Identification of Resonant Switch

Switching Cell Conversion Ratio

For Buck only \( M = \mu \)  
for PWM Buck, \( M = d \)

Replace \( d \) with \( M \) of any resonant switch cell, you get the behavior of the parent PWM converter with that switch cell.
Conversion Ratios of Various Switch Cells

\[
P_{1/2}(x) = \frac{1}{2\pi} \left[ \frac{1}{2} x + \pi + \sin^{-1} x + \frac{1}{x} \left(1 - \sqrt{1 - x^2}\right)\right]
\]

\[
P_1(x) = \frac{1}{2\pi} \left[ \frac{1}{2} x + 2\pi + \sin^{-1} x + \frac{1}{x} \left(1 - \sqrt{1 - x^2}\right)\right] \approx 1
\]

<table>
<thead>
<tr>
<th>Switch Cell</th>
<th>Conv. Ratio (\mu)</th>
<th>Load Current Range</th>
<th>Conv. Ratio Range</th>
<th>Requirements on (Q)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PWM</td>
<td>(D)</td>
<td>N/A</td>
<td></td>
<td>0 ≤ (\mu) ≤ 1</td>
</tr>
<tr>
<td>ZVS-QR (half)</td>
<td>(1 - FP_1\left(\frac{1}{J_L}\right))</td>
<td>(0 ≤ J_L ≤ \infty)</td>
<td>0 ≤ (\mu) ≤ 1</td>
<td></td>
</tr>
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<td>ZVS-QR (full)</td>
<td>(1 - FP_1\left(\frac{1}{J_L}\right))</td>
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<td>Bidirectional voltage</td>
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<td>Unidirectional Current*</td>
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</tr>
</tbody>
</table>

Resonant Switch Identification Examples
ZCS-QR Boost

\[ M = \frac{1}{1 - d(t)} \]

ZCS-QR Boost: \[ M = \frac{1}{1 - M(t)} \]

\[ m = F_{P,V_L}(3L) \] (if half-wave)

SSM - PWM Parent

\[ \langle v_s \rangle = d(t) \langle v_i \rangle \]

\[ \langle i_s \rangle = d(t) \langle i_2 \rangle \]

Linearize \( \ddot{C}_1 \) SSM

\[ \hat{v}_2 = v_i \hat{a} + D\hat{v}_1 \]

\[ \hat{\iota}_s = i_2 \hat{a} + D\hat{\iota}_1 \]
SSM, PWM Case

Textbook, Fig. 7.17(a)

ZVS-QR Switch Cell SSM

\[ M = 1 - \frac{E}{2\pi} \left[ \frac{1}{2J_c} + \pi + \sin^{-1}\left(\frac{1}{2J_c}\right) + \sqrt{J_c^2 - 1} + J_c \right] \]

\[ F = \frac{f_s}{f_o}, \quad J_c = \frac{I_c}{S_y} R_o \]

\[ M \] depends on \( f_s, I_c, \) and \( V_g \)

\[ M = k_i \dot{I}_c + k_e f_s + k_v \dot{V}_g \]

\[ \left\{ \begin{array}{l}
 k_i = \frac{\partial M}{\partial I_c} \bigg|_{dc} \\
 k_e = \frac{\partial M}{\partial f_s} \bigg|_{dc} \\
 k_v = \frac{\partial M}{\partial V_g} \bigg|_{dc}
\end{array} \right. \]
SSM, Soft-Switching Buck

![Diagram of a Soft-Switching Buck topology](Image)