On-campus students: turn in Midterm Exam

Off-campus students: Midterm Exam is on D2L. Due one week after the start time, but no later than 5pm MT Wednesday, March 28

Next week is Spring Break, no classes, no office hours

HW8 will be assigned Monday, April 2 after Spring Break
Using output-plane characteristic to design a parallel resonant converter

Given $V_g$, $V$, $P$ or $I$

Design:

$L, C, n, f_s$

Example 1: $n=1$, $\rightarrow L, C, f_s$
Using output-plane characteristic to design a parallel resonant converter

\[
C = \frac{1}{\omega_0 R_0}, \quad R_0 = \sqrt{\frac{E}{C}}
\]

\[
= \frac{F}{\omega_5 R_0}, \quad \omega_5 = 2\pi f_s, \quad f = \frac{f_s}{f_0}
\]

\[
L = \frac{R_0}{\omega_0} = \frac{F}{\omega_5 R_0}
\]

Selected \( M_{op} \), \( J_{op} \)

\[
M_{op} = \frac{V}{\sqrt{3}}, \quad \text{no choice} \ (n = 1)
\]

\[
J_{op} = \frac{I}{\sqrt{3}} = \frac{R_0 I}{\sqrt{3}} = R_0
\]

\[
F \text{ follows from the PRC char., or from the output plane graph.}
\]

Choose \( f_s \)

\[
L, C
\]

Design trade-offs:

\[
\begin{align*}
& (1) \text{ ZVS?} \\
& (2) \text{ Component stresses} \\
& (3) \text{ Constraints due to circuit parasitic components}
\end{align*}
\]
Using output-plane characteristics to design a parallel resonant converter

Numerical example

<table>
<thead>
<tr>
<th>$\text{Io}$</th>
<th>$F$</th>
<th>$f_0$</th>
<th>$R_0$</th>
<th>$L$</th>
<th>$C$</th>
<th>$I_{\text{buc}}$</th>
<th>$V_{\text{cap}}$</th>
<th>$I_{\text{LP}}$</th>
<th>$I_{\text{LP}}$</th>
<th>EVS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.8</td>
<td>1.1</td>
<td>910 kHz</td>
<td>480Ω</td>
<td>84μH</td>
<td>360pF</td>
<td>0.625A</td>
<td>1.7</td>
<td>510V</td>
<td>2.4</td>
<td>1.5A</td>
</tr>
<tr>
<td>0.5</td>
<td>1.25</td>
<td>800 kHz</td>
<td>300Ω</td>
<td>60μH</td>
<td>660pF</td>
<td>1A</td>
<td>1.7</td>
<td>510V</td>
<td>2.5</td>
<td>2.5A</td>
</tr>
</tbody>
</table>

From output plane graph

$\text{Io} = \frac{V_0}{\sqrt{2}}$

$\text{Mop} = \frac{V_0}{V_\text{in}} = 1.2$, no choice.

$F_s = 1 \text{ MHz}$

$I_{\text{LP}} = 0.5A$ $P = 180W$ $V = 360V$
PRC output plane characteristics
Peak tank capacitor voltage stresses
Proportional to output voltage in CCM

Peak capacitor voltage, CCM:

\[
M_{cp} = \begin{cases} 
\sqrt{(M_{c0} + 1)^2 + (J - J_{L,0})^2} - 1 & \text{when } (J_{L,0} > J) \\
\frac{\sqrt{1 + (J_{L,1} - J)^2} + 1}{2} & \text{when } (J_{L,0} < J)
\end{cases}
\]

DCVM:

\[
M_{cp} = \begin{cases} 
\frac{\sqrt{(M_{c0} + 1)^2 + (J - J_{L,0})^2} - 1}{2} & \text{when } (J_{L,0} > J) \\
\frac{\sqrt{1 + (J_{L,1} - J)^2} + 1}{2} & \text{when } (J_{L,0} \leq J)
\end{cases}
\]

(above equations are derived from the state plane trajectory)

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(the course notes include Fig. 5.26(b) that shows peak voltage stresses below the peak frequency in the double frequency region)
Fig. 5.26(a) Curves of constant $M_{cp}$, valid for both CCM and DCM, in the single frequency region of the output plane and above the peak frequency in the double frequency region.
Peak current stresses
Proportional to output voltage in CCM

Peak transistor current, CCM:

\[ J_{LP} = \begin{cases} J_{L0} & \text{when } (M_{C0} < 1 \text{ and } J_{L0} > 0) \\ J + \sqrt{(J_{L1} - J)^2 + 1} & \text{when } (M_{C0} > 1 \text{ or } J_{L0} < 0) \end{cases} \]

DCVM:

\[ J_{LP} = \begin{cases} J_{L0} & \text{when } (\gamma - \delta < \pi/2) \\ J + 1 & \text{when } (\gamma - \delta \geq \pi/2) \end{cases} \]

(above equations are derived from the state plane trajectory)

(above equations are derived from the state plane trajectory)

Fig. 5.25(a) Curves of constant \( J_{LP} \), valid for both CCM and DCM, in the single frequency region of the output plane and above the peak frequency in the double frequency region.

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Fig. 5.25(a)  Curves of constant $J_l$, valid for both CCM and DCM, in the single frequency region of the output plane and above the peak frequency in the double frequency region.