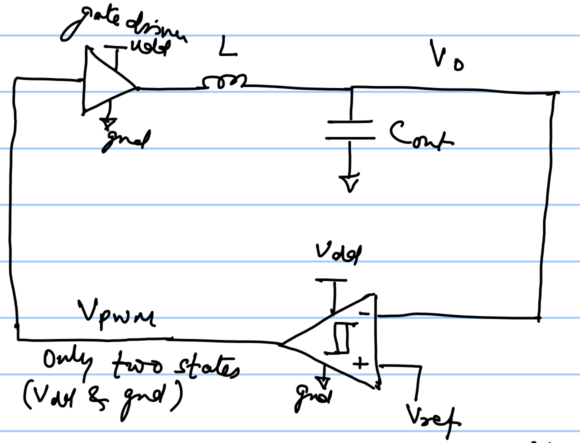
Non-linear control of dc-dc converters

Linear control
- Voltage Mode
- Current Mode

Non-linear control
- Hysteretic
- Constant-ON/OFF time
- V^2 control

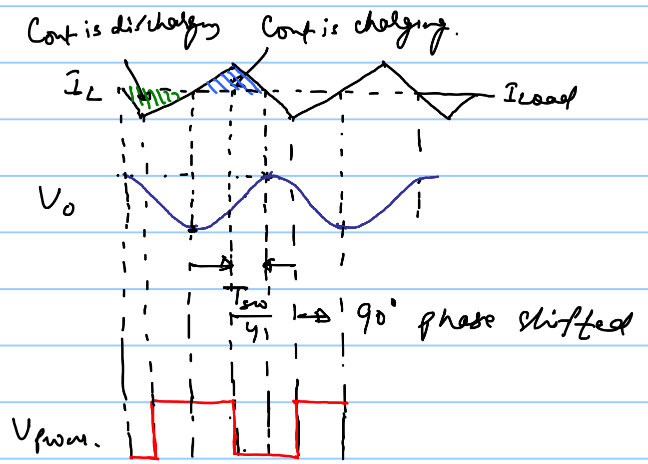
$\underbrace{\text{Hysteretic} \quad \text{Constant-ON/OFF time} \quad V^2 \text{ control}}_{\text{ripple base control.}}$



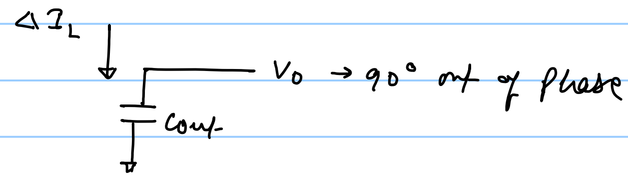
Hysteresis window = $\pm\frac{\Delta V_H}{2}$

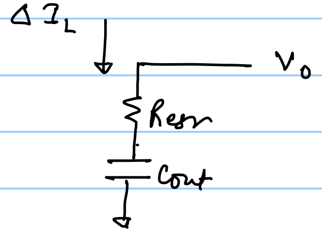
→ Bandwidth is not limited as comparator can respond to any change in V_o instantaneously.

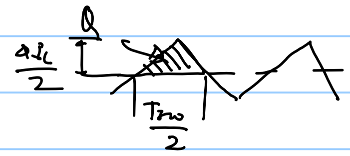
→ No PWM modulator delay ($t_d = (1-D)T_{sw}$ or $D \cdot T_{sw}$)



V_0 is not bounded between $V_{ref} \pm \frac{\Delta V_H}{2}$ due to 90° phase shift.
This mode is unstable.
In order to stabilize the output we want V_0 in phase with I_L







$$\Delta V_o = \Delta I_L R_{esr} + \frac{\Delta I_L}{8 C_{out} F_{sw}}$$

In phase — 90° out of phase.

$$\frac{1}{2} \times \frac{T_{sw}}{2} \times \frac{\Delta I_L}{2}$$

$$Q = C \Delta V_o \Rightarrow \Delta V_o = \frac{Q}{C}$$

$$\Delta I_L R_{esr} \gg \frac{\Delta I_L}{8 C_{out} F_{sw}}$$

Usually if $R_{esr} \cdot C_{out} > D \cdot \frac{T_{sw}}{2}$ & $(1-D) \frac{T_{sw}}{2}$

then output is stable $\rightarrow$ ΔV_o is in phase with ΔI_L and V_o is bounded.

for $D = 0$ to 1

$$R_{esr} \cdot C_{out} > \frac{T_{sw}}{2}$$

$\Delta I_L R_{esr} >> \frac{\Delta I_L}{8 C F_{sw}}$ then we can ignore $\frac{\Delta I_L}{8 C F_{sw}}$

$\Delta V_o = \Delta I_L \cdot R_{esr}$.

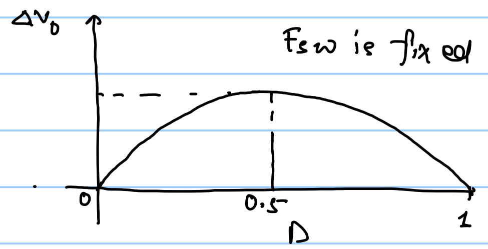
$$\Delta I_L = \frac{V_{in} D \cdot (1-D) T_{sw}}{L}$$

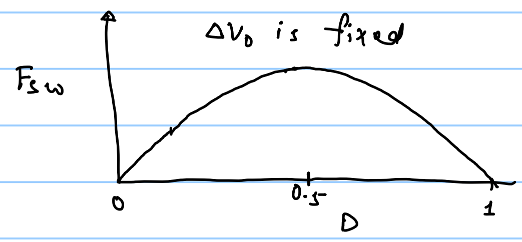
$$\Delta V_o = \frac{V_{in} D \cdot (1-D) T_{sw}}{L} \times R_{esr}$$

$\Delta V_o = \Delta V_H$

$$F_{sw} = \frac{1}{T_{sw}} = \frac{V_{in} D \cdot (1-D)}{\Delta V_H \cdot L} \times R_{esr}$$

Assume V_{in}, ΔV_H, L & R_{esr} are fixed but V_o is variable $\rightarrow$ D is varying





Switching frequency is not constant.

$$F_{sw} \propto V_{in} \cdot D(1-D) \cdot R_{esr}$$

$$F_{sw} \propto \frac{1}{\Delta V_H \cdot L}$$

$F_{sw} = 1\,MHz$ at $D = 0.5$

$V_{in} = 1.8\,V$, $L = 1\mu H$, $C_{out} = 10\mu H$

$\Delta V_H = 10\,mV$

$$F_{sw} = \frac{1}{T_{sw}} = \frac{V_{in}\, D.(1-D)}{\Delta V_H \cdot L} \times R_{esr}$$

$$R_{esr} = \frac{\cancel{10^6} \times 10^{-2} \times \cancel{10^{-6}}}{1.8 \times 0.5\,(1-0.5)} = \frac{10^{-2}}{1.8 \times 0.25} = \frac{10}{0.45} \approx 20\,m\Omega$$

$$R_{esr} \cdot C_{out} > \frac{T_{sw}}{2}$$

$$\frac{T_{sw}}{2} = 500\,ns$$

Resr. Const $= 20 \times 10^{-3} \times 10^{-5}$

$= 2 \times 10^{-7} = 200\,ns$