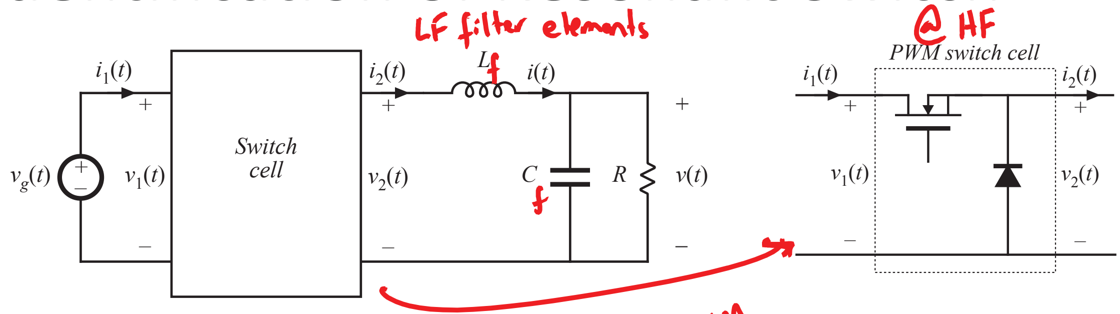
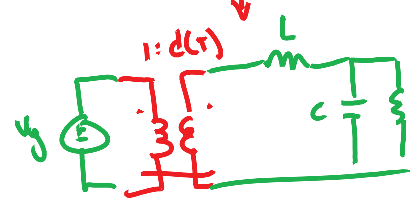
Identification of Resonant Switch



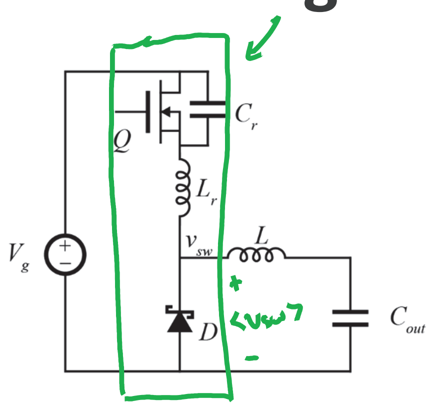
for PWM converter: $\langle v_2 \rangle = d(t)\langle v_1 \rangle$

$\langle i_1 \rangle = d(t)\langle i_2 \rangle$



Averaged, nonlinear

Switching Cell Conversion Ratio



$M = f(F, J_L)$ for ZVS-QR Buck

derived according to $\langle v_{sw} \rangle = V$

In this case: $M = \frac{V}{V_g} = \frac{\langle v_{sw} \rangle}{V_g}$

more generally

μ = switch cell conversion ratio → $\frac{\langle v_2 \rangle}{\langle v_1 \rangle}$

for Buck only $M = \mu$

for PWM buck, $\mu = d$

Replace d with μ of any resonant switch cell, you get the behavior of the parent PWM converter with that switch cell.

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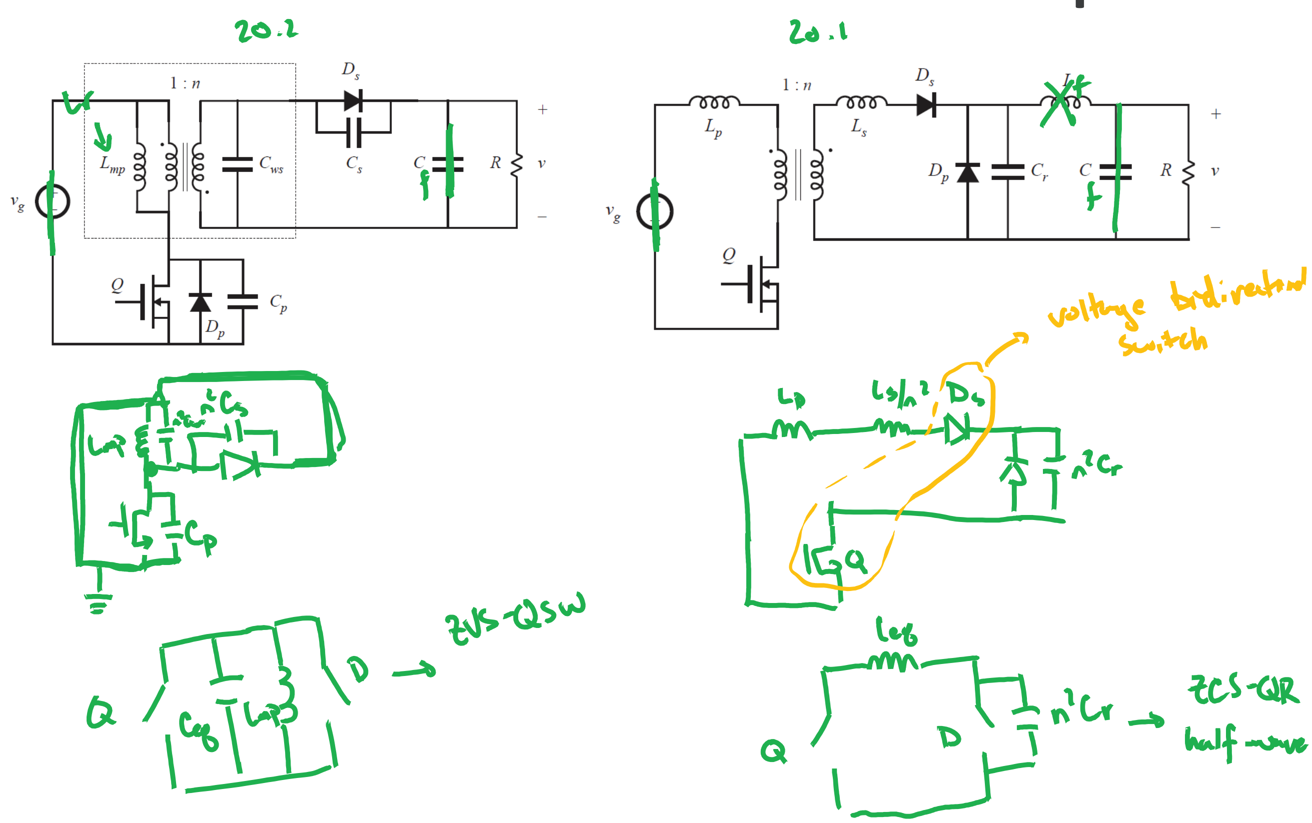
Conversion Ratios of Various Switch Cells

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

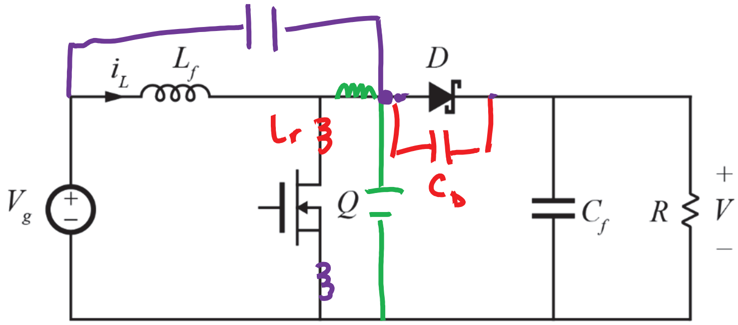
$$P_1(x) = \frac{1}{2\pi}\left[\frac{1}{2}x + 2\pi + \sin^{-1}x + \frac{1}{x}\left(1 - \sqrt{1 - x^2}\right)\right] \approx 1$$

Switch Cell	Conv. Ratio μ	Load Current Range	Conv. Ratio Range	Requirements on *Q*
PWM	D	N/A	$0 \le \mu \le 1$	
ZVS-QR (half)	$\mathbf{1 - FP_{\frac{1}{2}}\left(\frac{1}{J_L}\right)}$	$\mathbf{0 \le J_L \le \infty}$	$\mathbf{0 \le \mu \le 1}$	
ZVS-QR (full)	$1 - FP_1\left(\frac{1}{J_L}\right)$	$0 \le J_L \le \infty$	$0 \le \mu \le 1$	Bidirectional voltage
ZCS-QR (half)	$FP_{\frac{1}{2}}(J_L)$	$1 \le J_L \le \infty$	$0 \le \mu \le 1$	Unidirectional Current*
ZCS-QR (full)	$FP_1(J_L)$	$1 \le J_L \le \infty$	$0 \le \mu \le 1$	

Resonant Switch Identification Examples



ZCS-QR Boost

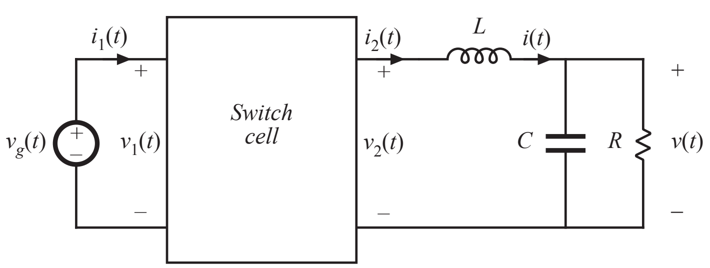


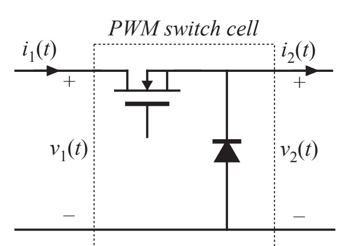
PWM Boost : $M = \frac{1}{1-d(t)}$

ZCS-QR Boost : $M = \frac{1}{1-\mu(t)}$

$\mu = F P_{1/2}(J_L)$ (if half-wave)

SSM - PWM Parent





PWM:

$\langle v_2 \rangle = d(t) \langle v_1 \rangle$

$\langle i_1 \rangle = d(t) \langle i_2 \rangle$

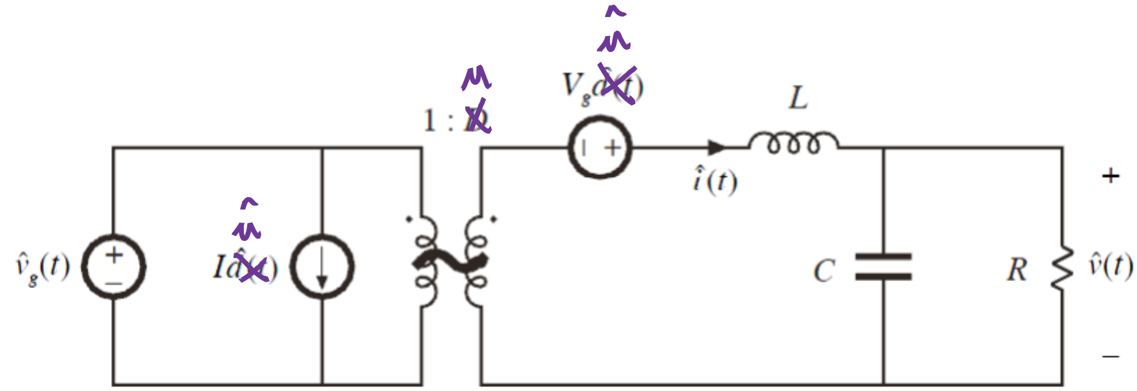
↓ Linearize, SSM

$\hat{v}_2 = V_1 \hat{d} + D \hat{v}_1$

$\hat{i}_1 = I_2 \hat{d} + D \hat{i}_2$

SSM, PWM Case

Textbook, Fig.7.17(a)



Replace $D \to \mu$ and $\hat{d} \to \hat{\mu}$ PWM converter AC SSM model becomes resonant switch SSM

ZVS-QR Switch Cell SSM

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

$$F = \frac{f_s}{f_0} \qquad J_L = \frac{I_L}{V_g} R_0$$

μ depends on f_s, i_L, and V_g

$$\hat{\mu} = K_i \hat{i}_L + K_f \hat{f}_s + K_v \hat{v}_g, \quad \begin{cases} K_i = \left.\frac{\partial \mu}{\partial i_L}\right|_{DC} \\ K_f = \left.\frac{\partial \mu}{\partial f_s}\right|_{DC} \\ K_v = \left.\frac{\partial \mu}{\partial v_g}\right|_{DC} \end{cases}$$

SSM, Soft-Switching Buck