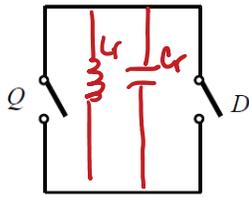


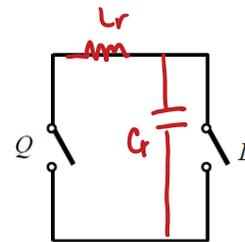
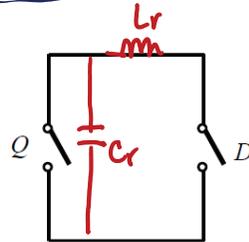
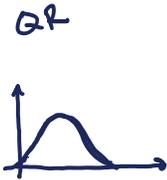
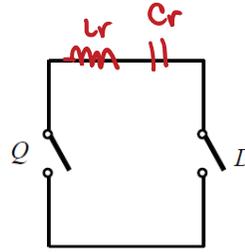
Classification of Resonant-Switch Converters

ZVS (of Q)

ZCS (of Q)

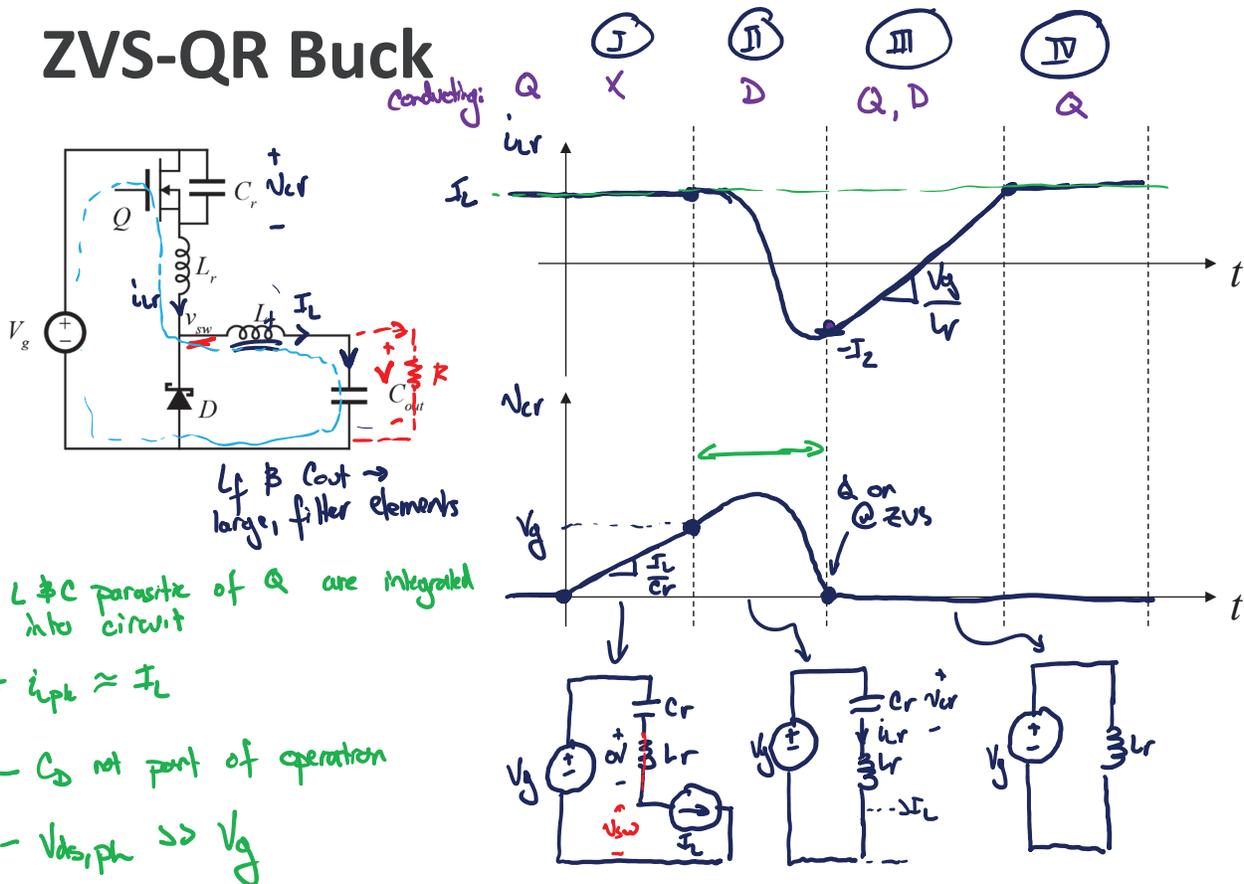


Covered in intro lectures



Covered in Book

ZVS-QR Buck



ZVS-QR State Plane

$$V_{base} = V_g, \quad R_o = \sqrt{\frac{L_r}{C_r}}, \quad I_{base} = \frac{V_g}{R_o}$$

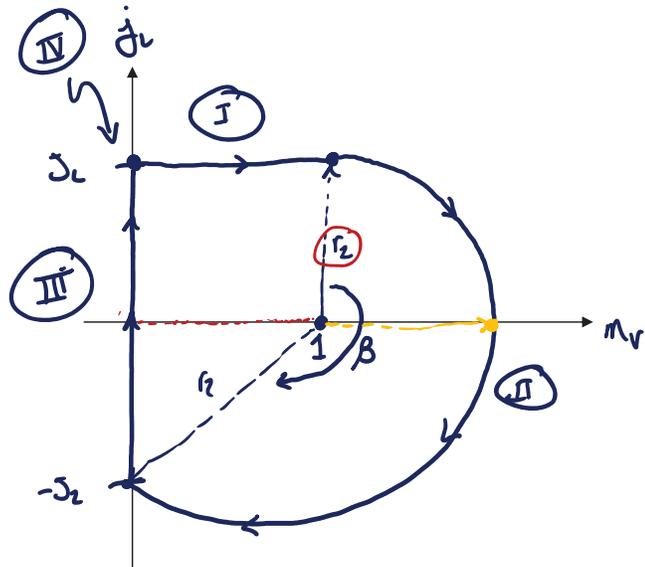
① $\frac{I_L}{C_r} t_1 = V_g$
 $\theta_1 = \frac{1}{J_1}$

② $J_1^2 = 1 + J_2^2$
 $\beta = \pi + \sin^{-1}\left(\frac{1}{J_1}\right)$

③ $\frac{V_g}{L_r} t_3 = I_L + I_2$
 $\theta_3 = J_1 + J_2$

④ χ

$$\theta_1 + \beta + \theta_3 + \theta_4 = \frac{2\pi}{F}$$



ZVS condition:
 $r_2 \geq 1 \rightarrow \underline{\underline{J_1 \geq 1}}$

Averaging

Cap-Q on Cout
 $\langle i_{out} \rangle = \phi = I_L - \frac{V}{R}$

Volt-sec balance on Lf
 $\langle v_{Lf} \rangle_{T_s} = \phi = V_g - \langle v_{cr} \rangle - \langle v_{cr} \rangle - V$

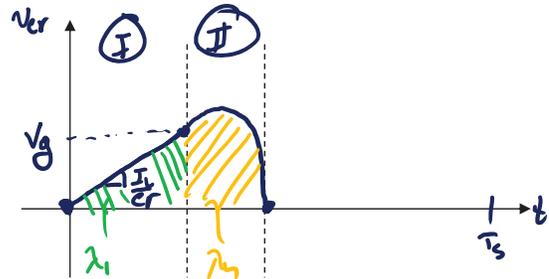
$$V = V_g - \langle v_{cr} \rangle_{T_s}$$

$$V = V_g - \frac{1}{T_s} \int_0^{T_s} v_{cr} dt = V_g - \frac{1}{T_s} [\lambda_1 + \lambda_2]$$

$$V = V_g - \frac{1}{T_s} \left[\frac{1}{2} t_1 V_g + V_g t_3 + L(I_2 + I_L) \right]$$

$$M = 1 - \frac{1}{T_s} \left[\frac{t_1}{2} + t_3 + L \frac{I_2 + I_L}{V_g} \right]$$

$$M = 1 - \frac{F}{2\pi} \left[\frac{\theta_1}{2} + \beta + J_2 + J_1 \right]$$



$$\lambda_1 = \frac{1}{2} t_1 V_g$$

$$\lambda_2 = \int_{t_1}^{t_1+t_3} v_{cr} dt = \int_{t_1}^{t_1+t_3} V_g - L \frac{di_{cr}}{dt} dt$$

$$\lambda_2 = V_g t_3 - L \int_{I_L}^{I_2} \frac{di}{dt} dt$$

$$\lambda_2 = V_g t_3 - L(I_2 - I_L)$$

Complete Solution

$$M = 1 - \frac{F}{2\pi} \left[\frac{\theta}{2} + \beta + \gamma_2 + \gamma_L \right]$$

$$M = 1 - \frac{F}{2\pi} \left[\frac{1}{2\gamma_L} + \pi + \sin^{-1}\left(\frac{1}{\gamma_L}\right) + \sqrt{\gamma_L^2 - 1} + \gamma_L \right] \quad \text{ZVS-QR}$$

→ same as 20.46 in Fundamentals of Power Electronics 2nd edition
23.46 in 3rd edition

$$M = 1 - FP_{\gamma_L} \left(\frac{1}{\gamma_L}\right)$$

e.g. $\gamma_L \rightarrow \frac{1}{2}$

ZCS-QR

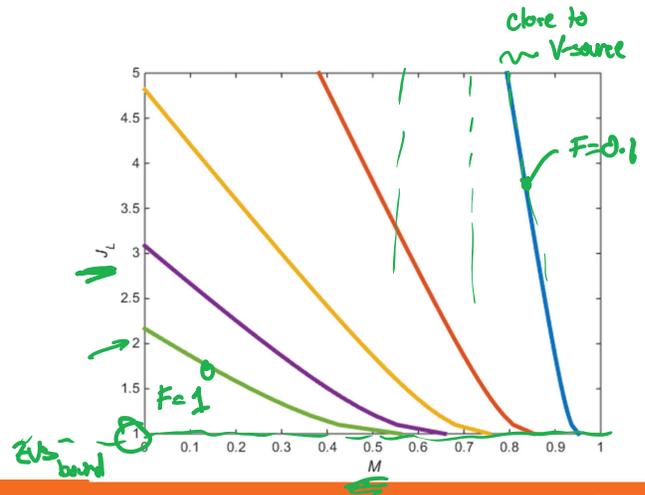
This is the half-wave implementation of a ZVS-QR Buck



A full-wave implementation



- Requires a bidirectional-blocking switch Q



MOSFET Voltage Stresses

Peak V_{ds} on FET:

$$M_{r,pl} = 1 + r_2 = 1 + \gamma_L$$

$$\gamma_L \geq 1 \quad \text{for ZVS}$$

so at minimum $V_{r,pl} = V_{ds,pl} = 2V_g$

ex if we want to keep ZVS for $P_{out} \geq 20\%$ of $P_{out,max}$

$$V_{r,pl} = (1 + 5) V_g = 6V_g$$