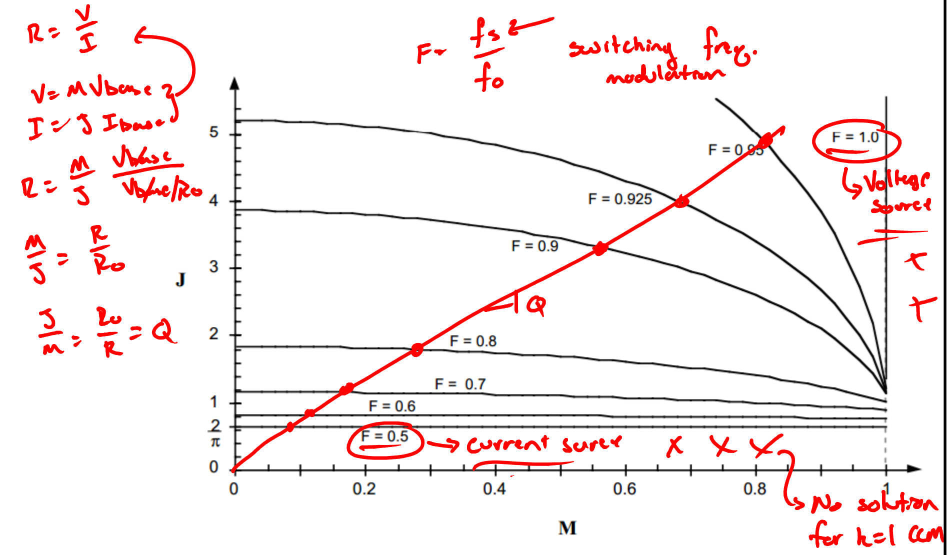
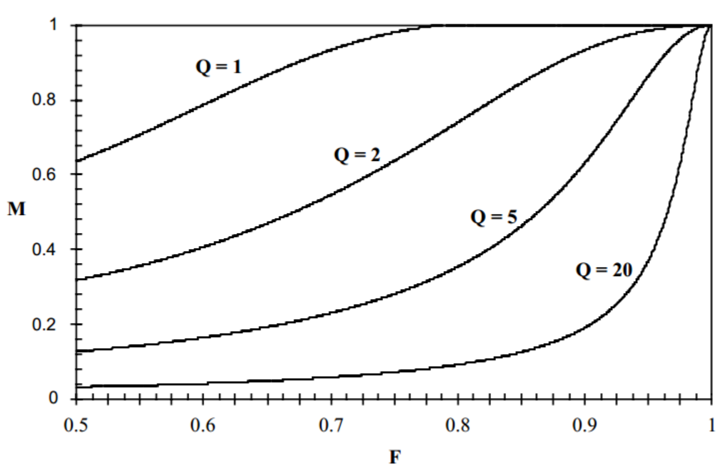
Output Plane

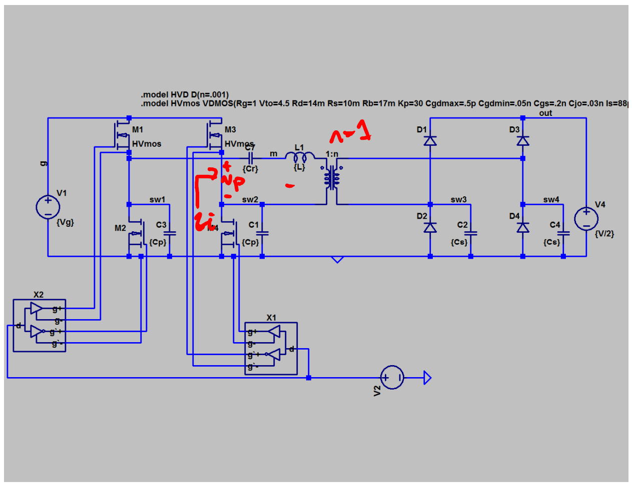


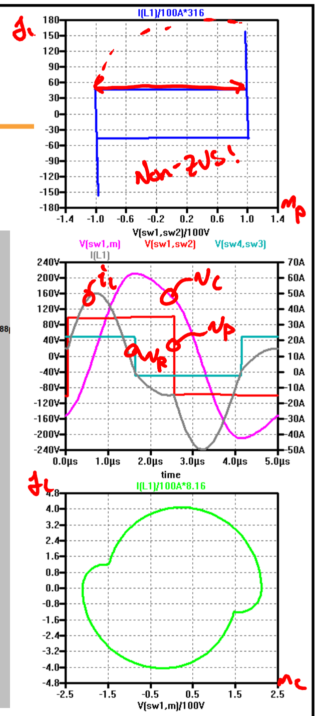
Frequency Modulation



Issues with k=1 CCM

M = ½
F = 0.69

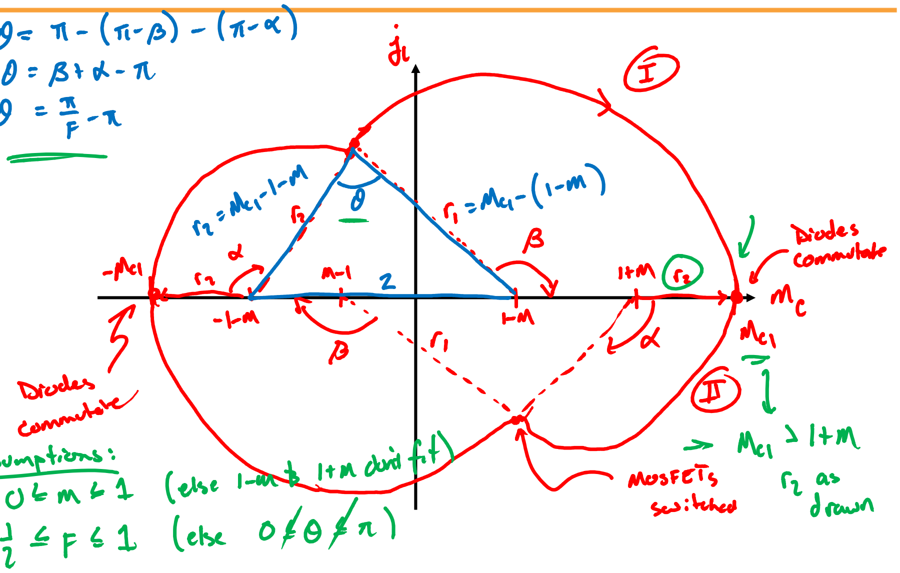




$\theta = \pi - (\pi - \beta) - (\pi - \alpha)$

$\theta = \beta + \alpha - \pi$

$\theta = \frac{\pi}{F} - \pi$



Assumptions:

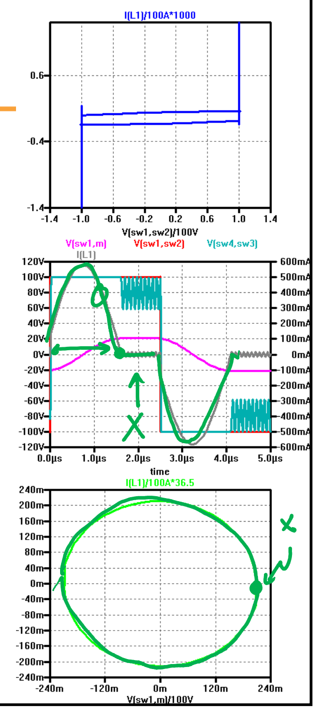
$0 \le M \le 1$ (else $1-M$ & $1+M$ don't fit)

$\frac{1}{2} \le F \le 1$ (else $0 \le \theta \le \pi$)

Mode Boundary

M = 1
F = 0.7

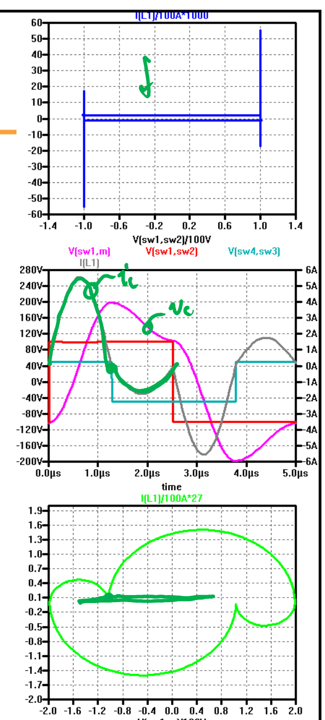
k = 1 DCM



Mode Boundary

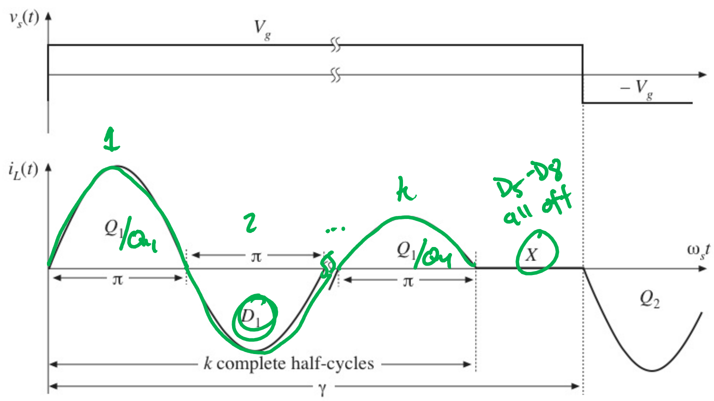
M = ½
F = ½

k = 2
CCM / DCM Boundary

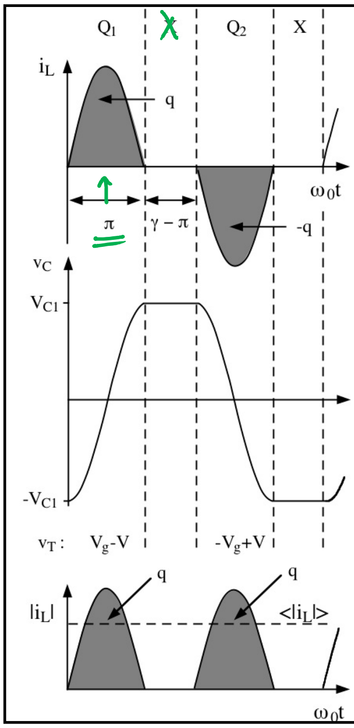


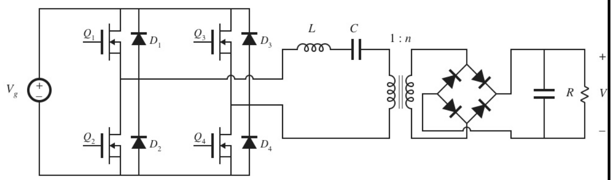
Discontinuous Conduction Modes

- In the "type *k*" discontinuous conduction mode, the tank rings through *k* complete half cycles during each half switching period. The output diode rectifiers then become reverse-biased, and remain off until the input bridge transistors switch to initiate the next half switching period.



The *k* = 1 DCM

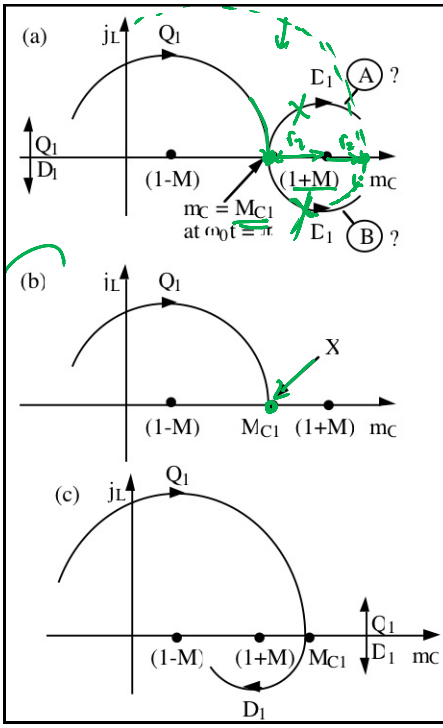




F ≤ 1 necessary

$M_{C1} \ngtr 1+M$

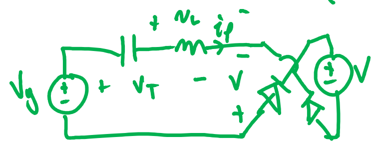
$J \frac{\pi}{2F} < 1+M$ ~ light load



Why DCM Occurs

If $M_{C1} < 1+M$:

(A) Would require negative current in D6 & D7 (not possible)



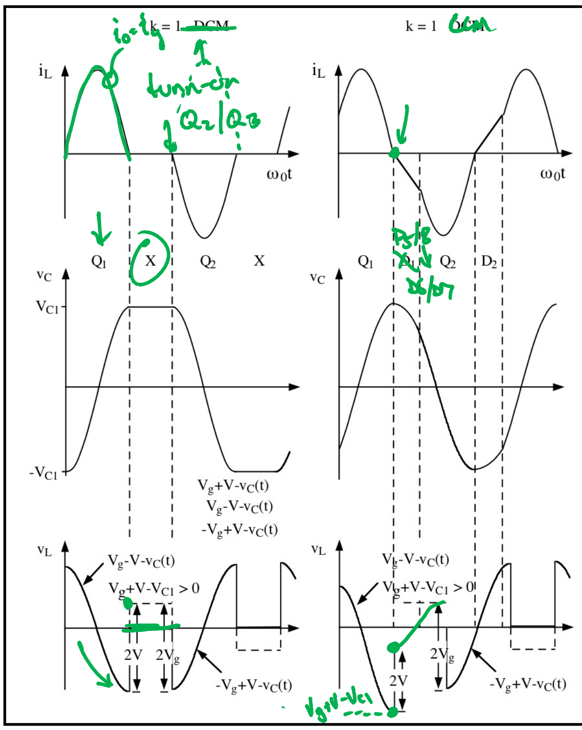
(B) $v_T = V_g + V$

$v_L = v_T - v_{C1}$

↓

$1+M - M_{C1} > 0$

i_L ↑ → contradiction



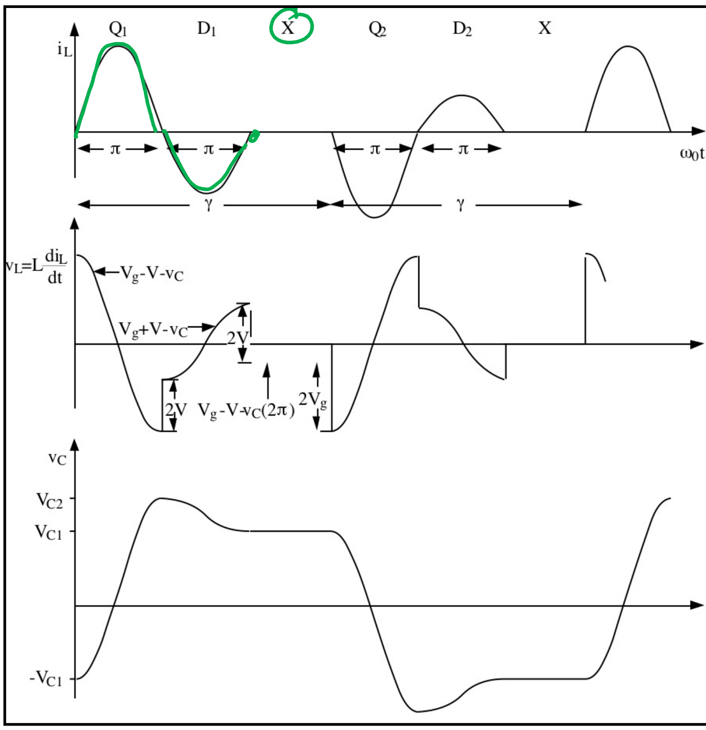
Inductor voltage argument

Summary of results k = 1 DCM

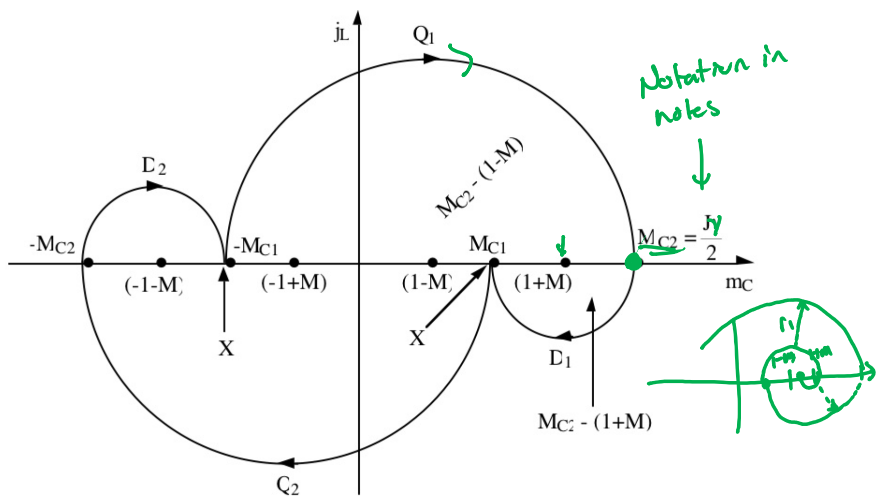
$|i_L| = i_g = i_o$

$\hookrightarrow V = V_g \rightarrow M = 1$

k = 2 DCM



State Plane Diagram k = 2 DCM

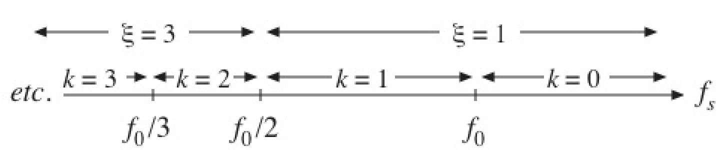


19.5 General Solution for the Steady-State Characteristics of the Series Resonant Converter

Mode index k and subharmonic number ξ

$$\frac{f_0}{k+1} < f_s < \frac{f_0}{k} \qquad \text{or} \qquad \frac{1}{k+1} < F < \frac{1}{k}$$

$$\xi = k + \frac{1 + (-1)^k}{2}$$



Type k CCM

Steady-State Solution

Elliptical output characteristic

$$M^2\xi^2\sin^2\left(\frac{\gamma}{2}\right)+\frac{1}{\xi^2}\left(\frac{J\gamma}{2}+(-1)^k\right)^2\cos^2\left(\frac{\gamma}{2}\right)=1$$

with

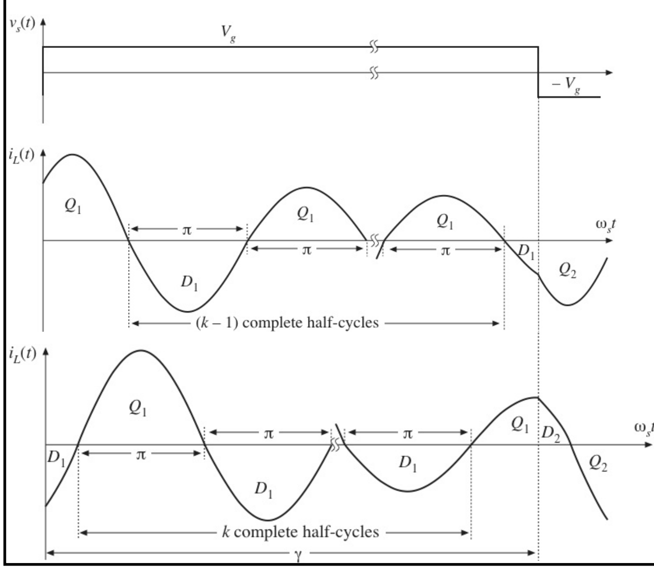
$$M=\frac{V}{nV_g}\qquad J=\frac{InR_0}{V_g}\qquad 0\le M\le\frac{1}{\xi}$$

Control plane characteristic

$$M=\frac{\left(\frac{Q\gamma}{2}\right)}{\xi^4\tan^2\left(\frac{\gamma}{2}\right)+\left(\frac{Q\gamma}{2}\right)^2}\left[(-1)^{k+1}+\sqrt{1+\frac{\left[\xi^2-\cos^2\left(\frac{\gamma}{2}\right)\right]\left[\xi^4\tan^2\left(\frac{\gamma}{2}\right)+\left(\frac{Q\gamma}{2}\right)^2\right]}{\left(\frac{Q\gamma}{2}\right)^2\cos^2\left(\frac{\gamma}{2}\right)}}\right]$$

Type k CCM

Waveforms



Switch network output voltage

Tank inductor current, odd k (ZCS)

Tank inductor current, even k (ZVS)

Type k DCM

Steady State Solution

Type k DCM, odd k

Output voltage $M = \frac{1}{k}$

Mode boundaries $f_s < \frac{f_0}{k}$ and $\frac{2(k+1)}{\gamma} > J > \frac{2(k-1)}{\gamma}$

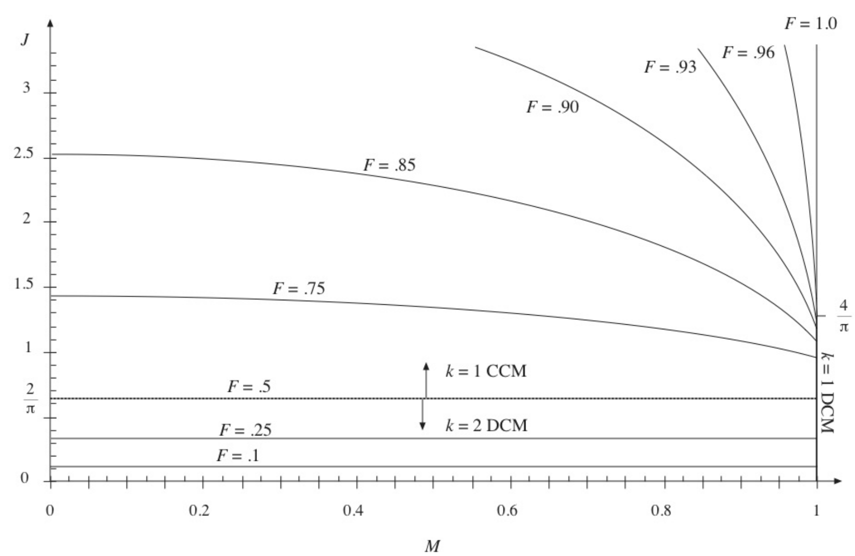
Type k DCM, even k

Output current $J = \frac{2k}{\gamma}$

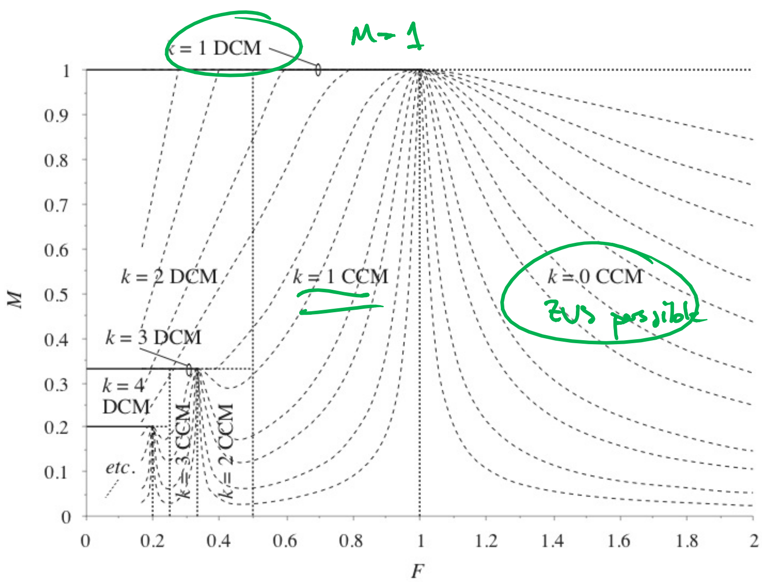
Mode boundaries $f_s < \frac{f_0}{k}$ and $\frac{1}{k-1} > M > \frac{1}{k+1}$

SRC Output Characteristics

Selected Modes Below Resonance



CCM and DCM Boundaries



Complete SRC Characteristics

Control Plane