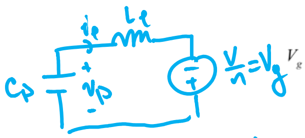
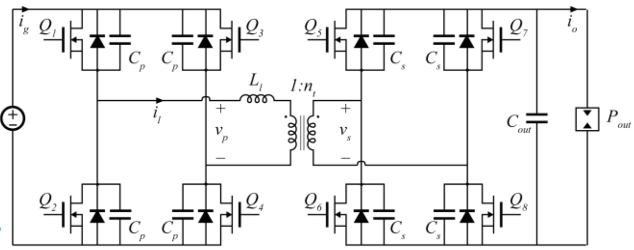
Dual Active Bridge Converter

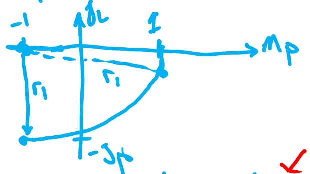
ZVS of primary





$v_p(0) = -V_g$, $i_p(0) = -I_p$ $\Big\}$ $\frac{\partial v_p(0)}{\partial t} > \phi$

Need large inductor for ZVS at low currents



Issues:

- ZVS lost at light load
- XF saturation may occur if v_p or v_s are not purely AC
- Performs poorly at $\frac{V}{V_g} \neq n$

$V_{base} = V_g$

ZVS condition: $r_1 > 2 \rightarrow J_p > 2$ → for primary bridge

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ZVS Cond'n on primary

$J_p > 2$

$V_{base} = V_g$

$I_{base} = \frac{V_g}{R_o}$ $\quad R_o = \sqrt{\frac{L_\ell}{C_p}}$

$I_{base} J_p > 2 I_{base}$

$I_p > 2 \frac{V_g}{R_o} = 2 V_g \sqrt{\frac{C_p}{L_\ell}}$

→ $\boxed{\frac{1}{2} L_\ell I_p^2 > (2V_g)^2 C_p \frac{1}{2}}$ → Large L_ℓ desired to obtain ZVS at low Pout

E in L_ℓ @ start of prim dead time > Energy needed to ZVS primary devices

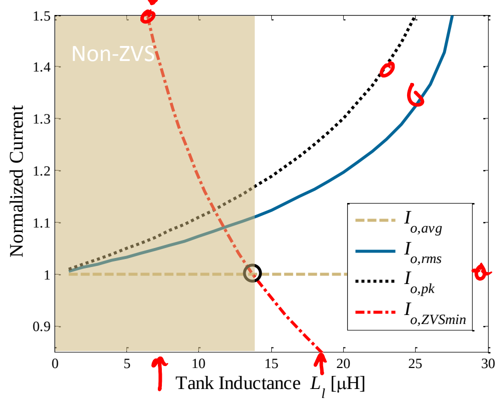
↓

∴ DAB in Phase-shift modulation will lose ZVS at light load

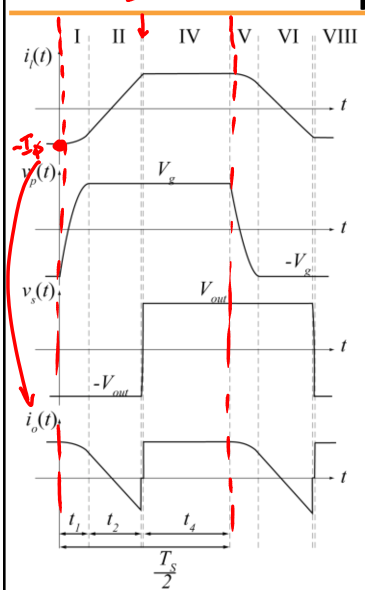
$I_p \longleftrightarrow I_{out}$

Constraints on Inductance

- From previous analysis, smaller L_l results in smaller RMS currents in converter
- However, L_l must be large enough to store energy necessary for ZVS
- Near-optimal design at a single operating point by selecting L_l just large enough to obtain ZVS



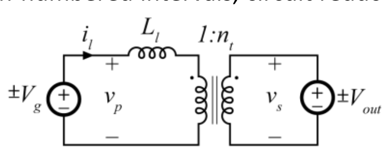
DAB Operation Analysis



- Phase-shifted DAB has four unique intervals per half-period
  - Primary dead time
  - Phase shift
  - Secondary dead time
  - Main power delivery
- Begin by considering DCX operation, where

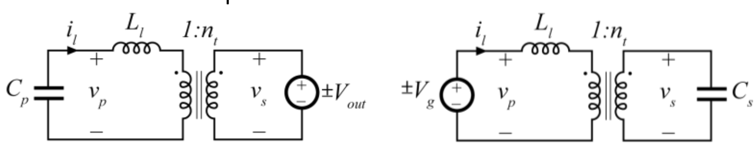
$$V_{out} = n_t V_g$$

- Even-numbered intervals, circuit reduces to

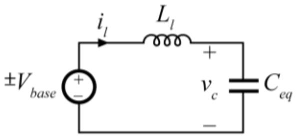


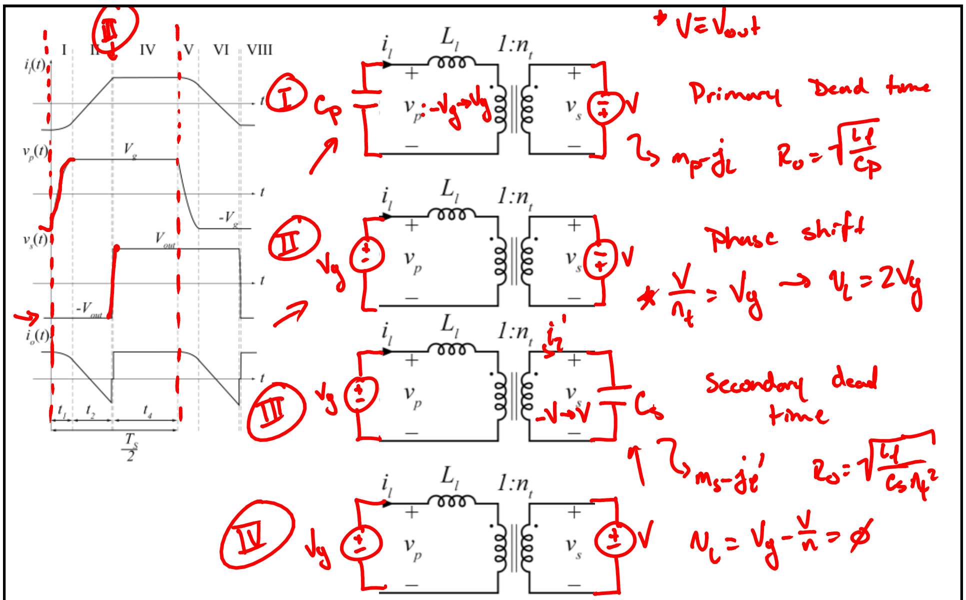
Resonant Interval Analysis

- Resonant intervals have equivalent circuits of the form:

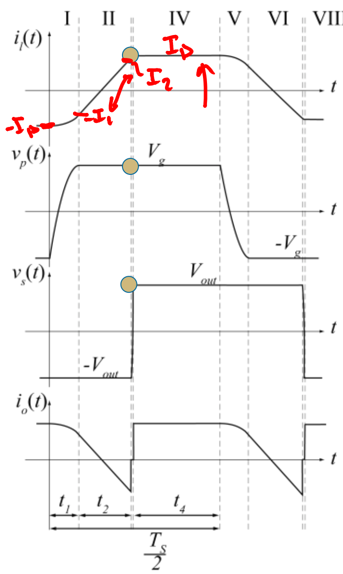


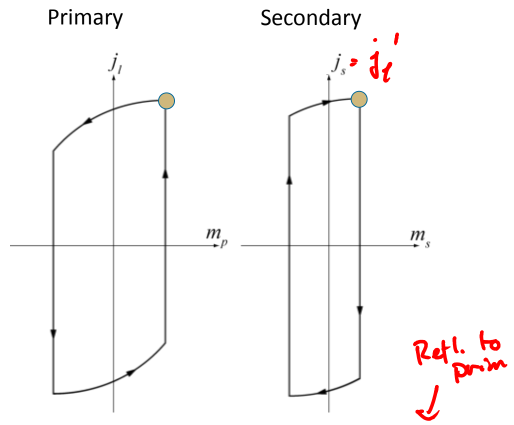
- Both of which can be simplified to:





State Plane Analysis of DAB Converter





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

State Plane Analysis of DAB Converter

(I) $\alpha = \sin^{-1}\left(\frac{2}{J_p}\right)$

$J_p = \sqrt{4 + J_1^2}$

(II) $\frac{(I_2+I_1)}{t_2\omega_0} = \frac{2V_g}{L_l\omega_0}$

$\frac{(I_2+I_1)}{\beta} = \frac{2V_g}{L_l \cdot \frac{1}{\sqrt{L_l C_p}}} = \frac{2V_g}{R_0}$

$J_2 + J_1 = 2\beta$

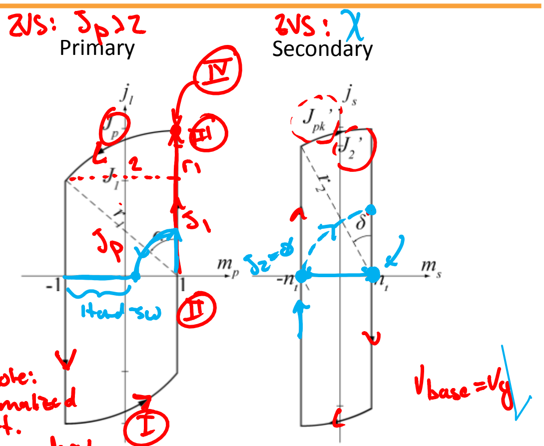
(III) $\delta' = \sin^{-1}\left(\frac{2n_t}{J_{pk}'}\right)$

$J_{pk}' = \sqrt{(2n_t)^2 + J_2'^2}$

* note: normalized wrt. secondary

(IV) $\rightarrow \chi$

↳ $T_s \cdot \frac{1}{2} = \frac{\alpha}{\omega_0} + \frac{\beta}{\omega_0} + \frac{\delta}{\omega_0} + \frac{\chi}{\omega_0} \rightarrow \frac{\pi}{F} = \alpha + \beta + \delta + \chi$



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