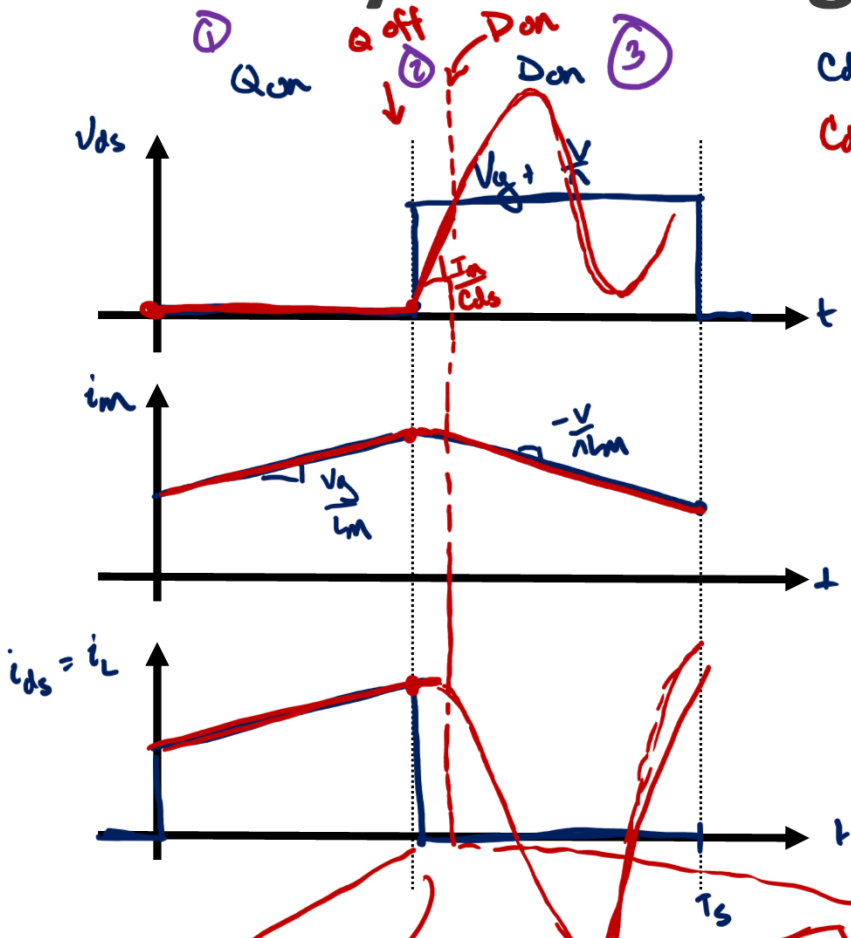
CCM Flyback: Ringing Due to L_l



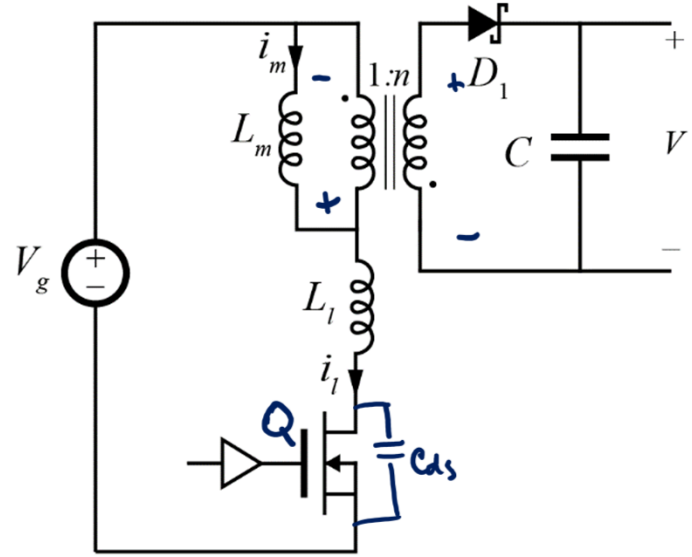
Cds = 0 . Ll = 0

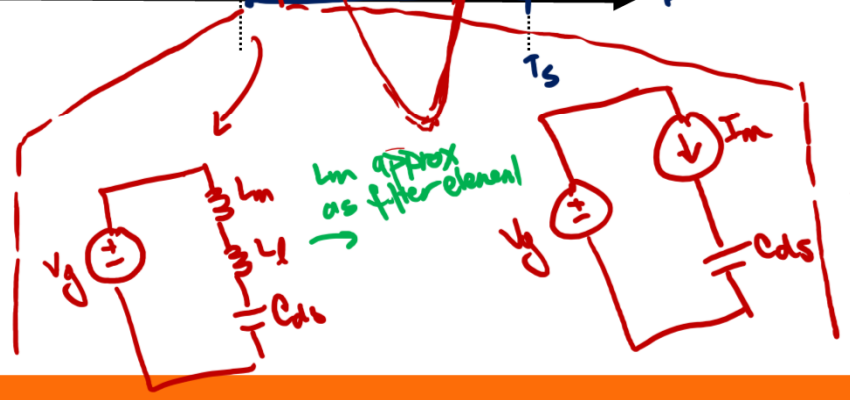
Cds > 0 & Ll > 0

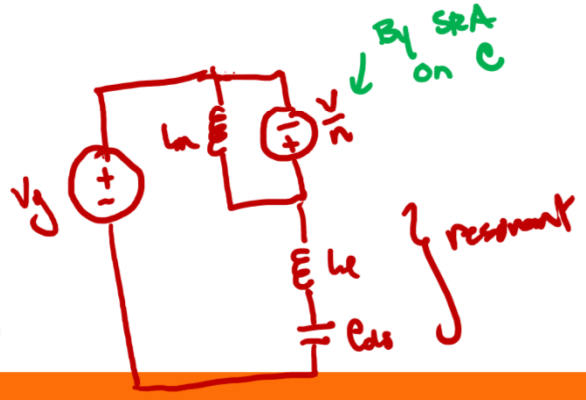
Assume Lm >> Ll

→ Lm + Ll ≈ Lm

SRA applies to C & Lm







③ DC: $v_{ds} \to V_g + \frac{V}{n}$

$i_L \to 0$

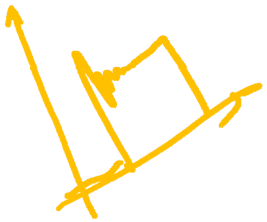
IC: $i_L \to I_m$

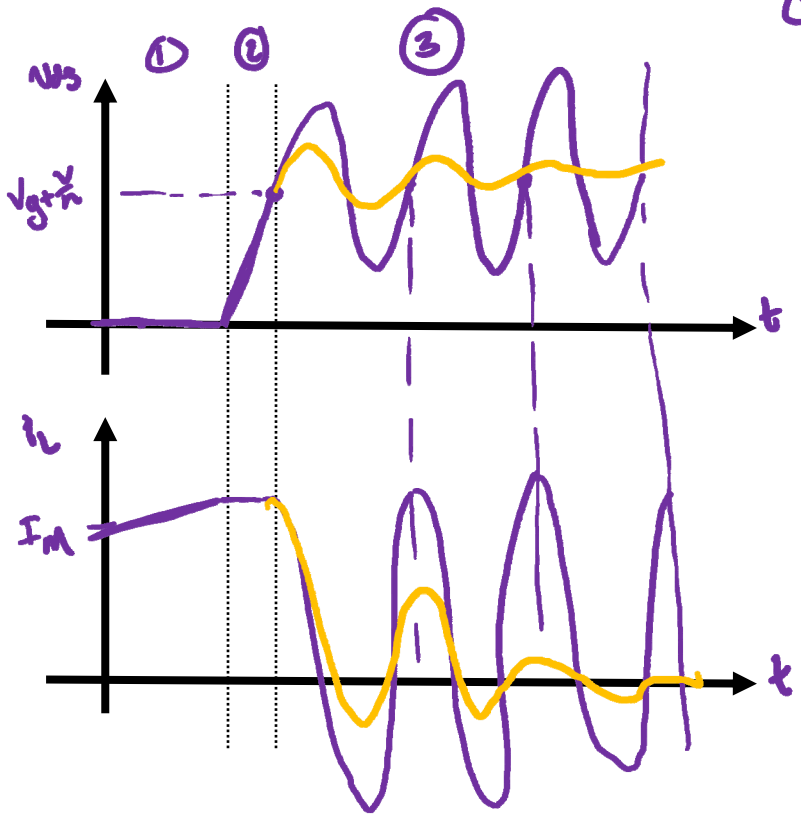
$v_{ds} \to V_g + \frac{V}{n}$

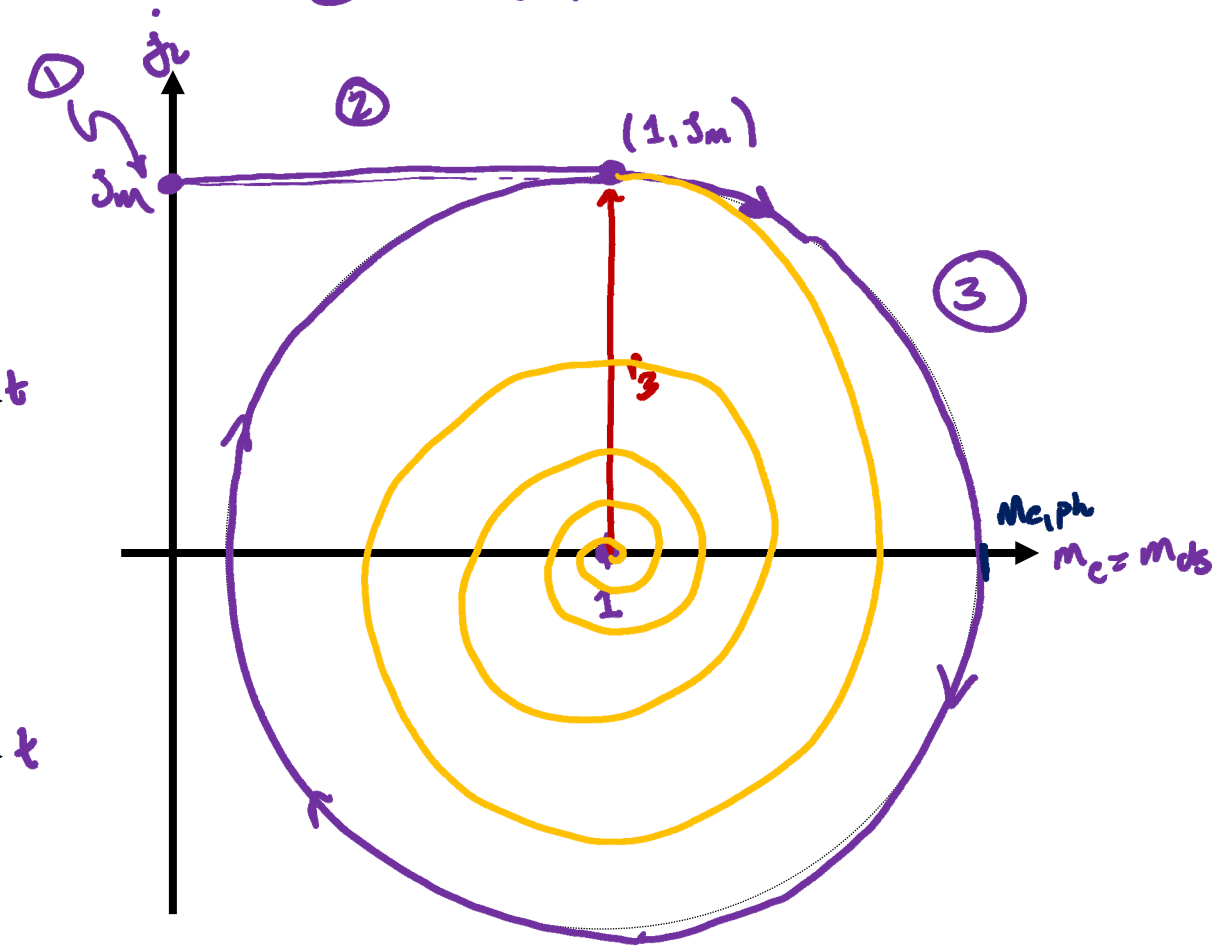
MOSFET Turn-off

$V_{base} = V_g + \frac{V}{n}$ $\quad I_{base} = \frac{V_{base}}{R_0}$

③ DC: $(1, \phi)$ $\quad$ Ic: $(1, J_M)$







Leakage Voltage Stress

$$M_{design} = 1 + r_3 = 1 + \partial_M$$

$$V_{ds,pk} = \underbrace{V_g + \frac{V}{n}}_{\text{Ideal}} + \underbrace{I_m R_0}_{\text{overvoltage stress}}$$

Example Design

$V_g = 400V$

$V = 10V$

$P = 100W$

$f_s = 1MHz$

$n = \frac{1}{40}$, $D = 0.5$

$C_{ds} = 100pF$

$L_m = 1.8mH$

$L_\ell = 35\mu H$ (2% of L_m)

$R_0 = \sqrt{\frac{L_\ell}{C_{ds}}} = 600\Omega$

$$I_m = \frac{n I_{out}}{D} = 500mA$$

$$V_{base} = V_g + \frac{V}{n} = 800V$$

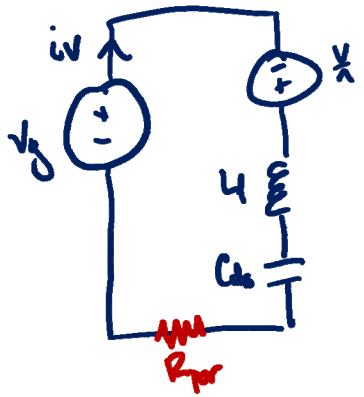
$$V_{ds,pk} = 800V + (.5)\cdot(600) = 1.1kV\ !$$

↓

Huge!

Leakage Switching Loss

If all energy is damped out in ③



$$E_{loss} = \Delta E_l + \Delta E_c + E_v$$

$$\Delta E_l = \frac{1}{2} L_l I_m^2 - \emptyset$$

$$\Delta E_c = \frac{1}{2} C_{ds} V_{base}^2 - \frac{1}{2} C_{ds} V_{base}^2 = \emptyset$$

$$E_v = \int_{③} i_v \cdot (V_g + \frac{V}{x}) dt = (V_g + \frac{V}{x}) \cdot \int_{③} i_c(t) dt = \emptyset$$

$Q_c = \emptyset$ because it starts & ends @ $V_g + \frac{V}{x}$

$$E_{loss} = \frac{1}{2} L_l I_m^2$$

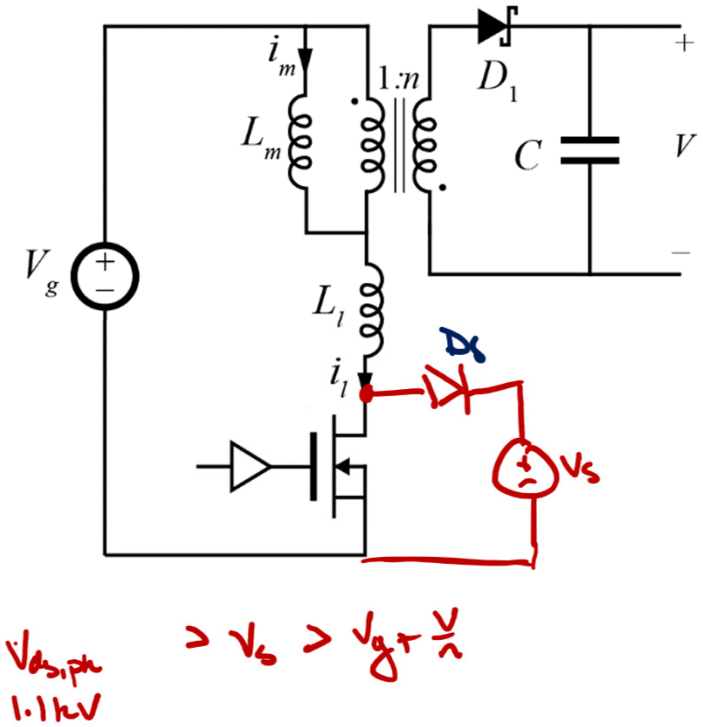
$$P_{loss} = \frac{1}{2} L_l I_m^2 f_s$$

Plug in example #'s

$E_{loss} = 4.4\mu J$

$P_{loss} = 4.4\,W$

CCM Flyback: Clamping Circuit



Clamped State Plane