Output Plane

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

For small \( F \), switching transitions occupy negligible portion of \( T_s \). As \( F \) approaches \( f_s \), approaching fully resonant waveforms.

Denormalizing

\[ \theta(t) = V_{dc} + V_{base} \cos(\omega t + \phi_0) \]

\[ i(t) = I_{dc} + I_{base} \sin(\omega t + \phi_0) \]

\[ i(t) = I_{dc} + I_{base} \sin \left[ \omega_0 (t - t_x) + \phi_0 \right] \]
Example Waveforms

\[ C_2 = \frac{C_1}{2} \]

\[ J_{pk} \]

ZVS boundary

DCX Output Plane
Example Waveforms
Example Waveforms

![Waveforms Diagram]

Designing Inductance

- **Hard switching** → **ZVS** → **Pout**
- Large \( L_p \) → **Transition** → Small \( f_L \) \( f_L > f_s \)

**ZVS:** Want large \( L_p \) so **ZVS** is maintained over a wide range of power (\( f_L > f_s \))

**Core loss:** Want small \( L_p \) so that
\[
F > \frac{f_s}{f_o} \Rightarrow \frac{f_s}{f_o} \text{ Core Loss} \text{ is small}
\]
Output Current Vs. Inductance

Normalized Output Current

- $L_1 = 5\mu H$
- $L_2 = 15\mu H$
- $L_3 = 25\mu H$

Time $t$ [µs]

Normalized Current

Tank Inductance $L_t$ [µH]

Normalized Current $I_{o, rms}$, $I_{o, avg}$, $I_{o, pk}$

RMS Currents

$\int_0^T i(t) = \frac{1}{T} \int_0^T i(t) dt$

$\kappa(t)$

$\theta_1$, $\theta_2$, $\theta_3$
Constraints on Inductance

Selection of Tank Inductance

Constraints on Inductance

Selection of Tank Inductance
Effects of primary-side device capacitance

Extending ZVS Range

1. Change Voltage Conversion Ratio

\[ \frac{V_{in}}{V_{out}} = 1 \]

Primary Hard Sw

All Soft Sw

ZVS

Pout

Sacardini

Hard Sw

\[ f_{sw} = 1 \text{ MHz} \]

\[ V_{in} = 400 \text{ V} \]

\[ V_{out} = 12 \text{ V} \]

\[ P_{out} = P_{min} = 150 \text{ W} \]

\[ f_{s} = 1 \text{ MHz} \]