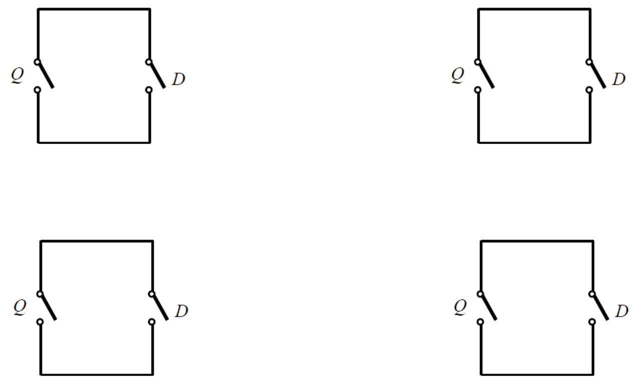
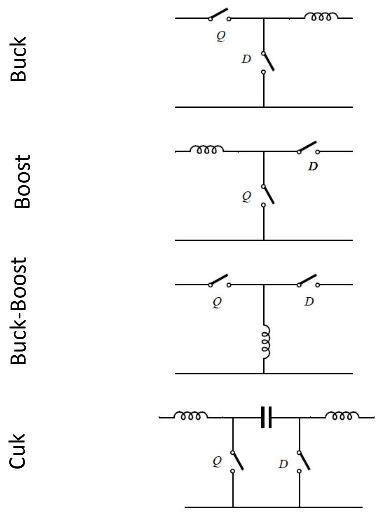
Classification of Resonant-Switch Converters

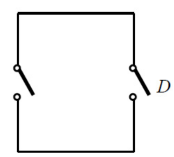


ZVS-QR

Converter examples

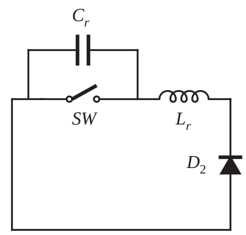


High-frequency view of the switch network

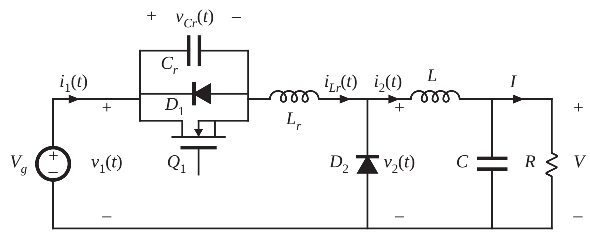


20.3.1 The zero-voltage-switching quasi-resonant switch cell

When the previously-described operations are followed, then the converter reduces to



A full-wave version based on the PWM buck converter:



ZVS-QR

Switch conversion ratio

$$\mu = 1 - FP_{\frac{1}{2}}\left(\frac{1}{J_s}\right) \qquad \textit{half-wave}$$

$$\mu = 1 - FP_1\left(\frac{1}{J_s}\right) \qquad \textit{full-wave}$$

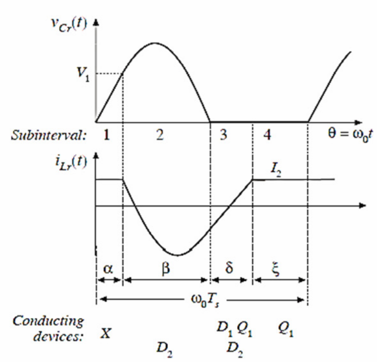
ZVS boundary

$$J_s \geq 1$$

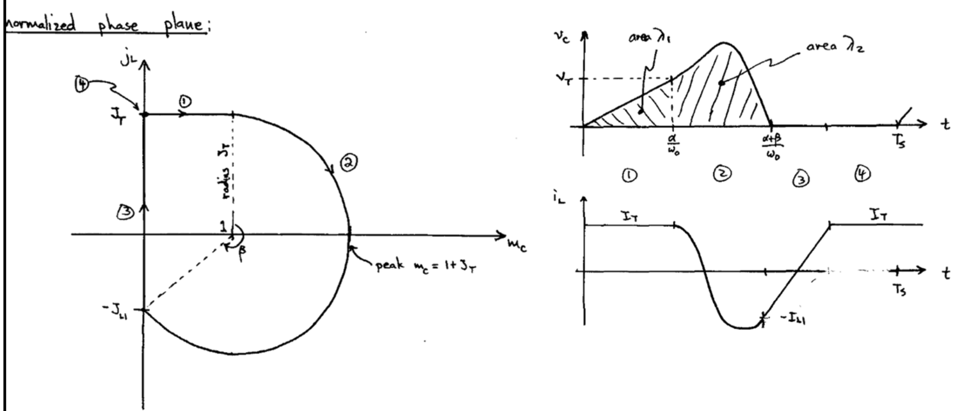
peak transistor voltage $V_{cr,pk} = (1 + J_s)\,V_1$

A problem with the quasi-resonant ZVS switch cell: peak transistor voltage becomes very large when zero voltage switching is required for a large range of load currents.

Tank waveforms



ZVS-QR State Plane Trajectory



The average output voltage

Average output voltage:

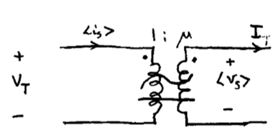
$$\langle m_s \rangle = 1 - \langle m_c \rangle$$

$$\langle v_s \rangle = \mu V_T \quad \text{with} \quad \mu = 1 - F P(J_T)$$

$$P = \frac{1}{2\pi}\left[\frac{1}{2}\frac{1}{J_T} + \pi + \sin^{-1}\frac{1}{J_T} + J_T + \sqrt{J_T^2 - 1}\right]$$

$$\text{type b} \quad P(J_T) = \text{type a} \quad P\left(\frac{1}{J_T}\right)$$

$$\underbrace{\begin{bmatrix} \langle v_s \rangle \\ \langle i_s \rangle \end{bmatrix}}_{\underline{x}_S} = \mu \underbrace{\begin{bmatrix} V_T \\ I_T \end{bmatrix}}_{\underline{x}_T}$$



dc transformer
μ controlled by F, but also depends on V_T and I_T

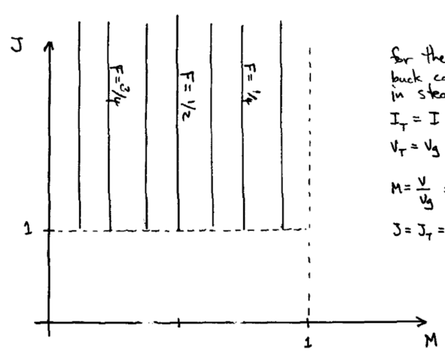
Results: Quasi-resonant switches

Switch	μ	$P(J_T)$	load current range	voltage conversion range
PWM	D	—	nearly infinite	$0 \le \mu \le 1$
type a, ½ wave	$F\,P(\ldots)$	$k_{\frac{1}{2}}(J_T)$	$0 \le J_T \le 1$	$0 \le \mu \le 1$
type a, full wave	$FP \approx F$	$k_1(J_T) \approx 1$	$0 \le J_T \le 1$	$0 \le \mu \le 1$
type b, ½ wave	$1 - FP(J_T)$	$k_{\frac{1}{2}}\left(\frac{1}{J_T}\right)$	$1 \le J_T \le \infty$	$0 \le \mu \le 1$
type b, full wave	$1 - FP \approx 1 - F$	$k_1\left(\frac{1}{J_T}\right) \approx 1$	$1 \le J_T \le \infty$	$0 \le \mu \le 1$

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

$$k_1(x) = \frac{1}{2\pi}\left[\frac{1}{2}x + 2\pi - \sin^{-1}x + \frac{1}{x}\left(1 - \sqrt{1-x^2}\right)\right]$$

Output characteristics: Full-wave ZVS buck



for the buck converter in steady state:

$I_T = I$ = load current

$V_T = V_g$

$M = \frac{V}{V_g} = \mu$

$J = J_T = \frac{I R_o}{V_g}$

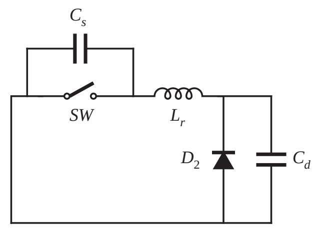
$V = \left(1 - \frac{f_s}{f_o}\right) V_g$ with $I \ge \frac{V_g}{R_o}$

with resistive load R: $I = V/R \ge V_g/R_o$

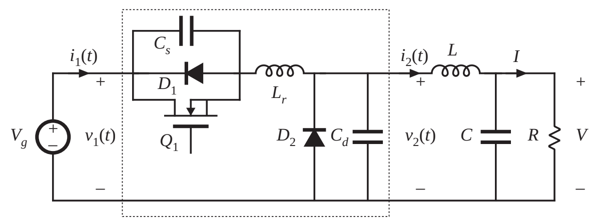
$\Rightarrow R \le \left(1 - \frac{f_s}{f_o}\right) R_o$

20.3.2 The ZVS multiresonant switch

When the previously-described operations are followed, then the converter reduces to

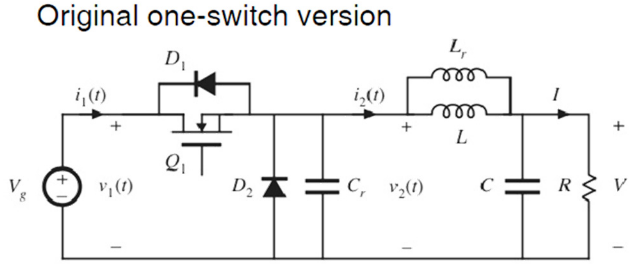


A half-wave version based on the PWM buck converter:

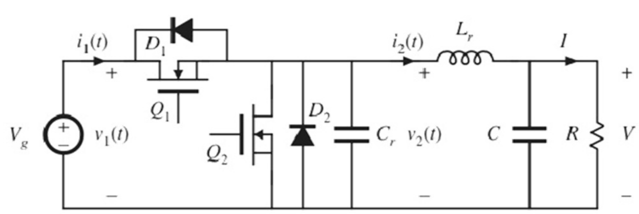


ZVS QSW Converters: Already Studied

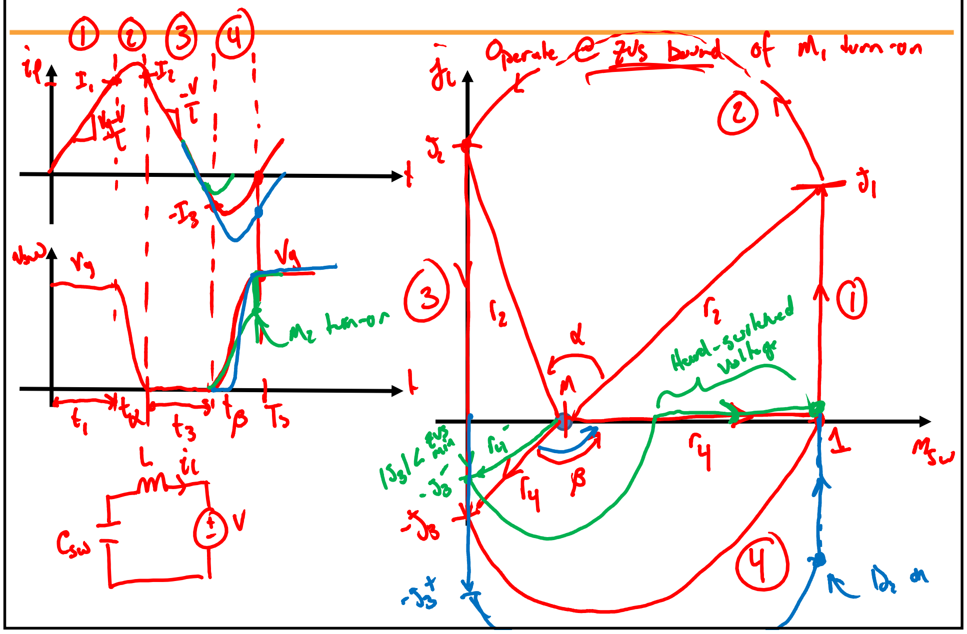
Original one-switch version



Add synchronous rectifier



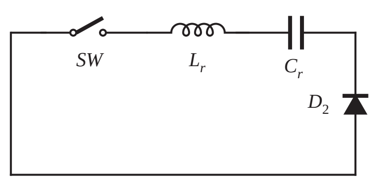
Lecture 21



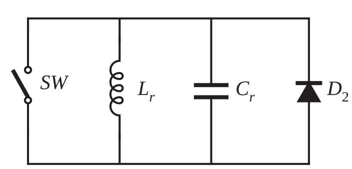
20.2.3 Quasi-square-wave resonant switches

When the previously-described operations are followed, then the converter reduces to

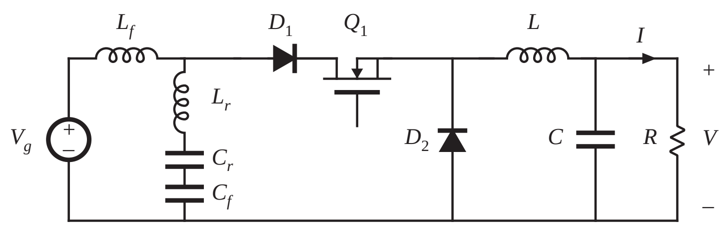
ZCS



ZVS



A quasi-square-wave ZCS buck with input filter



- The basic ZCS QSW switch cell is restricted to $0 \leq \mu \leq 0.5$
- Peak transistor current is equal to peak transistor current of PWM cell
- Peak transistor voltage is increased
- Zero-current switching in all semiconductor devices