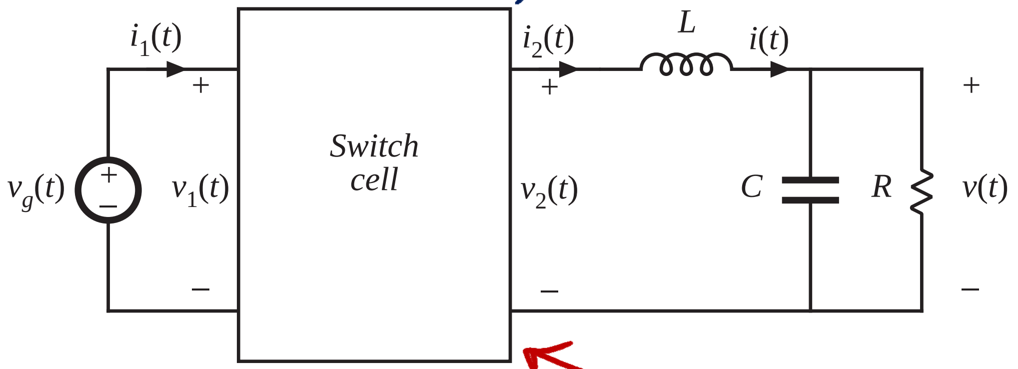
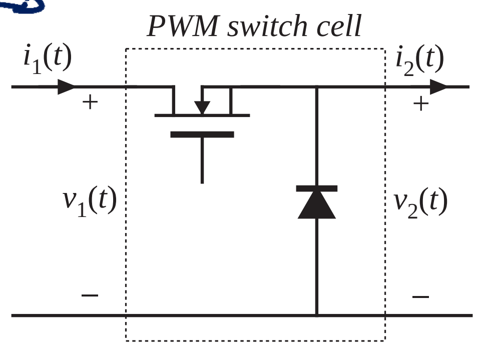
Identification of Resonant Switch

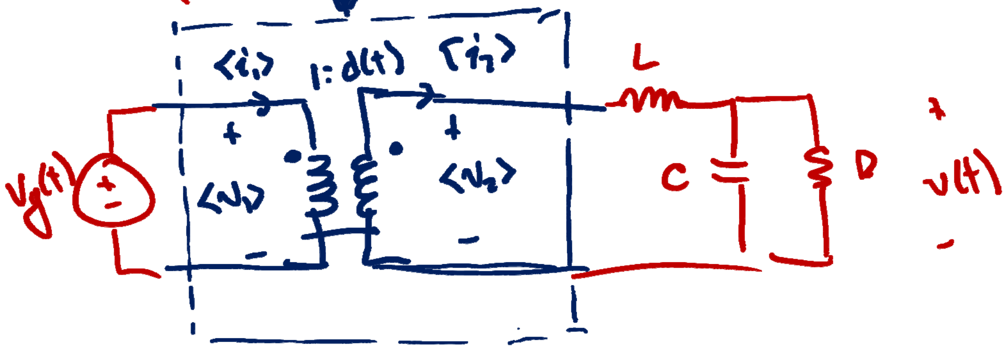




Review switch Averaging

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

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



Averaged, nonlinear switching network

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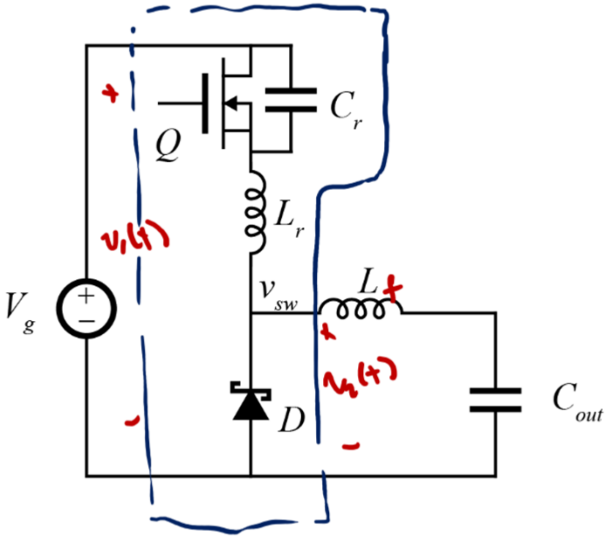
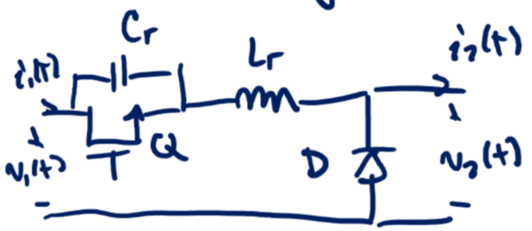
Switching Cell Conversion Ratio



ZVS - QR switching Network



By volt-sec balance on L_f, $\langle v_2(t)\rangle = V$

$\langle v_2\rangle = M\langle v_1\rangle$ ← unique to buck converter

M solved earlier for ZVS - QR Buck converter

Generalize to

$$\langle v_2\rangle = \mu(t)\langle v_1\rangle$$
$$\langle i_1\rangle = \mu(t)\langle i_2\rangle$$

$\mu(t)$ is the "switch cell conversion ratio"

To get the behavior of any 2-switch PWM converter with a resonant switching network, take PWM result & replace $d(t)$ with $\mu(t)$

E.g. for ZVS-QR boost, take $\underset{\text{PWM}}{M = \dfrac{1}{1-d(t)}} \rightarrow \underset{\text{ZVS-QR}}{M = \dfrac{1}{1-\mu(t)}}$

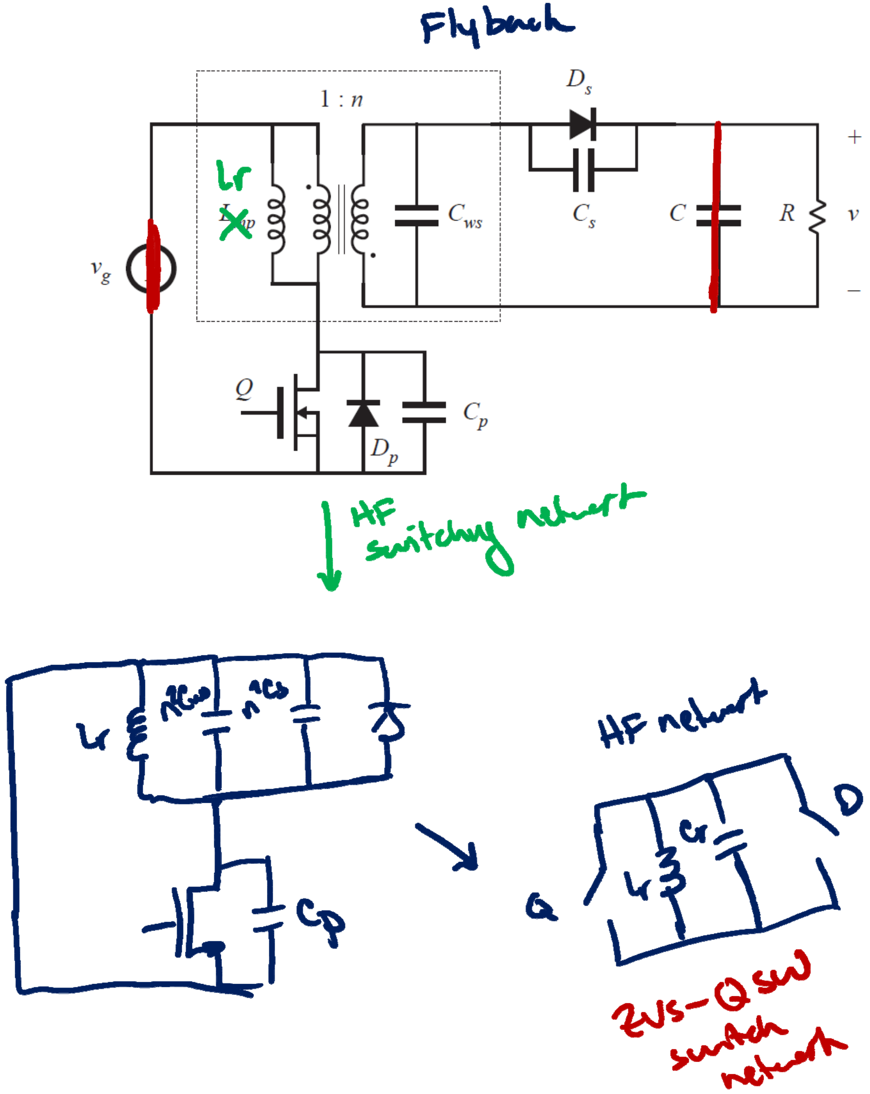
Conversion Ratios of Various Switch Cells

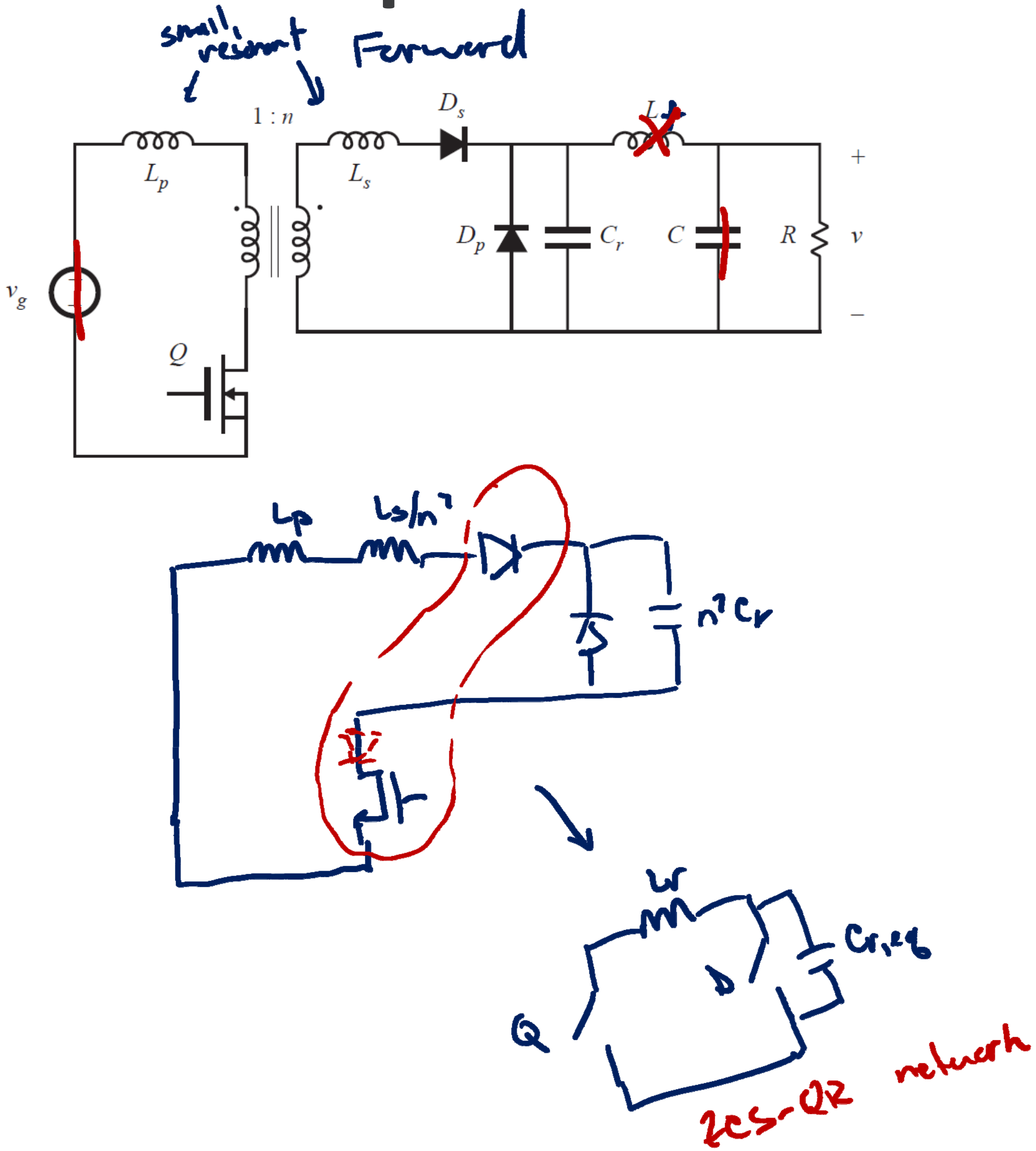
$$P_{1/2}(x) = \frac{1}{2\pi}\left[\frac{1}{2}x + \pi + \sin^{-1}x + \frac{1}{x}\left(1 - \sqrt{1 - x^2}\right)\right]$$

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

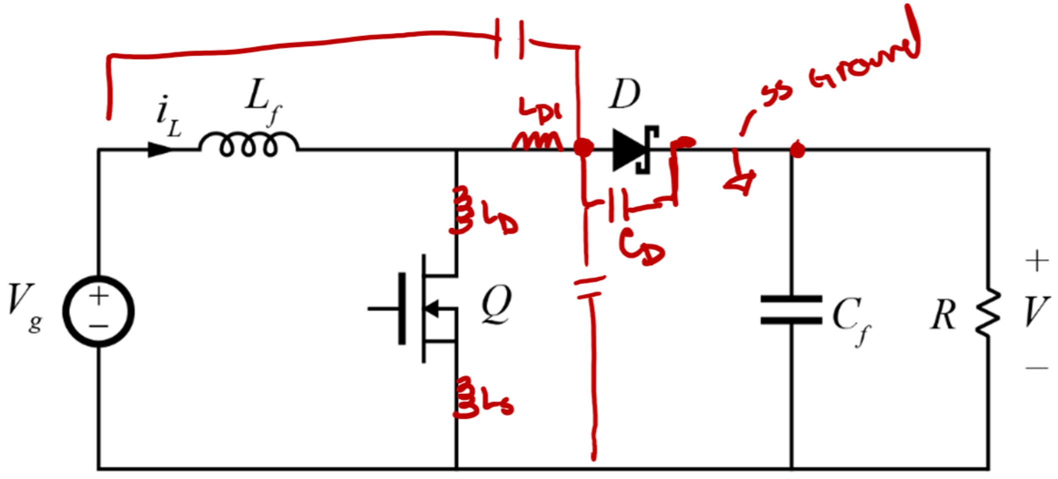
Switch Cell	Conv. Ratio μ	Current Range	Conv. Ratio Range	Requirements on *Q*
PWM	D	N/A	0≤μ≤1	
ZVS-QR (half)	$\mathbf{1 - FP_{\frac{1}{2}}\left(\frac{1}{J_L}\right)}$	$\mathbf{1 \le J_L \le \infty}$	**0≤μ≤1**	
ZVS-QR (full)	$1 - FP_1\left(\frac{1}{J_L}\right)$	$1 \le J_L \le \infty$	0≤μ≤1	Bidirectional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

Resonant Switch Identification Examples





ZCS-QR Boost

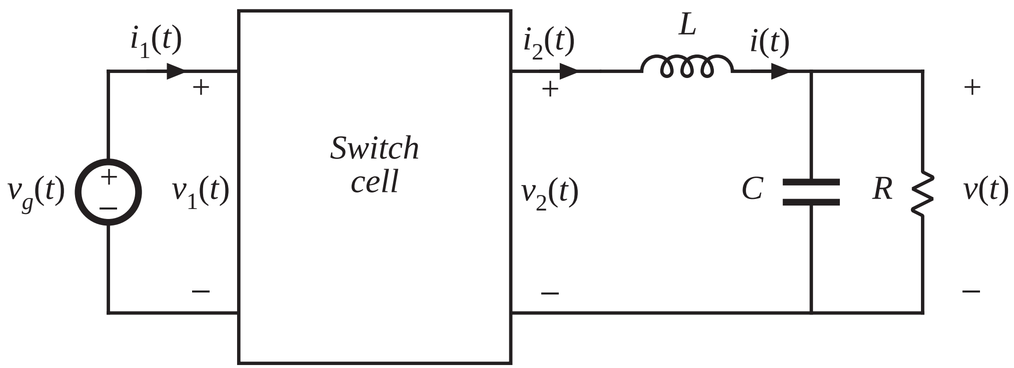


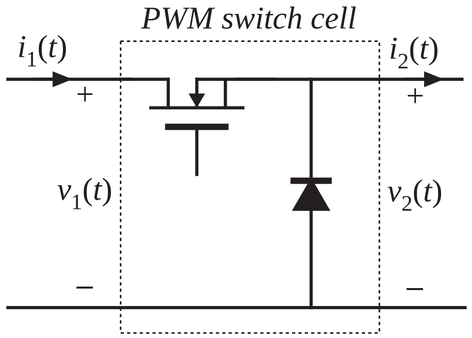
PWM solution to Boost $\quad M = \frac{1}{D'} = \frac{1}{1-d(t)}$

ZCS-QR solution $\quad M = \frac{1}{1-\mu(t)}$

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

SSM - PWM Parent



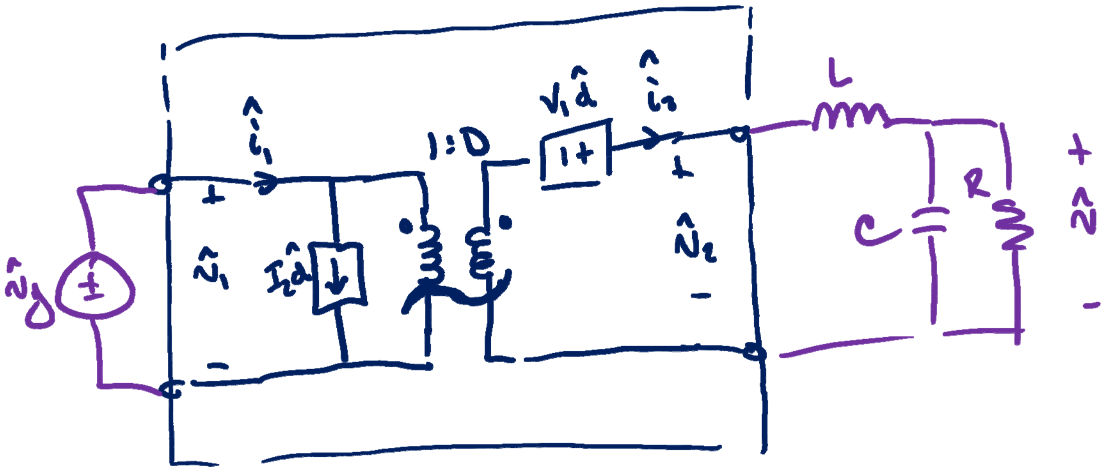


Review → SSM linearization

$$\left.\begin{aligned}\langle v_2\rangle &= d(t)\langle v_1\rangle\\ \langle i_1\rangle &= d(t)\langle i_2\rangle\end{aligned}\right\}\ \text{Averaged, nonlinear}$$

↓ SSM linearization

$$\left.\begin{aligned}\hat{v}_2 &= D\hat{v}_1 + \hat{d}V_1\\ \hat{i}_1 &= \underbrace{D\hat{i}_2}_{\text{XF}} + \underbrace{\hat{d}I_2}_{\text{controlled sources}}\end{aligned}\right\}\ \text{Averaged, linear}$$



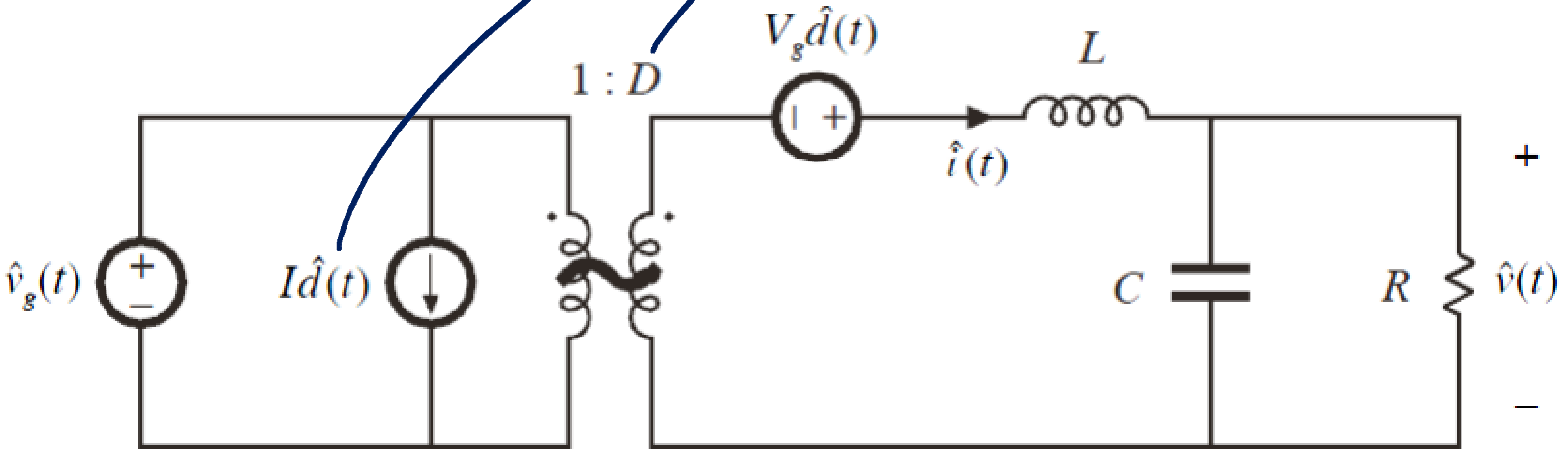
SSM, PWM Case

for resonant case, replace

$D \to \mu$

$\hat{d} \to \hat{\mu}$

Textbook, Fig.7.17(a)



ZVS-QR Switch Cell SSM

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

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

$$\mu = f(I_L, V_g, f_s)$$