State Plane Analysis

if lossless, r is constant

ex/ what is $i_{L,max}$?

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

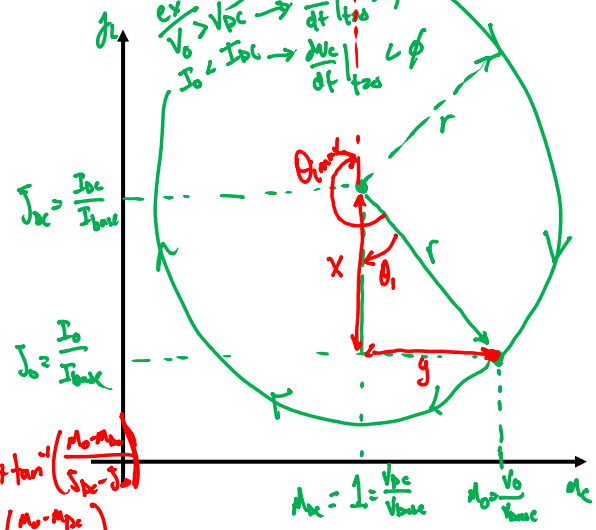
Denormalize

$i_{L,max} = j_{L,max} I_{base}$

$\boxed{= I_{DC} + r I_{base}}$

ex/ $V_0 > V_{DC} \rightarrow \left.\frac{di_L}{dt}\right|_{t=0} \angle \phi$

$J_0 < J_{DC} \rightarrow \left.\frac{dv_C}{dt}\right|_{t=0} \angle \phi$



ex/ when does $i_{L,max}$ occur? $J_0 = \frac{I_0}{I_{base}}$

$\theta_{i,max} = \theta_1 + \pi$

$= \pi + \tan^{-1}\left(\frac{y}{x}\right) = \pi + \tan^{-1}\left(\frac{m_0 - m_{DC}}{J_{DC} - J_0}\right)$

$t_{i,max} = \frac{\pi}{\omega_0} + \frac{1}{\omega_0}\tan^{-1}\left(\frac{m_0 - m_{DC}}{J_{DC} - J_0}\right)$

Algorithm

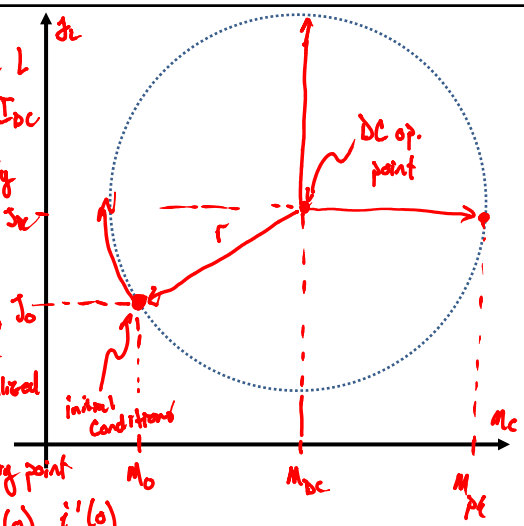
Start: Resonant L-C circuit w/ one L & one C & (potentially) V_{DC} & I_{DC}

① Select V_{base} → 'arbitrary' V/Vg are normally good choices

↳ $I_{base} = \frac{V_{base}}{R_0}$, $R_0 = \sqrt{\frac{L}{C}}$

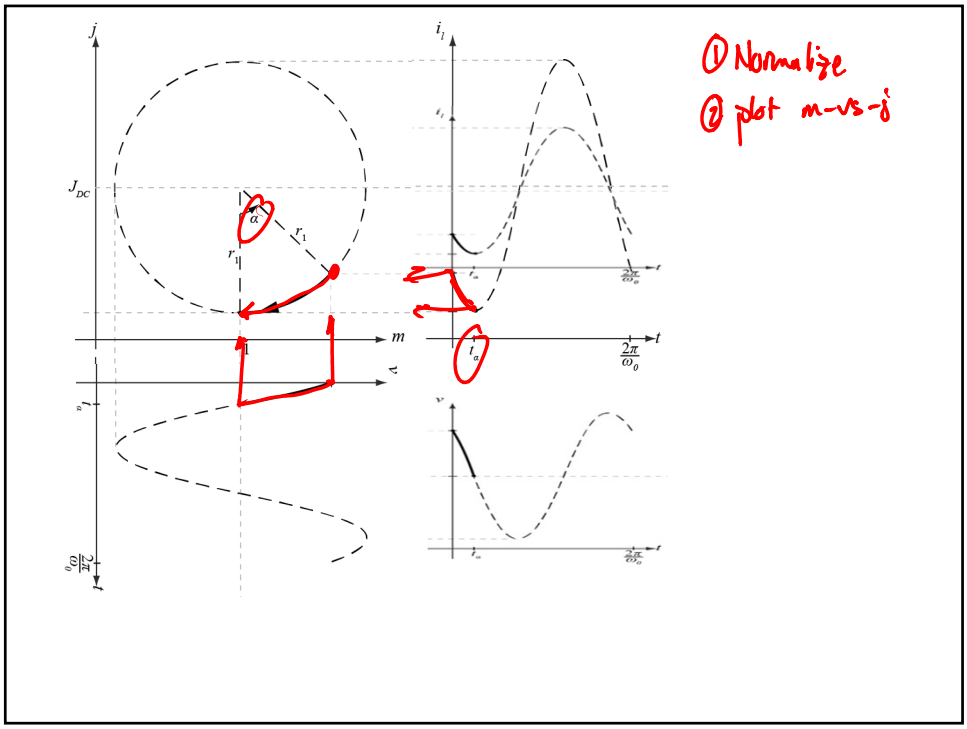
② Normalize & plot $m_c - j_L$ state plane

- Circle centered at the normalized DC operating point
- Radius is the distance to starting point
- Find direction according to $v_c'(0)$, $i_L'(0)$

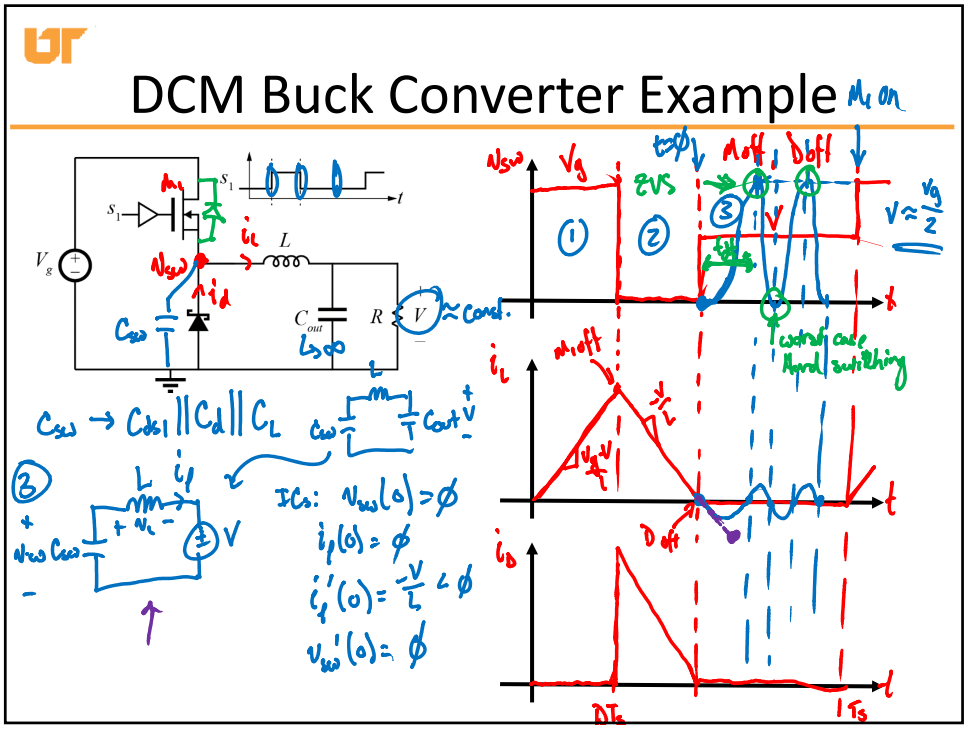


③ Solve for normalized j, m, θ

④ Denormalize according to $\begin{cases} i = j I_{base} \\ v = m V_{base} \\ t = \frac{1}{\omega_0}\theta \end{cases}$



DCM Buck Converter Example



DCM Buck State Plane

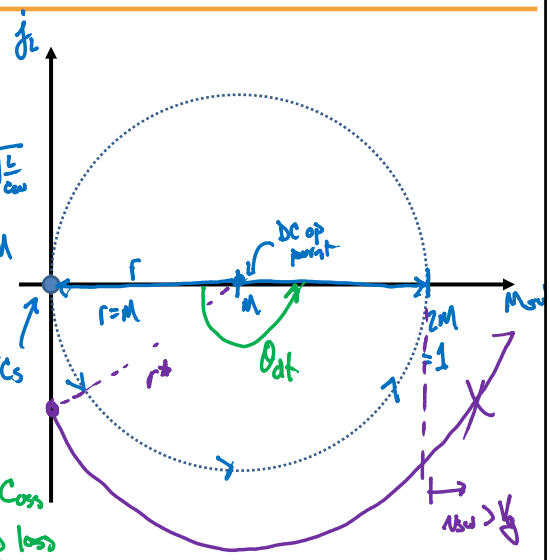
During interval ③
(m_1 off & D_0 off)

① Normalize: Pick $V_{base} = V_g$

$I_{base} = \frac{V_g}{R_0}$ $\quad Z_0 = \sqrt{\frac{L}{C_{sw}}}$

DC op point $\begin{cases} v_{sw} = V \\ i_L = \phi \end{cases}$ $\rightarrow M_{dc} = \frac{V}{V_g} = M$

$i_L'(0) < \phi \rightarrow$ CCW

$\theta_{dt} = \pi$

$t_{dt} = \frac{\pi}{\omega_0}$ → Eliminate C_{oss} & overlap loss