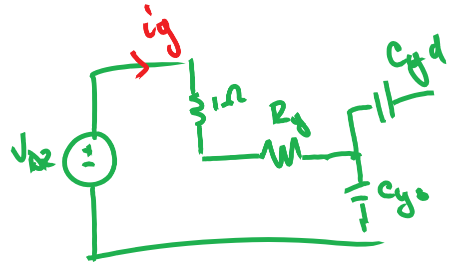
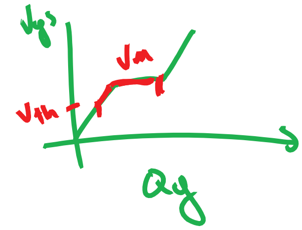
Announcements

- No Office Hours Tuesday, 9/18

$\approx V_m$

$$i_g = \frac{V_{DR} - V_{gs}}{1\Omega + R_g}$$

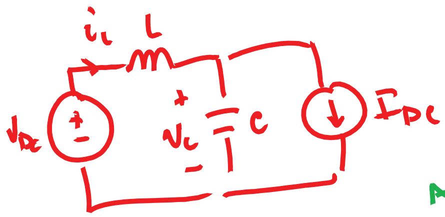




State Plane Analysis

Direction: look at 1st derivatives

@ t=0 : $C\frac{dv_c}{dt} = I_0 - I_{DC}$



$m_c = \frac{v_c}{V_{base}}$ V_{base} = Anything you want

$j_L = \frac{i_L}{I_{base}}$ $I_{base} = \frac{V_{base}}{R_0}$

Circle center = DC solution

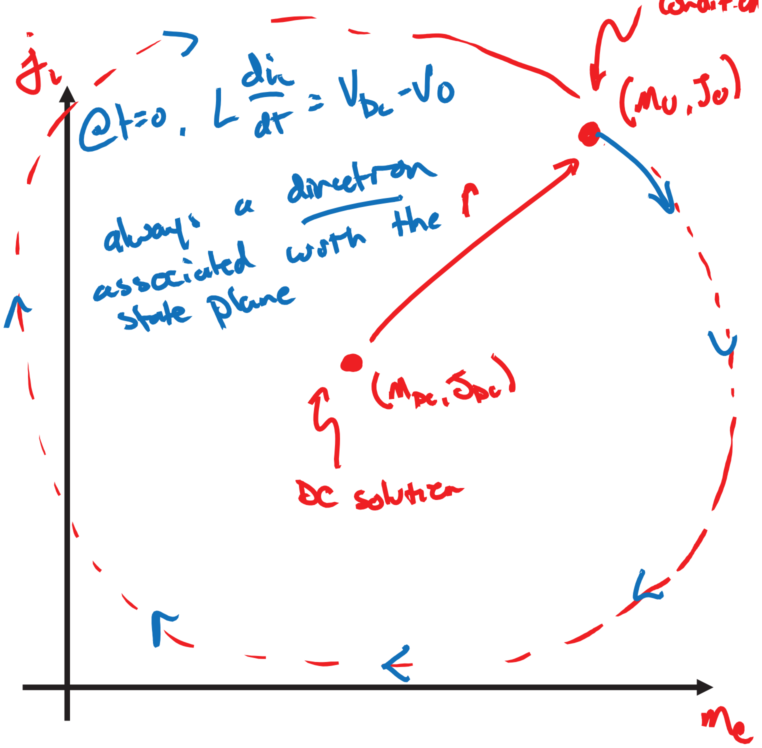
$v_c = V_{DC}$ $m_c = M_{DC}$

$i_L = I_{DC}$ $j_L = J_{DC}$

Initial condition:

$v_c(t=0) = V_0 \rightarrow M_0$

$i_L(t=0) = I_0 \rightarrow J_0$



[1] R. Oruganti and F. C. Lee, "Resonant Power Processors, Part I – State Plane Analysis", Industry Applications, IEEE Tran. on, vol. 21, no. 6, nov 1985.

[2] D. P. Atherton, Nonlinear Control Engineering. London: Van Nostrand Reinhold, 1982, Ch. 2.

Example Analysis

What is $i_{L,pk}$?

$$i_{L,pk} \cdot \frac{R_0}{V_{base}} = j_{L,pk}$$

$$i_{L,pk} = j_{L,pk} \frac{V_{base}}{R_0}$$

$$j_{L,pk} = J_{DC} + r$$

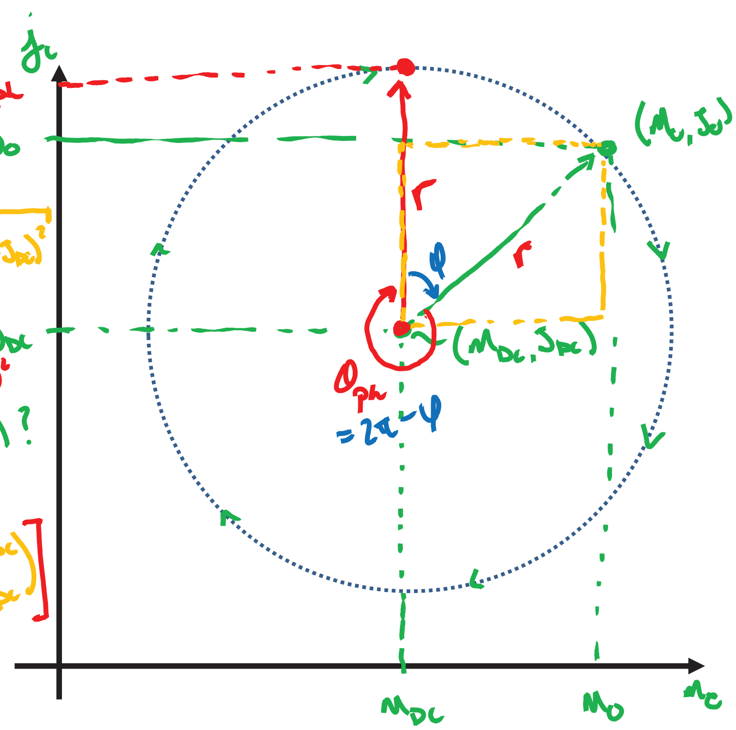
$$j_{L,pk} = J_{DC} + \sqrt{(M_0 - M_{DC})^2 + (J_0 - J_{DC})^2}$$

$$i_{L,pk} = I_{DC} + \frac{V_{base}}{R_0}\sqrt{(M_0 - M_{DC})^2 + (J_0 - J_{DC})^2}$$

When does $i_{L,pk}$ occur (in time)?

$$\theta_{pk} = \omega_0 t_{L,pk}$$

$$t_{L,pk} = \frac{1}{\omega_0}\left[2\pi - \tan^{-1}\left(\frac{M_0 - M_{DC}}{J_0 - J_{DC}}\right)\right]$$



State Plane Algorithm

Start w/ circuit with 1 L & 1 C & DC bias

- May require manipulation or approximation to reduce circuit to 1L - 1C.

(1) Normalize: $m_x = \frac{v_x}{V_{base}}$, V_{base} is unconstrained

$j_x = \frac{i_x}{I_{base}}$, $I_{base} = \frac{V_{base}}{R_0}$

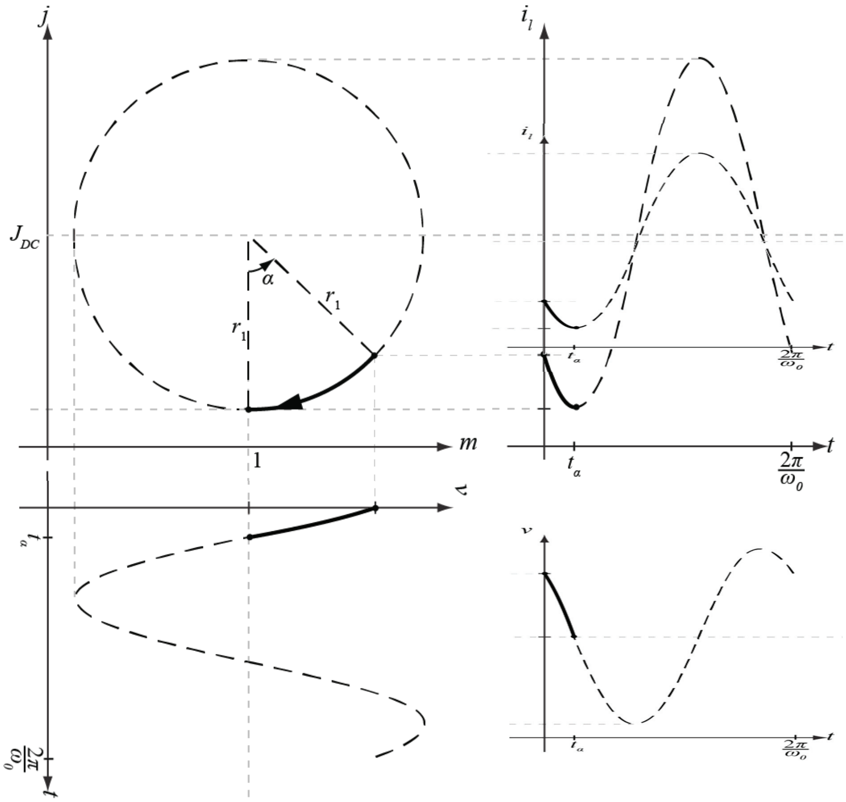
$$\theta_x = \omega_0 t_x$$

(2) Plot resonant trajectory on $m_x - j_x$ axes

- forms a circle with:
  - center @ DC solution
  - one point @ initial condition
  - direction from IC on first derivatives

(3) Solve for parameters of interest on state plane

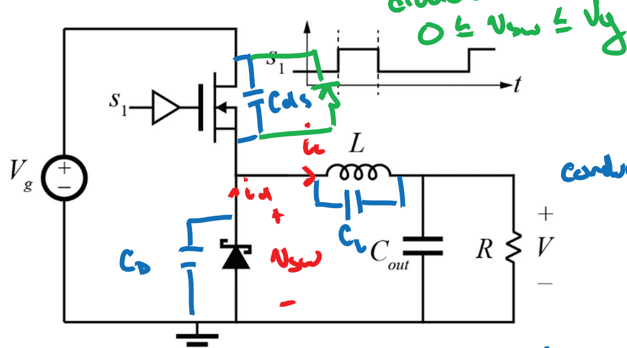
(4) Denormalize.



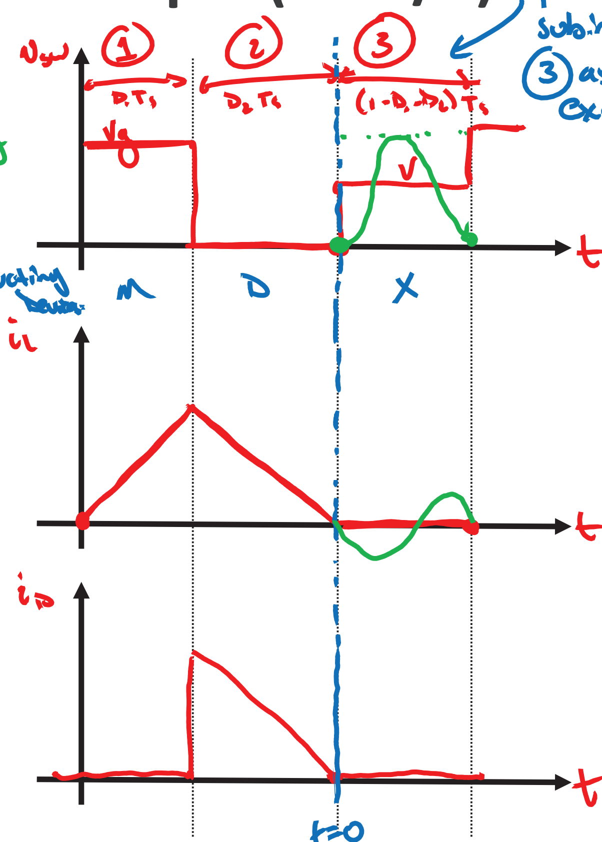
DCM Buck Converter Example (M=1/2)

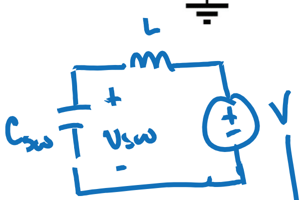
lets say $V = \frac{V_g}{2}$

diodes enforce $0 \le v_{sw} \le V_g$



focus on subinterval ③ as example





$C_{sw} = C_{ds} \| C_D \| C_L$

DC solution:

$v_{sw} = V$

$i_L = 0$

Initial Conditions:

$v_{sw}(t=0) = 0$

$i_L(t=0) = 0$

$v_{sw}'(t=0) = 0$

$i_L'(t=0) = -\frac{V}{L} < 0$

DCM Buck State Plane

in 3

$M = \frac{1}{2}$ when $V = \frac{V_g}{2}$

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

DC: $v_{sw} = V \longrightarrow m_{sw} = \frac{V}{V_g} = M$

$i_L = 0 \longrightarrow j_L = 0$

$\rightarrow$ center @ $(M, 0)$

IC:

$v_{sw} = 0 \longrightarrow m_{sw} = 0$

$i_L = 0 \longrightarrow j_L = 0$

Duration:

diode-limited

$0 \le v_{sw} \le V_g$

$0 \le m_{sw} \le 1$