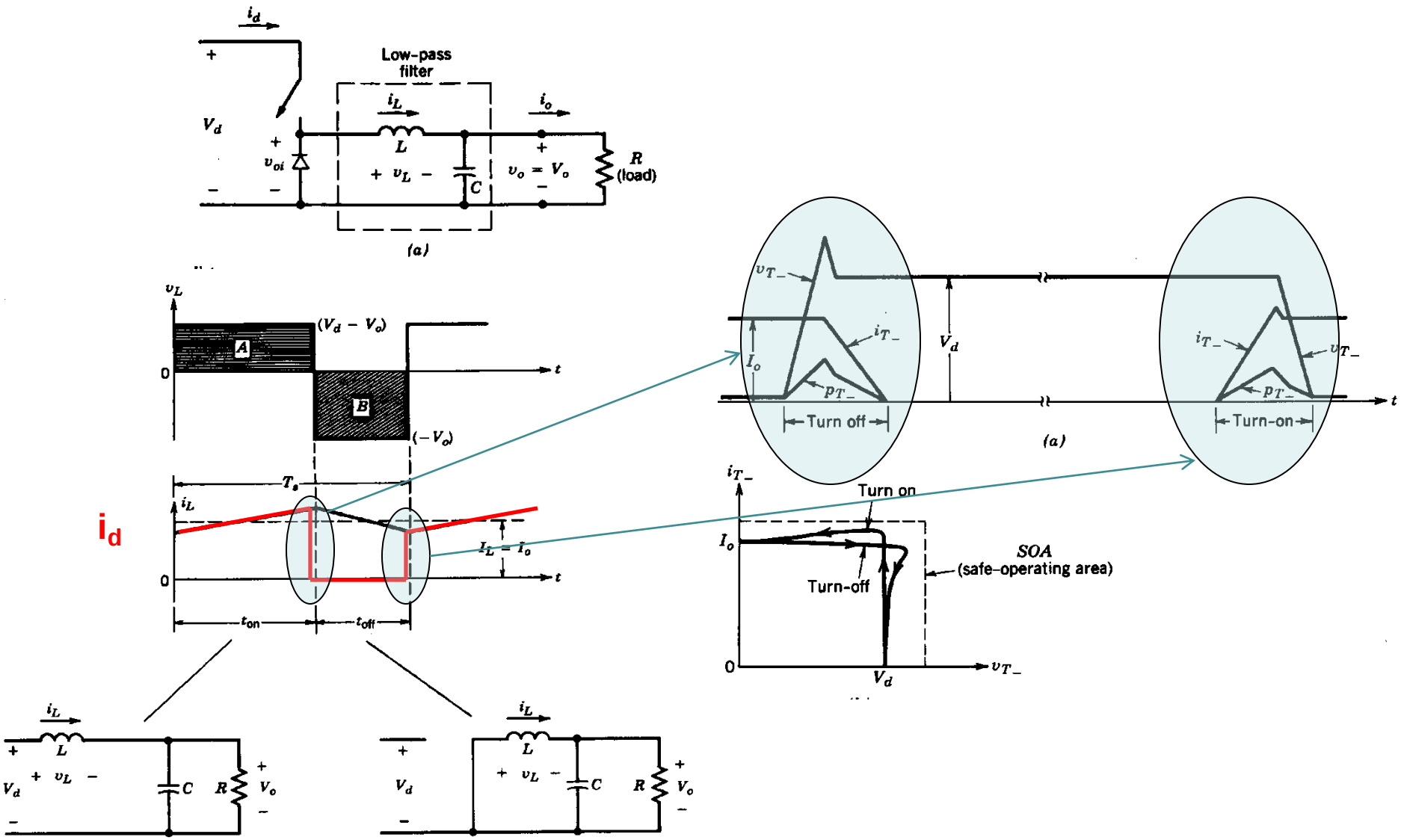
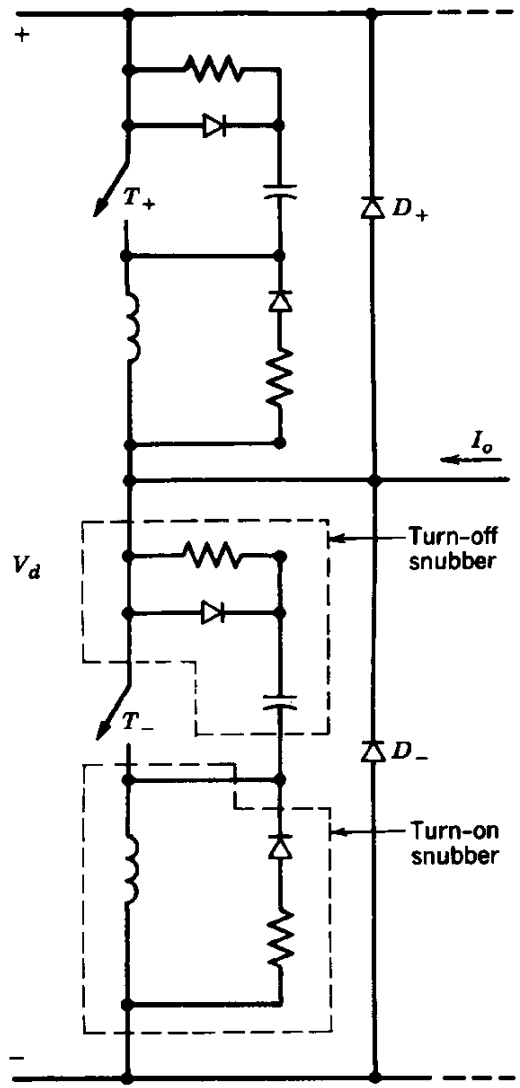
Resonant Converters

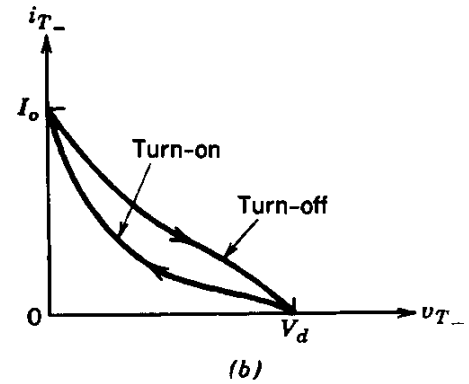
EE 442-642

Voltage and Current Waveforms across the switch of a Buck Converter



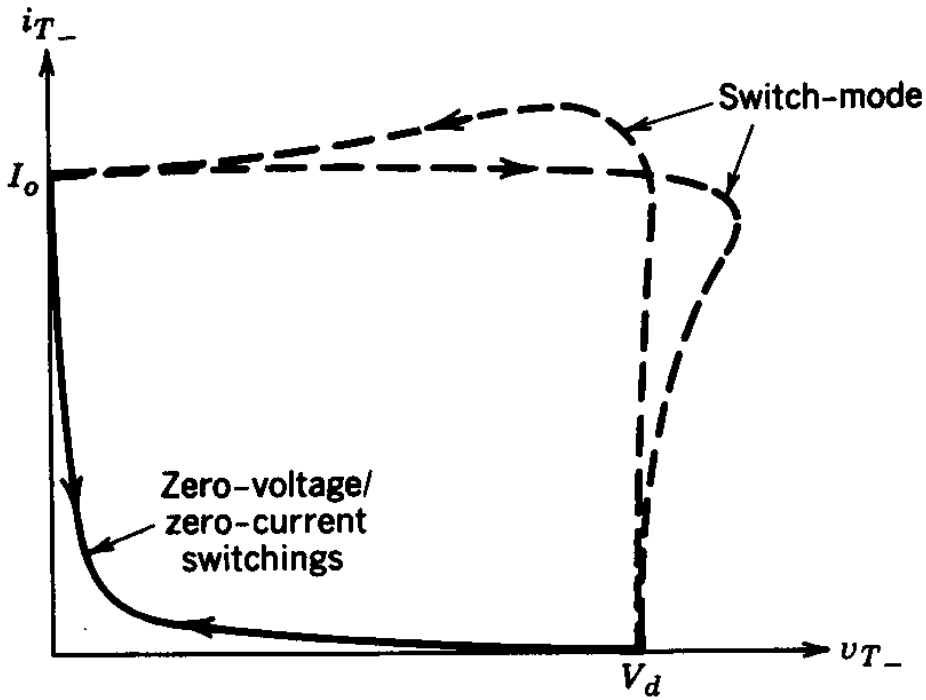
Turn-on and Turn-off Snubber Circuits



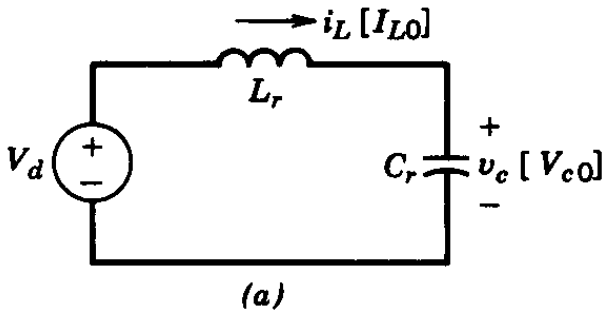


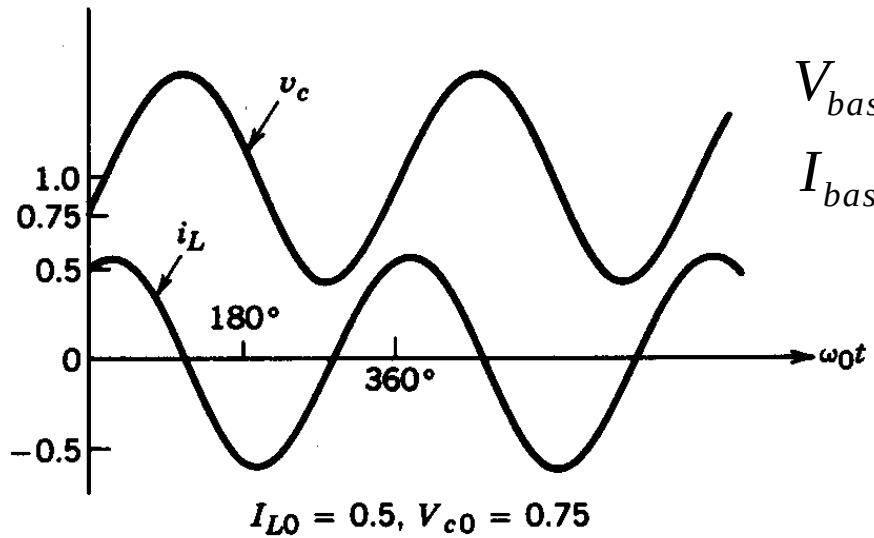
Power loss is shifted to snubber circuits.

Switching Trajectories of Hard and Soft Switching



Undamped Series-Resonant Circuit





$$V_{base} = V_d,$$
$$I_{base} = V_d / Z_o$$

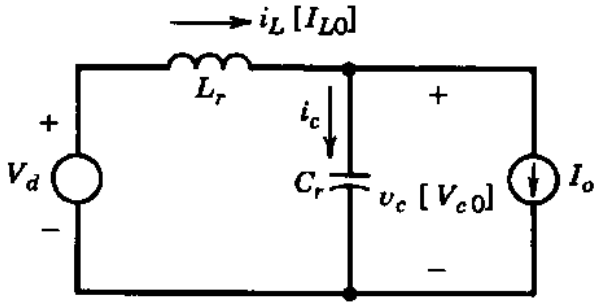
$$i_L(t) = I_{Lo}\cos(\omega_o t) + \frac{V_d - V_{co}}{Z_o}\sin(\omega_o t),$$

$$v_c(t) = V_d - (V_d - V_{co})\cos(\omega_o t) + Z_o I_{Lo}\sin(\omega_o t)$$

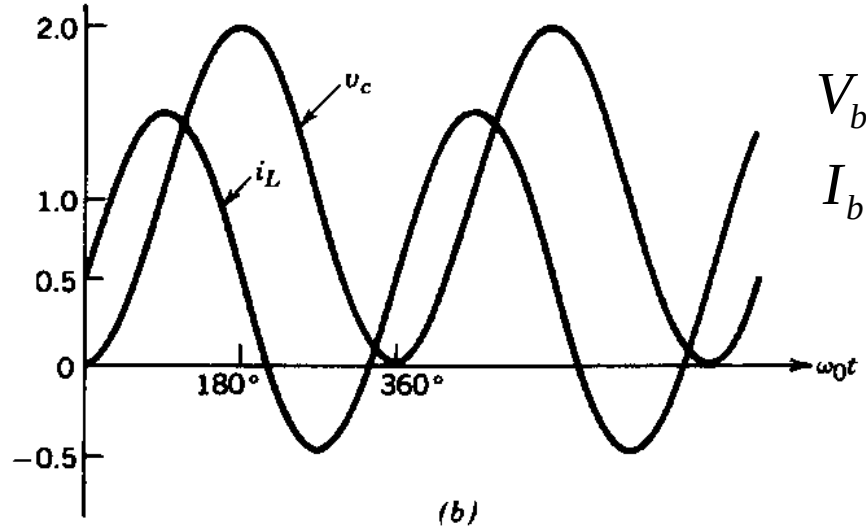
where

$$\omega_o = \frac{1}{\sqrt{L_r C_r}}, \qquad Z_o = \sqrt{\frac{L_r}{C_r}}$$

Series-Resonant Circuit with Capacitor-Parallel Load



(a)



(b)

$$V_{base} = V_d,$$
$$I_{base} = V_d / Z_o$$

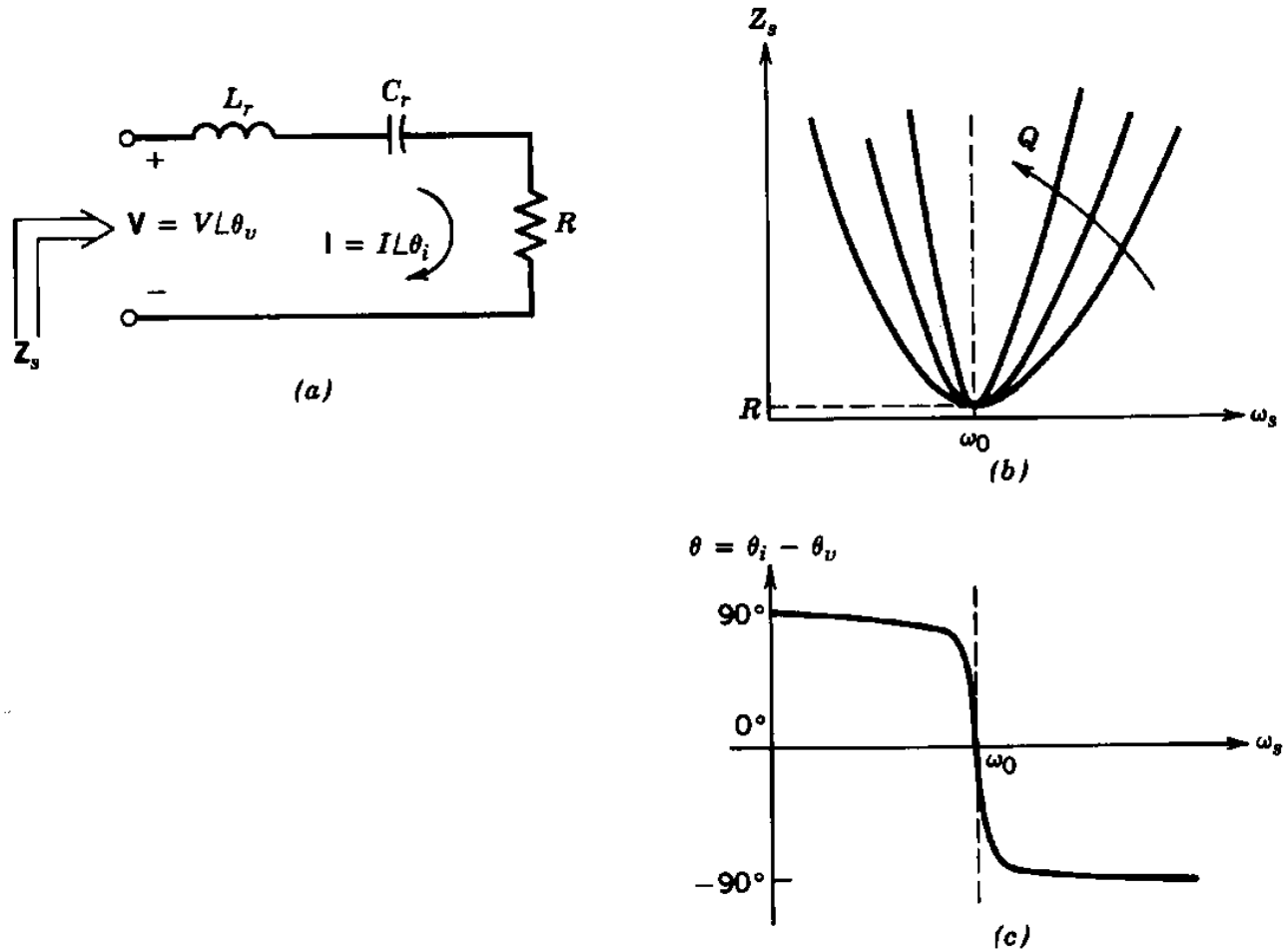
$$i_L(t) = I_o + (I_{Lo} - I_o)\cos(\omega_o t) + \frac{V_d - V_{co}}{Z_o}\sin(\omega_o t),$$

$$v_c(t) = V_d - (V_d - V_{co})\cos(\omega_o t) + Z_o(I_{Lo} - I_o)\sin(\omega_o t)$$

where

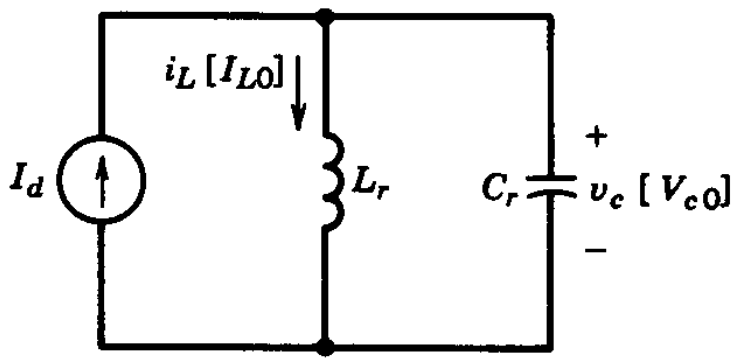
$$\omega_o = \frac{1}{\sqrt{L_r C_r}}, \qquad Z_o = \sqrt{\frac{L_r}{C_r}}$$

Impedance of a Series-Resonant Circuit



$$Quality\ Factor: \quad Q = \frac{\omega_o L_r}{R} = \frac{1}{\omega_o CR} = \frac{Z_o}{R}$$

Undamped Parallel-Resonant Circuit



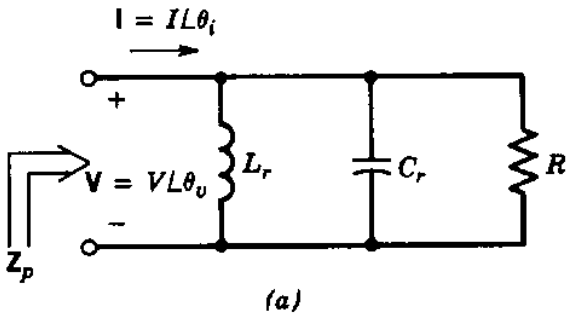
$$i_L(t) = I_d + (I_{Lo} - I_d)\cos(\omega_o t) + \frac{V_{co}}{Z_o}\sin(\omega_o t),$$

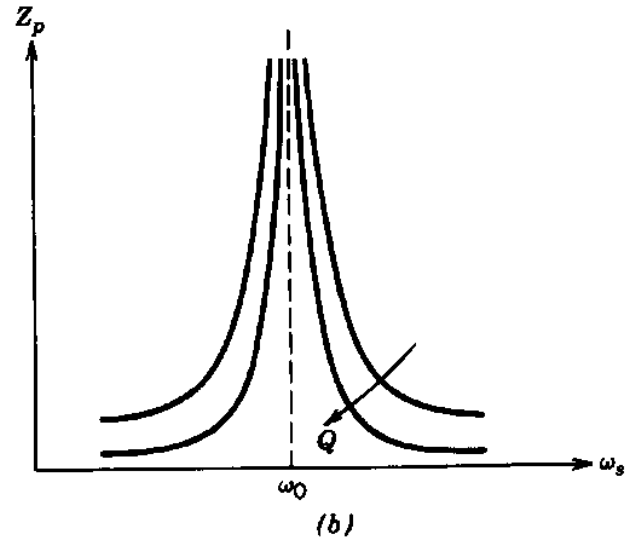
$$v_c(t) = V_{co}\cos(\omega_o t) + Z_o(I_d - I_{lo})\sin(\omega_o t)$$

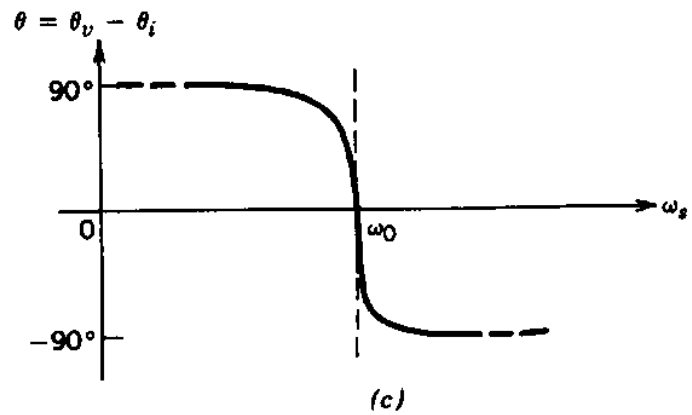
where

$$\omega_o = \frac{1}{\sqrt{L_r C_r}}, \qquad Z_o = \sqrt{\frac{L_r}{C_r}}$$

Impedance of a Parallel-Resonant Circuit



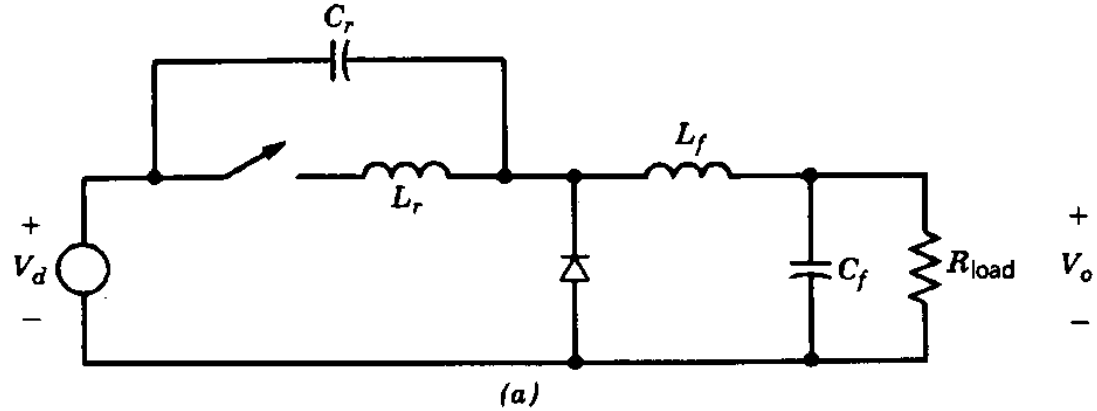




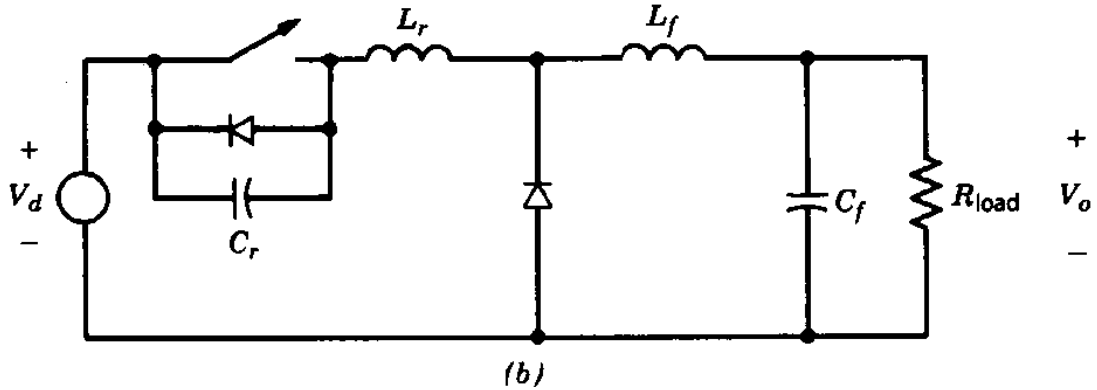
$$Quality\ Factor: \quad Q = \omega_o R C_r = \frac{R}{\omega_o L_r} = \frac{R}{Z_o}$$

Resonant Switch DC-DC Converters

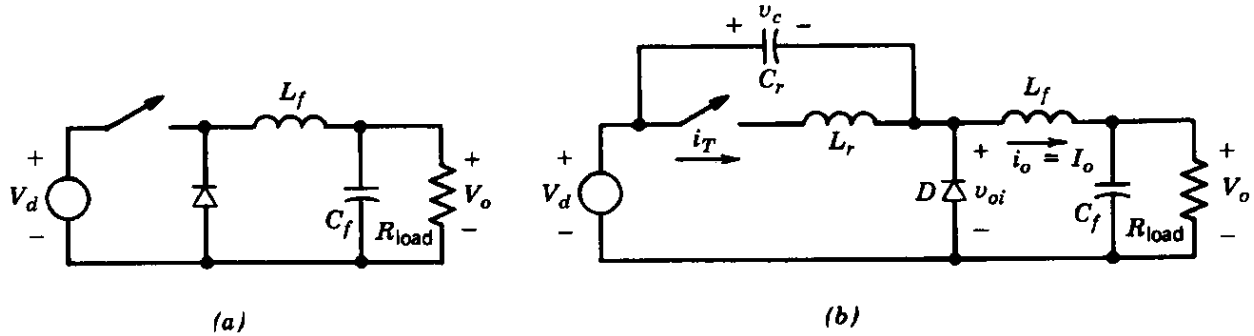
ZCS



ZVS

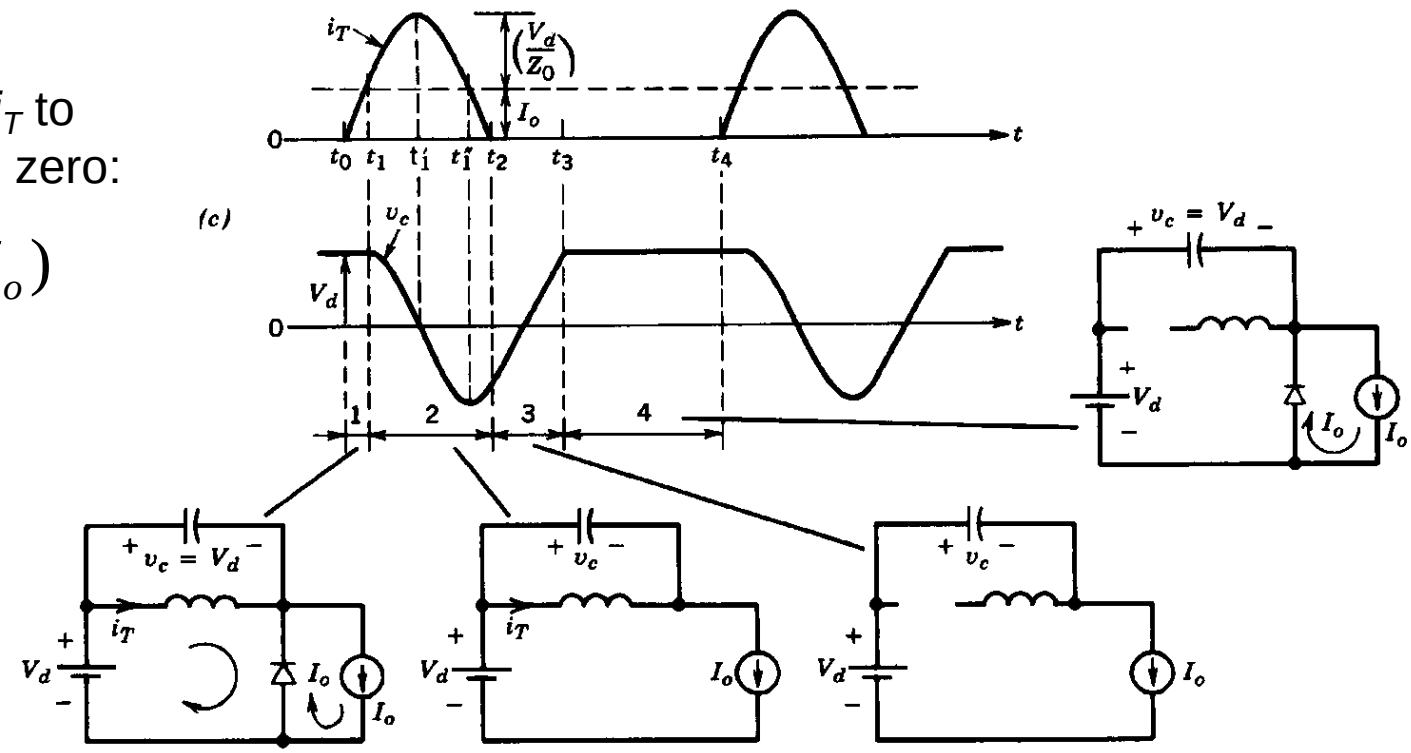


ZCS Resonant-Switch Converter

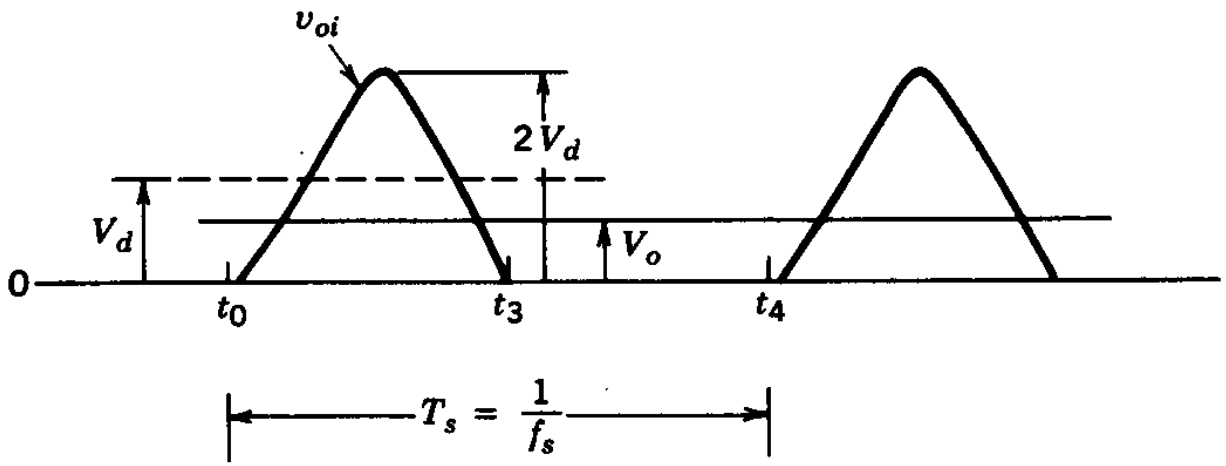


Necessary condition for i_T to come back to zero:

$$I_o < (V_d / Z_o)$$

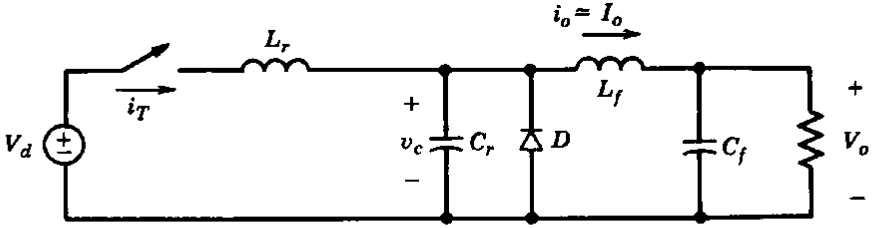


ZCS Resonant-Switch Converter

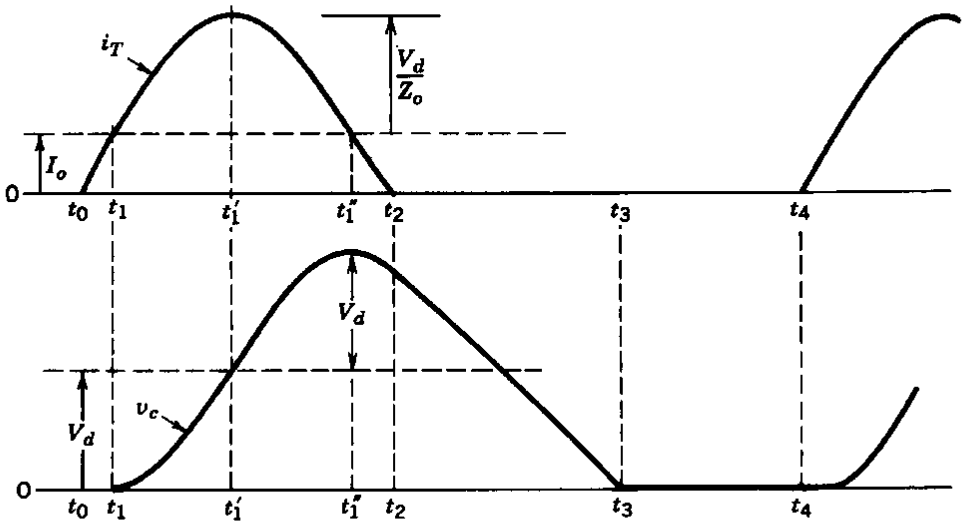


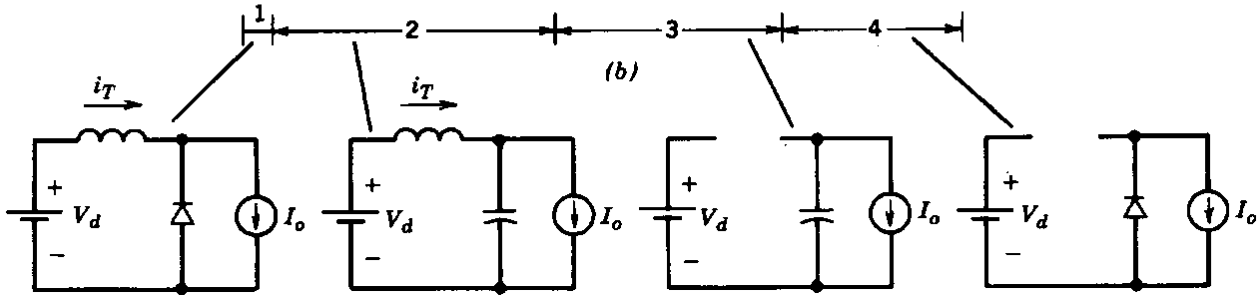
By controlling the switch-off time (t_4 - t_3), i.e., the switching frequency, the average value of v_{oi}, hence the average power supplied to the load can be controlled.

ZCS Resonant-Switch Converter- Alternate Config.



(a)

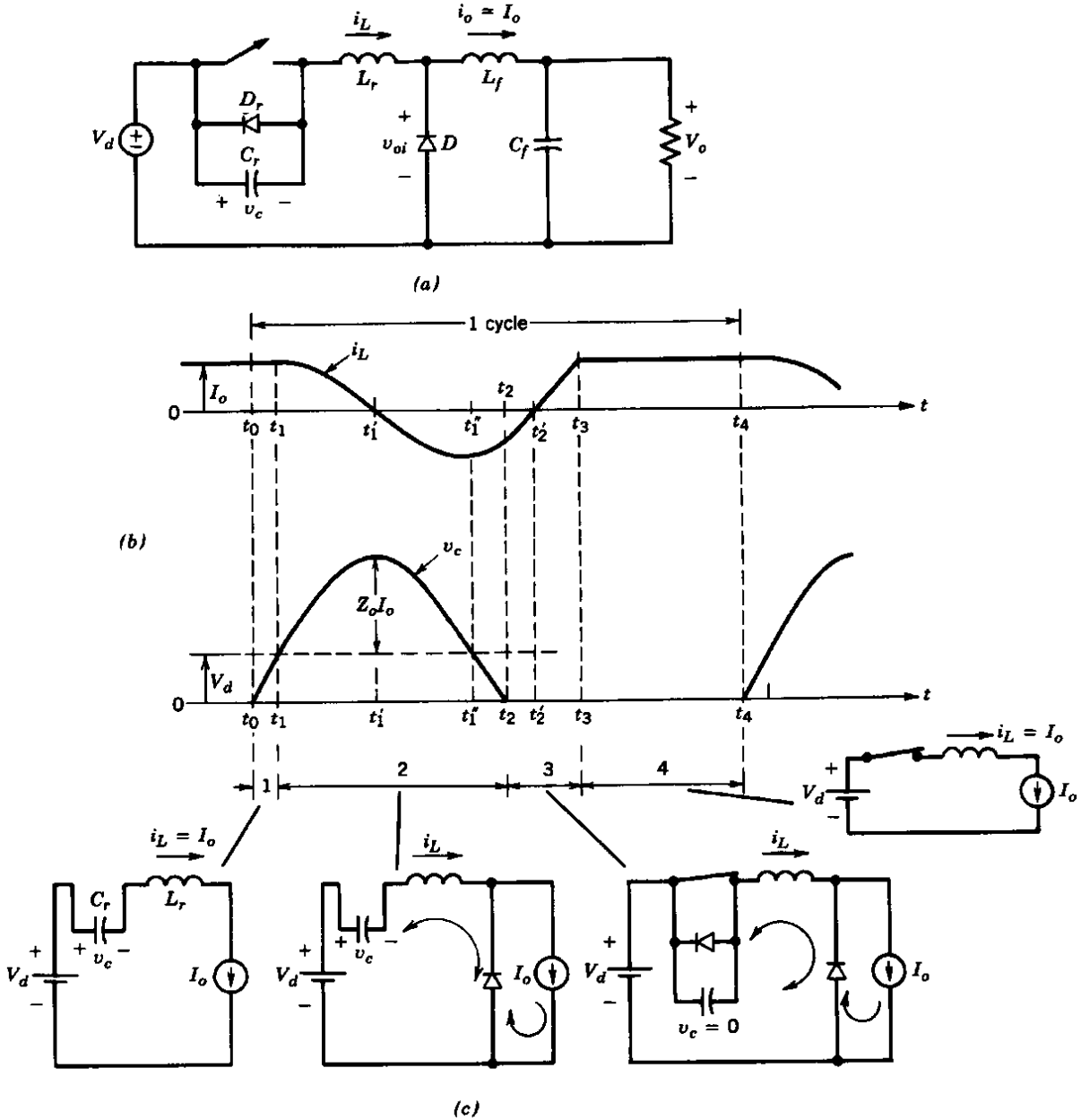




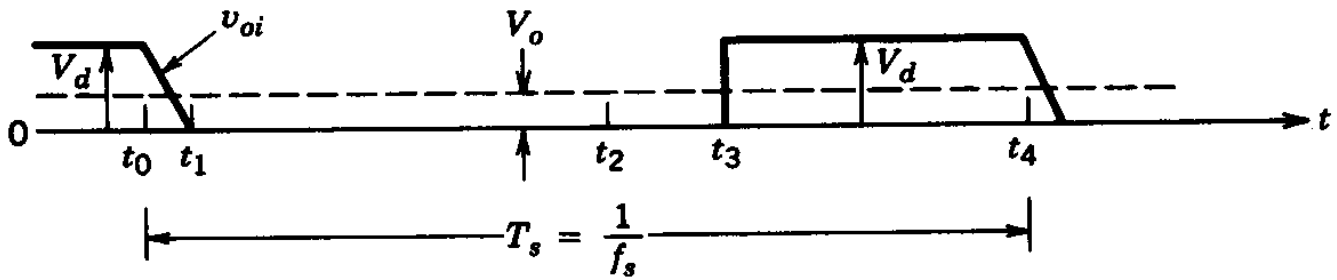
ZVS Resonant-Switch Converter

Necessary condition for v_c to come back to zero:

$$I_o > (V_d / Z_o)$$



ZVS Resonant-Switch Converter



By controlling the switch-on time (t_4 - t_3), i.e., the switching frequency, the average value of v_{oi}, hence the average power supplied to the load can be controlled.