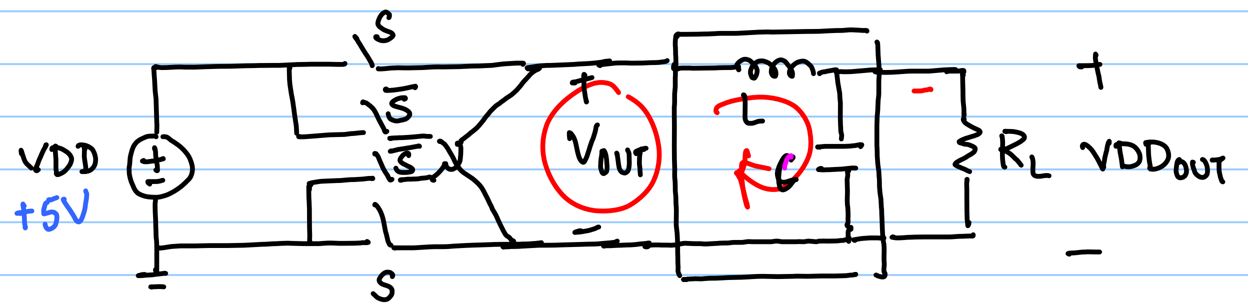
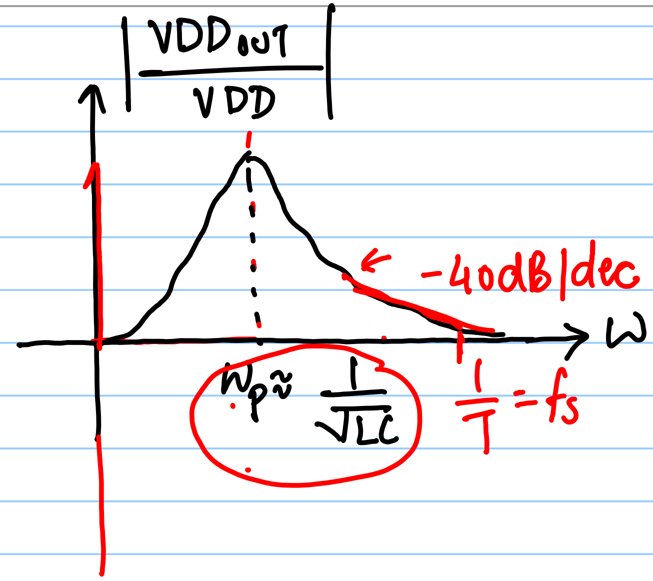
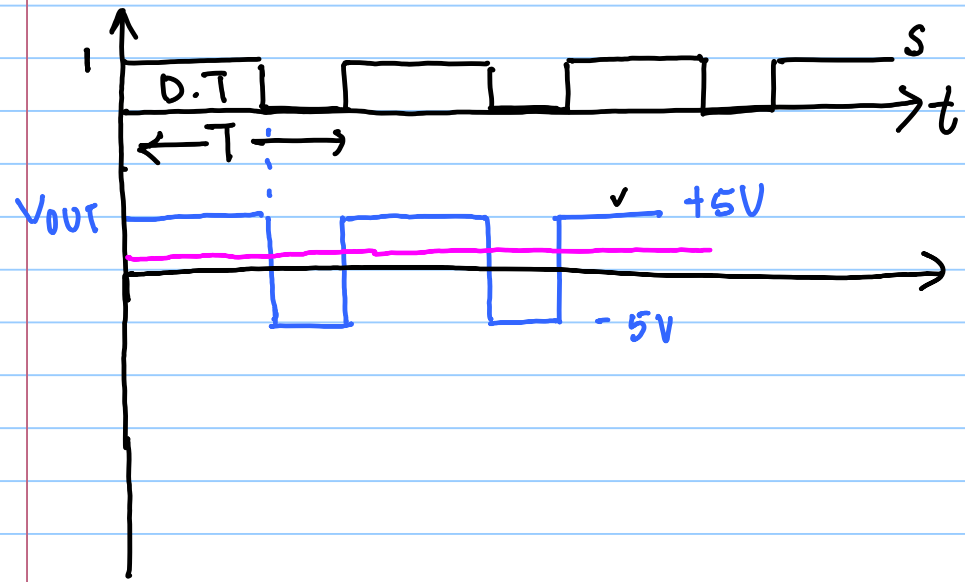
# Lecture # 29



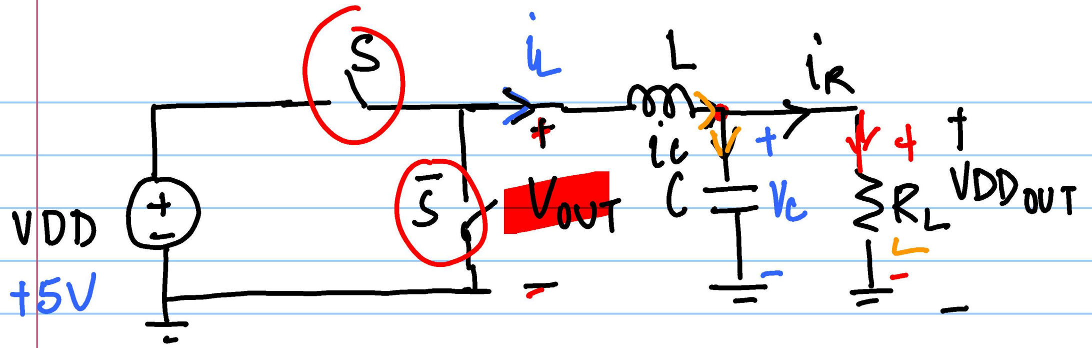




$VDD_{OUT} = VDD\ (2 \cdot D - 1)$

D = Duty Cycle




* $-VDD \leq VDD_{OUT} \leq +VDD$
* 1.0, 1.8, 2.5, 3.0 V.
*

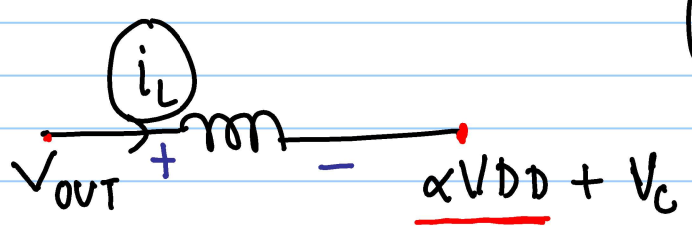



$$\overline{V_{OUT}} = \frac{VDD.\alpha T - (T-\alpha T.).0}{T}$$

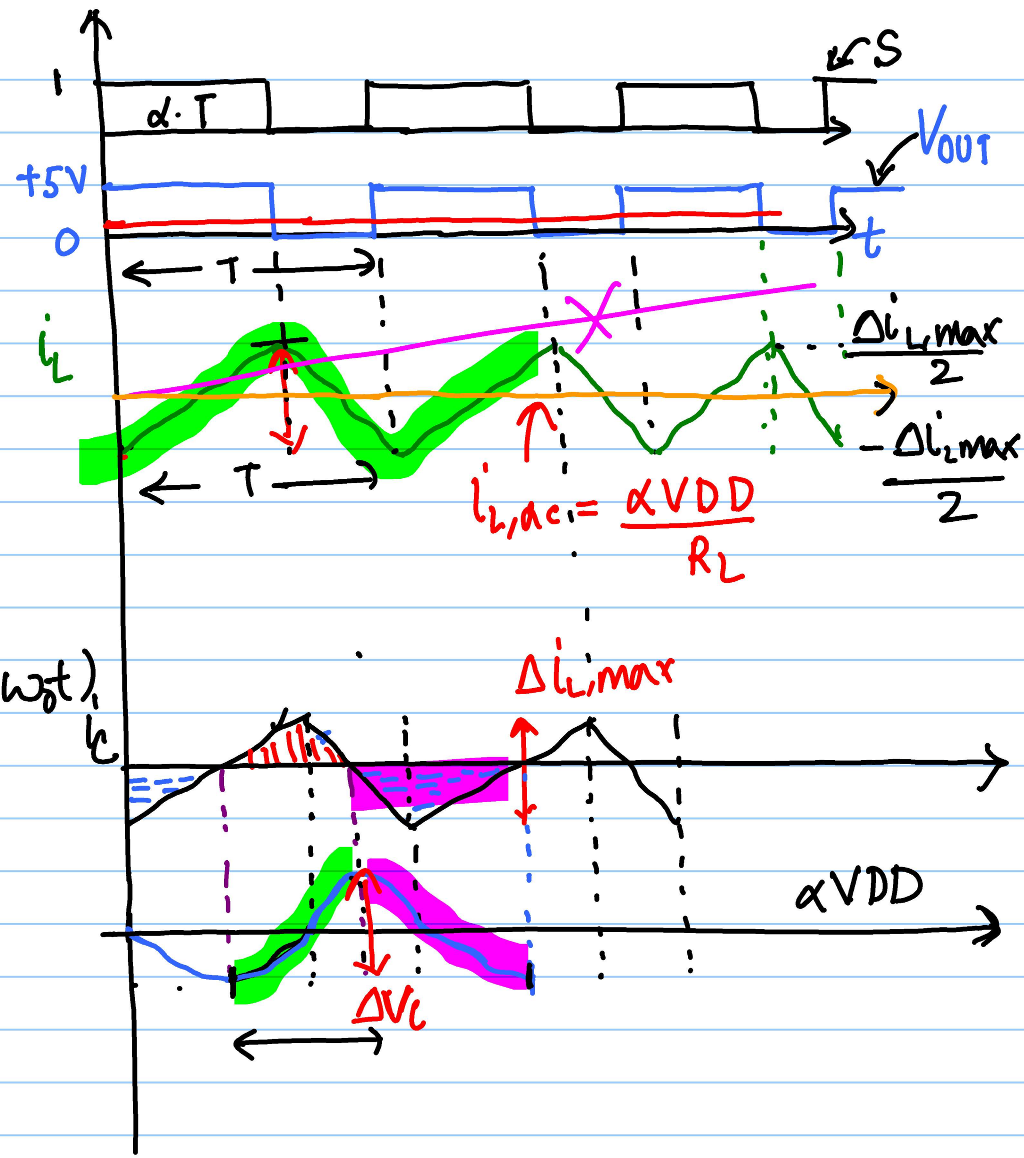
$$= \alpha . VDD$$

$$V_{OUT} = \alpha VDD + \sum_{n=1}^{\infty} a_n \cos(n\omega_0 t) + b_n \sin(n\omega_0 t)$$

$$\omega_0 = \frac{2\pi}{T}$$




$$V_L = L \frac{di}{dt}$$



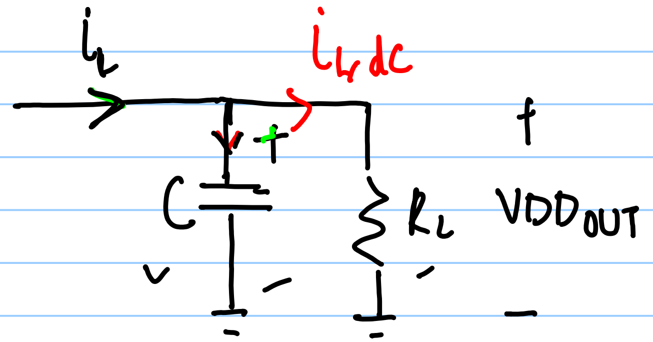
$\underline{S=1}$, $\quad VDD - \alpha VDD = L\frac{di_L}{dt} \Rightarrow i_L = \int \frac{1}{L} VDD(1-\alpha)\, dt$

$S=0$, $\quad 0 - \alpha VDD = L\frac{di_L}{dt} \Rightarrow i_L = -\frac{1}{L}\int \alpha VDD \, dt$

$$\boxed{\Delta i_{L,max} = \frac{VDD(1-\alpha)}{L\uparrow} \cdot \alpha T\downarrow}$$

$T\downarrow$ : fast switching freq.

$L\uparrow$ : large area.




$i_L = \frac{C\, d(VDD_{OUT})}{dt} + \frac{VDD_{OUT}}{R_L}$

$i_L = i_{L,dc} + \sum a_n \cos(n\omega_0 t) + b_n \sin(n\omega_0 t)$

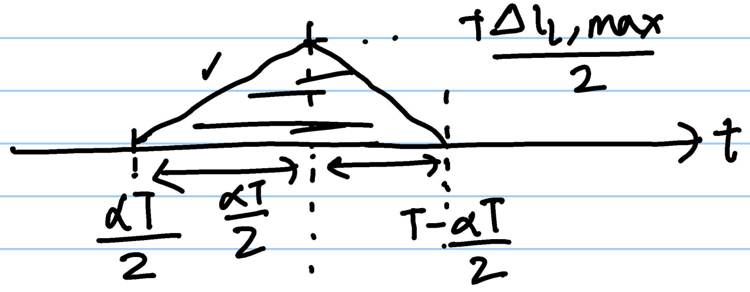
$\frac{1}{j\omega_0 C}$ $\qquad R_L$

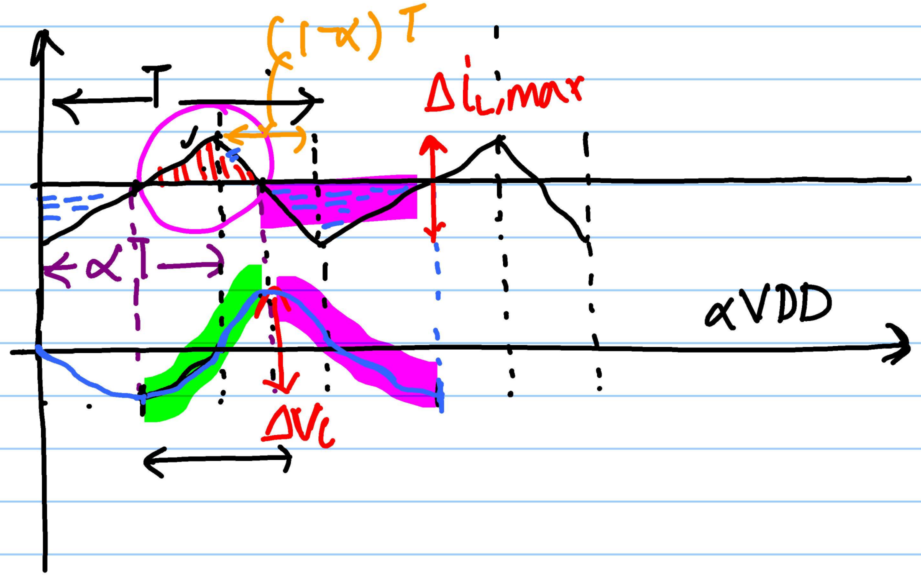
$i_c = C\frac{dV_c}{dt} \Rightarrow \Delta V_c = \frac{1}{C}\int_{t_1}^{t_2} i_L \, dt$

$$\Delta V_c = \frac{1}{C} \int i_c \, dt$$

$$= \frac{1}{C} \int \frac{1}{L} V_{DD} (1-\alpha) t \, dt$$

$$\Delta V_c = f(t^2)$$




$$q = CV$$

$$\Delta V = \frac{\Delta q}{C}$$

$$= \frac{\int i \, dt}{C} = \frac{1}{C} \, \frac{\frac{1}{2}\left(\frac{\alpha T}{2} + \frac{(1-\alpha)T}{2}\right)\frac{\Delta i_L}{2}}{C}$$

$$\Delta V_c = \frac{V_{DD}}{8LC} \cdot T^2 \alpha (1-\alpha)$$

Assume: Output voltage is fixed.

$$\Delta i_{L,max} = \frac{VDD}{L} \alpha(1-\alpha) T,$$

Assume: All ripple current goes through capacitor.

$$\Delta V_{C,max} = \frac{VDD}{8LC} T^2 \alpha(1-\alpha),$$

Reduce ripple voltage

- Increase switching freq. $f_s = \frac{1}{T}$
- Reduce $\omega_p = \frac{1}{\sqrt{LC}}$

$$\Delta V_c = \frac{VDD}{8LC} \frac{1}{f_s^2} \alpha(1-\alpha)$$

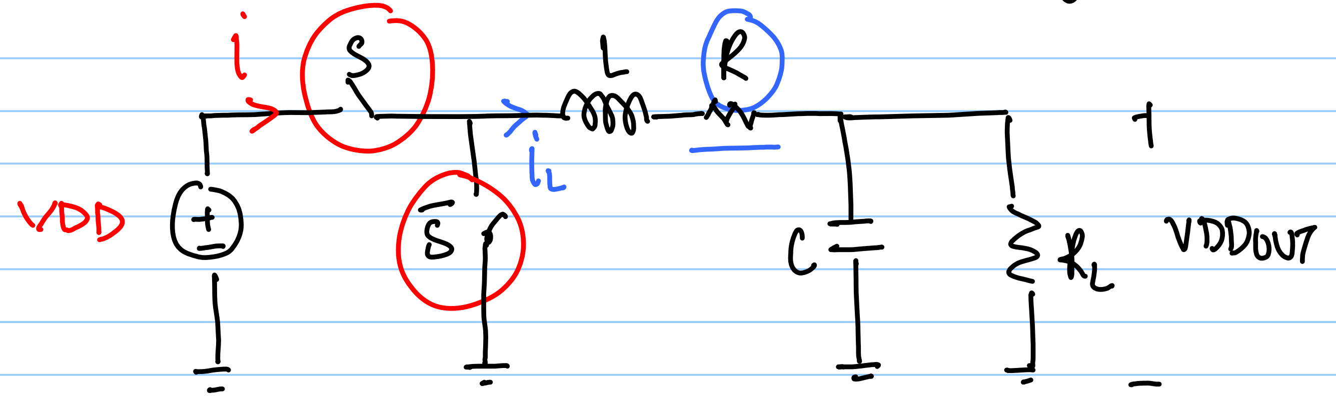
$$\Delta V_c = \frac{VDD}{8} \frac{\omega_p^2}{f_s^2} \alpha(1-\alpha) \quad \Big| \quad \omega_p = \frac{1}{\sqrt{LC}}, \quad f_s = \frac{1}{T}.$$

To reduce voltage ripple.

- $\omega_p \downarrow$
- $f_s \uparrow$

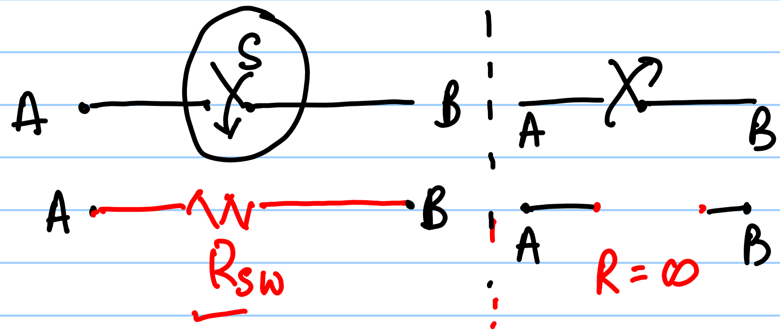
Maximum Ripple voltage
Max. Ripple current } $\alpha = \frac{1}{2}$

# "Switching Regulators:"




Power Loss :

- Resistor associated with inductor
- Switch finite resistance loss
- Switching loss due to finite capacitance of real switches.




- Turning ON / OFF
- Capacitance ($C_{sw}$) associated w/ switch
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