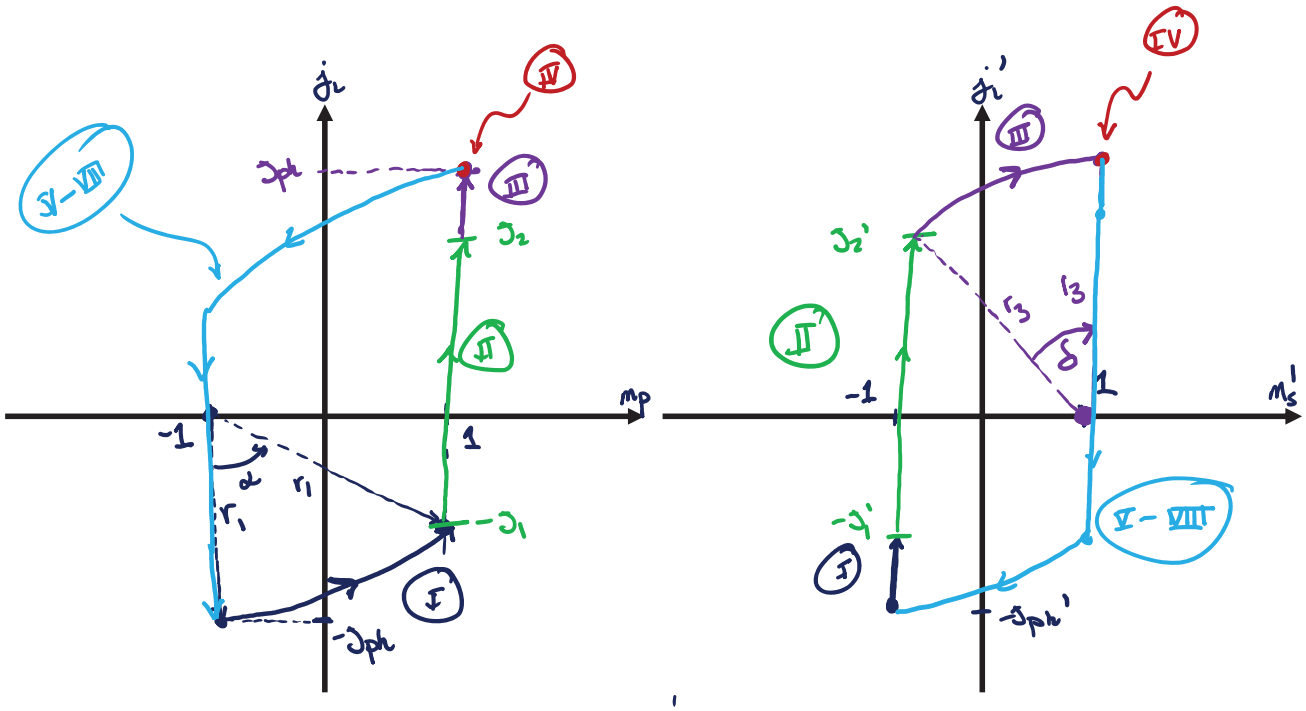
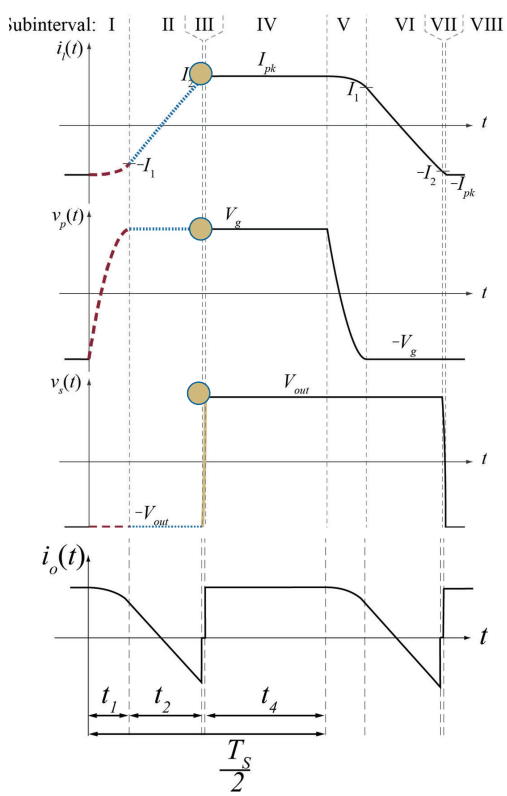
DAB State Plane

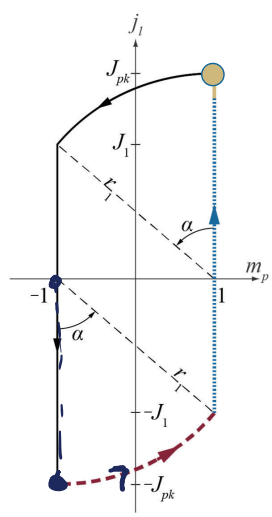


$V_{base} = V_g$ $\quad I_{base} = \frac{V_g}{R_0}$, $R_0 = \sqrt{\frac{L_l}{C_p}}$ $\quad V_{base}' = V_{out}$, $I_{base}' = \frac{V_{out}}{R_0'}$ $\quad R_0' = \sqrt{\frac{n_t^2 L_l}{C_s}}$

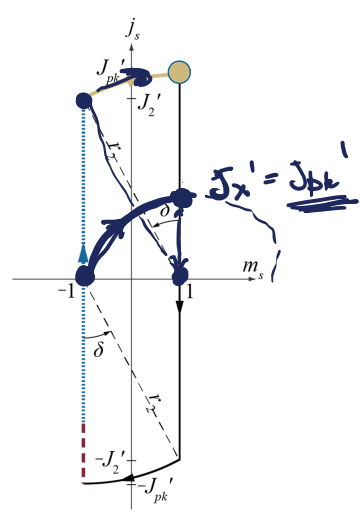
State Plane Analysis of DAB Converter



Primary



Secondary



$$I_{base} = V_g \sqrt{\frac{C_p}{L_l}}$$

$$I_{base} = V_g \sqrt{\frac{C_s}{n_t^2 L_l}}$$

ZVS Condition

Primary :

$r_1 = \boxed{J_{pk} \geq 2}$

$I_{pk} \geq 2 I_{base} = 2 \frac{V_g}{\sqrt{L_p/C_p}}$

$\underbrace{\frac{1}{2} L_p I_{pk}^2}_{E_{L_p}} \geq \frac{1}{2} C_p (2V_g)^2$

$E_{L_p} \geq E_{C_p}$ to go $-V_g \rightarrow +V_g$

Secondary:

No ZVS constraint for this mode of operation

State Plane Solution

(I) $\boxed{J_{pk}^2 = J_1^2 + 4}$

$\boxed{\alpha = \tan^{-1}\left(\frac{2}{J_1}\right)}$

(II) $t_2 \frac{V_g + \frac{V_{out}}{n_t}}{L_l} = (I_1 + I_2)$

$\boxed{2\theta_2 = J_1 + J_2}$

(III) $\boxed{(J_{pk}')^2 = (J_2')^2 + 4}$

$\boxed{\delta' = \tan^{-1}\left(\frac{2}{J_2'}\right)}$

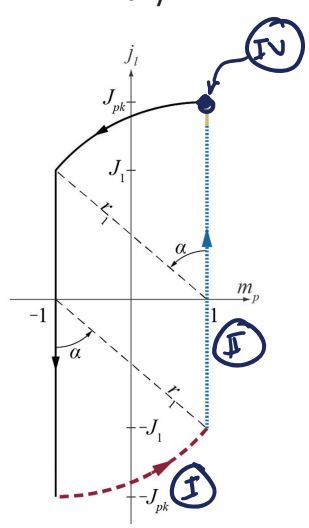
(IV) $\rightarrow$ X

$\frac{T_s}{2} = t_1 + t_2 + t_3 + t_4$

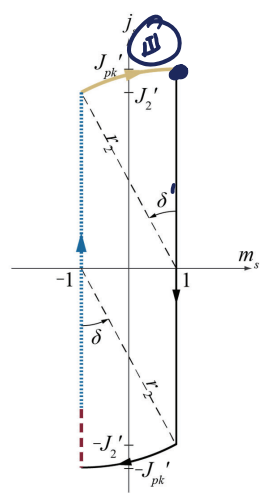
$\boxed{\frac{\pi}{F} = \alpha + \theta_2 + \delta + \theta_4}$

$V_g + \frac{V_{out}}{n_t} = 2V_g$

Primary

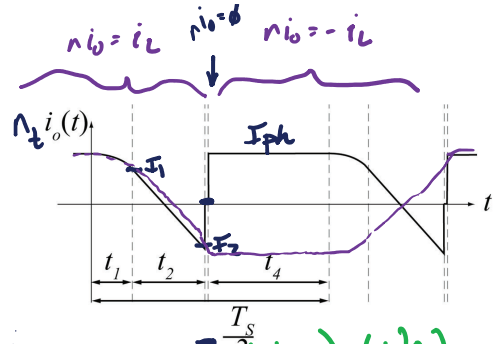


Secondary



$I_{base} = V_g \sqrt{\frac{C_p}{L_l}}$ $\qquad$ $I_{base} = V_g \sqrt{\frac{C_s}{n_t^2 L_l}}$

Averaging Step



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

$$n_t \langle i_{out} \rangle = \frac{2}{T_s}\left[q_1 + q_2 + q_3 + q_4 \right]$$

$$\left(\frac{1}{I_{base}}\right) n_t \langle i_{out} \rangle = \frac{2}{T_s}\left[C_p (2V_g) + t_2 \frac{I_1 - I_L}{2} + \phi + I_{pk} t_4 \right] \left(\frac{1}{I_{base}}\right)\left(\frac{\omega_0}{\omega_0}\right)$$

$$J = n_t J_{out} = \frac{2 f_s}{\omega_0}\left[2 \cancel{C_p R_0 \omega_0}^{\,1} + \theta_2 \frac{J_1 - J_2}{2} + J_{pk} \theta_4 \right]$$

$$R_0 \omega_0 = \sqrt{\frac{L}{C_p}} \frac{1}{\sqrt{L C_p}} = \frac{1}{C_p}$$

$$\boxed{J = n_t J_{out} = \frac{F}{\pi}\left[2 + \theta_2 \frac{J_1 - J_2}{2} + J_{pk} \theta_4 \right]}$$

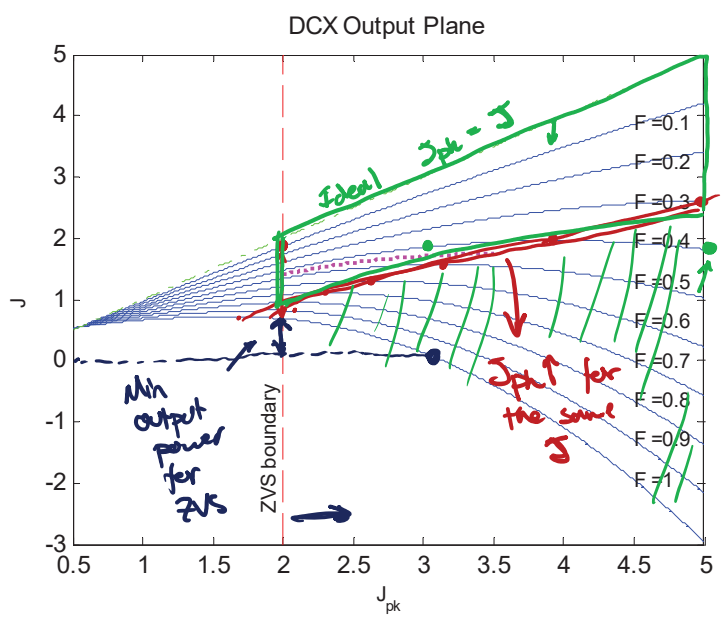
Output Plane

$$J = \frac{n\langle i_{out} \rangle}{I_{base}} = \frac{F}{\pi}\left[2 + \frac{1}{4}\left(J_1^2 - J_2^2\right) + J_p\left(\frac{\pi}{F} - \alpha - \cancel{\beta}^{\,\theta_2} - \delta \right) \right]$$

$$F = \frac{f_s}{f_0}$$

$F \ll 1$

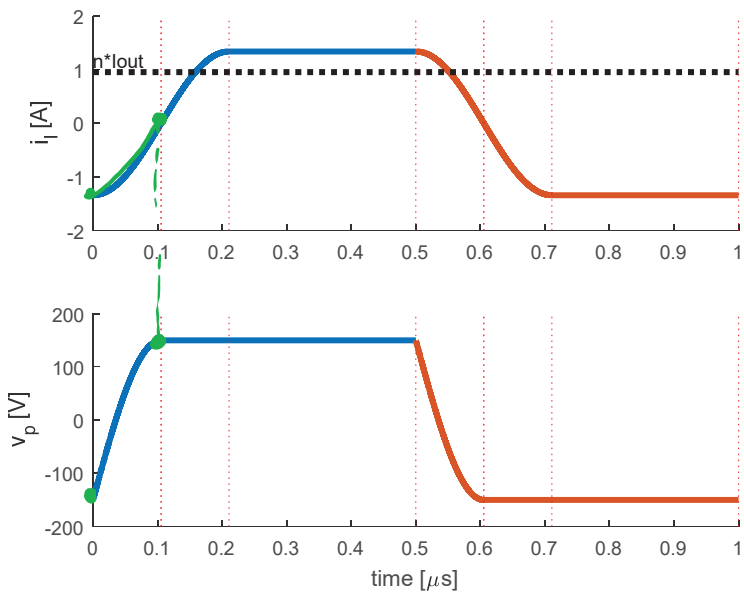
$f_s \ll f_0$

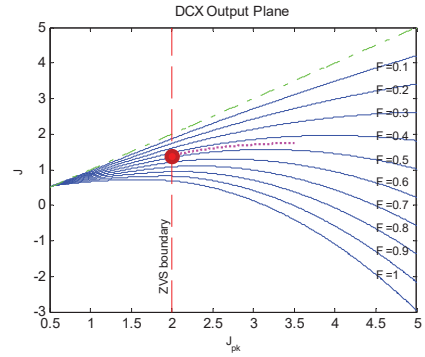


Example Waveforms

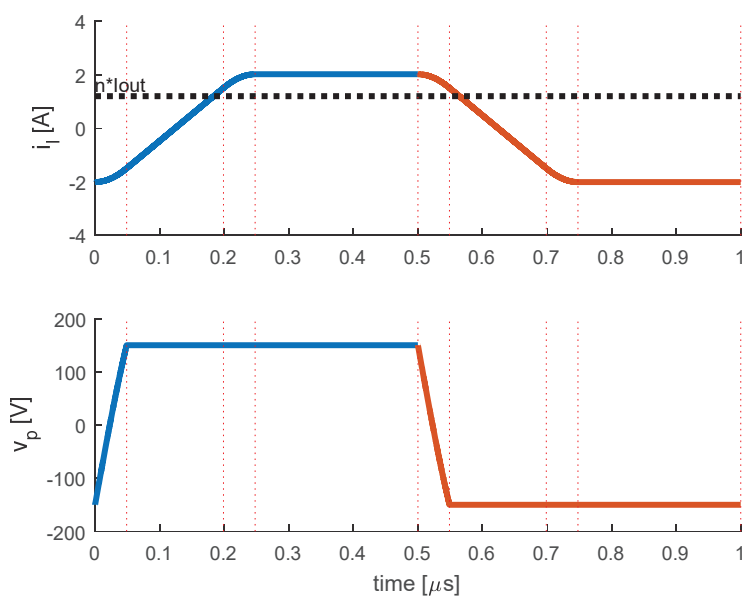
$f_s = 1MHz$ $V_{out} = 12V$ $V_g = 150V$

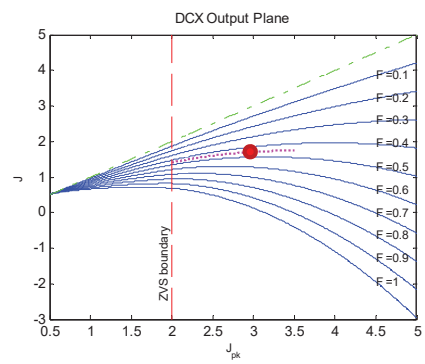
$L_\ell = 15\mu H$ $C_p = 300pF$ $C_s = \frac{C_p}{n^2}$



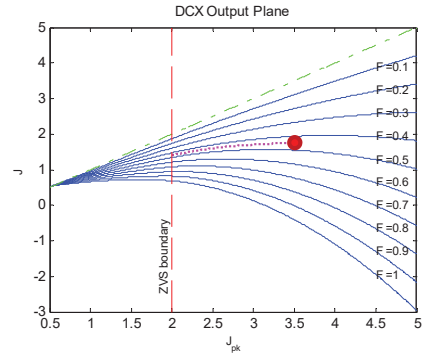


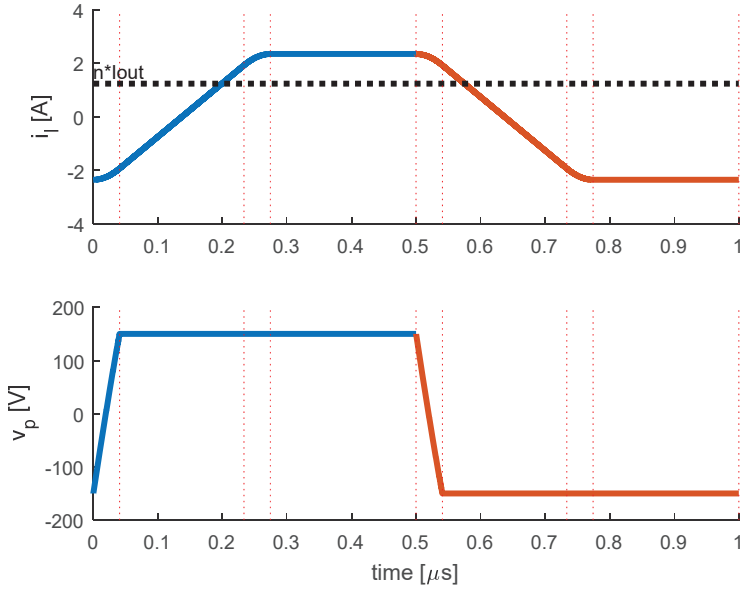
Example Waveforms



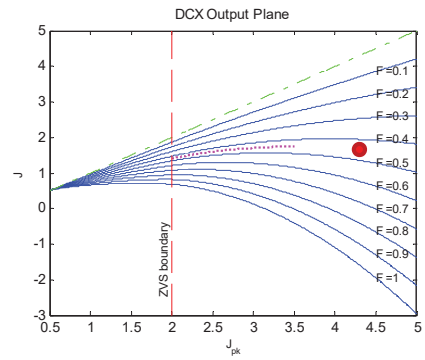


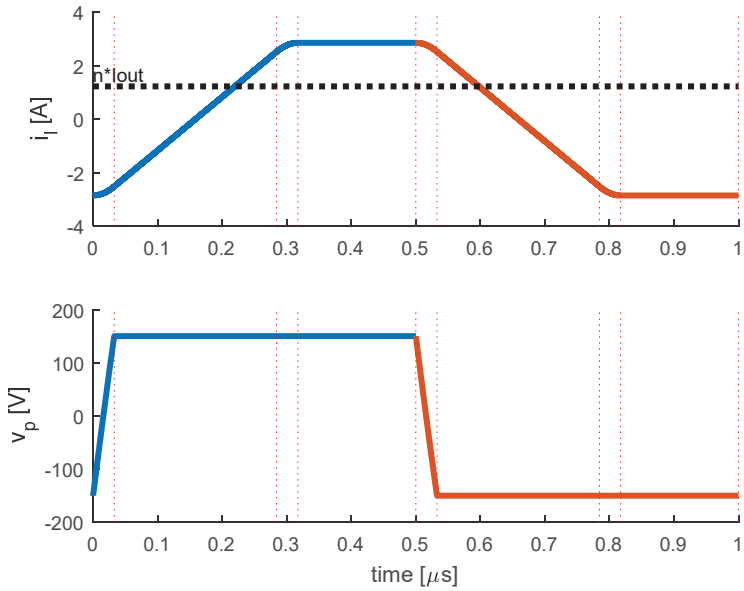
Example Waveforms





Example Waveforms





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Example Waveforms