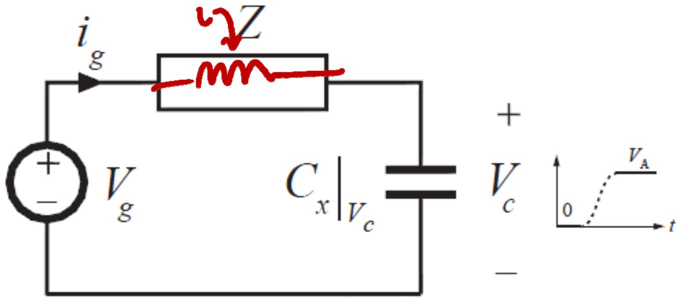
Example Simulation

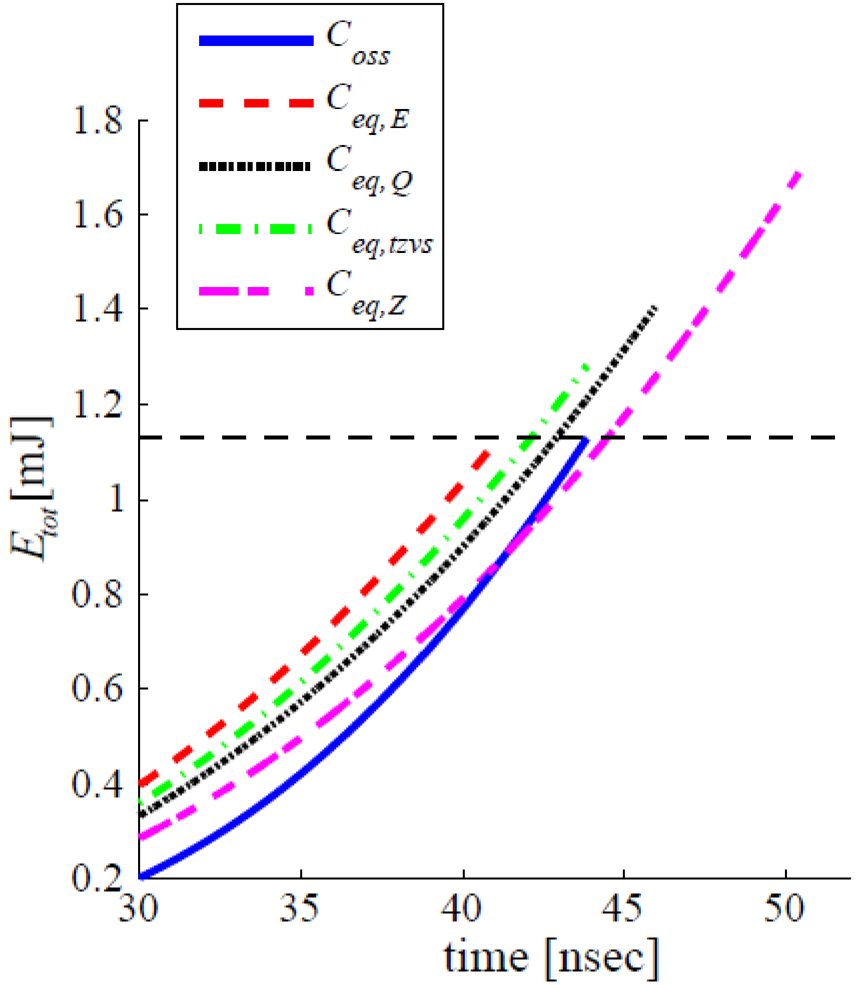


$C_{eq,Q} = 70.5$ pF,
≈ middle

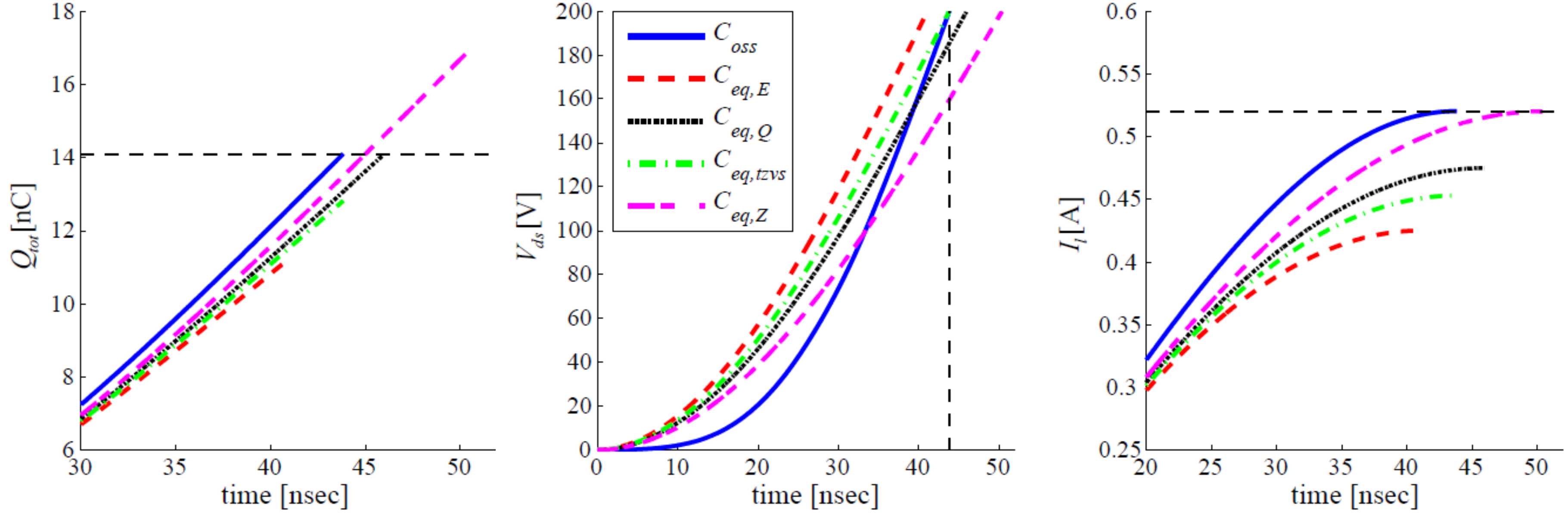
$C_{eq,E} = 56.4$ pF,
smallest

$C_{eq,tzvs} = 64.1$ pF

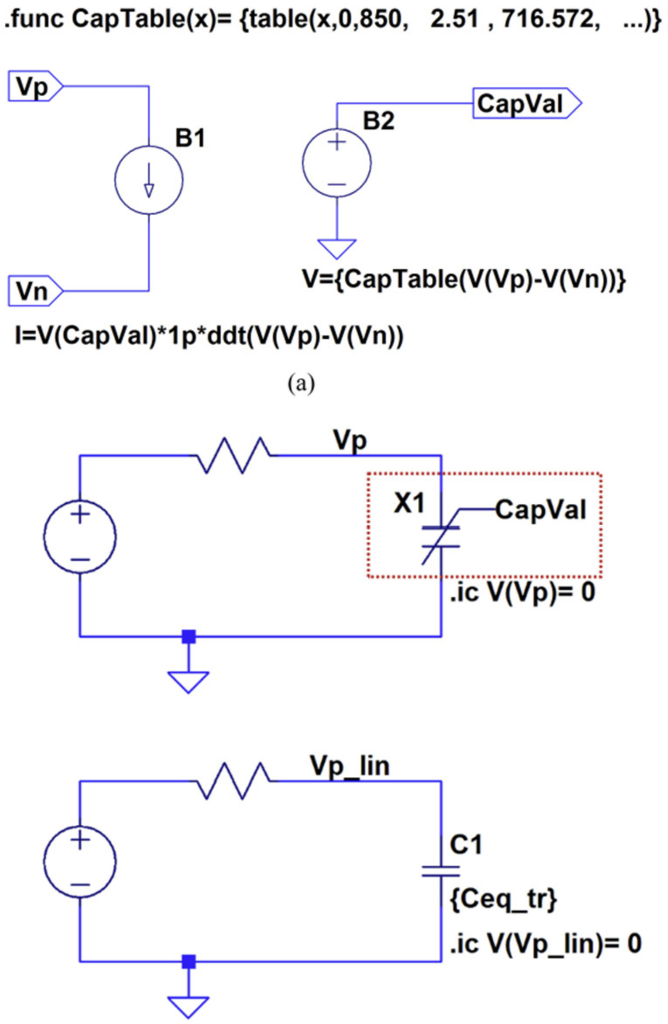
$C_{eq,Z} = 84.5$ pF.



Further Simulation

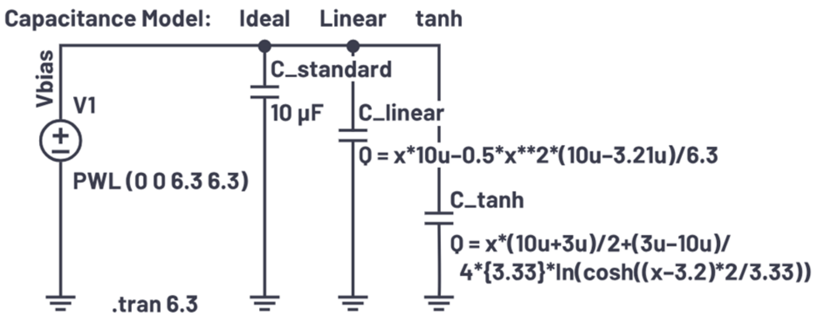


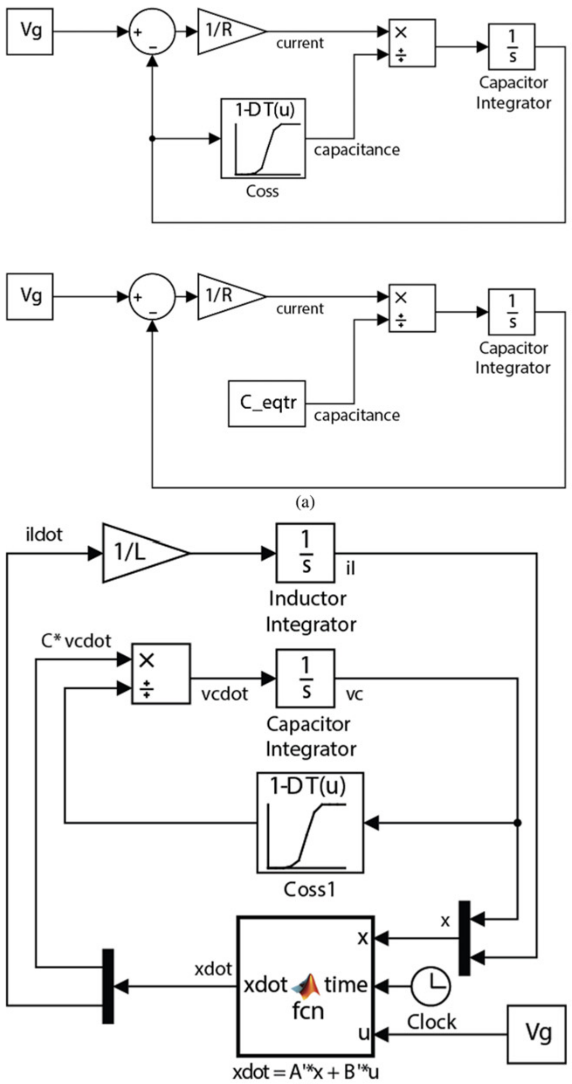
Nonlinear Cap Simulation Implementations



(a)

(b)

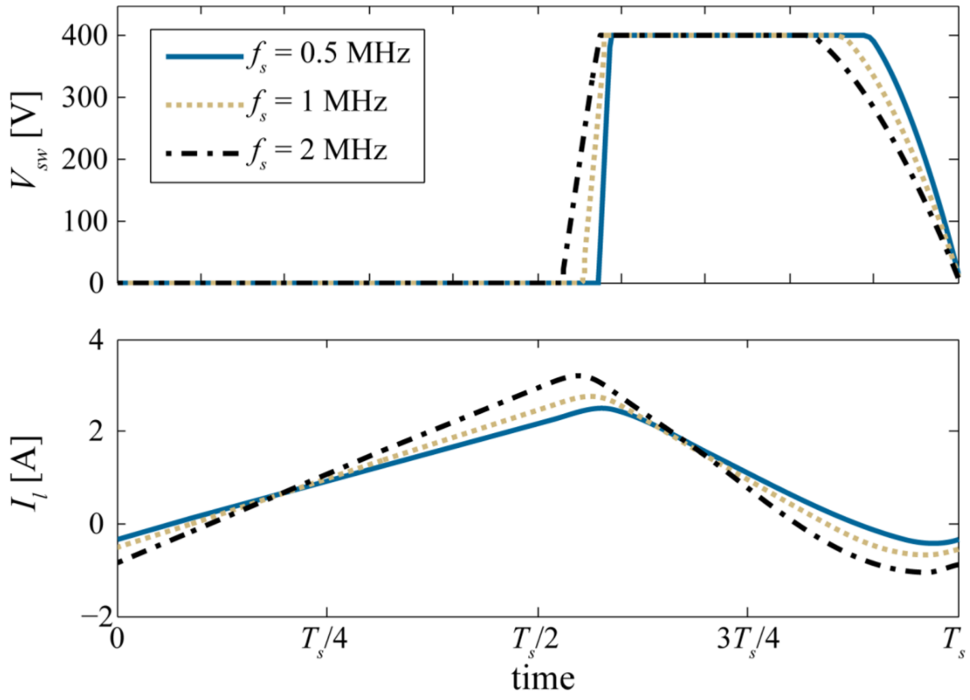




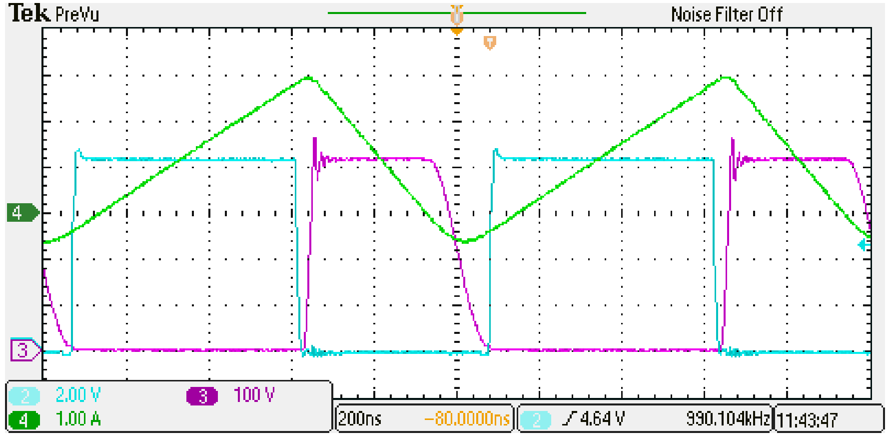
Solving resonance in power electronics

STATE PLANE ANALYSIS

Motivation

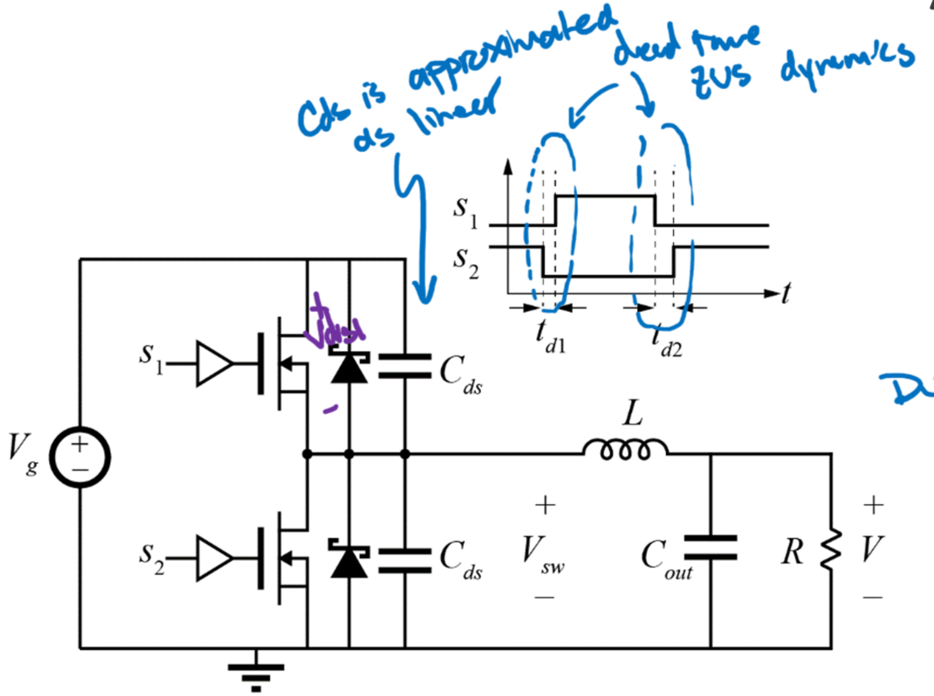


f_s = 0.5 MHz
f_s = 1 MHz
f_s = 2 MHz
V_{sw} [V]
I_l [A]
0
$T_s/4$
$T_s/2$
$3T_s/4$
T_s
time

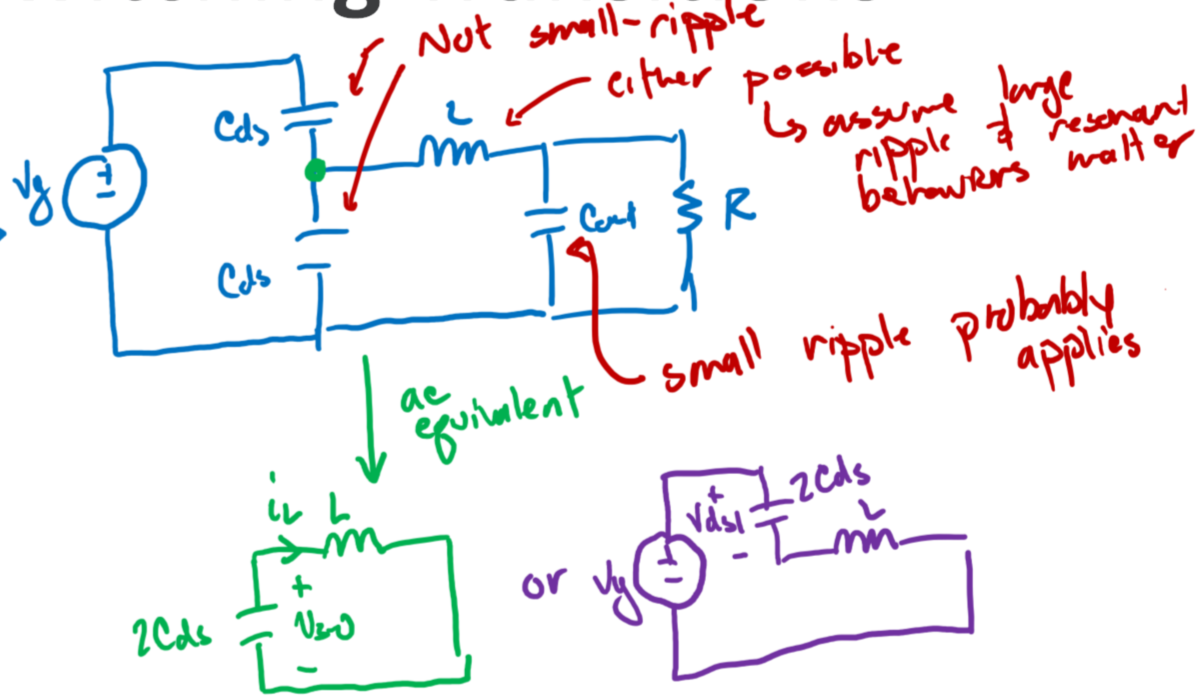


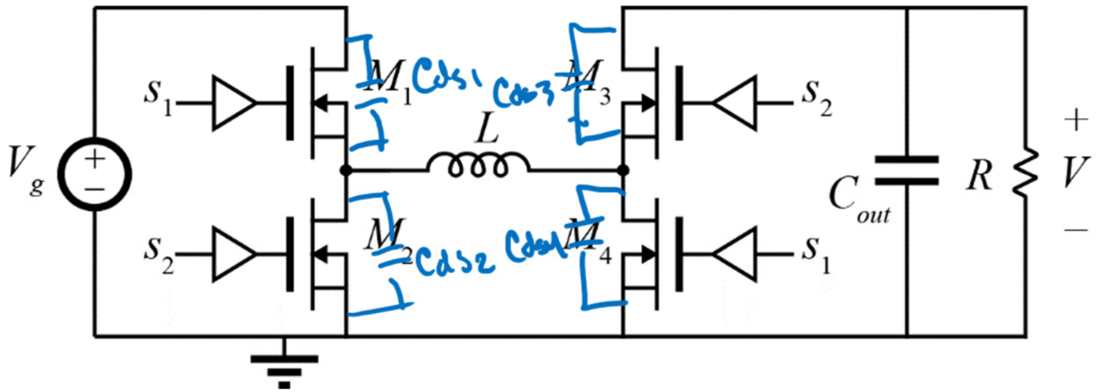
Tek PreVu
Noise Filter Off
2.00 V
100 V
1.00 A
200ns
−80.0000ns
4.64 V
990.104kHz
11:43:47

Time-Domain Analysis of Switching Transitions

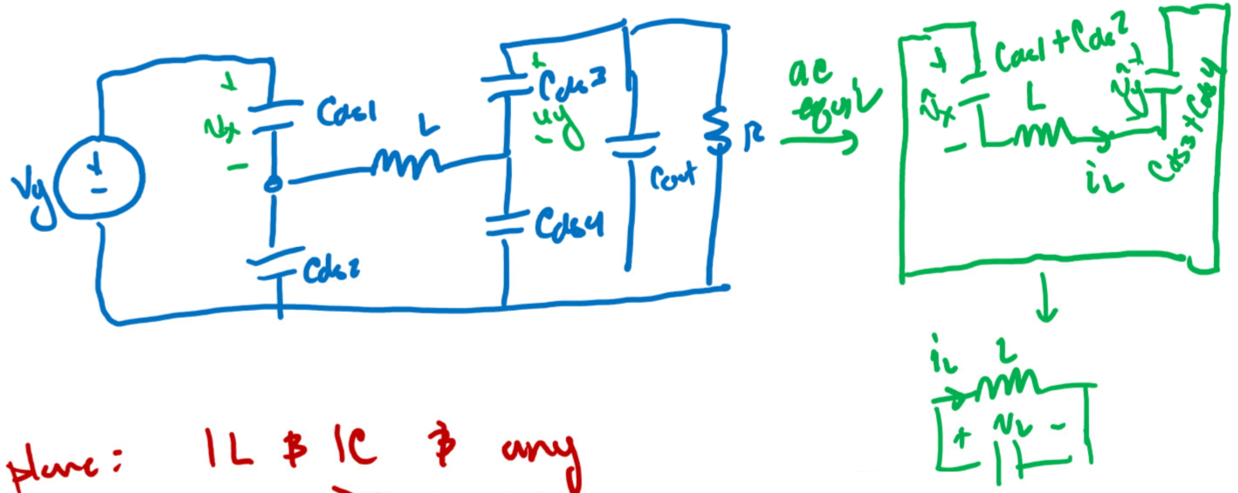


During td1





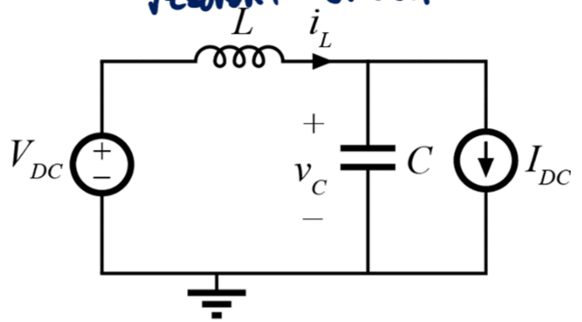
During td1



State plane: IL & IC & any DC sources

Resonant Circuit Solution

Generic 2nd order lossless resonant circuit



Initial Conditions

@ $t=0$

$v_c(t=0) = V_0$

$i_L(t=0) = I_0$

$$\text{①} \quad C\frac{dv_c}{dt} = i_L(t) - I_{DC}$$

$$\text{②} \quad L\frac{di_L}{dt} = V_{DC} - v_c(t)$$

$$V_{DC} - v_c(t) = L\frac{d}{dt}\left(C\frac{dv_c}{dt} + \cancel{I_{DC}}^{\,0}\right)$$

$$LC\frac{d^2v_c}{dt^2} + v_c(t) - V_{DC} = 0$$

$$v_{c,h}(t) = A\cos(\omega t) + B\sin(\omega t)$$

$$v_{c,p}(t) = V_{DC}$$

$$LCs^2 + 1 = 0$$

$$s = \pm j\frac{1}{\sqrt{LC}}$$

$$v_{c,h}(t) = Ce^{j\frac{1}{\sqrt{LC}}t} + De^{-j\frac{1}{\sqrt{LC}}t}$$

$$v_c(t) = V_{DC} + (V_0 - V_{DC})\cos\left(\frac{t}{\sqrt{LC}}\right) + (I_0 - I_{DC})\sqrt{\frac{L}{C}}\sin\left(\frac{t}{\sqrt{LC}}\right)$$

$$i_L(t) = I_{DC} + (I_0 - I_{DC})\cos\left(\frac{t}{\sqrt{LC}}\right) + (V_{DC} - V_0)\sqrt{\frac{C}{L}}\sin\left(\frac{t}{\sqrt{LC}}\right)$$

Normalization and Notation

Notation: $2\pi f_0 = \omega_0 = \frac{1}{\sqrt{LC}}$ $R_0 = \sqrt{\frac{L}{C}}$

$$v_c(t) = V_{DC} + (V_0 - V_{DC})\cos(\omega_0 t) + R_0(I_0 - I_{DC})\sin(\omega_0 t)$$

$$i_L(t) = I_{DC} + (I_0 - I_{DC})\cos(\omega_0 t) + \frac{1}{R_0}(V_{DC} - V_0)\sin(\omega_0 t)$$

Normalization:

$m_c(t) = \frac{v_c(t)}{V_{base}}$

V_{base} is anything you want

$I_{base} \equiv \frac{V_{base}}{R_0}$

$j_L(t) = \frac{i_L(t)}{I_{base}}$

$\theta_x = \omega_0 t_x$

$V_{base} = V_{DC}$

$I_{base} = \frac{V_{DC}}{R_0}$

$$\begin{cases} v_c(t) = V_{DC} + (V_0 - V_{DC})\cos(\omega_0 t) + R_0(I_0 - I_{DC})\sin(\omega_0 t) \\ i_L(t) = I_{DC} + (I_0 - I_{DC})\cos(\omega_0 t) + \frac{1}{R_0}(V_{DC} - V_0)\sin(\omega_0 t) \end{cases}$$

$\frac{R_0}{V_{base}}(I_0 - I_{DC}) = \frac{I_0 - I_{DC}}{I_{base}}$

$$\begin{cases} m_c(t) = \frac{v_c(t)}{V_{base}} = m_{DC} + (m_0 - m_{DC})\cos(\theta) + (j_0 - j_{DC})\sin(\theta) \\ j_L(t) = \frac{i_L(t)}{I_{base}} = j_{DC} + (j_0 - j_{DC})\cos(\theta) + (m_{DC} - m_0)\sin(\theta) \end{cases}$$