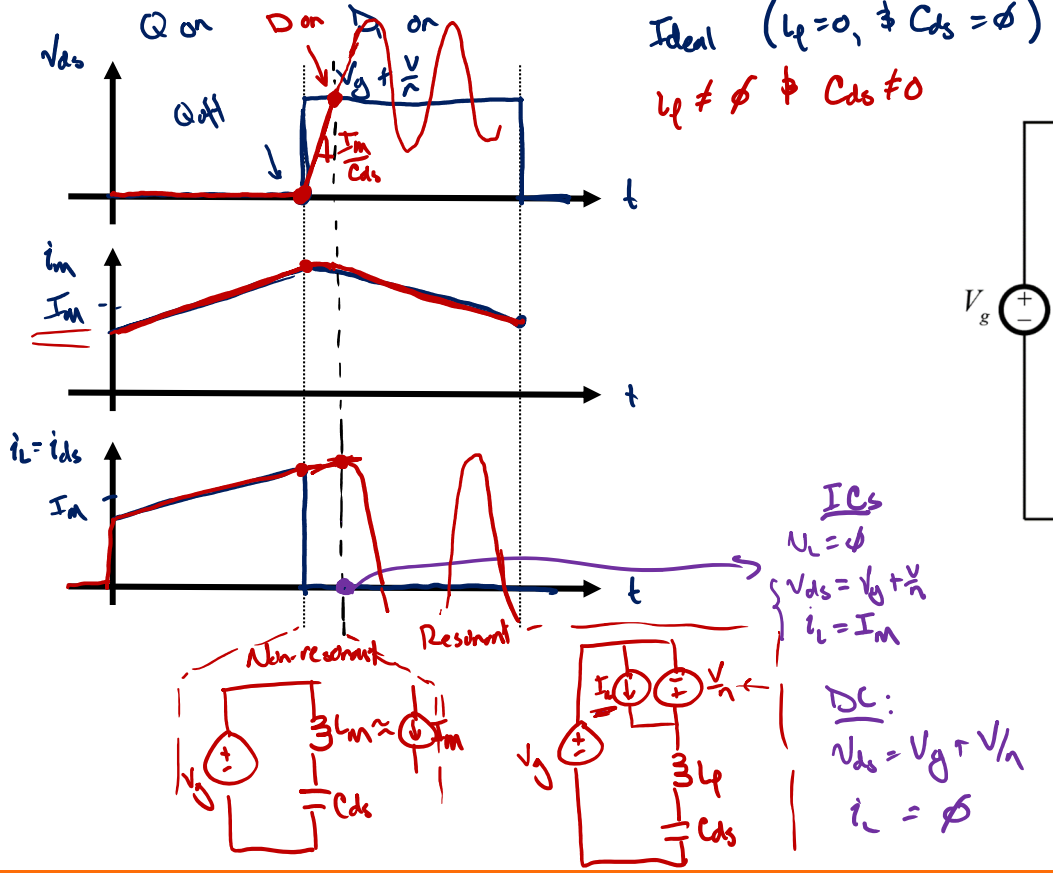
CCM Flyback: Ringing Due to L_l



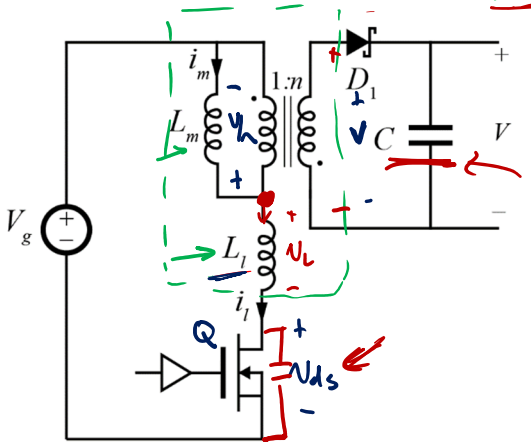
Ideal ($L_l = 0$, & $C_{ds} = 0$)

$L_l \neq 0$ & $C_{ds} \neq 0$

Assume L_m & C are filter elements

Assume $L_l \ll L_m$

$L_l + L_m \approx L_m$



ICs

$v_L = 0$

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

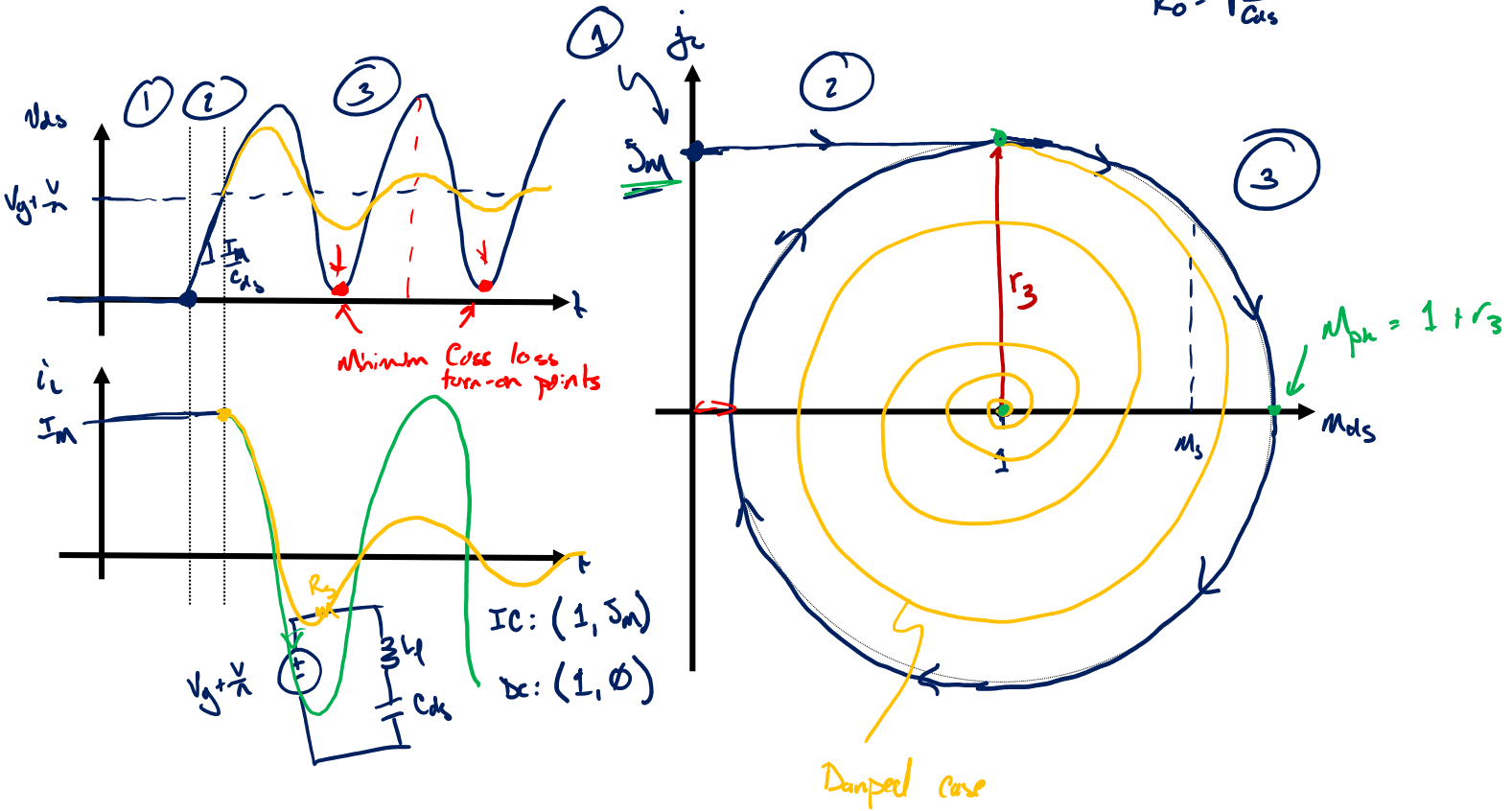
$i_L = I_m$

DC:

$v_{ds} = V_g + V/n$

$i_L = 0$

MOSFET Turn-off



Leakage Voltage Stress

$$J_M = \frac{I_M}{I_{base}} = \frac{I_M R_0}{V_{base}}$$

$$M_{pk} = 1 + r_3 = 1 + J_M$$

$$V_{ds,pk} = V_g + \frac{V}{n} + I_M R_0$$

Example Numbers

$V_g = 400V$

$V = 10V$

$P = 100W$

$f_s = 1MHz$

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

$C_{ds} = 100pF$

$L_M = 1.8mH$

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

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

$$I_M = \frac{nI_{out}}{D'} = 500mA$$

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

$$V_{ds,pk} = 800V + (0.5)(600)$$

$$= 1.1kV\ !$$

Leakage Switching Loss

For the damped case where we converge to the DC operating point in (3)

From the state plane:

$$E_{start} = \frac{1}{2} C_{ds} \left(V_g + \frac{V}{n}\right)^2 + \frac{1}{2} L_l I_m^2$$

$$E_{end} = \frac{1}{2} C_{ds} \left(V_g + \frac{V}{n}\right)^2$$

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

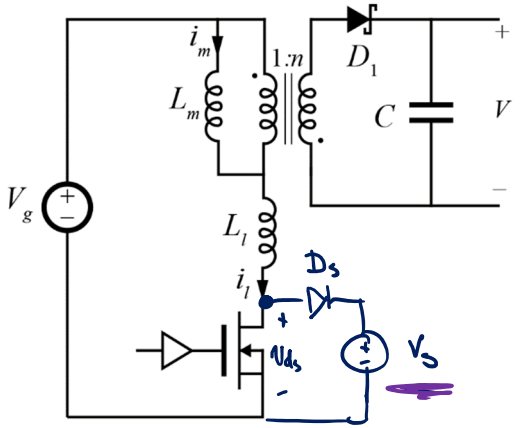
Note: $E_{removed}$ could be loss or recovered into a source

In this case, $E_{source} = 0$, $E_{removed} = E_{loss}$

$$E_{loss} = 4.4\mu J$$

$$P_{loss} = 4.4\,W$$

CCM Flyback: Clamping Circuit



design $V_g \frac{V}{n} < V_3 < V_{ds,pk}$

Clamped State Plane