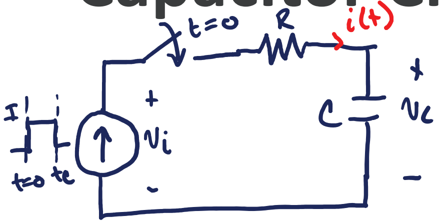
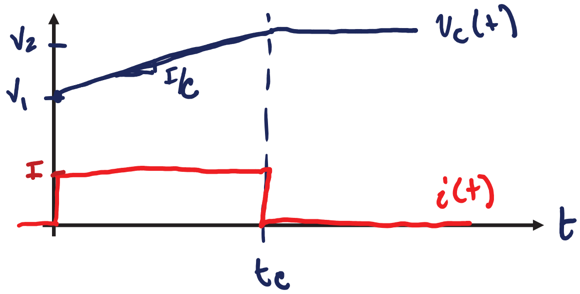
Capacitor Charging: Current Source



$v_c(t<0) = V_1$



$$I = \frac{\Delta Q_c}{t_e} = \frac{C(V_2 - V_1)}{t_e}$$

$$\Delta E_c = \boxed{\frac{1}{2}C\left(V_2^2 - V_1^2\right)} \quad \text{(same)}$$

$$\Delta E_I = \int_0^{t_e} v_i \cdot I\, dt = I\int_0^{t_e}\left(v_c + IR\right) dt = I\left(\frac{V_1 + V_2}{2}\right) t_e + I^2 R t_e$$

$$= \frac{C(V_2 - V_1)}{\cancel{t_e}}\left(\frac{V_1 + V_2}{2}\right)\cancel{t_e} + \left(\frac{C(V_2 - V_1)}{t_e}\right)^2 R\, \cancel{t_e}$$

$$= \underbrace{\frac{1}{2}C\left(V_2^2 - V_1^2\right)}_{\Delta E_c} + \underbrace{\overbrace{\frac{1}{2}C\left(V_2 - V_1\right)^2}^{E_{loss} \text{ in V-src case}} \boxed{\frac{RC}{t_e}2}}_{\text{Loss}}$$

scale factor difference between V-src & I-src

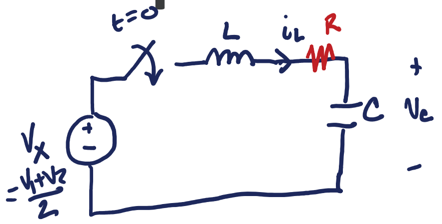
Voltage source case: $E_{loss} = \frac{1}{2}C\left(V_2 - V_1\right)^2$

Current source case: $E_{loss} = \frac{1}{2}C\left(V_2 - V_1\right)^2 \boxed{2\frac{RC}{t_e}}$

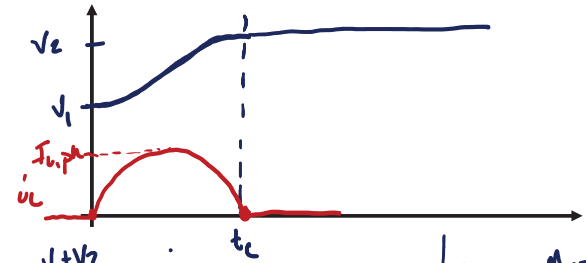
if $t_e \gg RC$ → current source has less loss

if $t_e \ll RC$ → Don't know
V-src charging analysis assumes $t_e \gg RC$

Capacitor Charging: Resonant

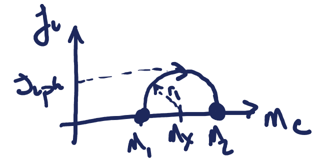


$v_c(t<0) = V_1$



High-efficiency approx: assume $R=0$ when solving waveforms

$V_x = \frac{V_1+V_2}{2}$



$J_{L,pk} = M_x - M_1 = \frac{M_2 - M_1}{2}$

$I_{L,pk} = J_{L,pk} I_{base} = \frac{V_2 - V_1}{2R_0}$

$t_c = \frac{\pi}{\omega_0}$

$\frac{1}{R_0\omega_0} = \frac{\sqrt{LC}}{\sqrt{L/C}} = C$

$\Delta E_c = \frac{1}{2}C\left(V_2^2 - V_1^2\right)$

$E_{loss} = I_{L,rms}^2 R t_c = \frac{I_{L,pk}^2}{2} R t_c$

$= \left(\frac{V_2 - V_1}{2R_0}\right)^2 \frac{R t_c}{2} = \frac{(V_2 - V_1)^2}{4R_0^2} \frac{R\pi}{2\omega_0}$

$E_{loss} = \frac{(V_2-V_1)^2}{4R_0} \frac{RC\pi}{2}$

$E_{loss} = \underbrace{\frac{1}{2}C(V_2 - V_1)^2}_{\text{Loss in V-src case}} \boxed{\frac{R\pi}{4R_0}}$

$\frac{R}{R_0} \rightarrow$ small for high-Q resonance

$R_0 >> R$

$\frac{R\pi}{4R_0} = \frac{R\pi\omega_0 C}{4} = \boxed{\frac{\pi^2 RC}{4t_c}} \rightarrow t_c >> RC$

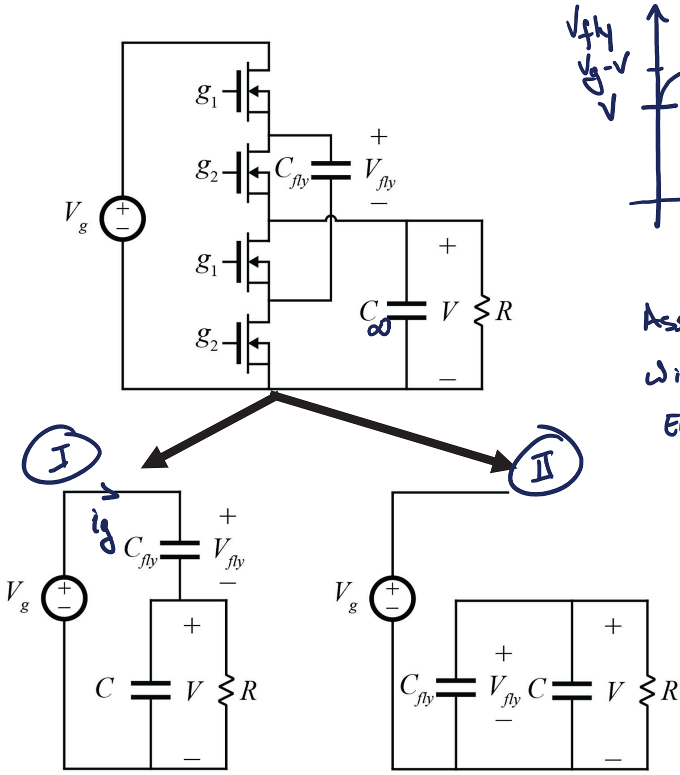
$\frac{\pi^2}{4} \approx 2.5$

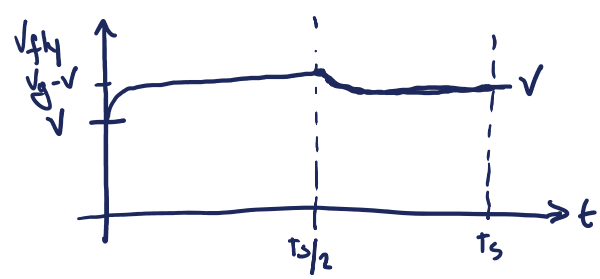
Comparison of Capacitor Charging

for capacitor charged from V_1 to V_2 in time t_c

	E_{loss}	Assumptions
Voltage-source	$\frac{1}{2}C(V_2-V_1)^2$	$t_c \gg RC = \tau$
Current-source	$\frac{1}{2}C(V_2-V_1)^2 \boxed{\frac{2RC}{t_c}}$	X
Resonant	$\frac{1}{2}C(V_2-V_1)^2 \boxed{\frac{\pi^2 RC}{4t_c}}$	High-Q resonance $R_0 \gg R$

2:1 SC Revisited





Assume $t_c \gg RC_{fly} = \tau$

with finite C_{fly} $\quad V < V_g - V$

Energy loss:
$$\begin{cases} \text{I} & \frac{1}{2}C_{fly}(V_g - V - V)^2 \\ \text{II} & \frac{1}{2}C_{fly}(V - (V_g - V))^2 \end{cases}$$

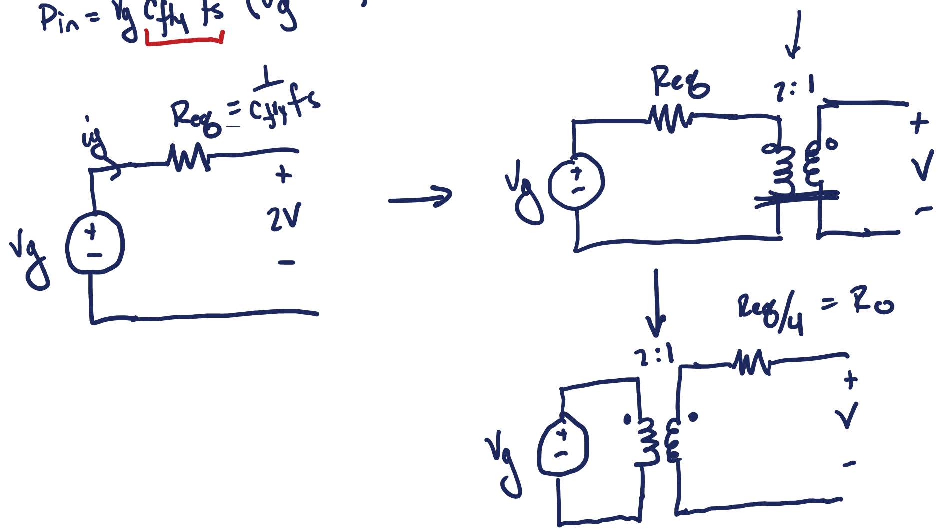
$$P_{loss} = C_{fly}(V_g - 2V)^2 f_s$$

$$P_{in} = V_g C_{fly}(V_g - 2V) f_s$$

Equivalent Circuit Model

$P_{loss} = \underline{C_{fly} f_s} \left(V_g - 2V\right)^2$ $\qquad$ $R_{eq} = \frac{1}{C_{fly} f_s}$

$P_{in} = V_g \underline{C_{fly} f_s} \left(V_g - 2V\right)$



for high η, want small R_{eq}

$\frac{1}{C_{fly} f_s} \longrightarrow$ large C_{fly}, large f_s