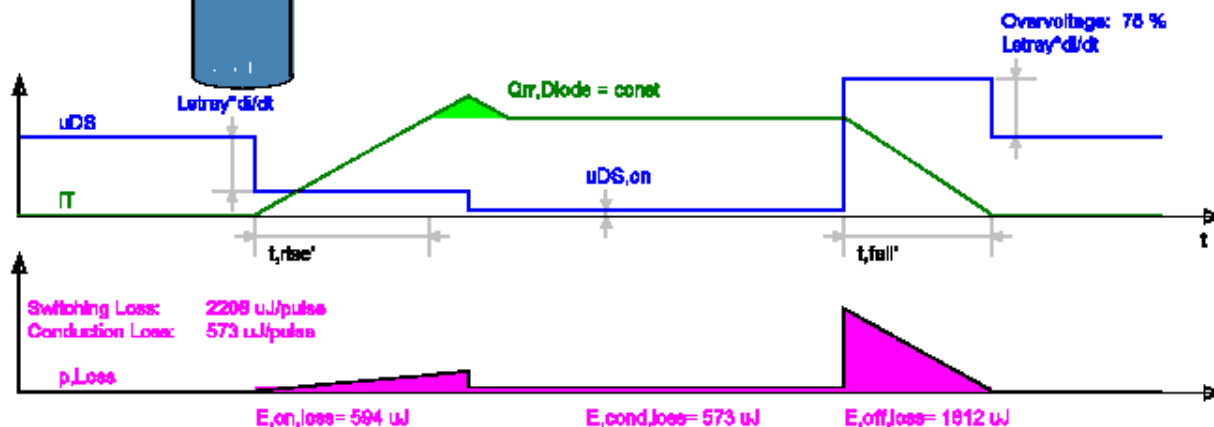
ETH Zurich

iPES-Home



SIMPLIFIED TRANSISTOR MODEL:

(du/dt) not limited
 (di/dt), ON limited via $t_{rise}=const1$ (for $L_{stray}=0$)
 (di/dt), OFF limited via $t_{fall}=const2$ (for $L_{stray}=0$)
 otherwise ideal switch



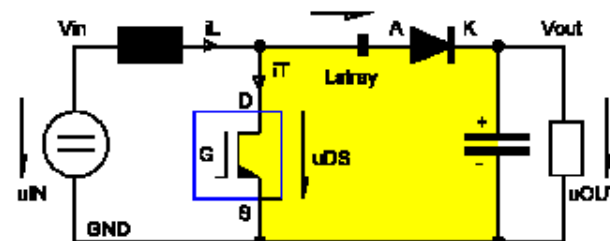
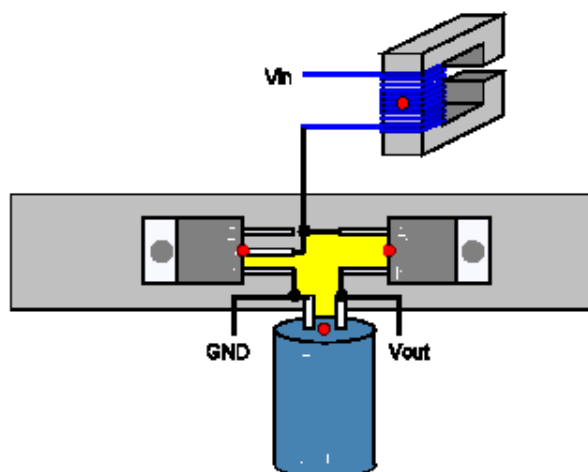
(1) Drag one of the four red dots with the mouse to change the position of one of the components of the

Resonant Converters

iPES-Home

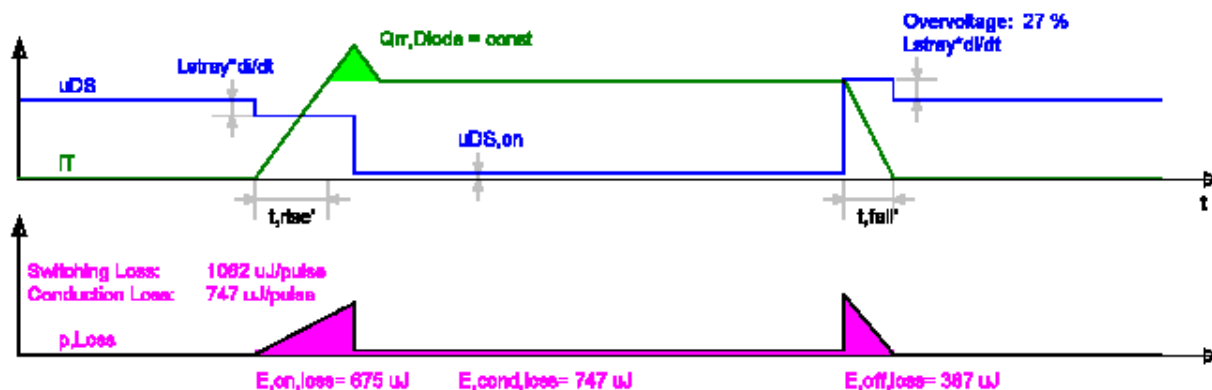
Influence of Wiring Inductance on Switching Losses

ETH Zurich



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 (di/dt), OFF limited via $t_{fall}=const2$ (for $L_{stray}=0$)
 otherwise ideal switch

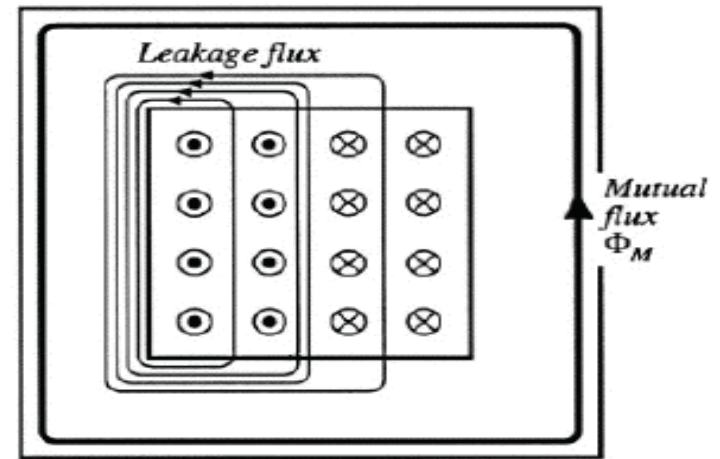
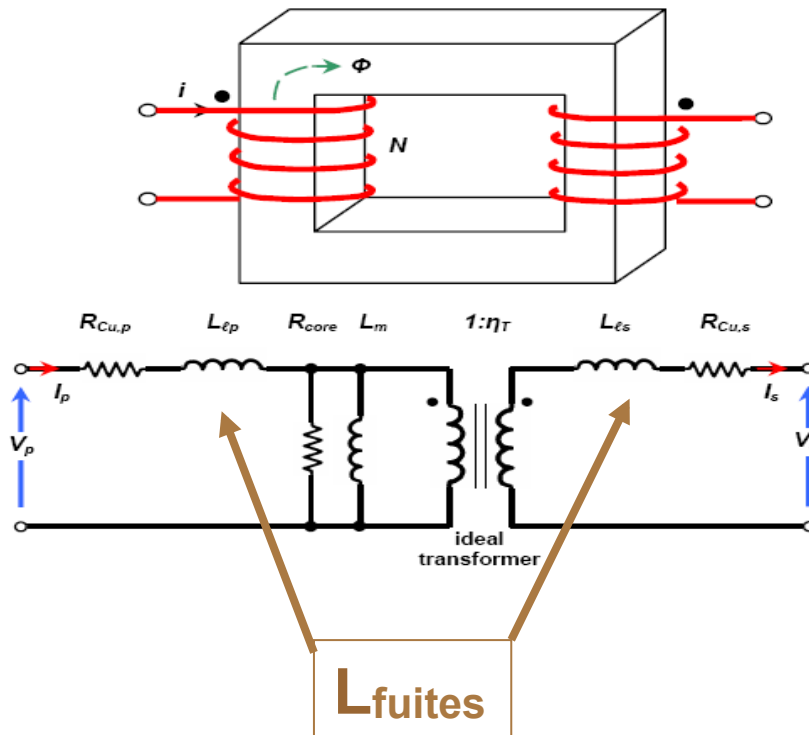


(1) Drag one of the four red dots with the mouse to change the position of one of the components of the

Power Transformer Model

$L_{sc} = L_{pri} (L_{sec})$ when $L_{sec} (L_{pri})$ is a Short Circuit $= \sim L_{fuite}$

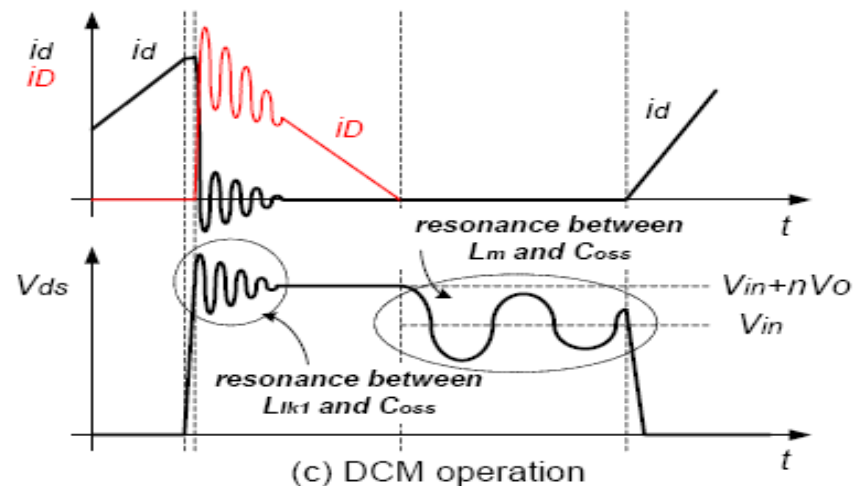
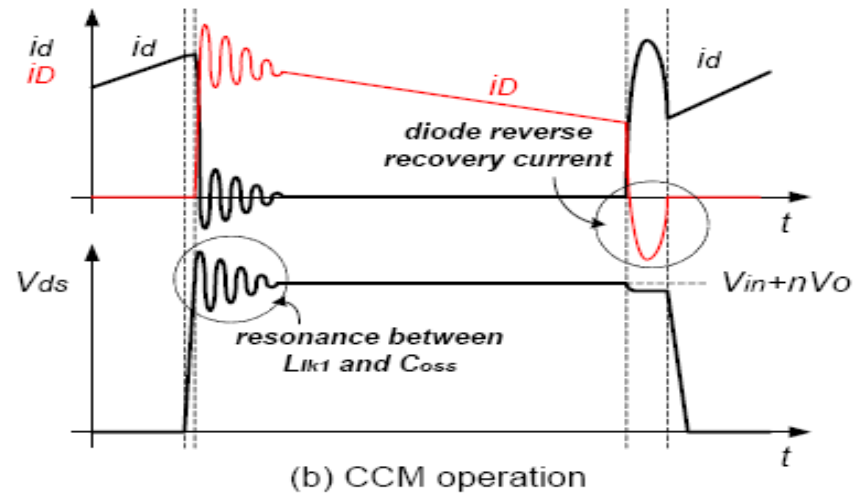
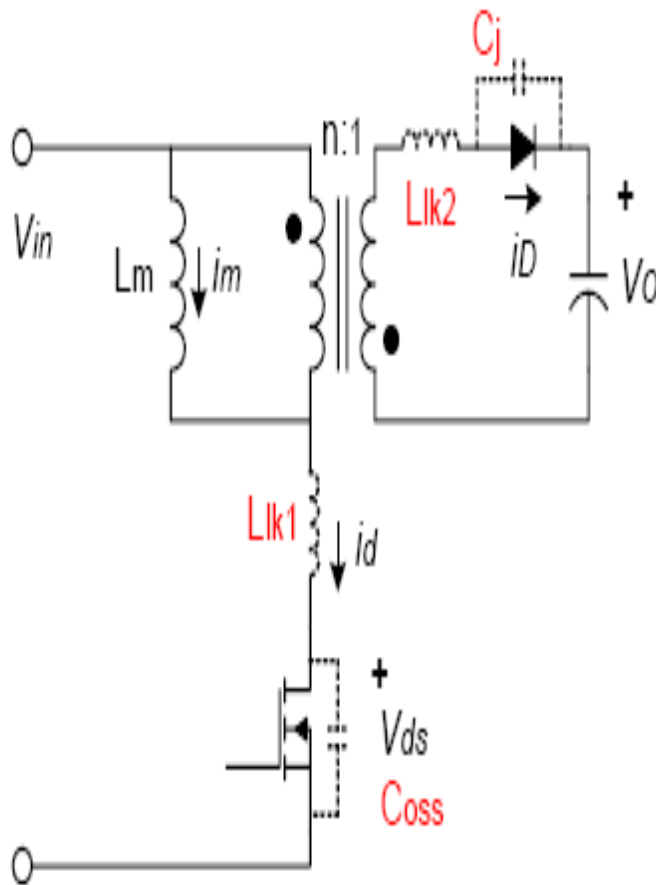
$L_{oc} = L_{pri} (L_{sec})$ when $L_{sec} (L_{pri})$ is an Open Circuit $= \sim L_{Mag}$



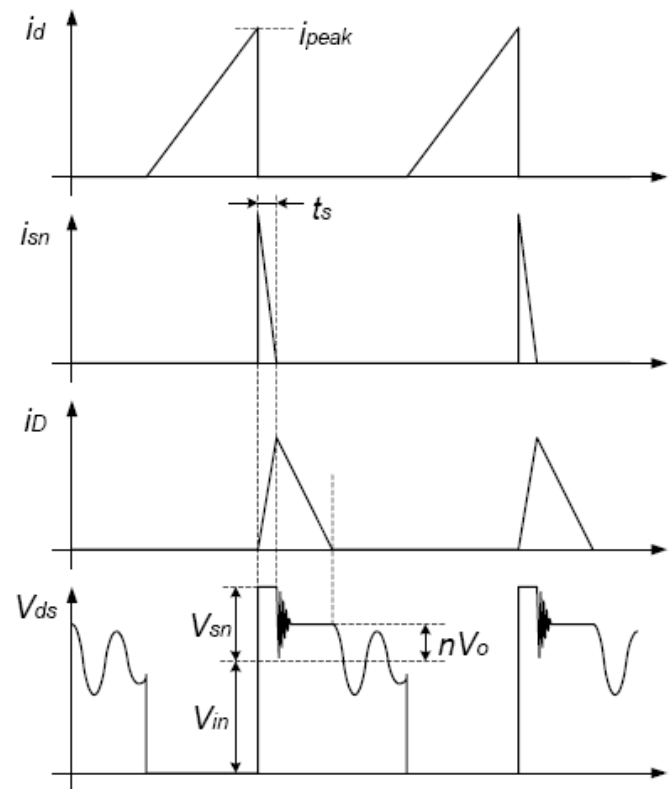
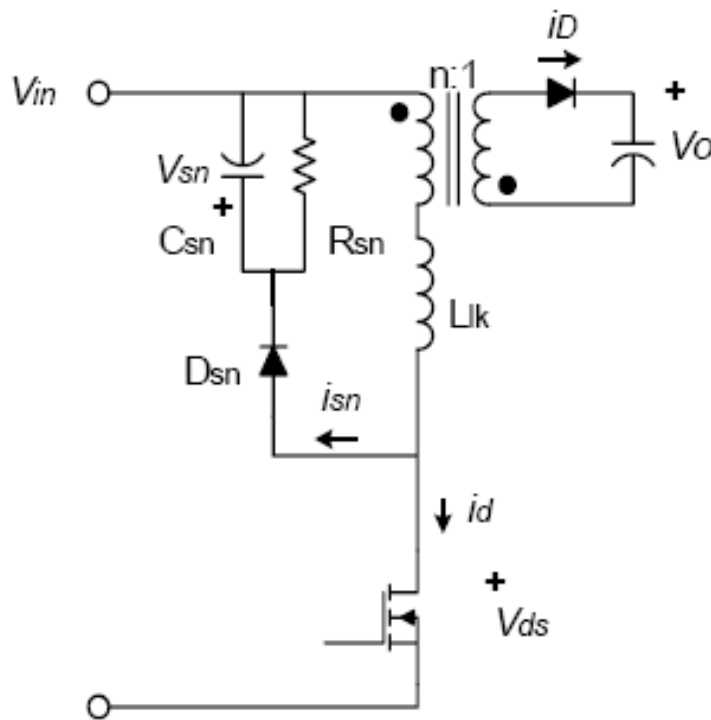
$$k = \frac{L_{12}}{\sqrt{L_{11} L_{22}}}$$

$$k = \sqrt{\frac{L_{oc} - L_{sc}}{L_{oc}}}$$

Flyback 375Vin / 5Vout-10W



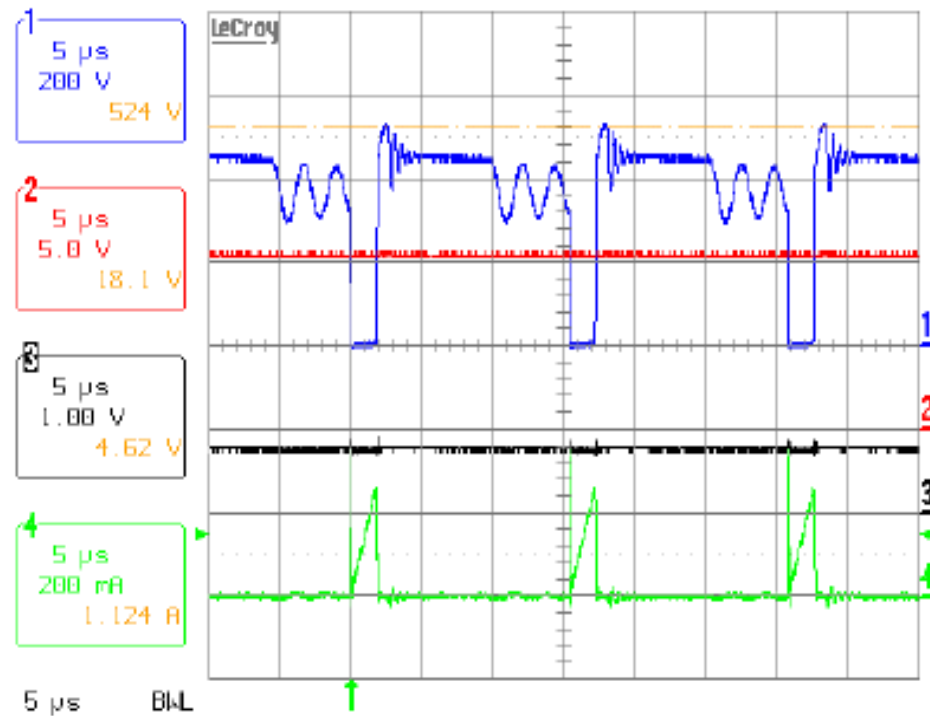
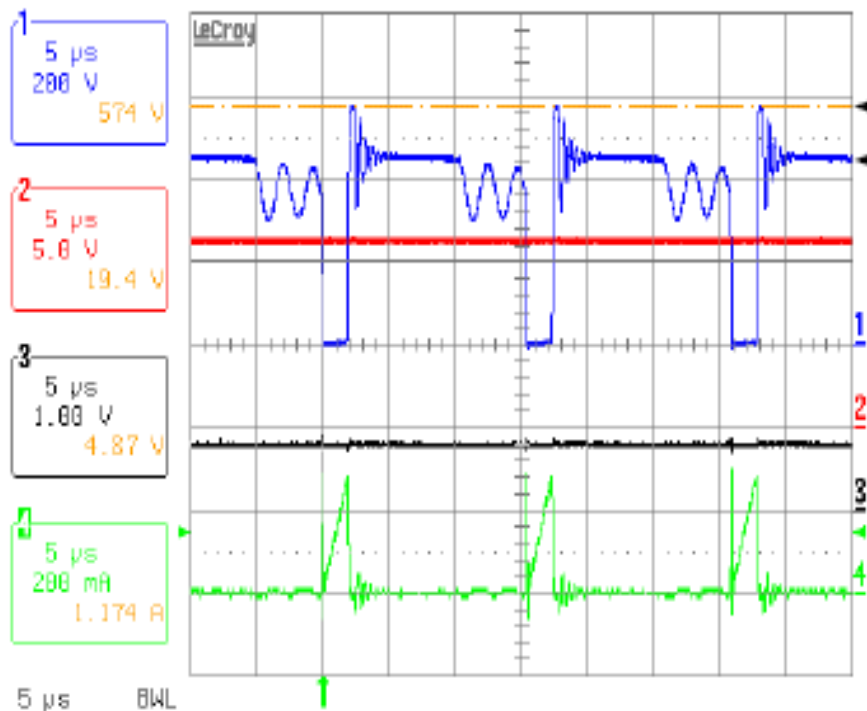
Flyback Snubber DCM



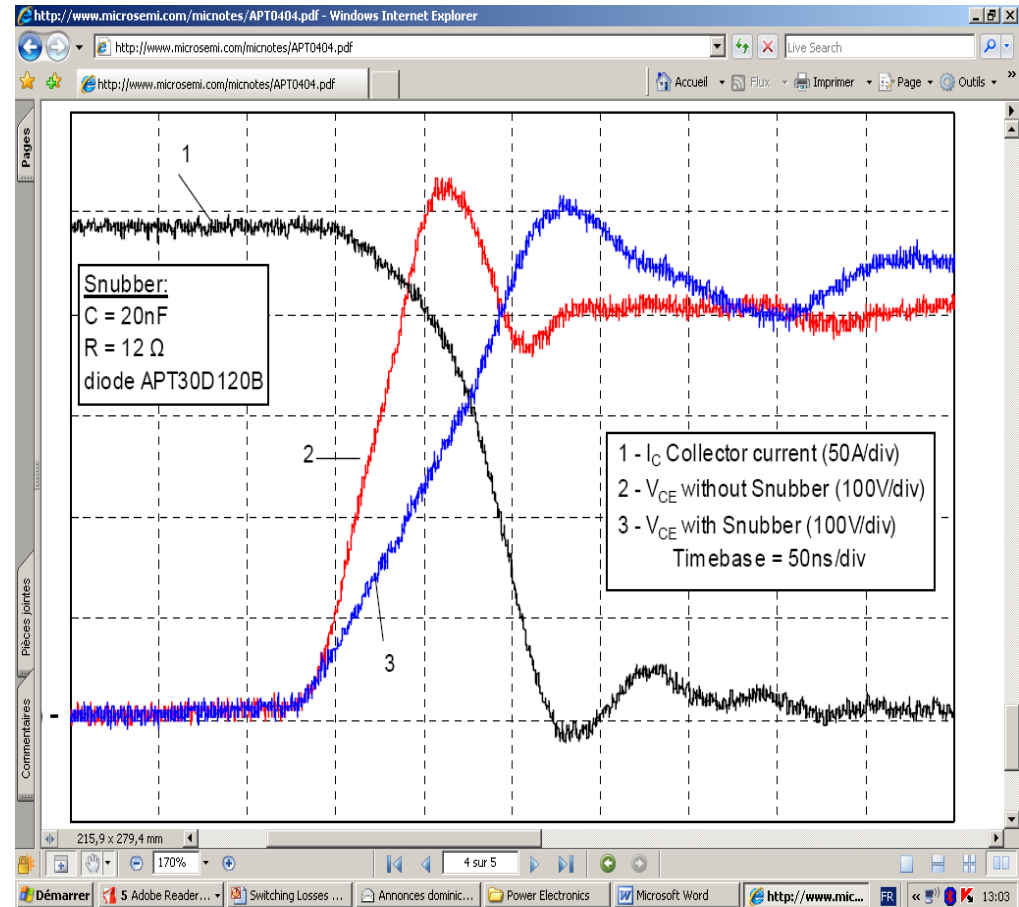
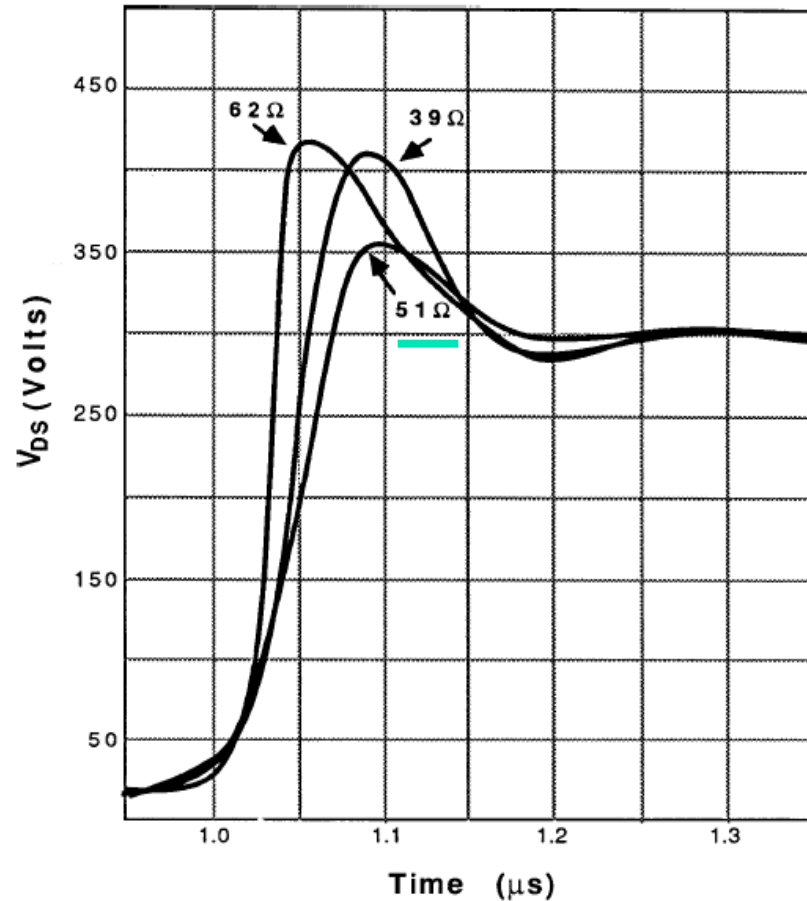
RCD SNUBBER

$R=480k / 1 \text{ nF}$

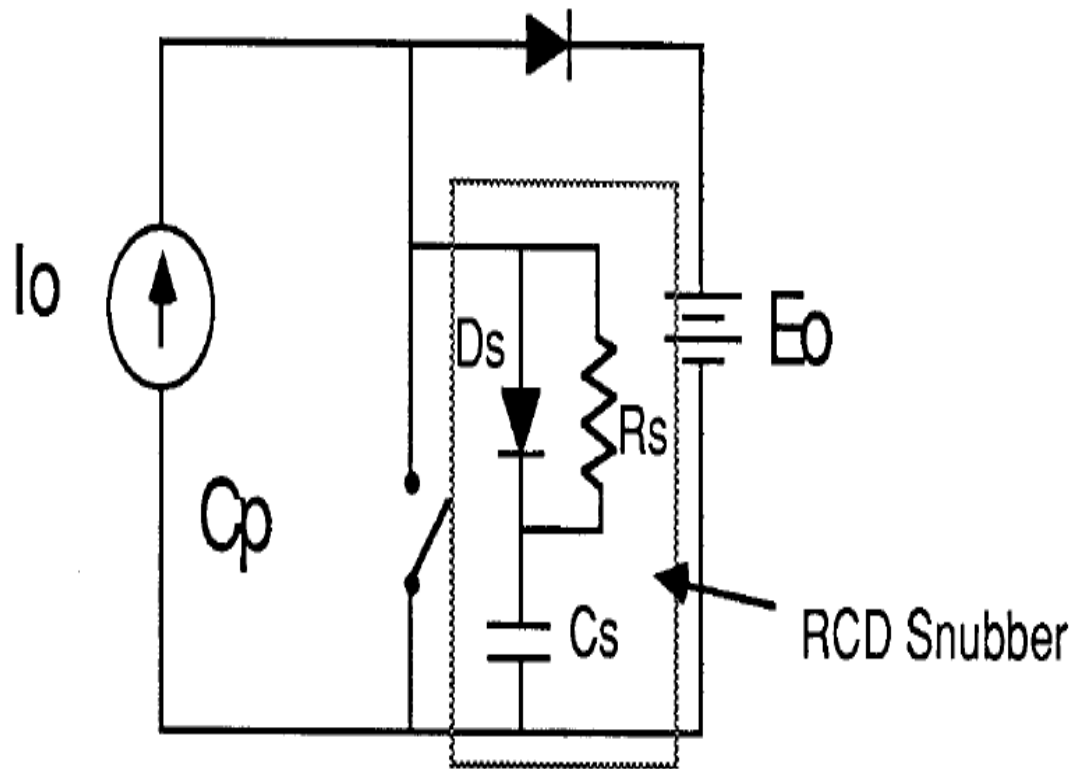
$R=14k\text{-}3W / 10 \text{ nF}$



Rs Cs Switching Effect

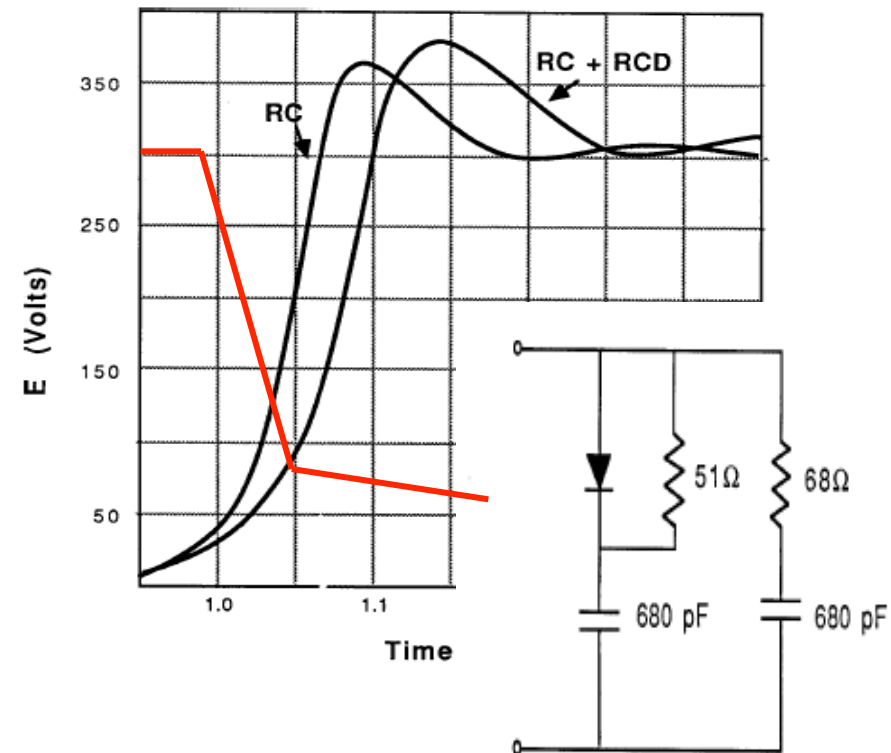
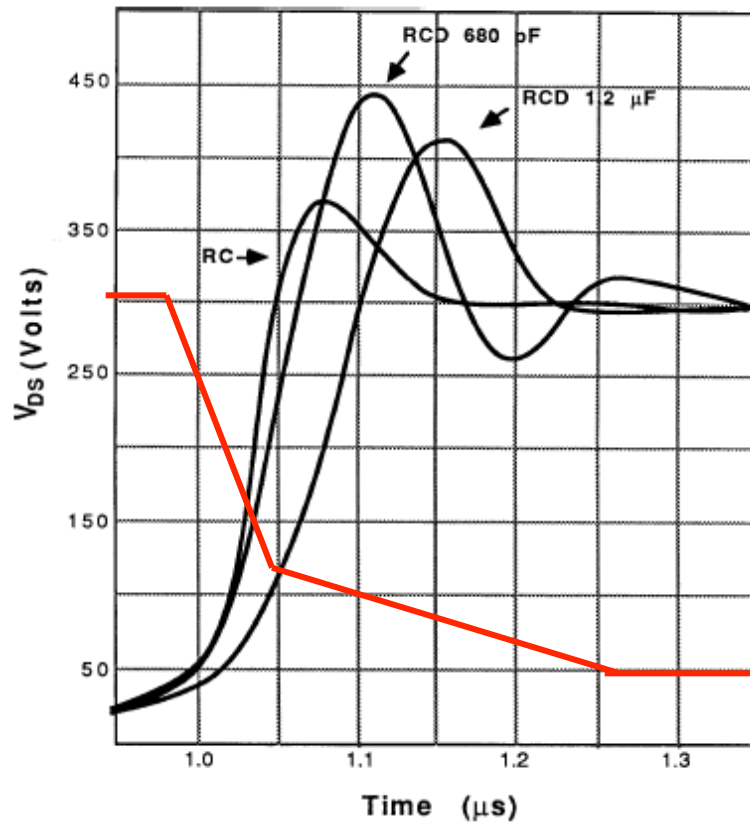


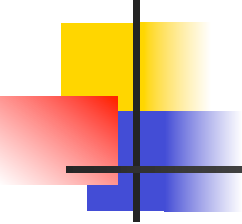
RCD Snubber



$$R = \frac{2}{t_{on \min} C_s}$$

RCD compare to RC // RCD





Conclusions

- RC snubber dissipates more:
 - => Evaluate Total Losses in the converter:
 - Lower Ratings Switch w/ less losses
 - Lower EMI w/ size reduced Filter => less loss
- RCD "non dissipative" snubber but higher overvoltage
=> higher losses in switches & filter.
- Snubber not efficient with small impedance sources
=> try to reduce parasitic elements (PCB, Trsf, ..)
- Use LC or LCD snubber for bigger power converter.