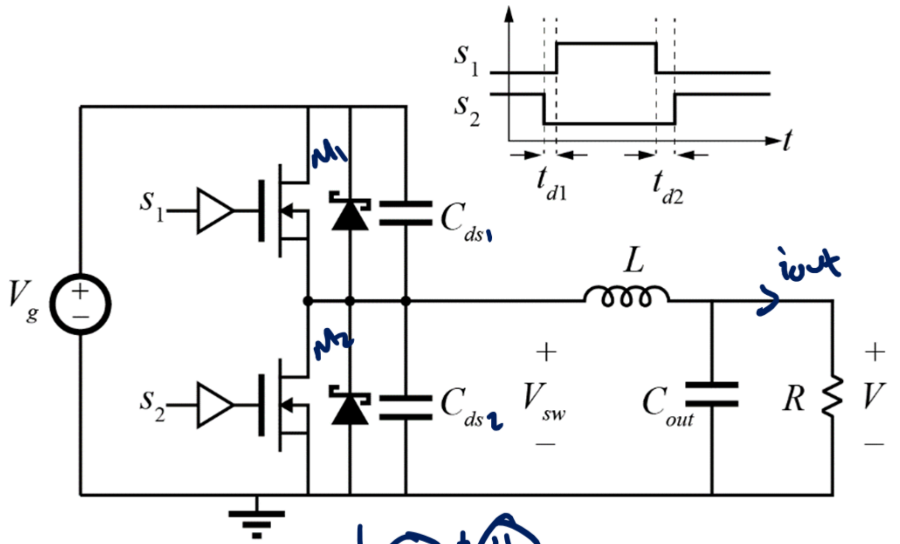
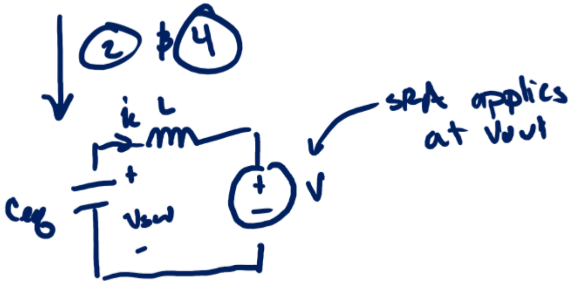
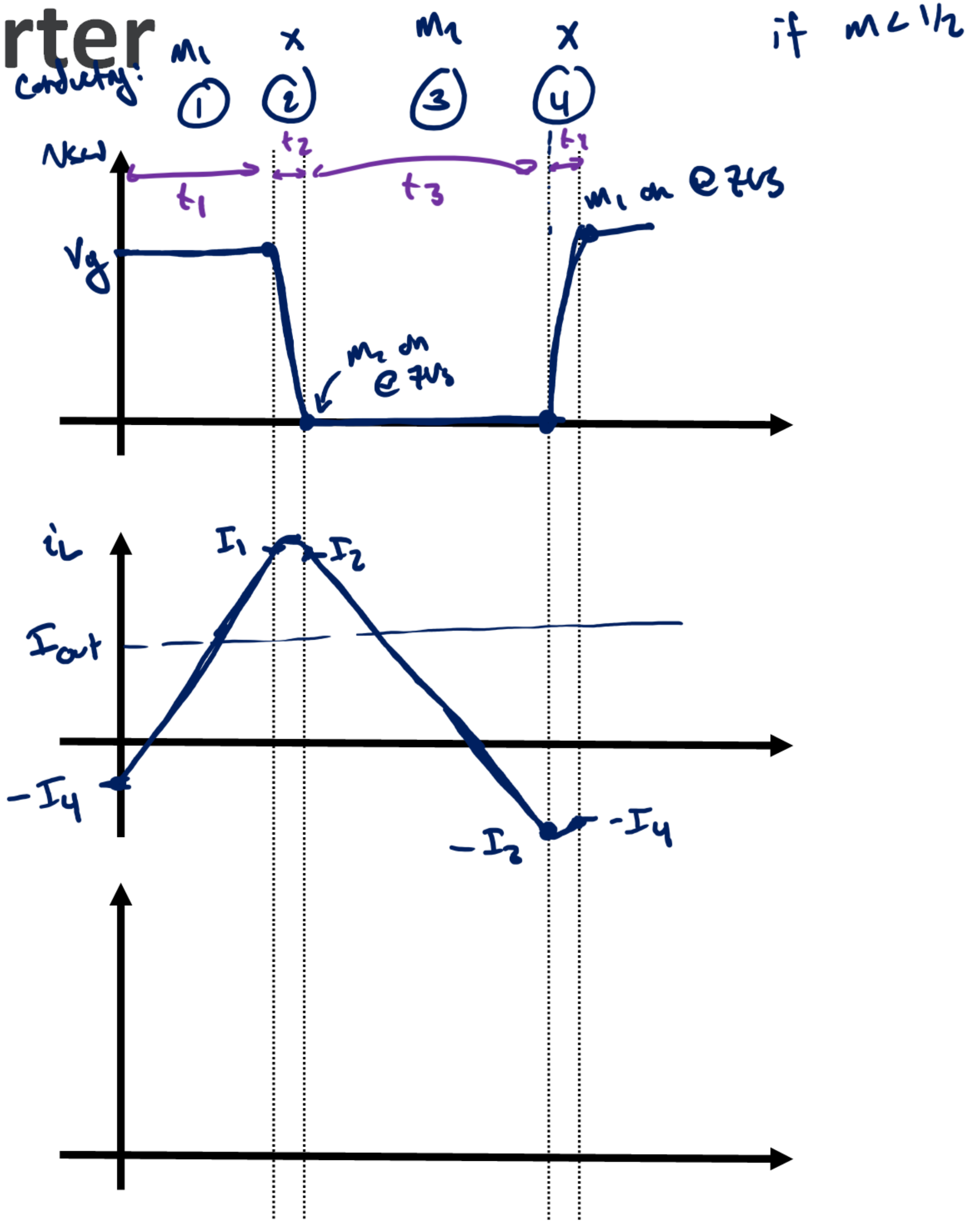
Synchronous Buck Converter





Ceq = Cds1||Cds2



DC solution: Vsw → V iL → 0

Initial condition varies for ② & ④

for ④ Vsw(t=0) = 0
iL(t=0) = −I3

Sync-Buck State Plane

During ④

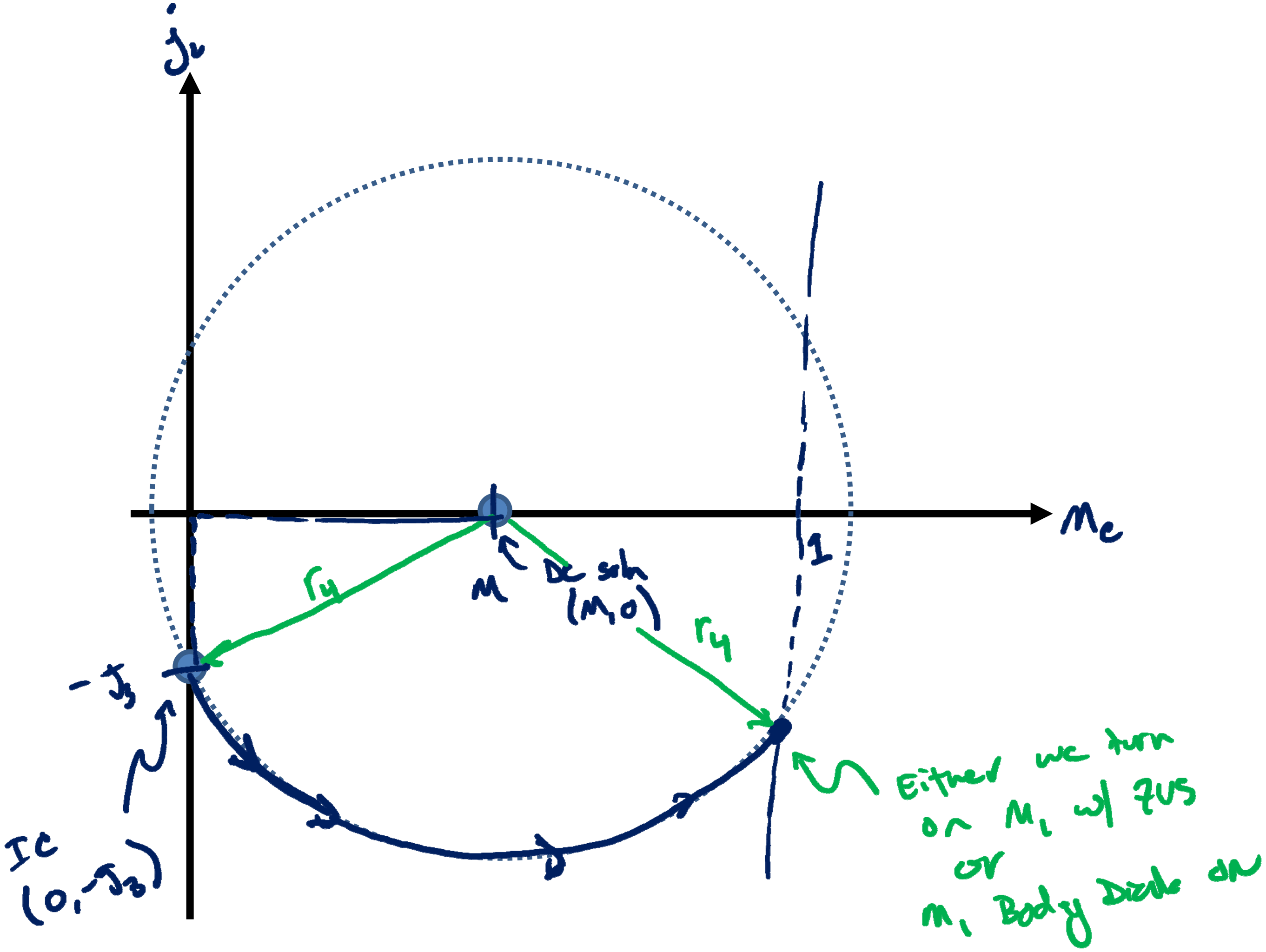
$V_{base} = V_g$ $\quad I_{base} = \frac{V_g}{R_0}$

DC: (M, ϕ)

IC: $(0, -J_3)$, $-J_3 = \frac{-I_3}{I_{base}}$

Initial Direction:

$\left.\frac{du_{sw}}{dt}\right|_{t=0} > \phi$ because $-J_3 < 0$



Sync-Buck ZVS Condition

Can get ZVS as long as

$$r_4 \geq 1 - M \quad , \qquad r_4 = \sqrt{J_3^2 + M^2}$$

$$\sqrt{J_3^2 + M^2} + M \geq 1$$

$$\sqrt{\left(\frac{I_3 R_0}{V_g}\right)^2 + \left(\frac{V}{V_g}\right)^2} + \frac{V}{V_g} \geq 1 \qquad R_0 = \sqrt{\frac{L}{C_{eq}}}$$

$$\left(\frac{I_3 R_0}{V_g}\right)^2 + \left(\frac{V}{V_g}\right)^2 \geq \left(1 - \frac{V}{V_g}\right)^2$$

$$(I_3 R_0)^2 + V^2 \geq (V_g - V)^2$$

$$\frac{1}{2} I_3^2 L + \frac{1}{2} C_{eq} V^2 \geq \frac{1}{2} C_{eq} (V_g - V)^2$$

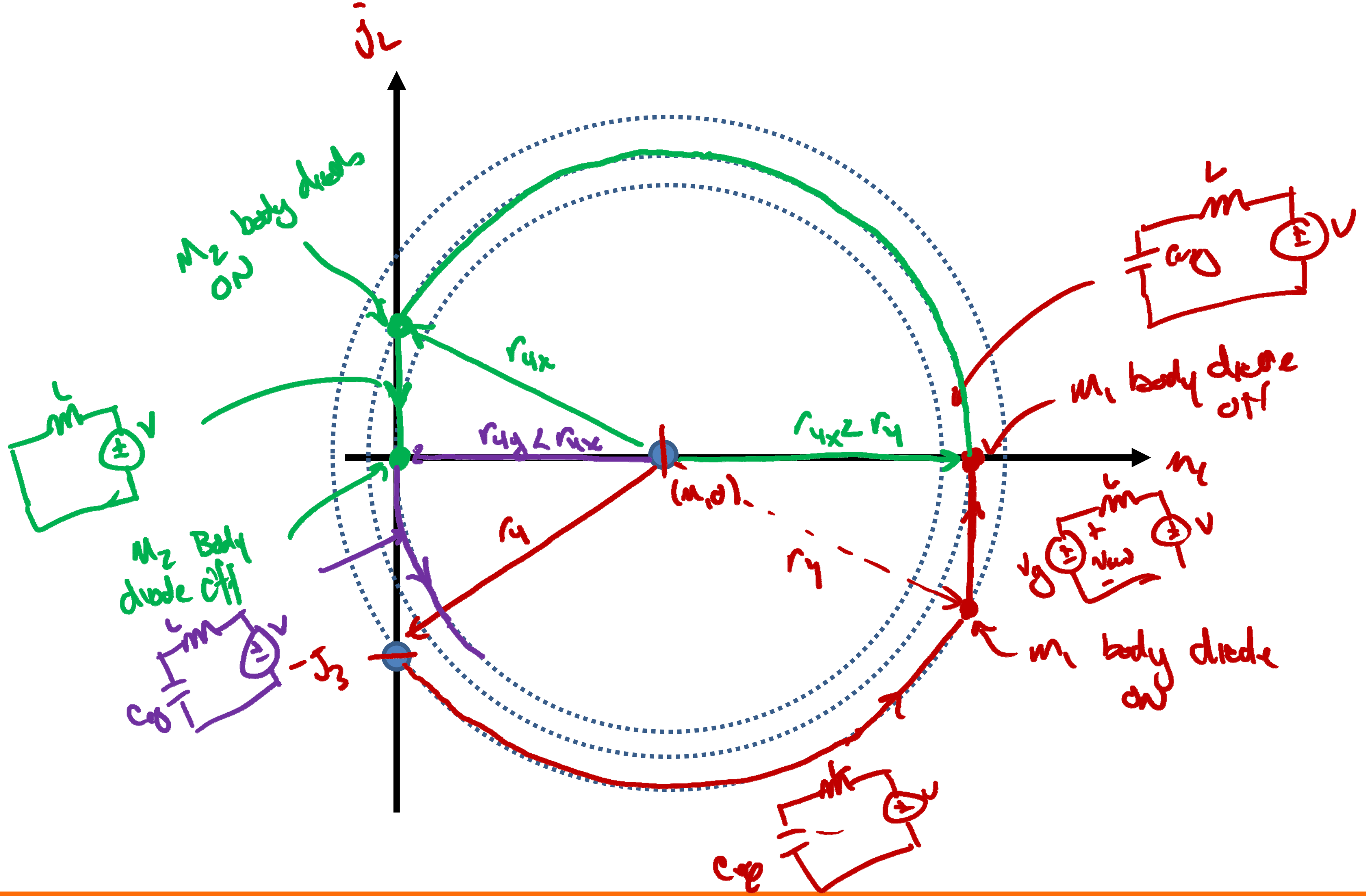
$$\frac{1}{2} L I_3^2 \geq -\cancel{\frac{1}{2} C_{eq} V^2} + \frac{1}{2} C_{eq} V_g^2 + \cancel{\frac{1}{2} C_{eq} V^2} - \underbrace{C_{eq} V_g}\, V$$

Initial inductor energy

energy into C_{eq} for ZVS

Q into V_g $= \int i_L\, dt$

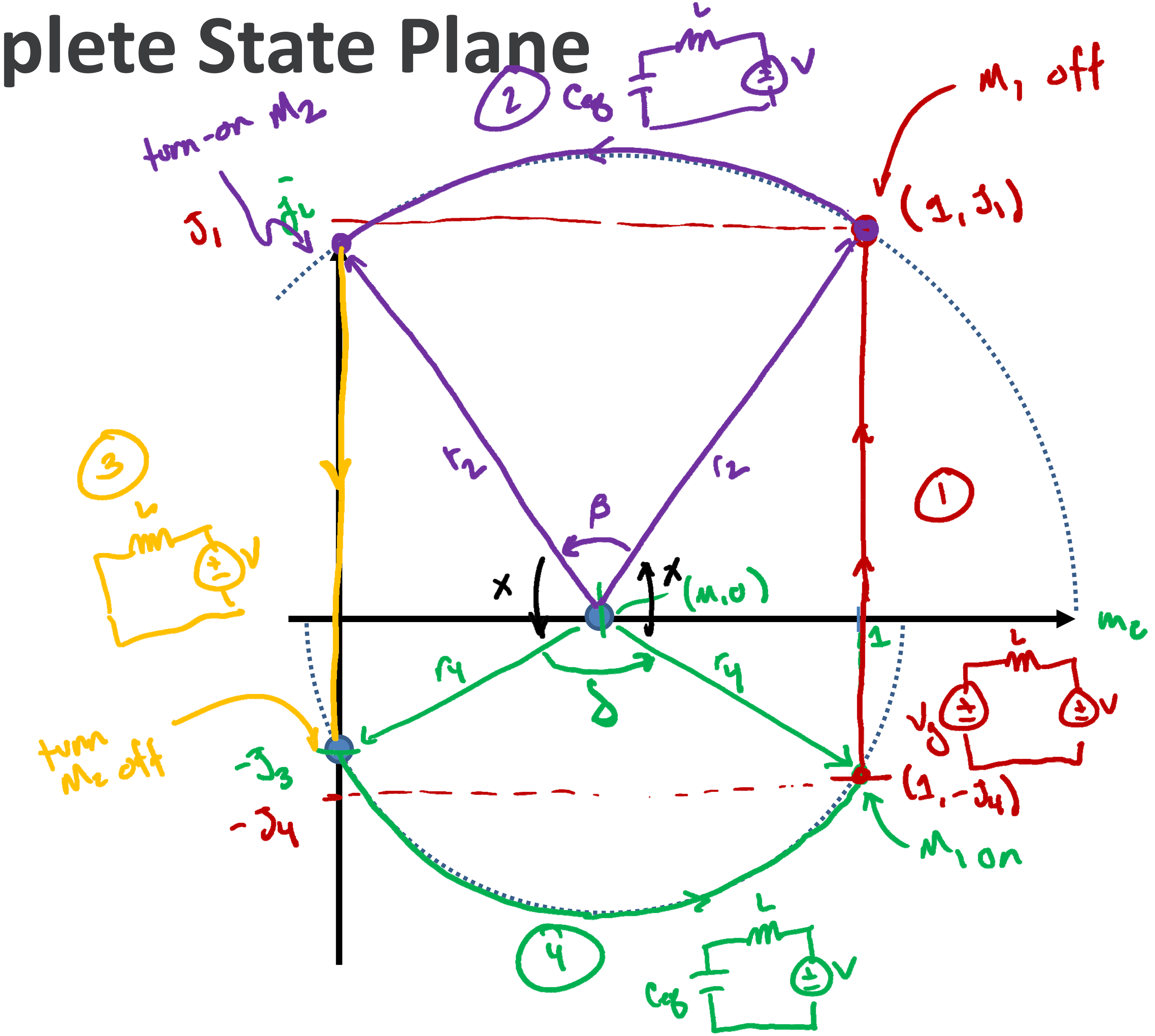
Sync-Buck State Plane (Ring out)



Sync-Buck Complete State Plane

$\beta = t_2 \omega_0$

$\delta = t_4 \omega_0$



ZVS conditions:

④ $r_4 = \sqrt{M^2 + J_3^2} \geq 1 - M$

② $r_2 \geq M$

$\sqrt{J_1^2 + (1-M)^2} \geq M$