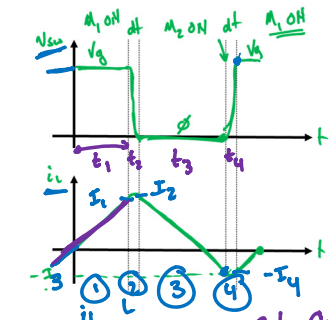
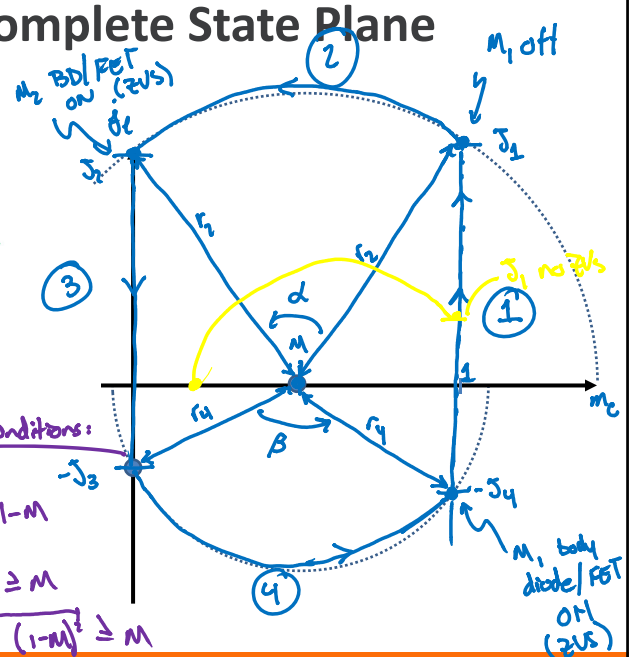
Sync-Buck Complete State Plane

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





ZVS Conditions:

4: $r_4 \geq 1-M$

2: $r_2 \geq M$

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

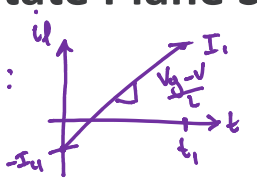
2: ICs:

$v_c(0) = V_g$

$i_L(0) = I_1$

State Plane Solution: Intervals 1 & 2

1:



$$\left(\frac{1}{I_{base}}\right)\frac{V_g - V}{L} t_1 = I_1 + I_4 \left(\frac{1}{I_{base}}\right)$$

$$\frac{R_o}{V_g}\frac{V_g - V}{L} t_1 = J_1 + J_4$$

$$\frac{R_o}{L}\frac{V_g - V}{V_g} t_1 = J_1 + J_4$$

$$\frac{R_o}{L} = \frac{\sqrt{L/C_{sw}}}{L} = \frac{1}{\sqrt{LC_{sw}}} = \omega_o$$

$\theta_1 = \omega_o t_1$

$$\boxed{\theta_1 (1-M) = J_1 + J_4}$$

2:

$$r_2^2 = \left\{ \begin{array}{l} J_1^2 + (1-M)^2 \\ J_2^2 + M^2 \end{array} \right\} \rightarrow \boxed{J_1^2 + (1-M)^2 = J_2^2 + M^2}$$

$$\boxed{\alpha = \pi - \tan^{-1}\left(\frac{J_1}{1-M}\right) - \tan^{-1}\left(\frac{J_2}{M}\right)}$$

State Plane Solution: Intervals 3 & 4

③: $-\frac{V}{L} t_3 = -(I_2 + I_3)$

$\boxed{M D_3 = S_2 + S_3}$

same process

④: $r_3^2 = \boxed{S_3^2 + M^2 = S_4^2 + (1-M)^2}$

$$\boxed{\beta = \pi - \tan^{-1}\left(\frac{S_3}{M}\right) - \tan^{-1}\left(\frac{S_4}{1-M}\right)}$$

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State Plane Solution: Averaging Step

$$\langle i_{out} \rangle \big|_{T_s} = I_{out} = \langle i_L \rangle \big|_{T_s} = \frac{1}{T_s} \int_0^{T_s} i_L \, dt$$

$$I_{out} = \frac{1}{T_s} \left[\int_0^{t_1} i_L \, dt + \int_{t_1}^{t_2} i_L \, dt + \dots \right]$$

$$I_{out} = \frac{1}{T_s} \left[\underbrace{\frac{I_1 - I_4}{2} t_1}_{①} + \underbrace{\cancel{-\delta c}}_{②} + \underbrace{\frac{I_2 - I_3}{2} t_3}_{③} + \underbrace{\cancel{\delta c}}_{④} \right]$$

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