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

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

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

where

\[ \omega_o = \frac{1}{\sqrt{L_r C_r}}, \quad Z_o = \sqrt{\frac{L_r}{C_r}} \]

\[ V_{base} = V_d, \]

\[ I_{base} = \frac{V_d}{Z_o} \]
Series-Resonant Circuit with Capacitor-Parallel Load

\[ V_{\text{base}} = V_d, \]
\[ I_{\text{base}} = V_d / Z_o \]

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

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

where

\[ \omega_o = \frac{1}{\sqrt{L_r C_r}}, \quad Z_o = \sqrt{\frac{L_r}{C_r}} \]
Impedance of a Series-Resonant Circuit

\[ Q = \frac{\omega_0 L_r}{R} = \frac{1}{\omega_0 CR} = \frac{Z_o}{R} \]
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

\[ \omega_o = \frac{1}{\sqrt{L_r C_r}}, \quad Z_o = \sqrt{\frac{L_r}{C_r}} \]
Impedance of a Parallel-Resonant Circuit

$\theta = \theta_v - \theta_i$

Quality Factor: $Q = \omega_0 RC_r = \frac{R}{\omega_0 L_r} = \frac{R}{Z_o}$
Resonant Switch DC-DC Converters

ZCS

\[ V_d \]

\[ + \]

\[ - \]

ZVS

\[ V_d \]

\[ + \]

\[ - \]
ZCS Resonant-Switch Converter

Necessary condition for $i_T$ to come back to zero:

$$I_o < \left( \frac{V_d}{Z_0} \right)$$
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)

(b)
Necessary condition for $v_c$ to come back to zero:

$$I_o > \left( \frac{V_d}{Z_o} \right)$$
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.