Chapter 20: Resonant Switch Topologies

2nd Ed. Chapter 23 in 3rd Edition

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  - 20.1.1 Waveforms of the half-wave ZCS quasi-resonant switch cell
  - 20.1.2 The average terminal waveforms
  - 20.1.3 The full-wave ZCS quasi-resonant switch cell
- 20.2 Resonant switch topologies
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  - 20.2.2 The zero-voltage-switching multiresonant switch
  - 20.2.3 Quasi-square-wave resonant switches
- 20.3 Ac modeling of quasi-resonant converters
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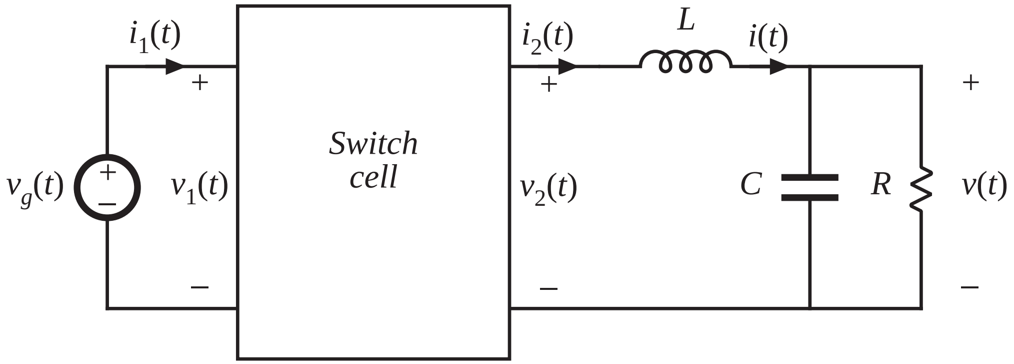
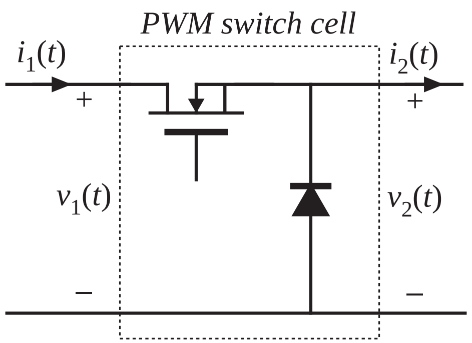
The resonant switch concept

General idea:

- PWM switch network is replaced by a resonant switch network
- This leads to a quasi-resonant or quasi-squarewave version of the original PWM converter

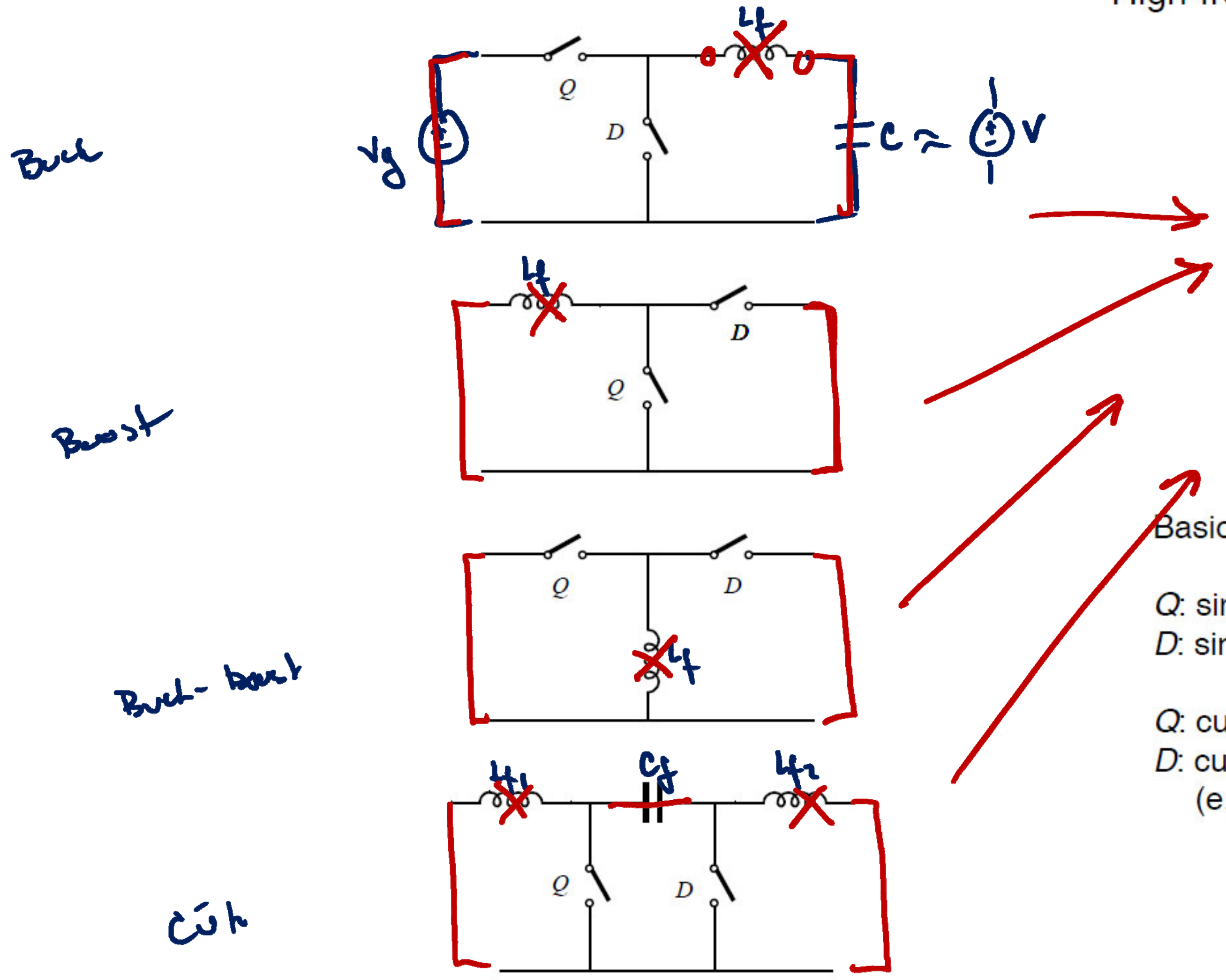




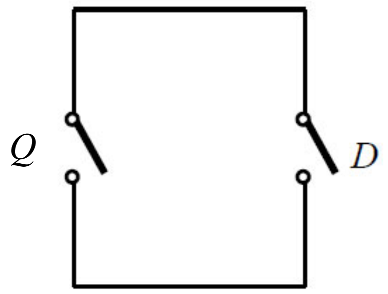
Example: realization of the switch cell in the buck converter

High Frequency Switch Network

Converter examples



High-frequency view of the switch network



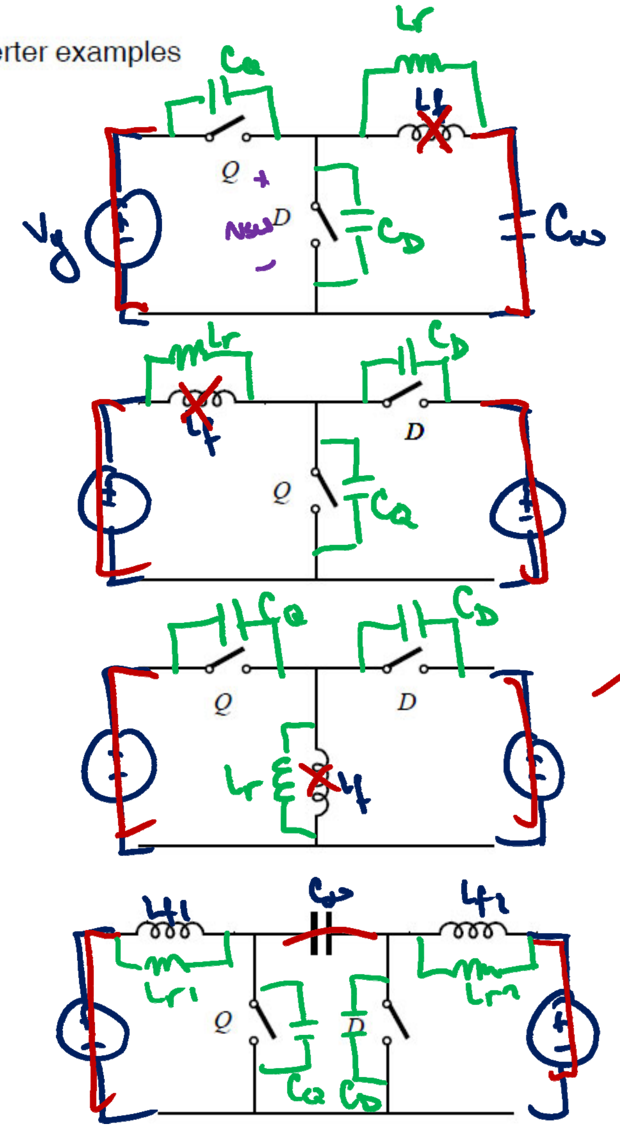
Basic switch implementation options

Q: single-quadrant (transistor)
D: single-quadrant (diode)

Q: current-bidirectional (e.g. MOSFET)
D: current-bidirectional synchronous rectifier (e.g. MOSFET)

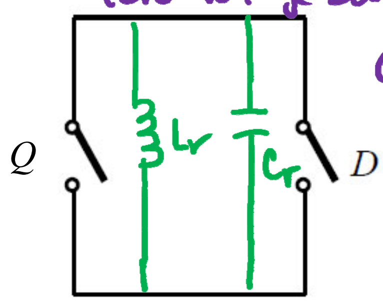
ZVS-QSW: Review

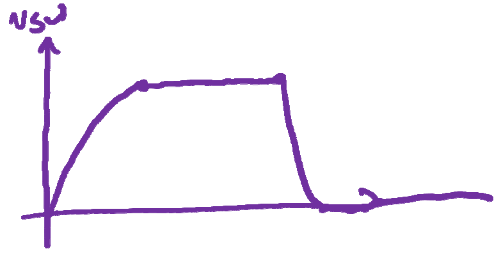
Converter examples



High-frequency view of the switch network

ZVS - QSW
zero voltage switching
Quasi - Squarewave





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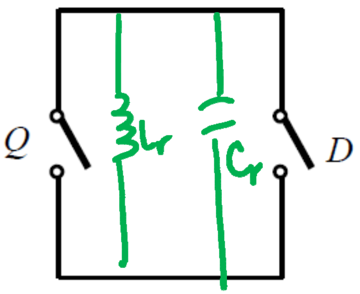
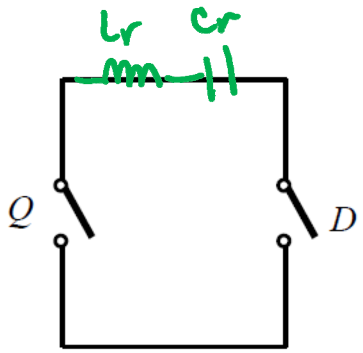
Classification of Resonant-Switch Converters

ZVS of Q

ZCS of Q

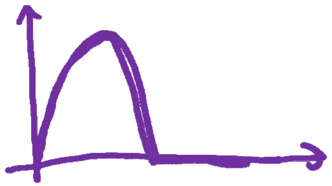
Discussed in class extensively

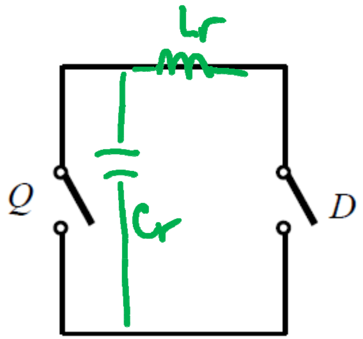




Qsw

QR





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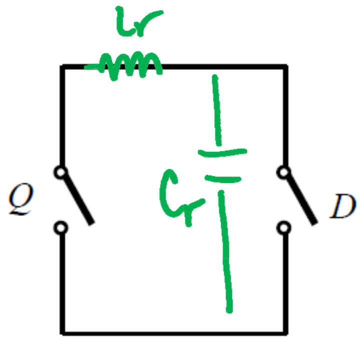
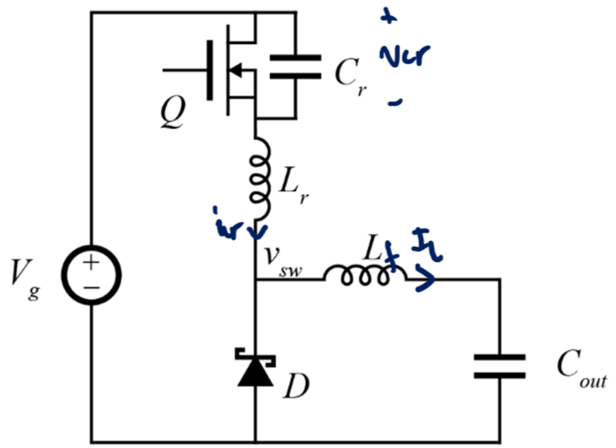
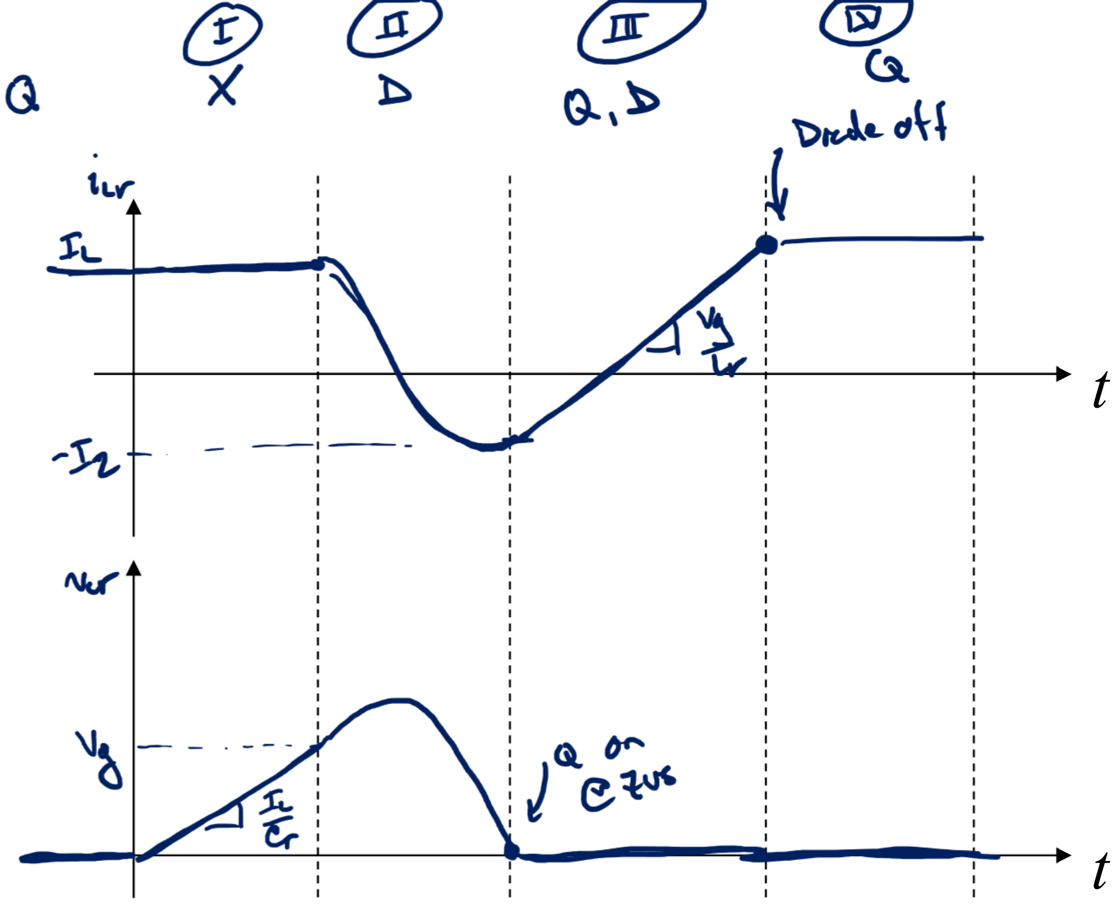
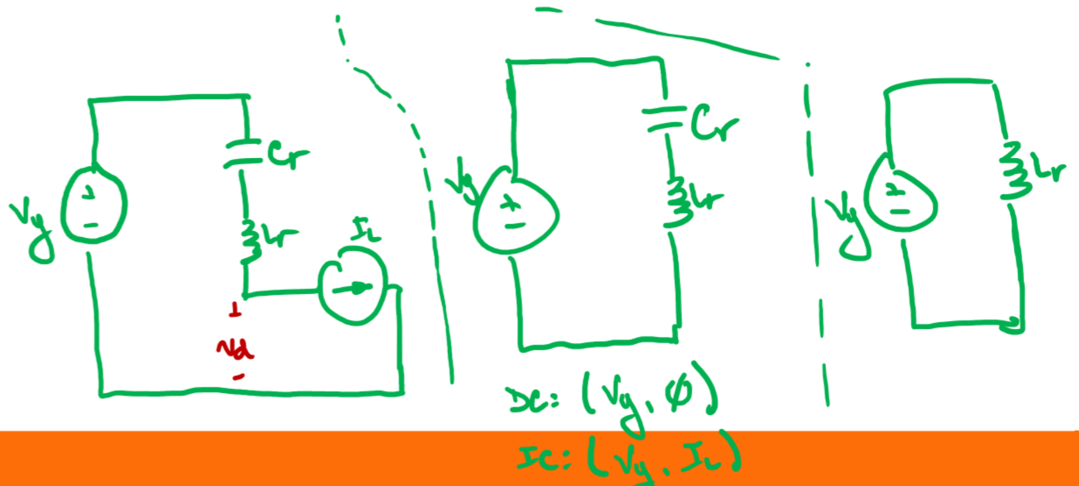


Covered in textbook

ZVS-QR Buck







Resonance starts w/ $v_{ds} = V_g$

- Will increase voltage stress

+ Incorporates power loop inductance & active device capacitance

- Does not integrate diode capacitance

+ I_L is small-ripple

+ $i_{ds,pk} = I_L \approx I_{out}$

ZVS-QR State Plane

$V_{base} = V_g \qquad I_{base} = \frac{V_g}{R_0} \qquad R_0 = \sqrt{\frac{L_r}{C_r}}$

I $\quad \frac{I_L}{C_r} t_1 = V_g$

$$\boxed{\theta_1 = \frac{1}{J_L}}$$

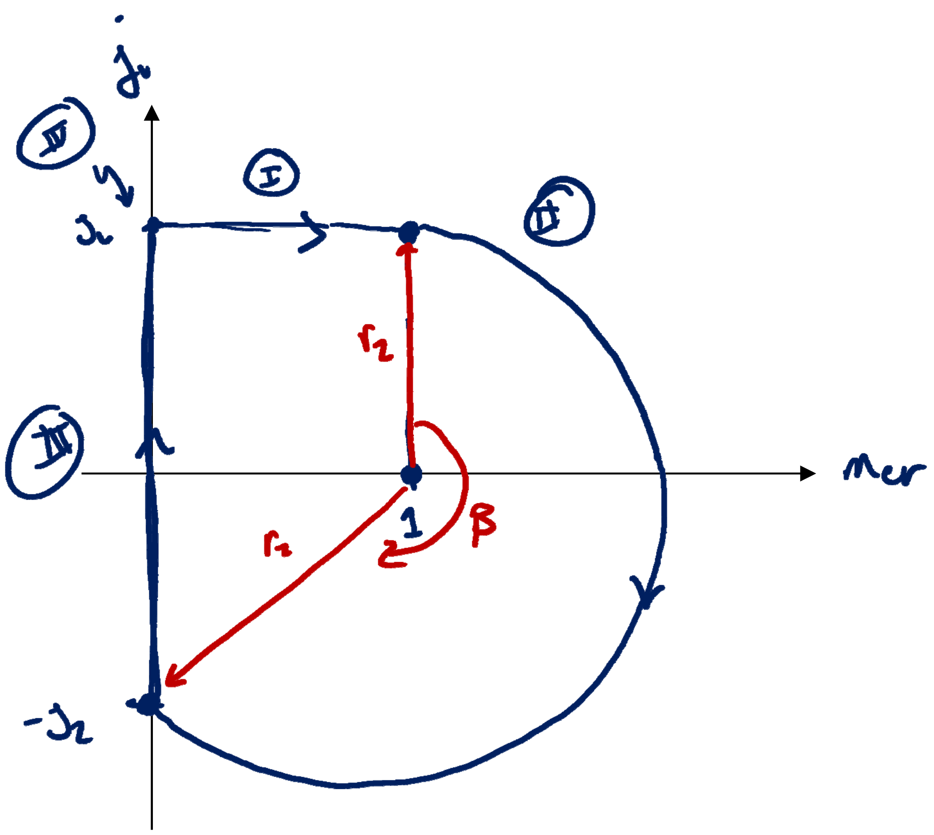
II $\quad \boxed{J_L^2 = 1 + J_2^2}$

$$\boxed{\beta = \pi + \sin^{-1}\left(\frac{1}{J_L}\right)}$$

III $\quad \frac{V_g}{L_r} t_3 = I_L + I_2$

$$\boxed{\theta_3 = J_L + J_2}$$

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



ZVS condition: $\quad r_2 = \boxed{J_L \geq 1}$

Averaging

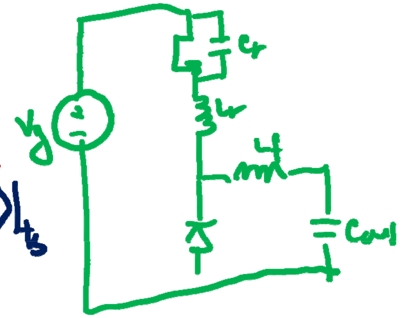
2 filter elements

for C_{out} : $\langle i_{co}\rangle = \emptyset \rightarrow I_L = \frac{V}{R}$

for L_f

$$\langle v_{Lf}\rangle\big|_{T_s} = \emptyset = V_g - V - \langle v_{cr}\rangle\big|_{T_s} - \cancel{\langle v_{Lr}\rangle\big|_{T_s}}^{\,\emptyset}$$

$$v_{Lf}(t) = V_g - v_{cr}(t) - v_{Lf}(t) - V$$

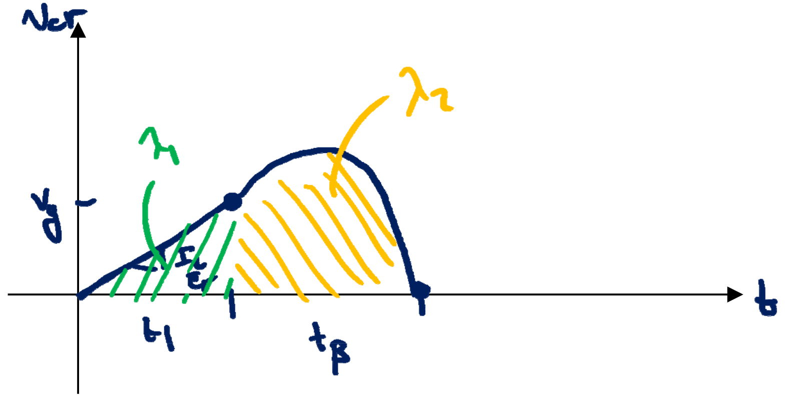


$\downarrow$

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

$$M = \frac{V}{V_g} = 1 - \frac{1}{T_s}\left[\frac{1}{2}t_1 + t_\beta + \frac{L_r}{V_g}(I_L + I_2)\right]$$

$$\boxed{M = 1 - \frac{F}{2\pi}\left(\frac{\theta_1}{2} + \beta + J_2 + J_L\right)}$$



$$\langle v_{cr}\rangle\big|_{T_s} = \frac{1}{T_s}\int_0^{T_s} v_{cr}(t) = \frac{1}{T_s}\left[\lambda_1 + \lambda_2\right]$$

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

$$\lambda_2 = \int_{t_1}^{t_1+t_\beta}(V_g - v_{Lr})\,dt = \int_{t_1}^{t_1+t_\beta} V_g - L_r\frac{di_{Lr}}{dt}\,dt$$

$$= V_g t_\beta - L_r(-I_L - I_2)$$