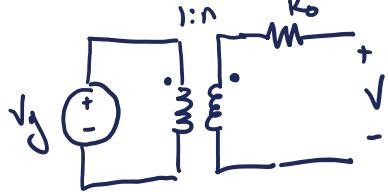


Generalized Equivalent Circuit

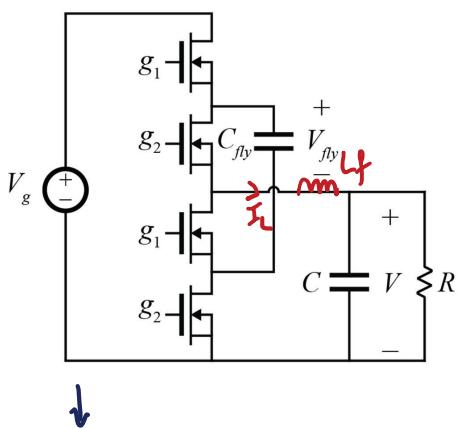


$n \rightarrow$ Ideal conversion ratio
assuming lossless, zero-ripple

$$R_0 \rightarrow \frac{n}{c f_s}$$

Note: Circuit Model encapsulates only charge-sharing losses
- No CoSS / overlap / gate, etc. losses included

2:1 – Current Loaded



Hybrid 2:1 SC converter
3-Level Buck converter
2:1 FCLL converter

Regulation possible with
Duty cycle

current-source type charge & discharge

$$\bar{E}_{loss} = \left[\frac{1}{2} C (V_2 - V_1)^2 \frac{2R_c}{t_1} \right] + \left[\frac{1}{2} C (V_2 - V_1)^2 \frac{2R_c}{t_2} \right]$$

$$t_1 = t_2 = \frac{T_S}{2}$$

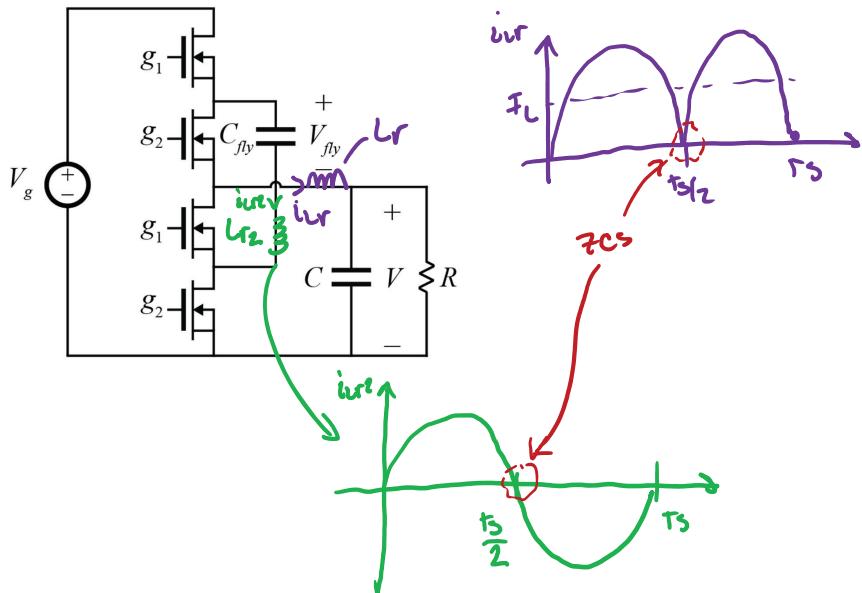
$$\bar{E}_{loss} = \underbrace{C^2 (V_2 - V_1)^2 \frac{4R}{T_S}}_{[C(V_2 - V_1)]^2} = \Delta Q^2 = (I_L \frac{T_S}{2})^2$$

$$\bar{E}_{loss} = (I_L \frac{T_S}{2})^2 \frac{4R}{T_S}$$

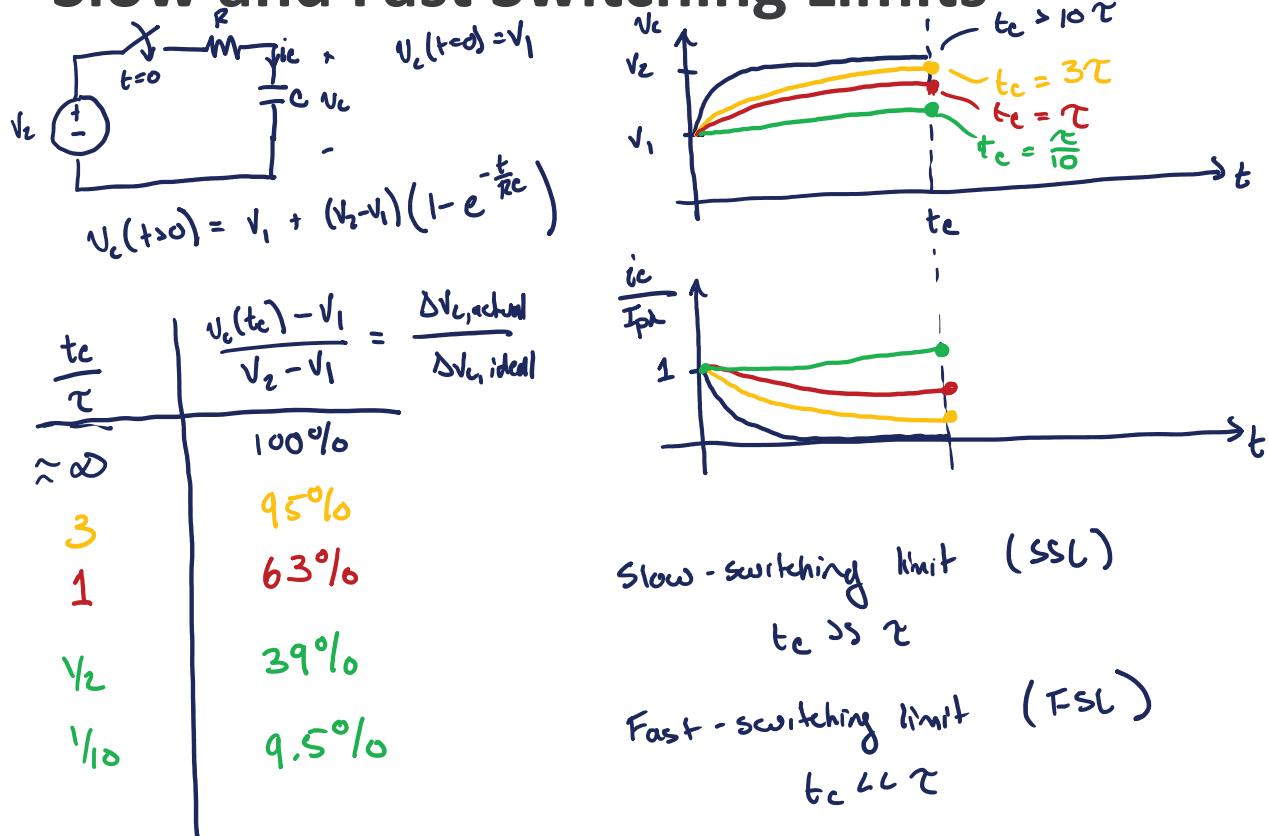
$$P_{loss} = E_{loss} f_S = \boxed{I_L^2 R}$$

$$R = Z_{on} + R_L + BSR_C$$

2:1 – Resonant Implementation



Slow and Fast Switching Limits



2:1 SC – FSL Model

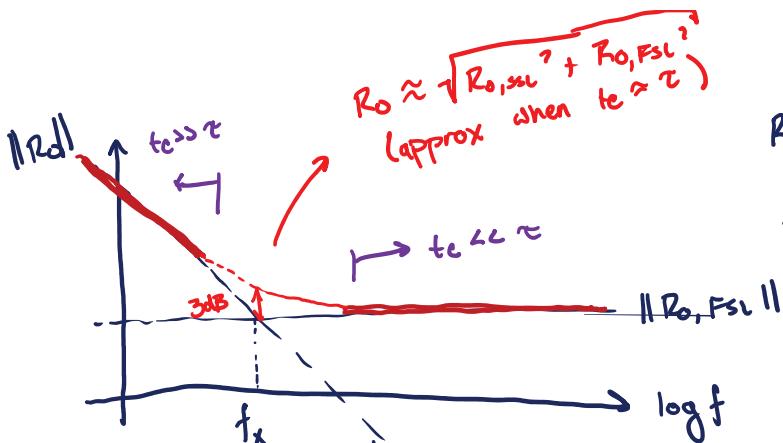
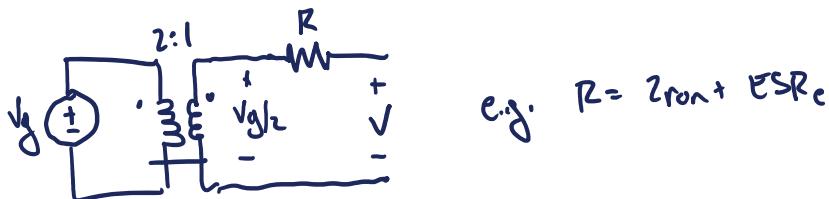
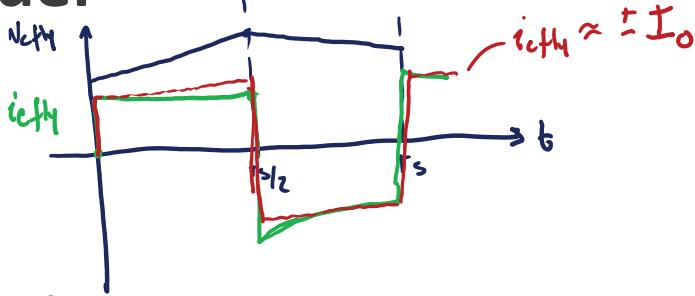
Assume $t_c \ll RC = \tau$

$$P_{out} = V \cdot I_0$$

$$I_0 = \frac{1}{T_S} \int_0^{T_S} i_0(t) dt$$

$$= \frac{1}{T_S} \left[\frac{V_g - V_{fN}}{R} \cdot \frac{T_S}{2} + \frac{V_{fN} - V}{R} \frac{T_S}{2} \right]$$

$$= \frac{V_g - 2V}{2R} = \frac{\sqrt{g/2} - V}{R}$$



$$R_{o,SSL} = \frac{1}{4C_{FL}f_S} \quad (t_c \gg \tau)$$

$$R_{o,FSL} = 2r_{on} + ESR_C \quad (t_c \ll \tau)$$

Higher f_S reduces R_o (Power)
- but, will increase switching loss

- Minimal incremental benefit to increasing f_S beyond "knee" at f_x

$$\frac{1}{4C_{FL}f_x} = R_{o,FSL}$$

$$f_x = \frac{1}{4C_{FL}R_{o,FSL}} = \frac{1}{4C_{FL}R}$$

$$\frac{1}{f_x} = T_S = 2t_c = \frac{1}{4C_{FL}R}$$

$$t_c = C_{FL}R @ f_x$$