State Plane Solution

I $\quad r_1^2 = M_1^2 + J_1^2 = M_2^2 + J_2^2$

$$\alpha = \tan^{-1}\left(\frac{M_1}{J_1}\right) + \tan^{-1}\left(\frac{M_2}{J_2}\right)$$

II $\quad r_2^2 = (2+M_1)^2 + J_1^2 = (2+M_2)^2 + J_2^2$

$$\beta = \tan^{-1}\left(\frac{J_1}{2+M_1}\right) + \tan^{-1}\left(\frac{J_2}{2+M_2}\right)$$

Period:

$$\frac{T_s}{2} = t_1 + t_2$$

$$\boxed{\frac{\pi}{F} = \alpha + \beta}$$

$$4 + 4M_1 + M_1^2 + J_1^2 = 4 + 4M_2 + M_2^2 + J_2^2$$

$$-(M_1^2 + J_1^2) = -(M_2^2 + J_2^2)$$

$$4 + 4M_1 = 4 + 4M_2$$

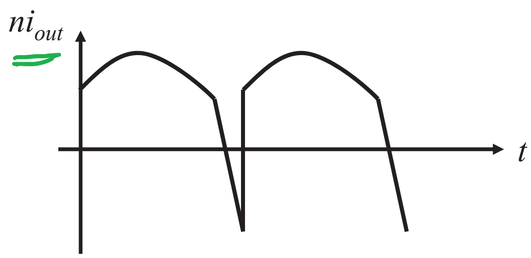
$$\boxed{M_1 = M_2} \quad \& \quad \boxed{J_1 = J_2}$$

specific simplification for PSM & $V_{out} = nV_g$

Averaging Step

$$n\langle i_{out}\rangle\Big|_{T_s/2} = \frac{2}{T_s}\int_0^{T_s/2} i_L(t)\,dt$$

$n\,i_{out}(t) = i_L(t)$ in I & II



$$nJ_{out} = \frac{2}{T_s}\left[q_1 + q_2\right]$$

$$nI_{out} = \frac{2}{T_s}\left[\underbrace{C_r(V_1+V_2)}_{C_r 2V_1 = C_r 2V_2} + \underbrace{C_r(V_1-V_2)}_{\phi}\right]$$

Recall: $M_1 = M_2$, $V_1 = V_2$

$$nI_{out} = \frac{2}{T_s} C_r 2V_1$$

$$nJ_{out} = \boxed{J = \frac{F}{\pi} 2 M_1}$$

Closed-Form Solution

$J = \frac{F}{\pi} 2M_1$ $\quad\Big|\quad$ $\frac{\pi}{F} = \alpha + \beta$ $\quad\Big|\quad$ $\alpha = 2\tan^{-1}\left(\frac{M_1}{J_1}\right)$

$\alpha = \frac{\pi}{F} - \beta$ $\qquad$ $\beta = 2\tan^{-1}\left(\frac{J_1}{2+M_1}\right)$

$$M_1 = J_1 \tan\left(\frac{\alpha}{2}\right) \qquad J_1 = \tan\left(\frac{\beta}{2}\right)(2+M_1)$$

$$M_1 = \tan\left(\frac{\alpha}{2}\right)\tan\left(\frac{\beta}{2}\right)(2+M_1)$$

$$M_1 = \frac{2\tan\left(\frac{\alpha}{2}\right)\tan\left(\frac{\beta}{2}\right)}{1-\tan\left(\frac{\alpha}{2}\right)\tan\left(\frac{\beta}{2}\right)}$$

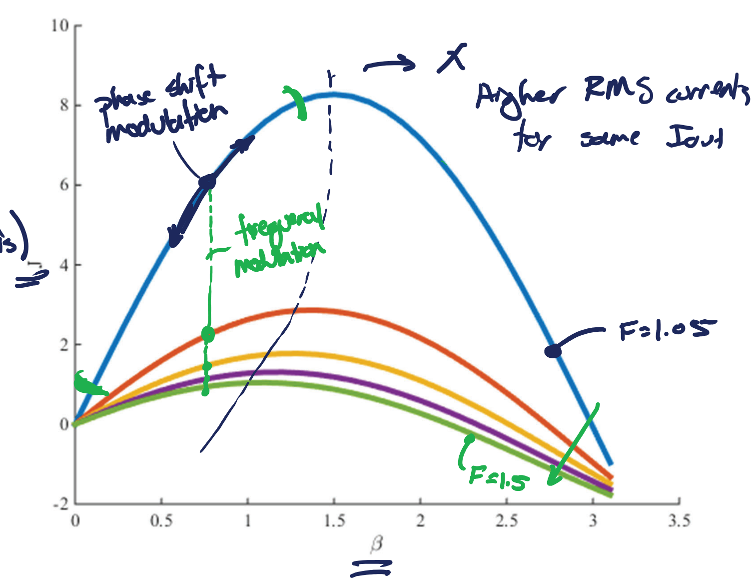
$$\boxed{J = 4\frac{F}{\pi}\,\frac{\tan\left(\frac{\pi}{2F}-\frac{\beta}{2}\right)\tan\left(\frac{\beta}{2}\right)}{1-\tan\left(\frac{\pi}{2F}-\frac{\beta}{2}\right)\tan\left(\frac{\beta}{2}\right)}}$$

SRC Control Trajectory

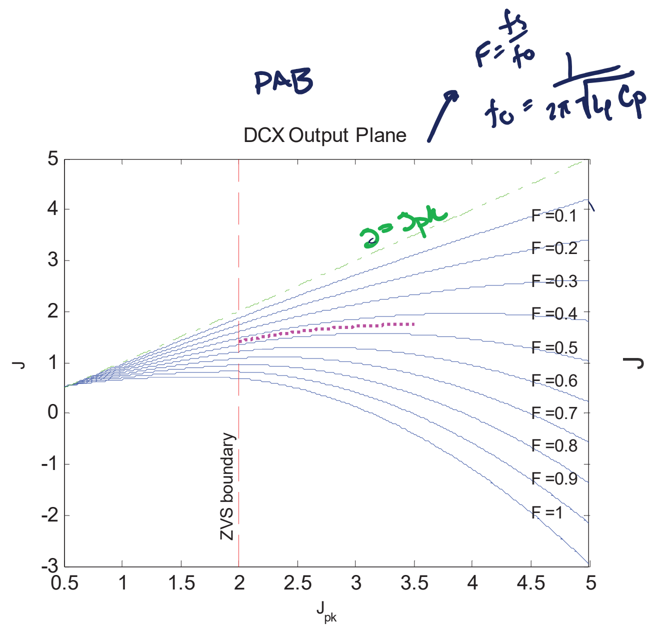
Normally, $F > 1$ in SRC

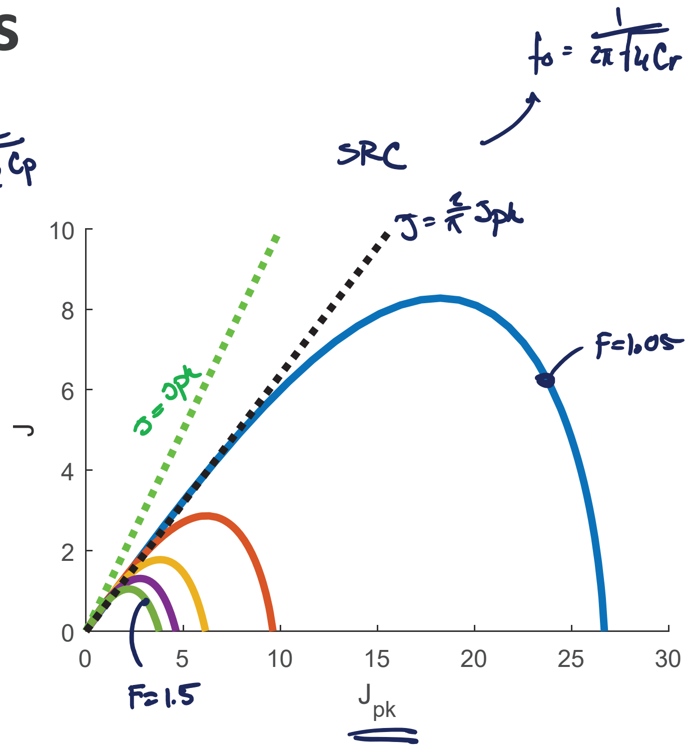
$F = \frac{f_s}{f_o} > 1 \rightarrow f_s > f_o$

Gives the possibility of getting ZVS (subject to further analysis)



SRC Current Stress

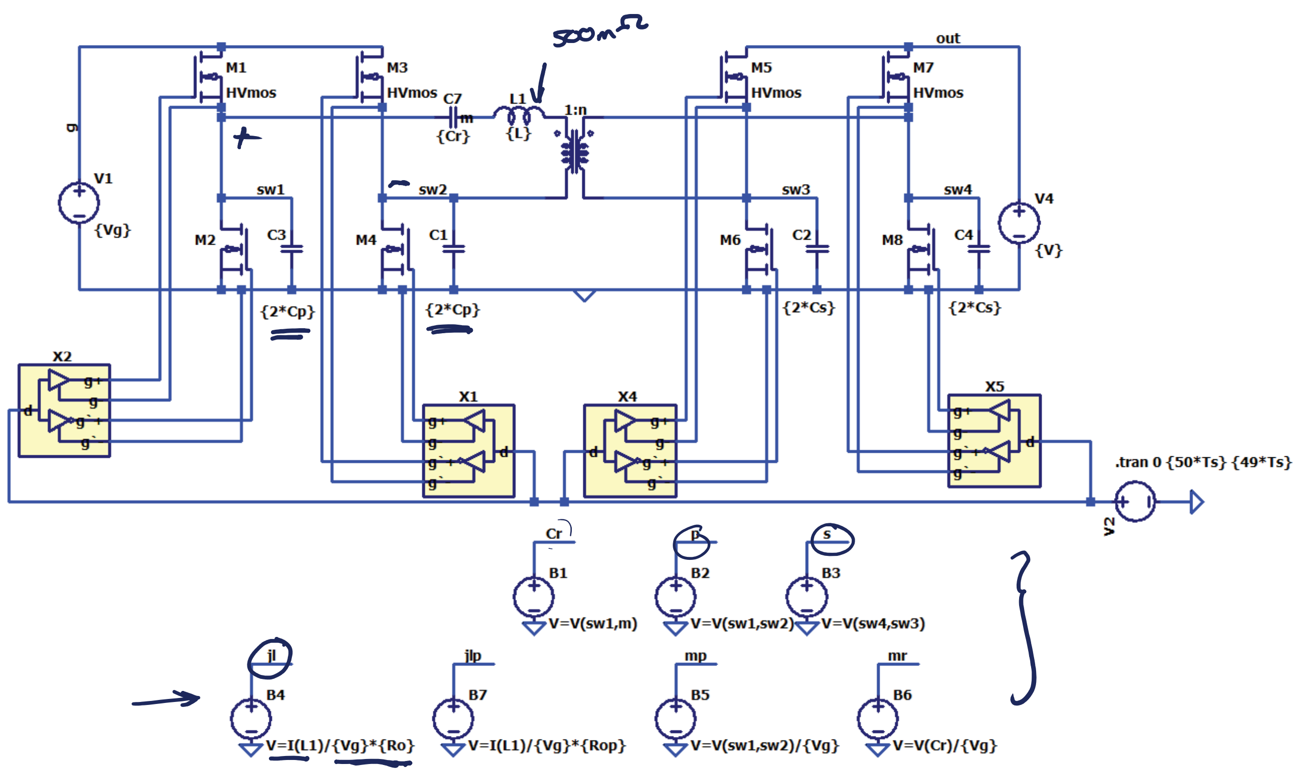




$F_{C_r} >> 1$

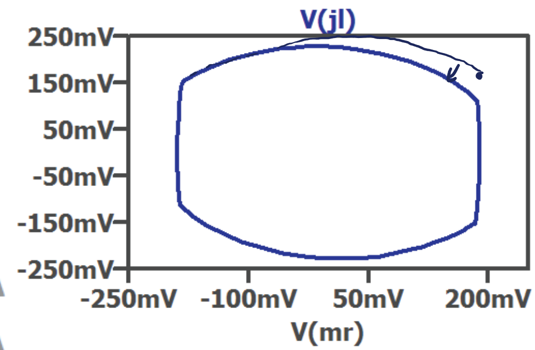
Example Simulation

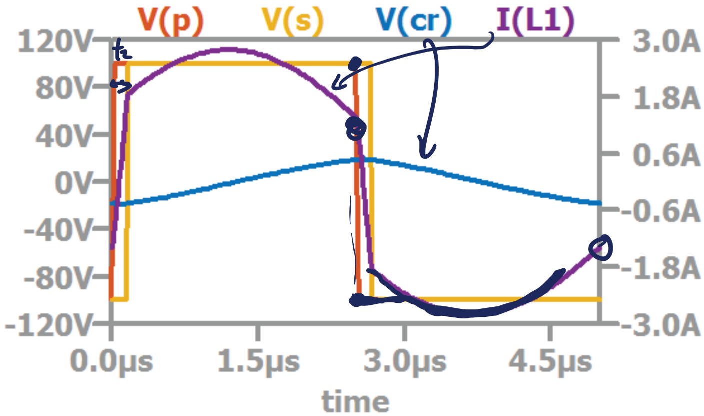
.param Cr={150n} Ro={(L/Cr)**.5} td=70n phi={Ts/2+150n} Rop={(L/Cp)**.5}
.param fs=750k Ts={1/fs} Vg=100 V={Vg} C={100u} Cp=200p Cs={Cp} L={10u}

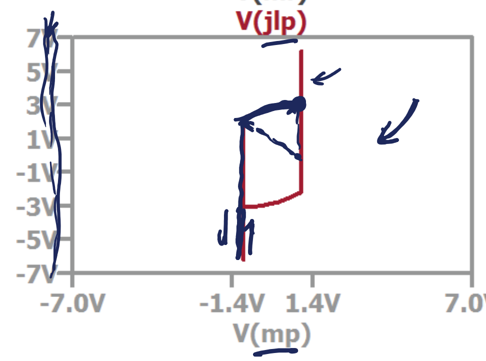


SRC Simulation

I_{out} = 2A
f_s = 200kHz
f_o = 130kHz
V_g = 100V
V_{out} = 100V

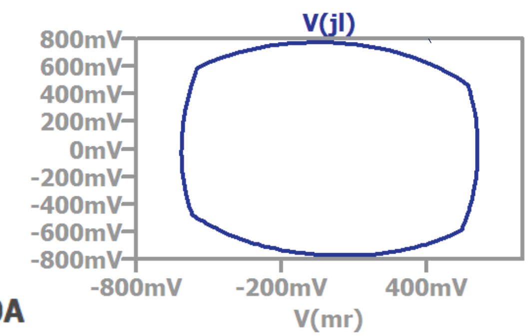


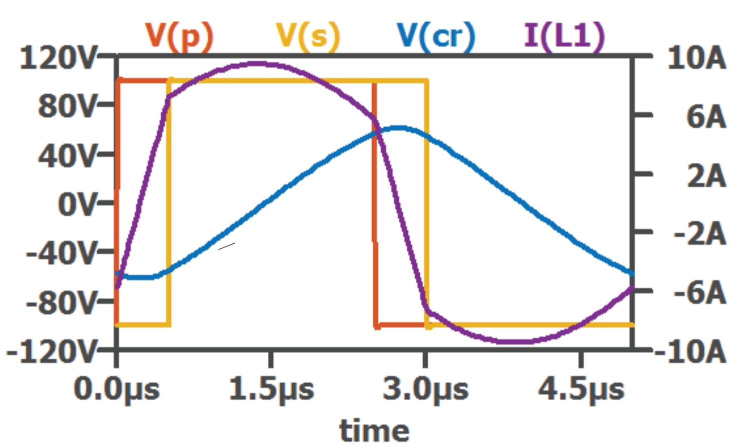


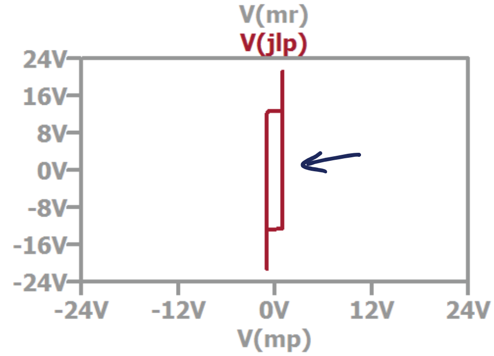


SRC Simulation

I_{out} = 6.5A
f_s = 200kHz
f_o = 130kHz
V_g = 100V
V_{out} = 100V







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SRC Simulation

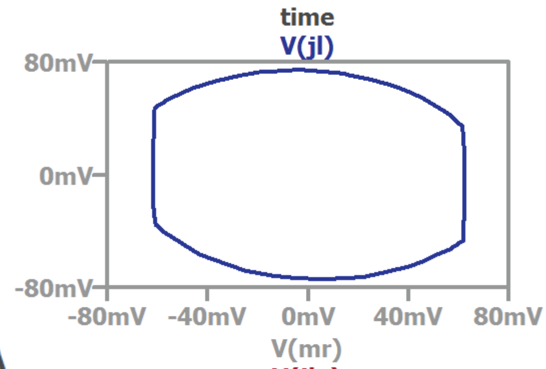
I_{out} = 500mA

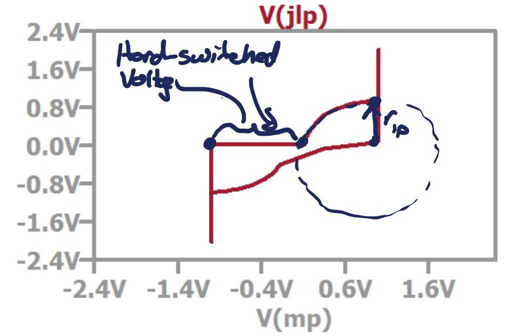
f_s = 200kHz

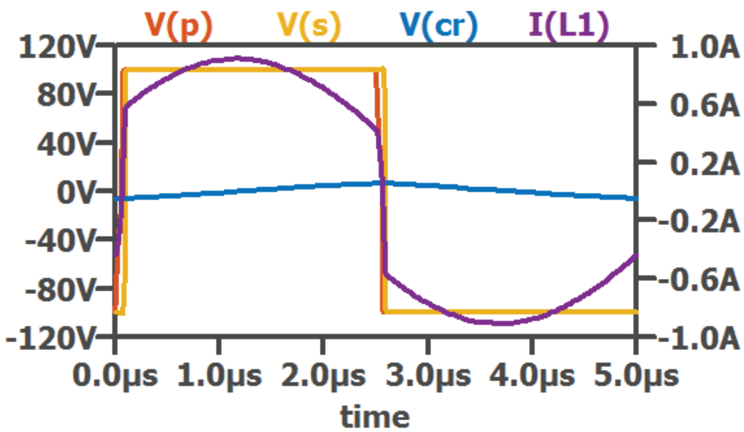
f_o = 130kHz

V_g = 100V

V_{out} = 100V







SRC Simulation

I_{out} = 1.2A

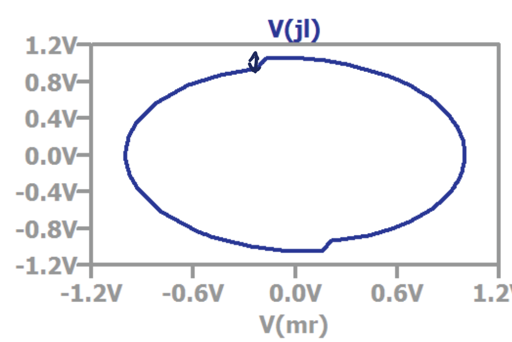
f_s = 130kHz

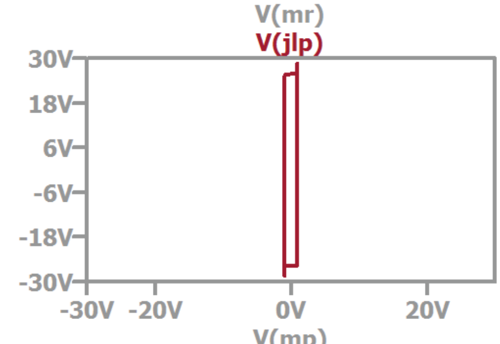
f_o = 130kHz

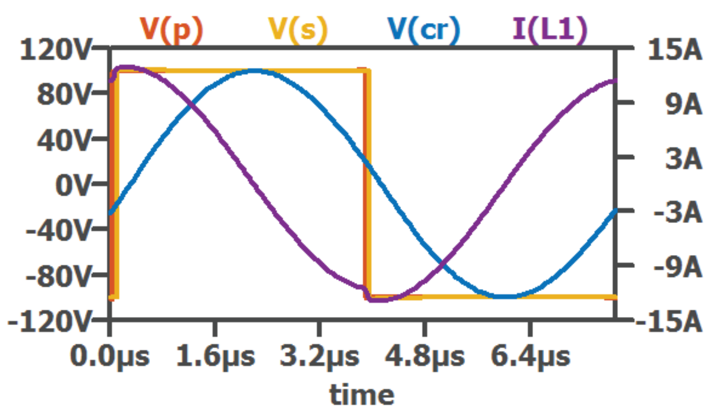
$F=1$

V_g = 100V

V_{out} = 100V

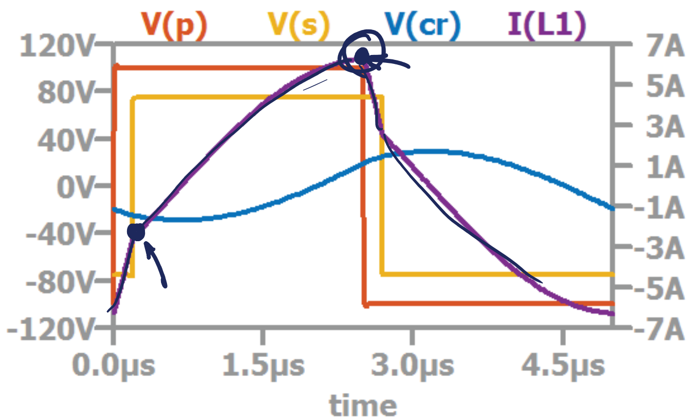


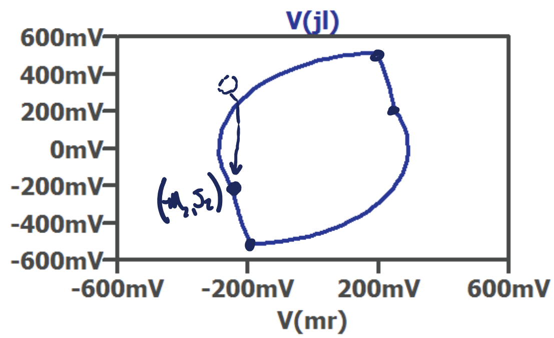


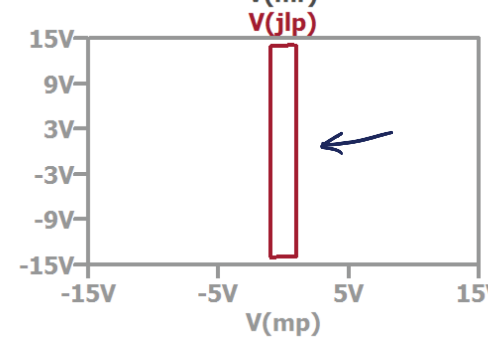


SRC Simulation

I_{out} = 3A
f_s = 200kHz
f_o = 130kHz
V_g = 100V
V_{out} = 75V

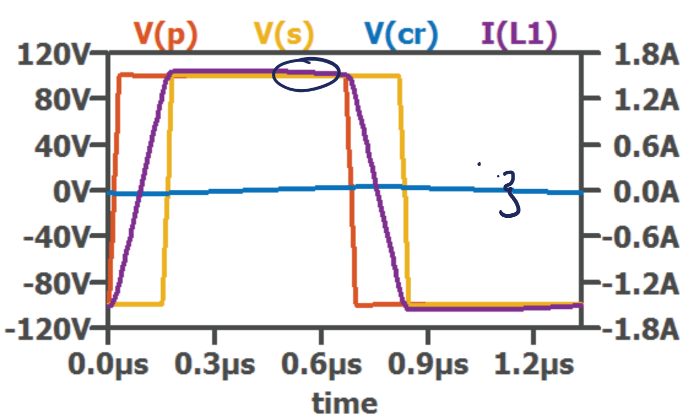


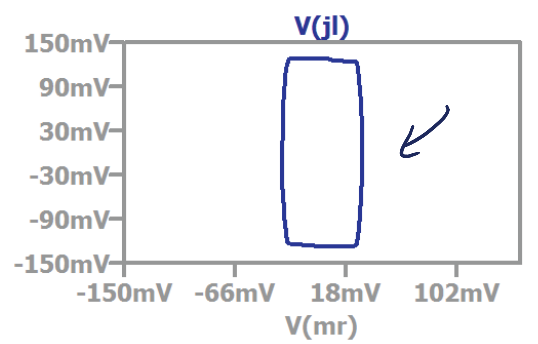


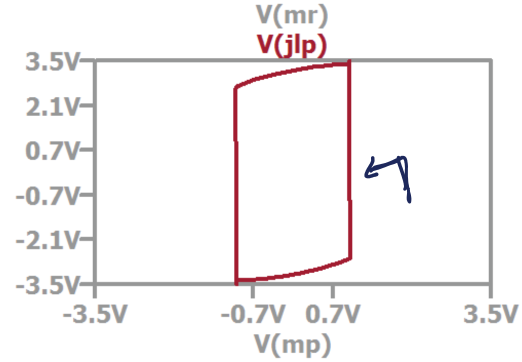


SRC Simulation

I_{out} = 1A
f_s = 750kHz $f_s >> f_o$
f_o = 130kHz
V_g = 100V
V_{out} = 100V





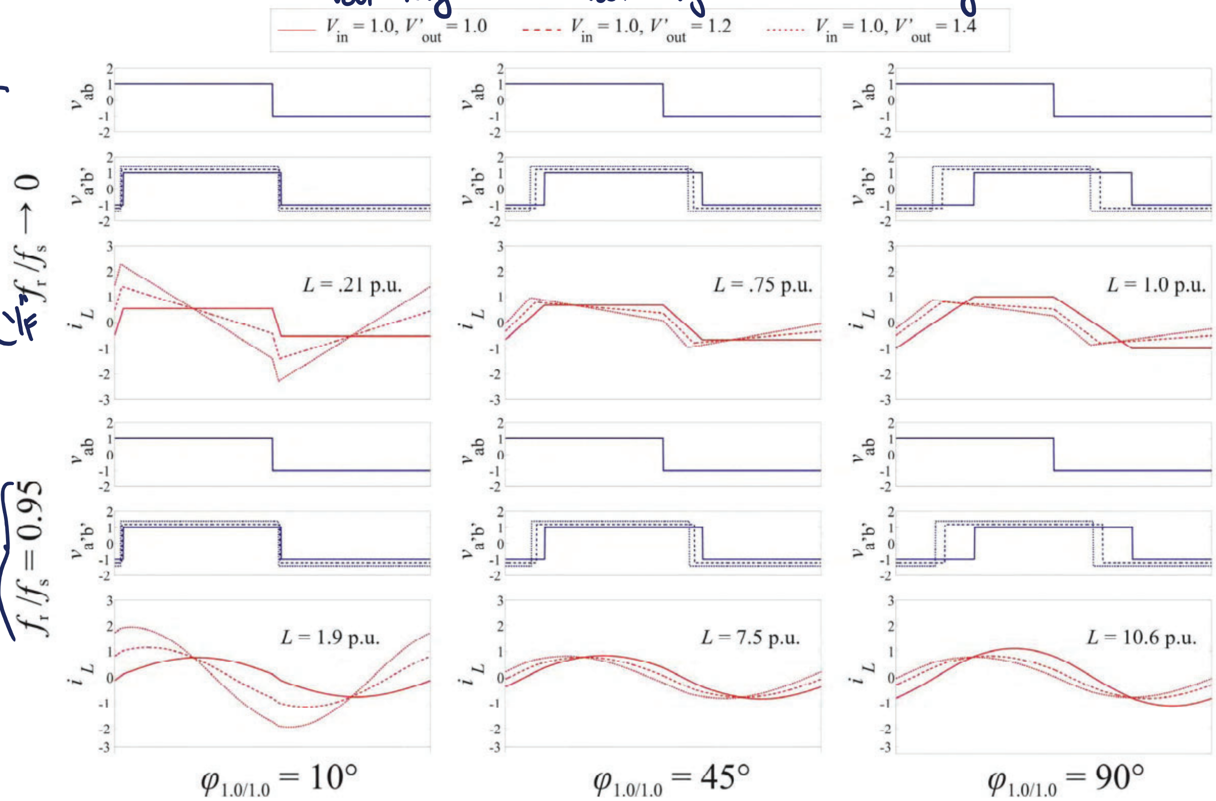


DAB vs SRC

Vout = nVg   Vout > nVg   Vout >> nVg

DAB

SRC



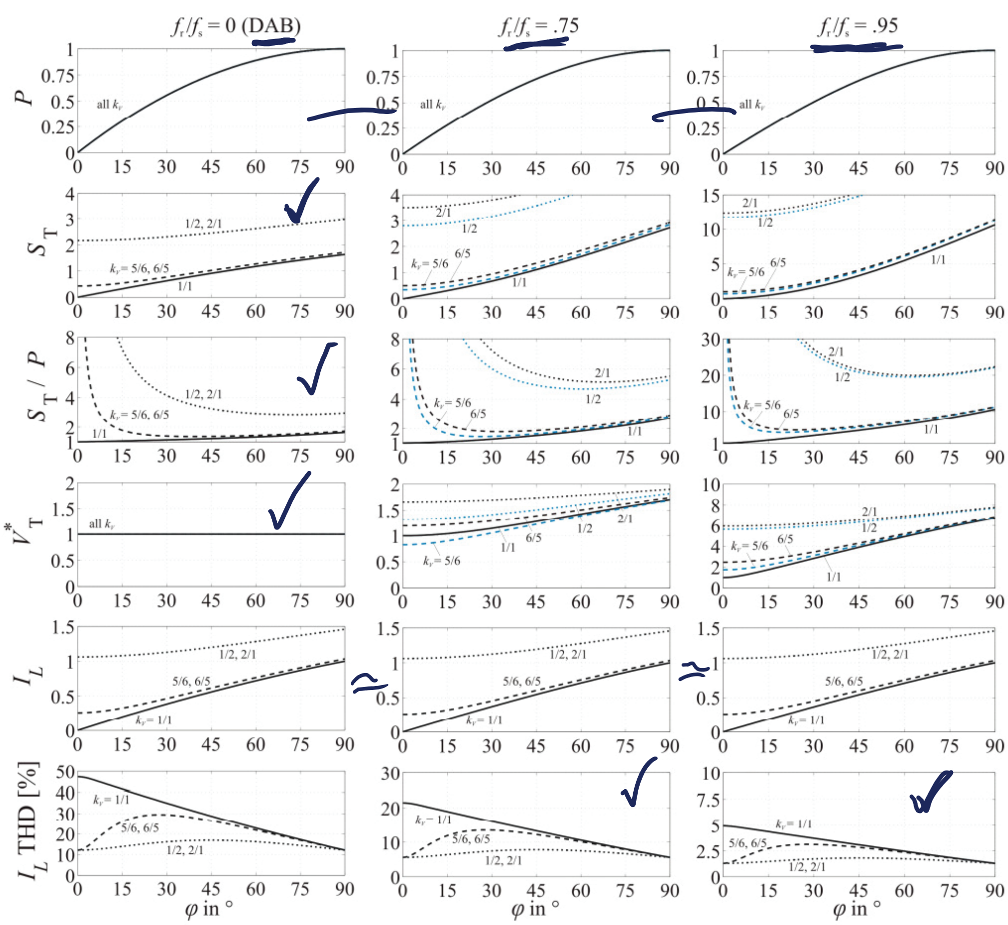
Pout

$S_T = V_T \cdot I_{T\,(rms)}$

Normalized St

XF Voltage

I(rms) current in XF



DAB vs SRC: Conclusions

DAB

+ Smaller resonant tank
+ Smaller RMS currents
+ Wider Soft-switching range

SRC

+ Can be designed with larger XF inductance
+ Lower AC winding losses
+ Reduced device turn-off losses