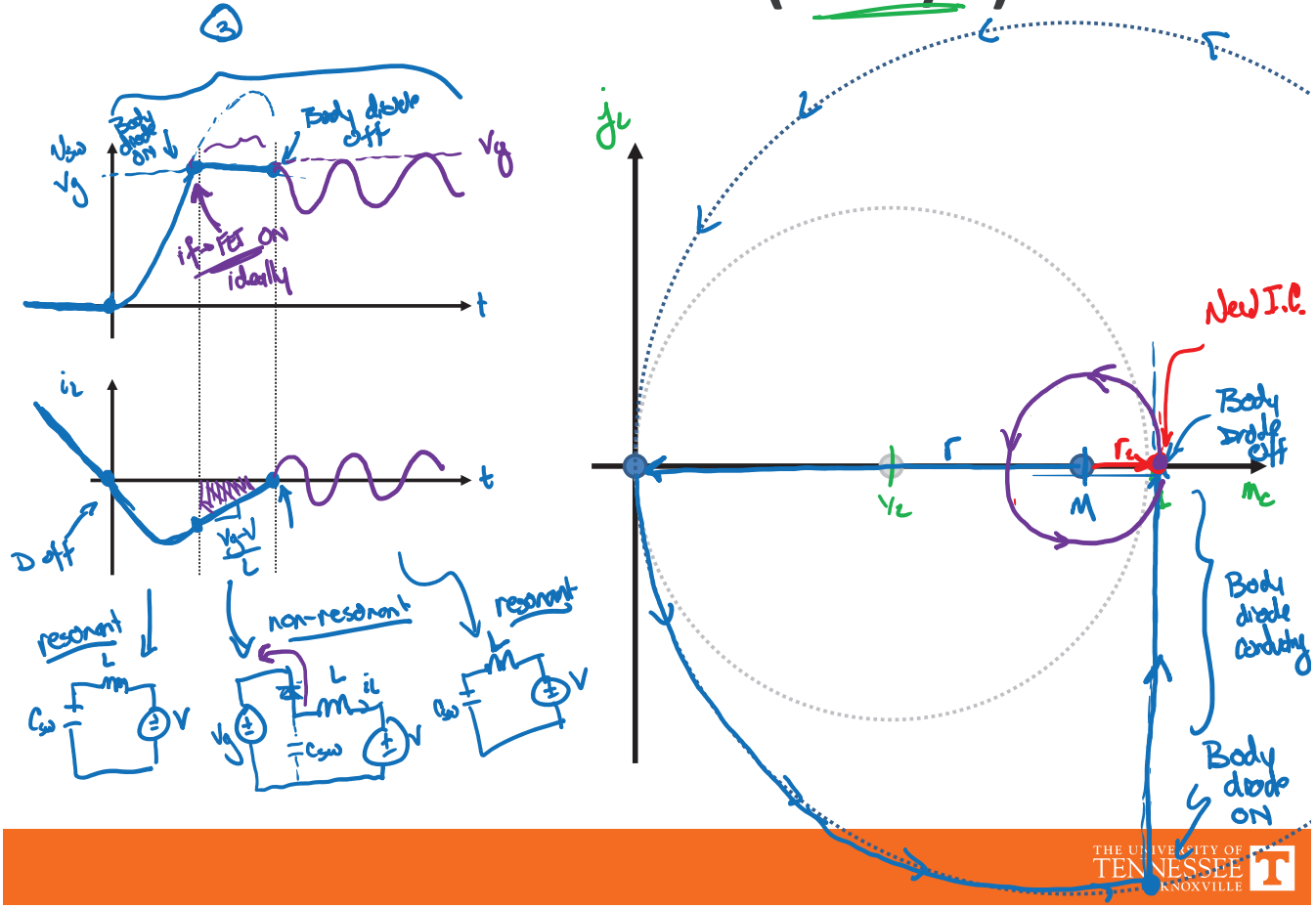
DCM Buck State Plane (M>1/2)



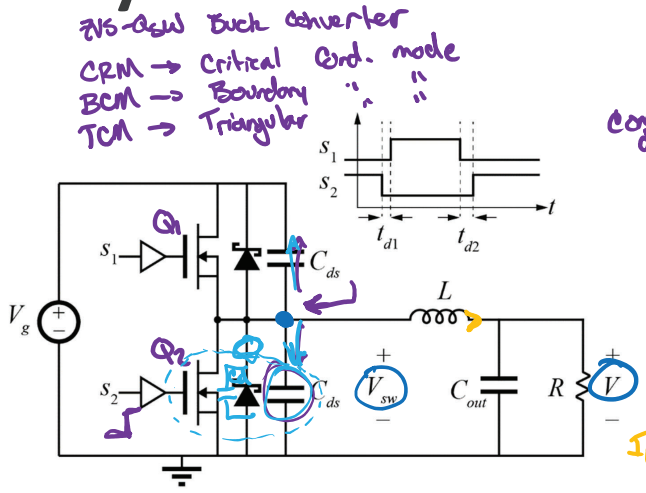
Synchronous Buck Converter

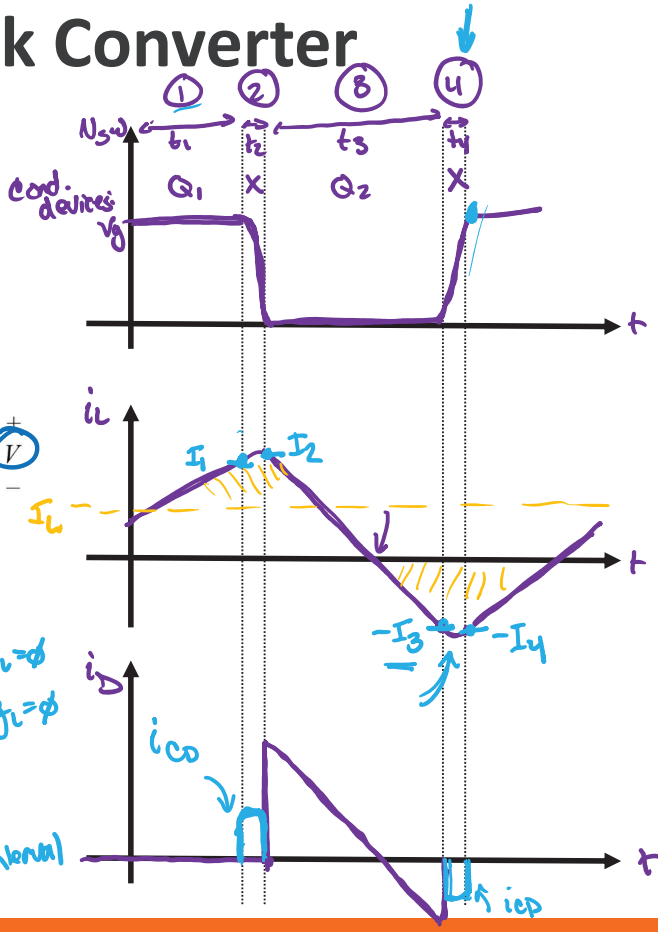
ZVS-CSW Buck converter

CRM → Critical Cond. mode

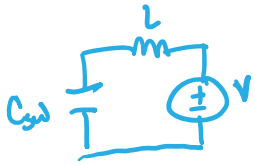
BCM → Boundary "

TCM → Triangular "





② & ④ equivalent ac circuit:



DC: $V_{sw} = V$, $i_L = 0$

$m_c = M$, $j_L = 0$

w/ $V_{base} = V_g$

IC: vary by interval

Sync-Buck State Plane

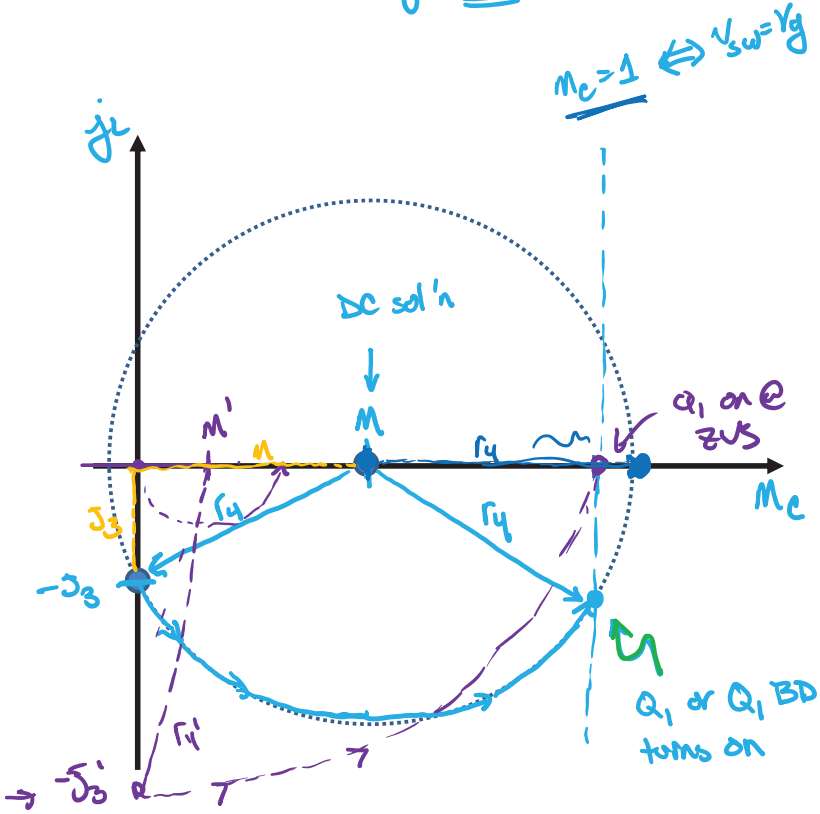
During (4)

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

DC: $(M, 0)$

IC: $i_L = -I_3$ $v_{sw} = 0$

$j_L = -J_3$, $m_c = 0$



Sync-Buck ZVS Condition

for ZVS turn-on of Q_1.

$r_4 = \sqrt{M^2 + J^2}$

$M + r_4 \geq 1$

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

Denormalize:

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

$$V^2 + I_3^2 \frac{L}{C_{sw}} \geq (V_g - V)^2, \quad R_0 = \sqrt{\frac{L}{C_{sw}}}$$

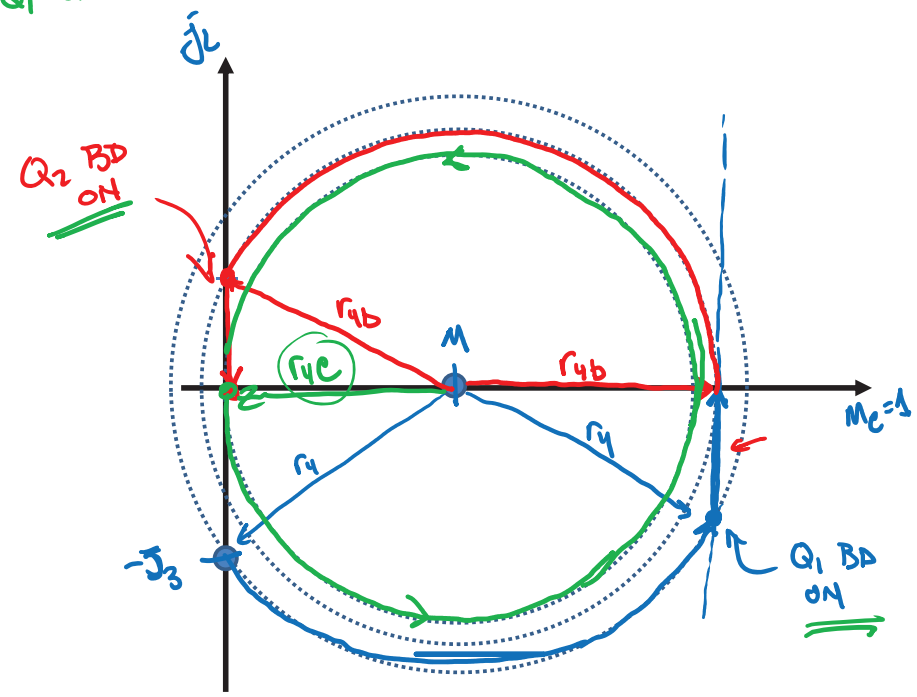
$$C_{sw} V^2 + L I_3^2 \geq C_{sw} (V_g - V)^2$$

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

↑ L initial energy

Sync-Buck State Plane (Ring out)

If we never turn Q_1 on after interval (4)



Sync-Buck Complete State Plane

(2): IC: $i_L = I_1$ $v_{sw} = v_g$
$j_L = J_1$ $m_c = 1$