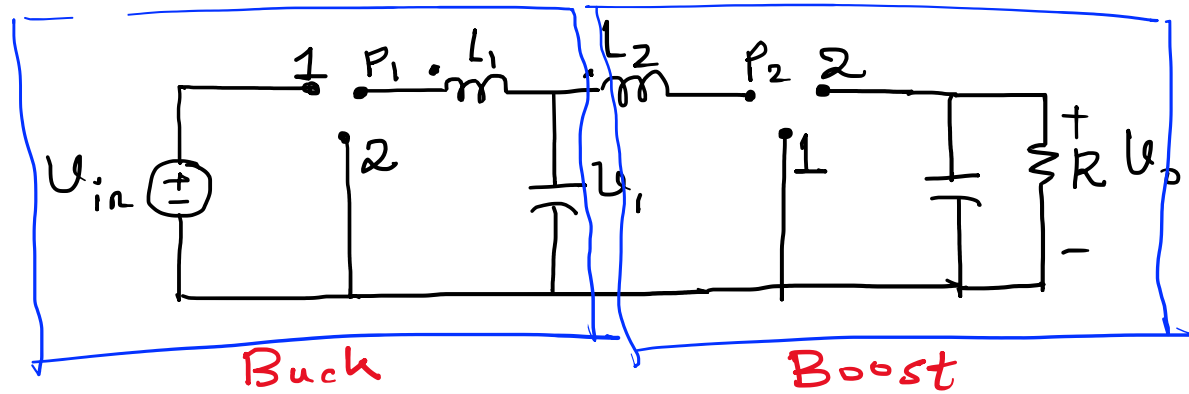


Switched Mode Power Conversion

Semester II Academic Year 2025-26

Lecture 21-22

13th March 2026



$$\frac{U_1}{U_{in}} = D$$

$$\frac{U_o}{U_1} = \frac{1}{1-D}$$

$$\therefore \frac{U_o}{U_{in}} = \frac{D}{1-D}$$

[Buck-boost]

$$0 \leq D \leq 1$$

$$0 \leq D < 0.5 \quad \frac{D}{1-D} < 1$$

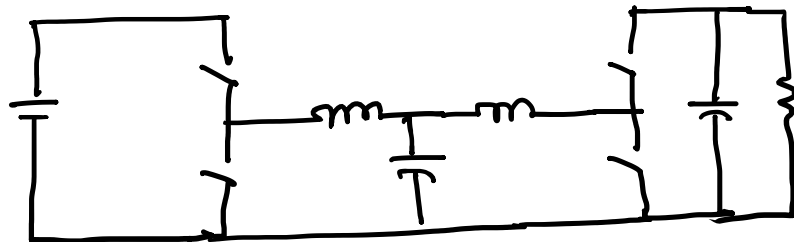
[Buck]

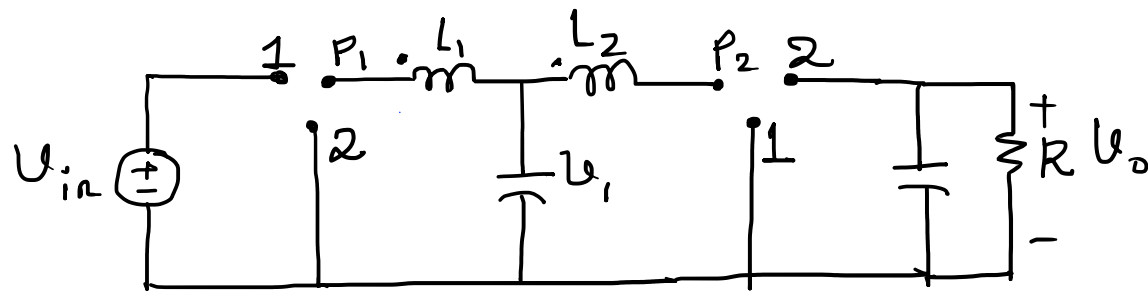
$$0.5 < D \leq 1 \quad \frac{D}{1-D} > 1$$

[Boost]

Buck - step down
Boost - step up

$$\begin{aligned} \frac{U_o}{U_{in}} &= \frac{U_o}{U_1} \times \frac{U_1}{U_{in}} \\ &= \frac{1}{1-D} \times D = \frac{D}{1-D} \end{aligned}$$



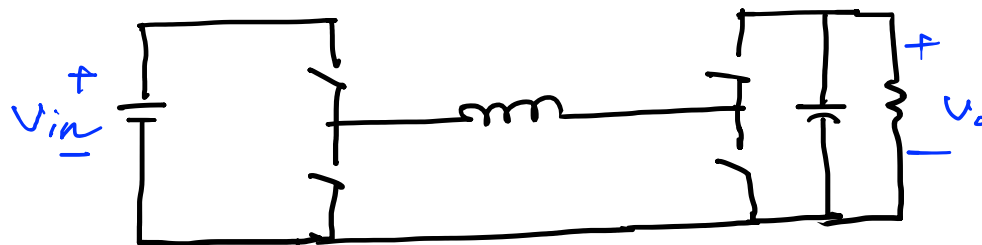
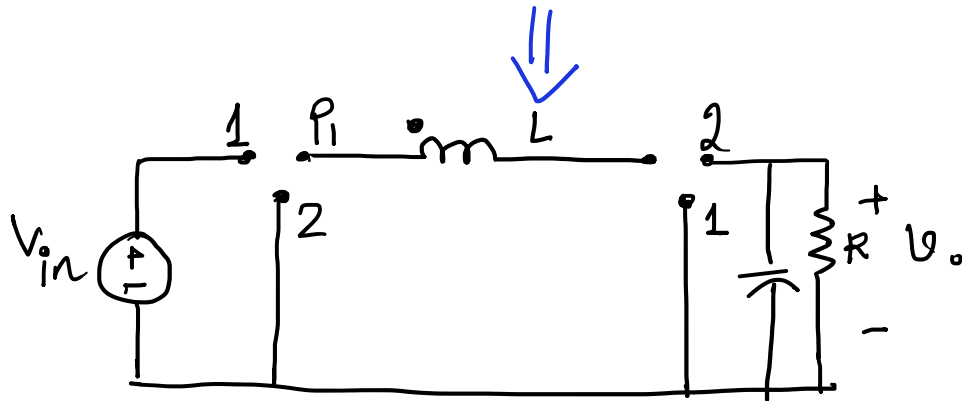


$$\frac{V_1}{V_{in}} = D$$

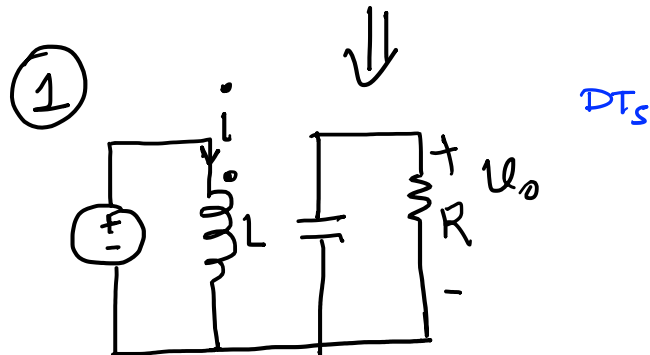
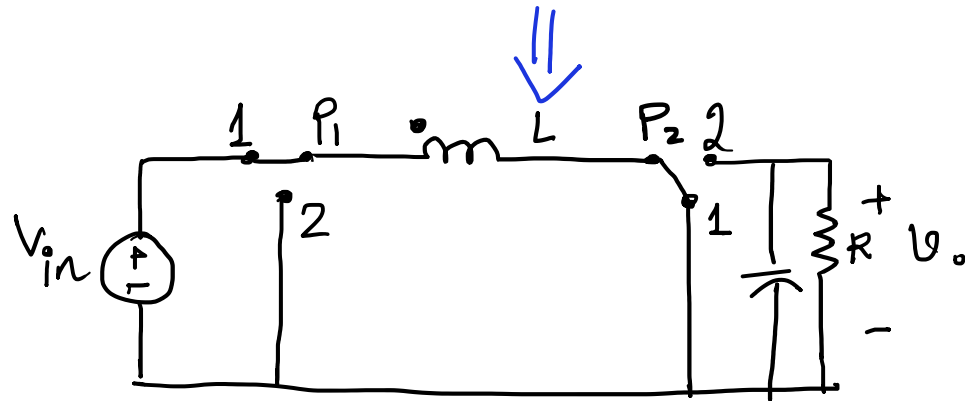
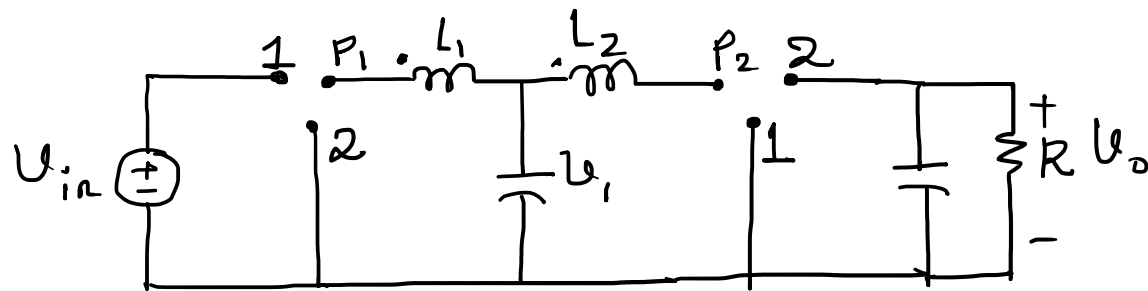
$$\frac{V_o}{V_1} = \frac{1}{1-D}$$

$$\therefore \frac{V_o}{V_{in}} = \frac{D}{1-D}$$

[Buck-boost]
[Non inverting]



Non-inverting buck-boost

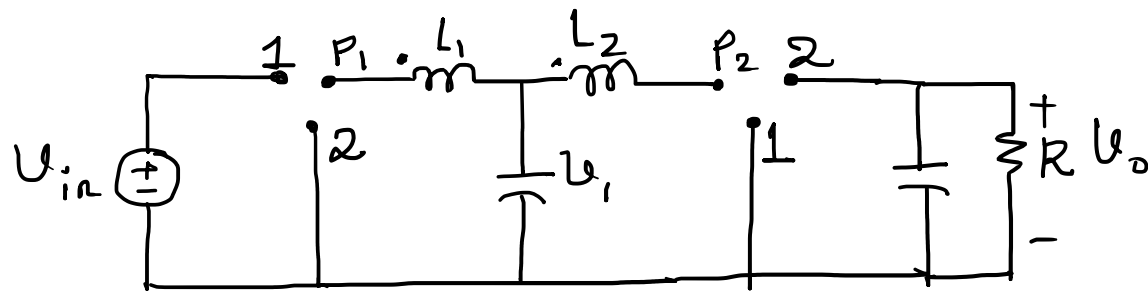


$$\frac{V_1}{V_{in}} = D$$

$$\frac{V_o}{V_1} = \frac{1}{1-D}$$

$$\therefore \frac{V_o}{V_{in}} = \frac{D}{1-D}$$

[Buck-boost]
[Non inverting]

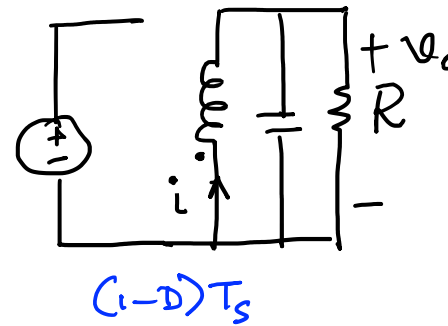
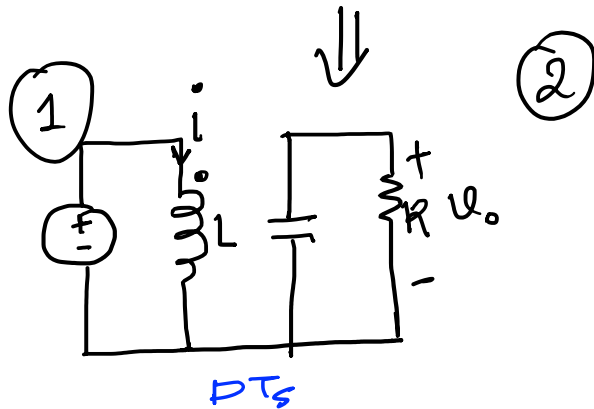
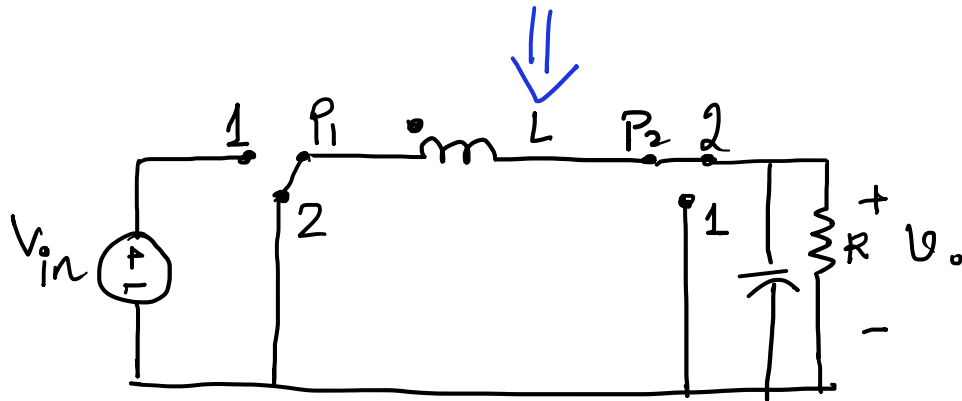


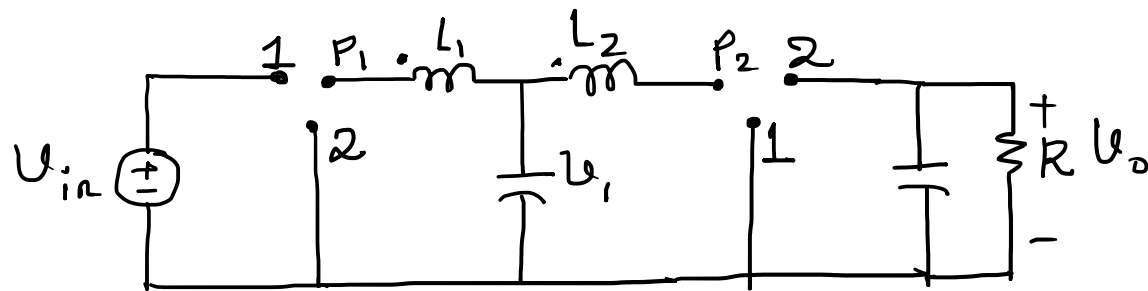
$$\frac{V_o}{V_{in}} = D$$

$$\frac{V_o}{V_i} = \frac{1}{1-D}$$

$$\therefore \frac{V_o}{V_{in}} = \frac{D}{1-D}$$

[Buck-boost]
[Non inverting]



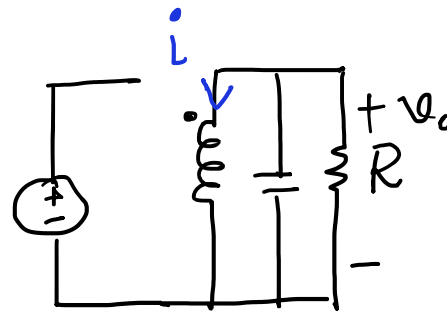
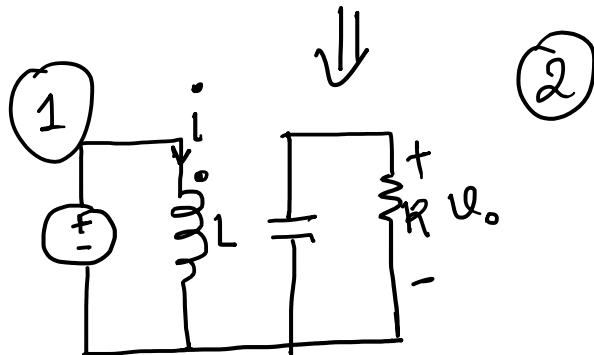
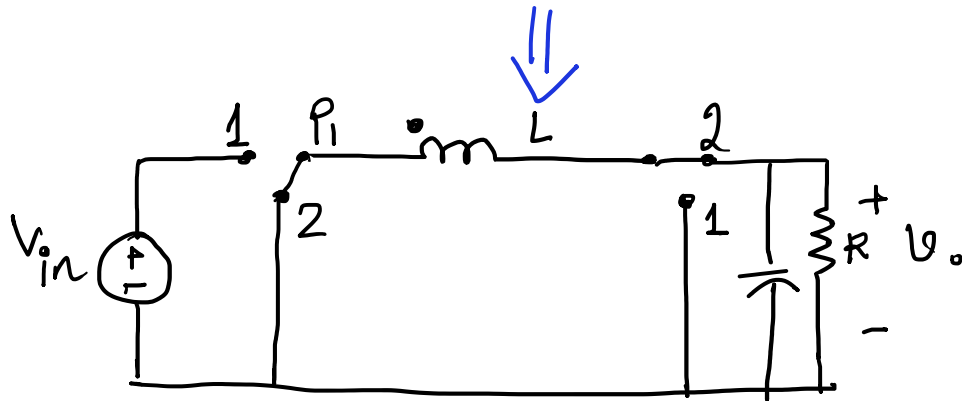


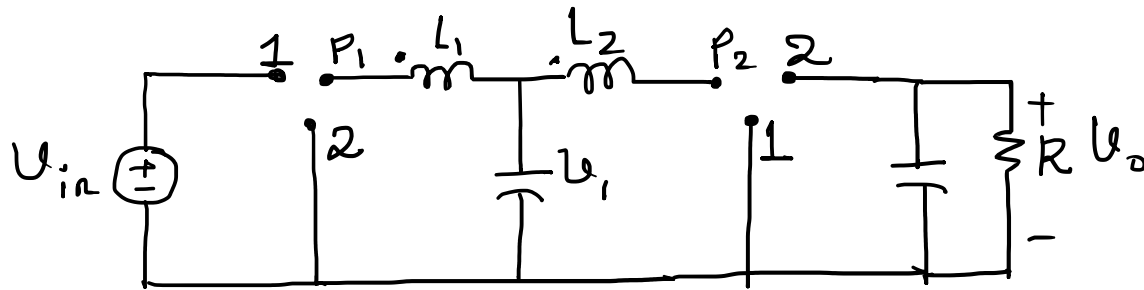
$$\frac{V_o}{V_{in}} = D$$

$$\frac{V_o}{V_i} = \frac{1}{1-D}$$

$$\therefore \frac{V_o}{V_{in}} = \frac{D}{1-D}$$

[Buck-boost]
[Non inverting]



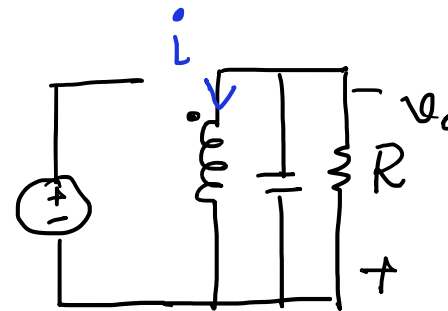
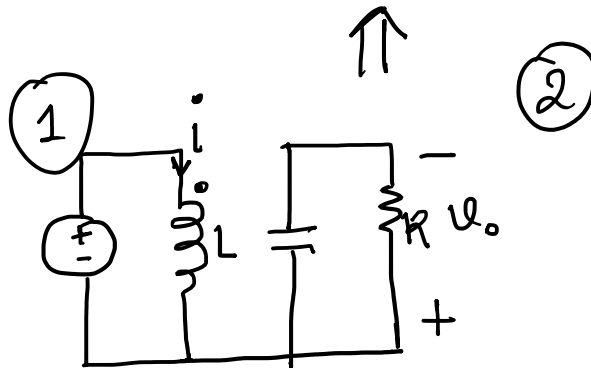
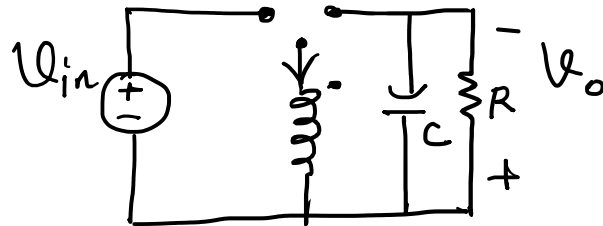


$$\frac{U_o}{U_{in}} = D$$

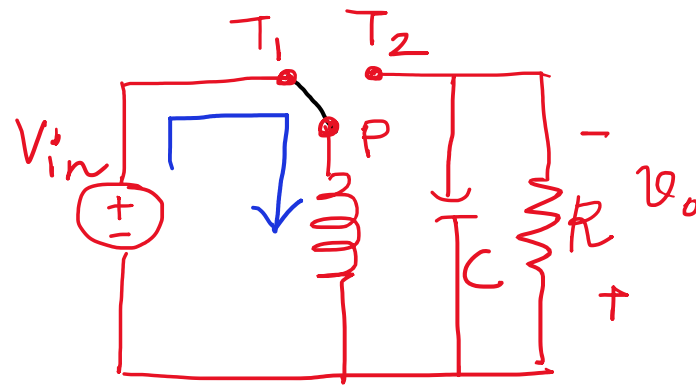
$$\frac{U_o}{U_i} = \frac{1}{1-D}$$

$$\therefore \frac{U_o}{U_{in}} = \frac{D}{1-D}$$

[Buck-boost]
[inverting]



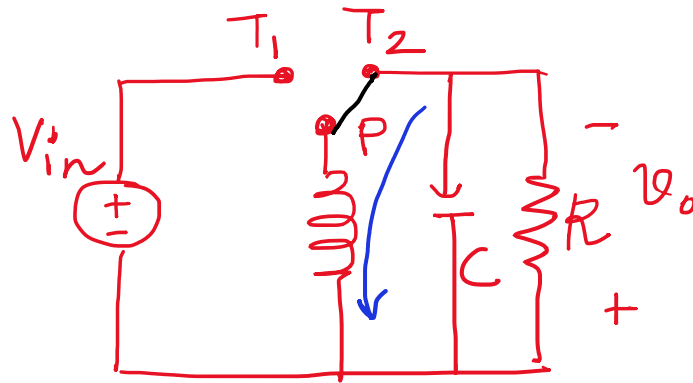
Buck-Boost



$$I_{T_1 P} > 0$$

$$V_{T_2 P} < 0$$

Buck-Boost



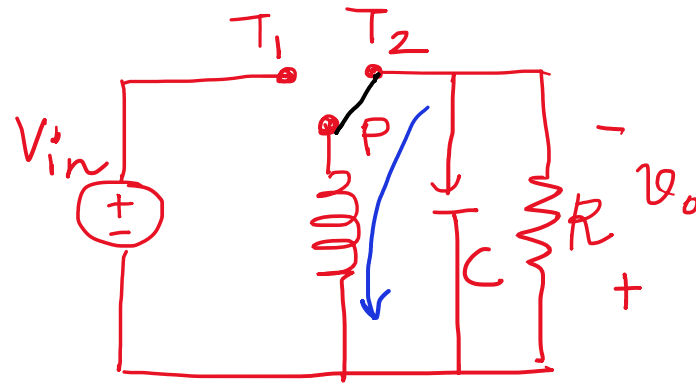
$$I_{T_1 P} > 0$$

$$V_{T_1 P} > 0$$

$$V_{T_2 P} < 0$$

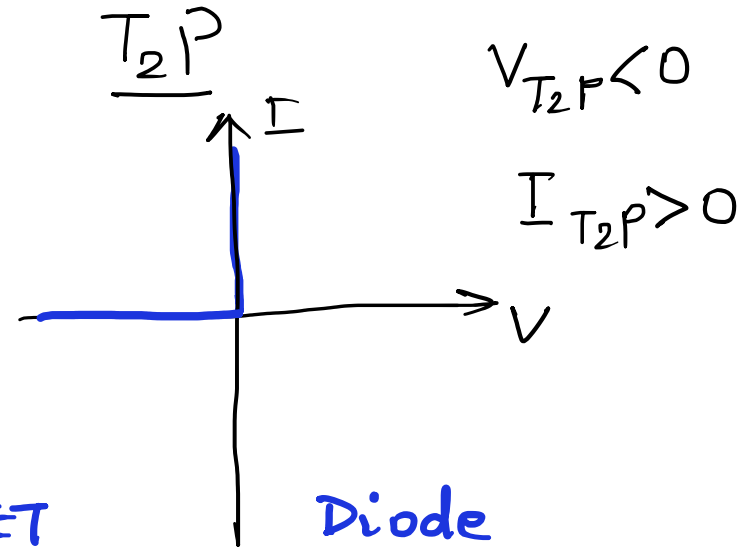
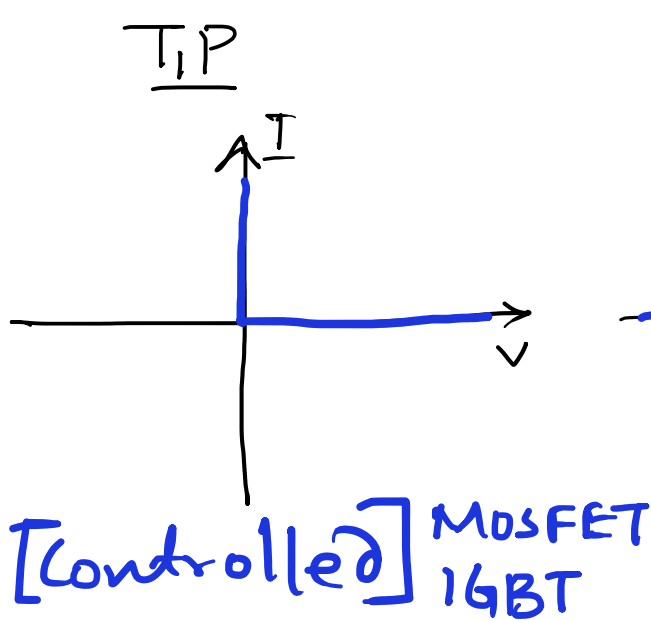
$$I_{T_2 P} > 0$$

Buck-Boost



$$I_{T_1P} > 0$$

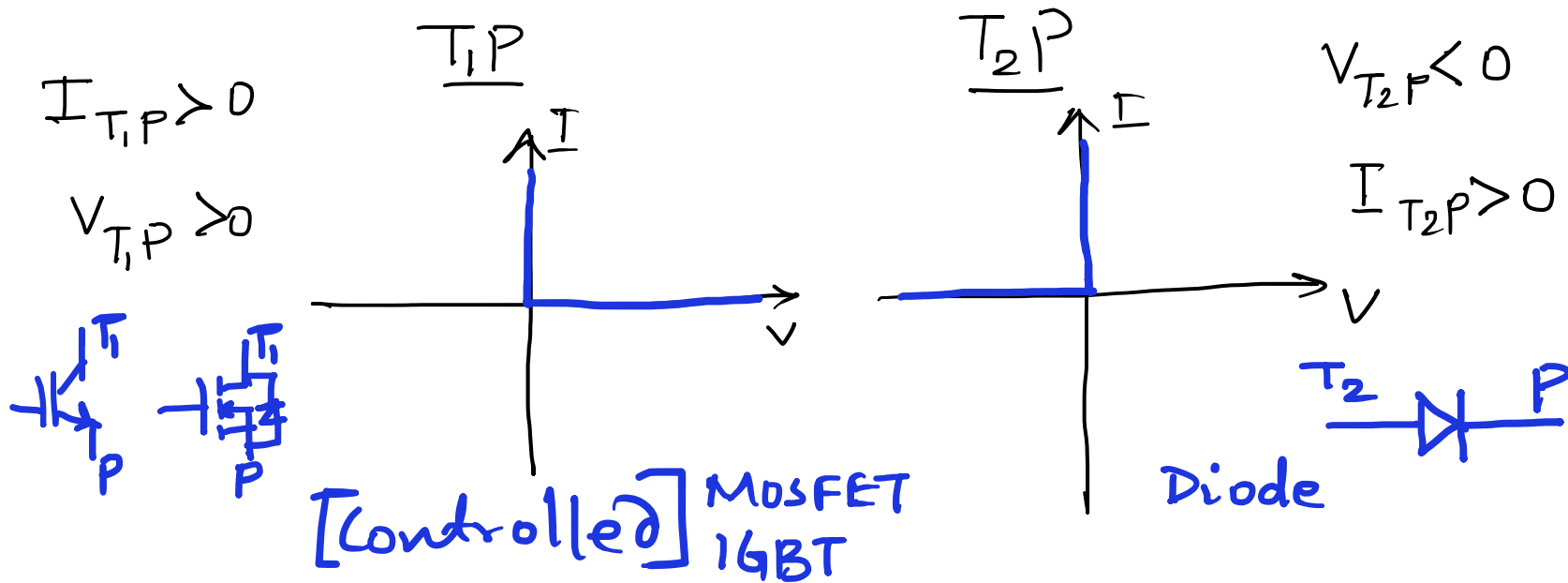
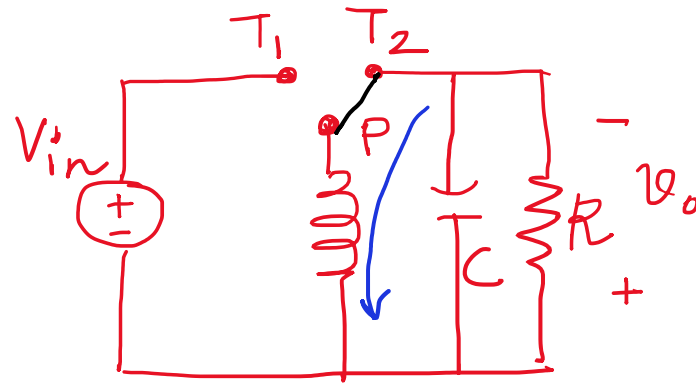
$$V_{T_1P} > 0$$



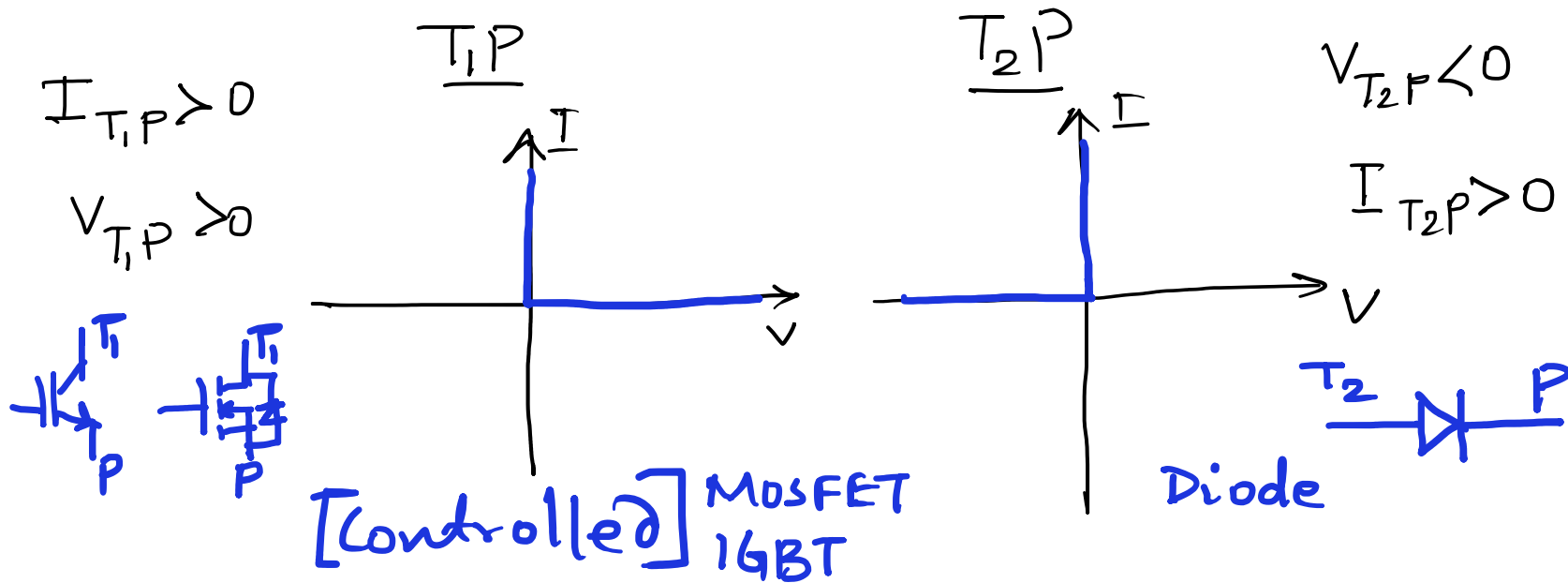
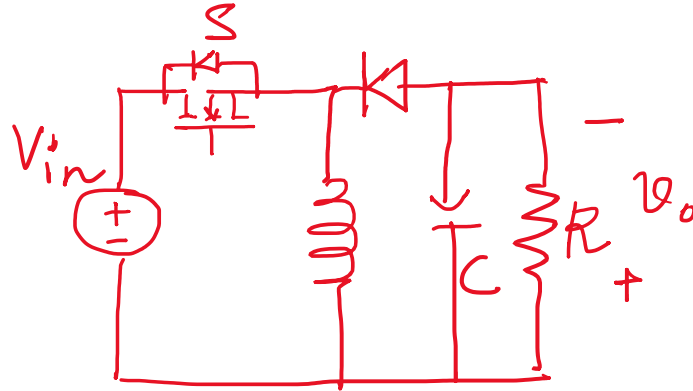
$$V_{T_2P} < 0$$

$$I_{T_2P} > 0$$

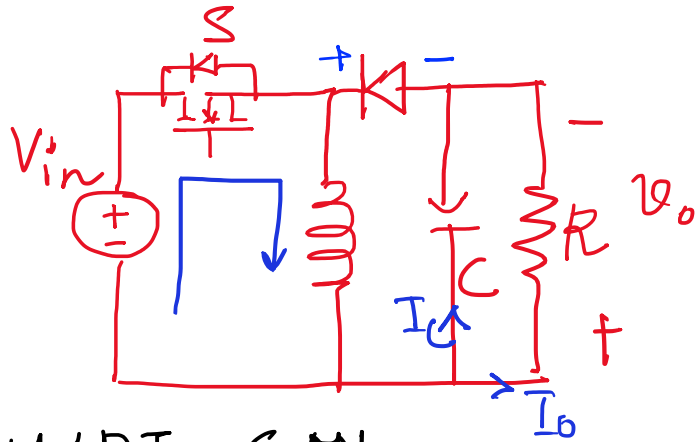
Buck-Boost



Buck-Boost



Buck-Boost [Steady State]

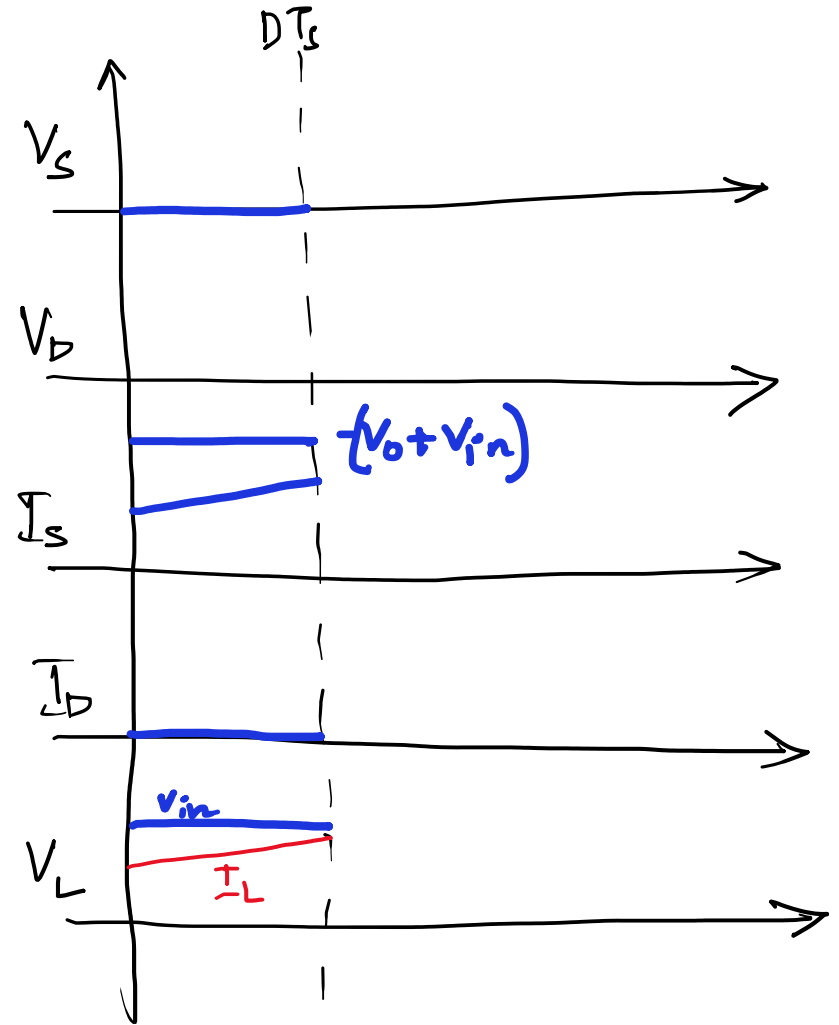


$$0 < t < DT_s \leq ON$$

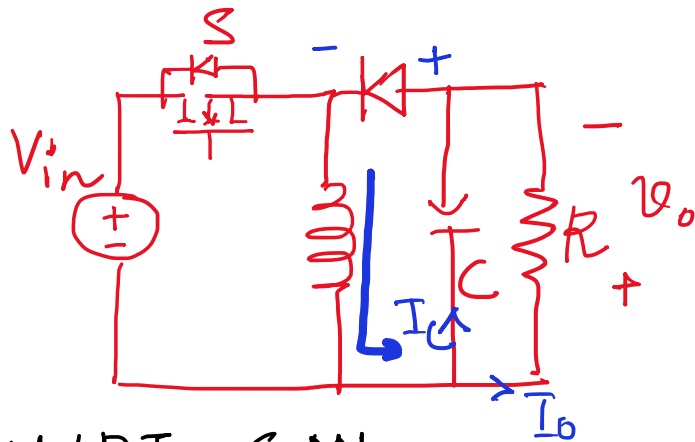
$$V_L = V_{in}$$

$$V_D = -(V_{in} + V_o)$$

$$I_C = -I_o$$



Buck-Boost [Steady State]



$$0 < t < DT_s \quad S \text{ ON}$$

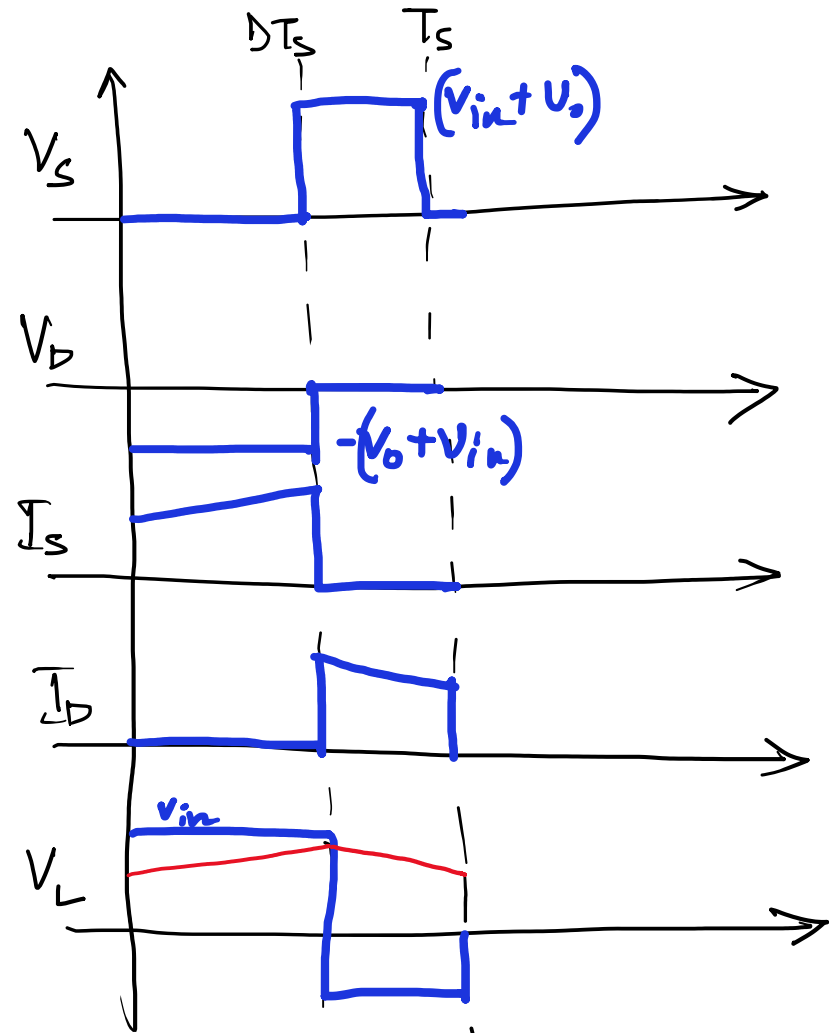
$$V_L = V_{in} \quad V_D = -V_o$$

$$I_C = -I_o$$

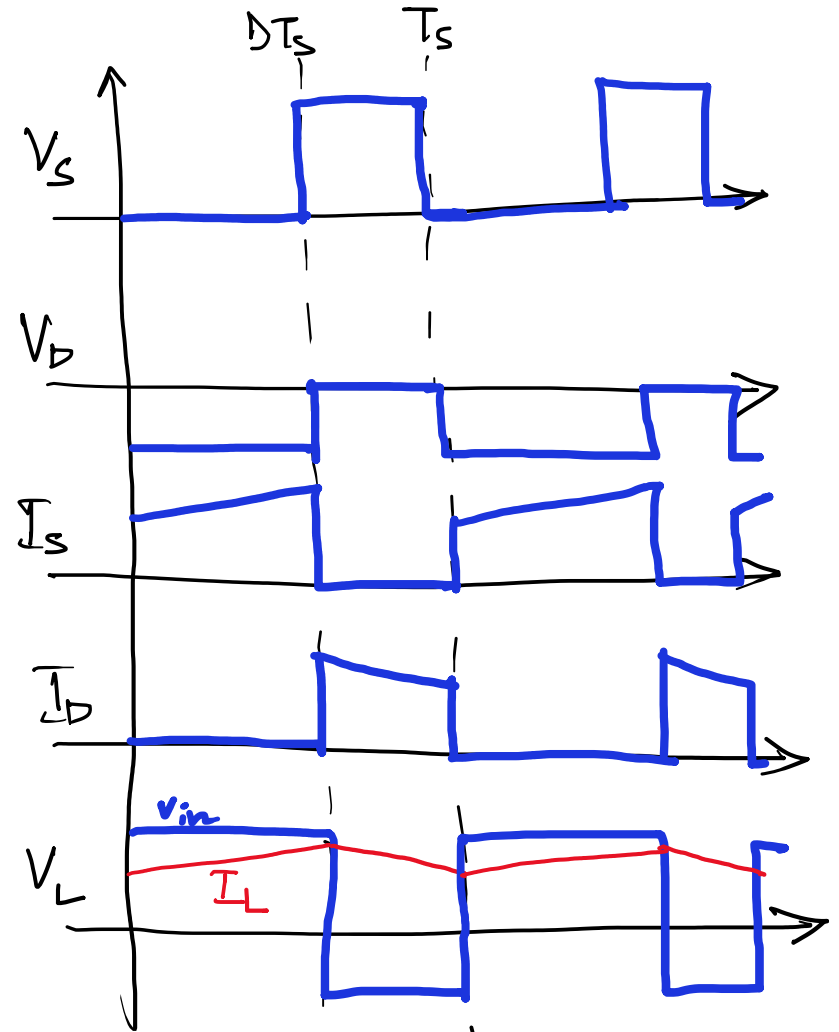
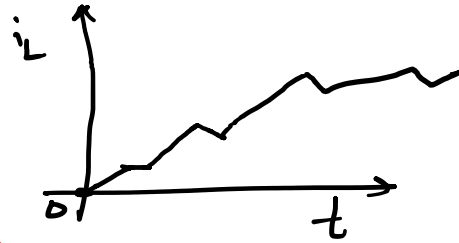
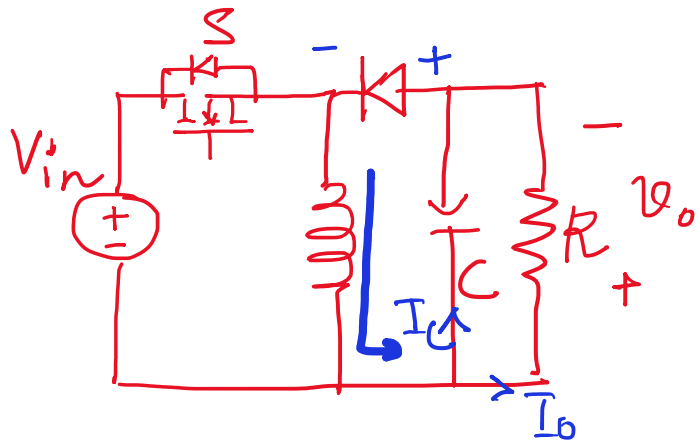
$$DT_s < t < T_s \quad S \text{ OFF}$$

$$V_L = -V_o \quad V_S = V_{in} + V_o$$

$$I_C = I_L - I_o$$



Buck-Boost [Steady State]



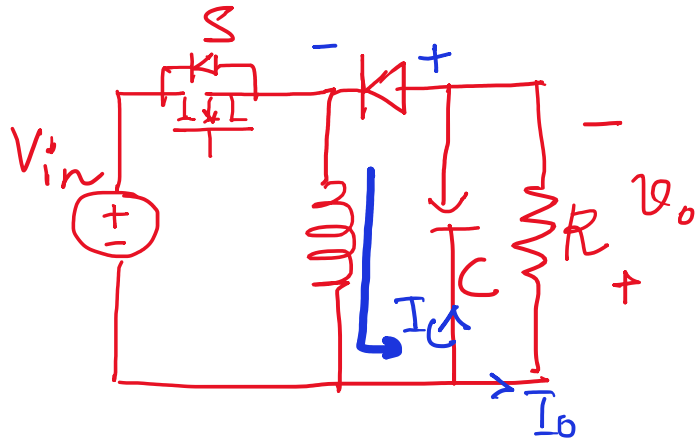
Volt-second balance;

$$V_{in}D - V_o(1-D) = 0$$

$$\Rightarrow \boxed{V_o = \frac{V_{in}D}{1-D}}$$

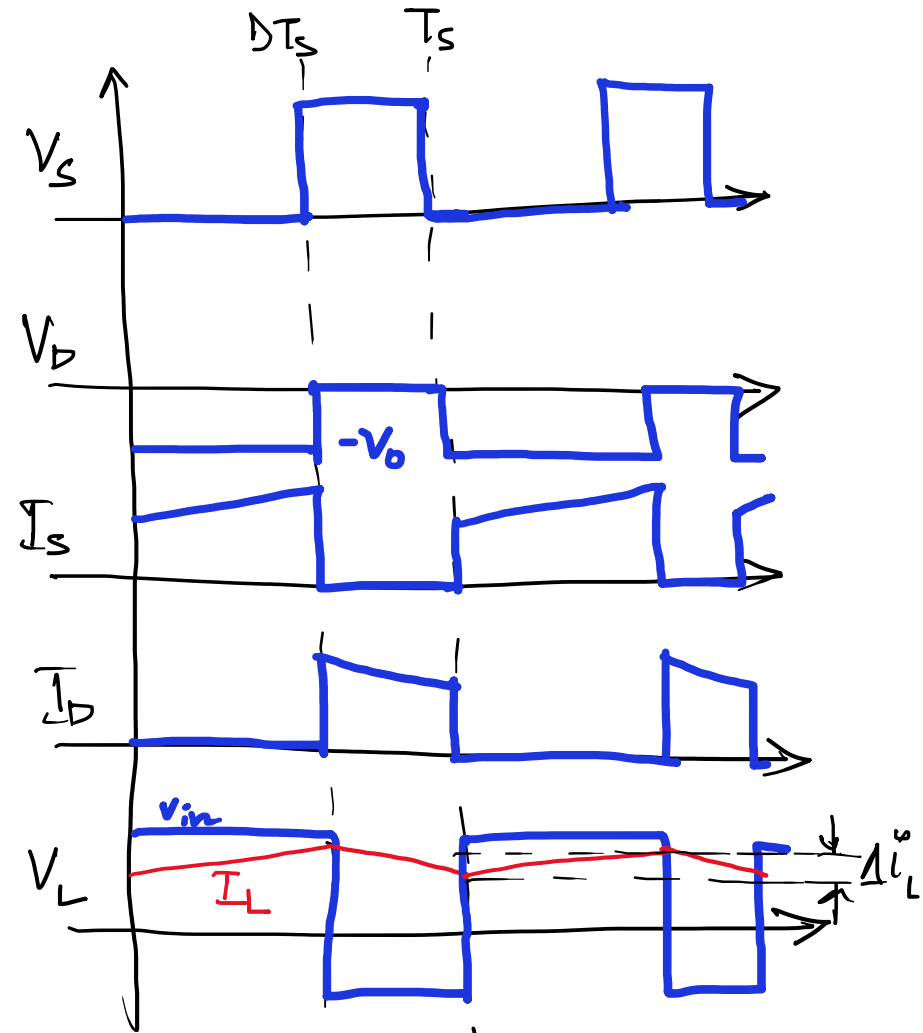
$D < 0.5$ Buck
 $D > 0.5$ Boost

Buck-Boost [Steady State]

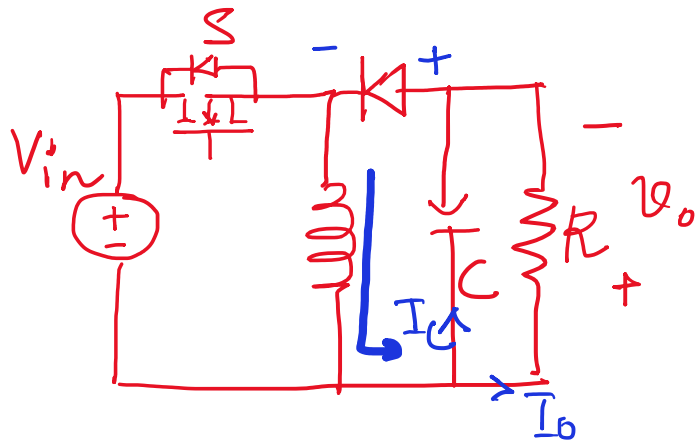


$$L \frac{\Delta i_L}{DT_s} = V_{in}$$

$$L = \frac{V_{in} DT_s}{\Delta i_L}$$



Buck-Boost [Steady State]

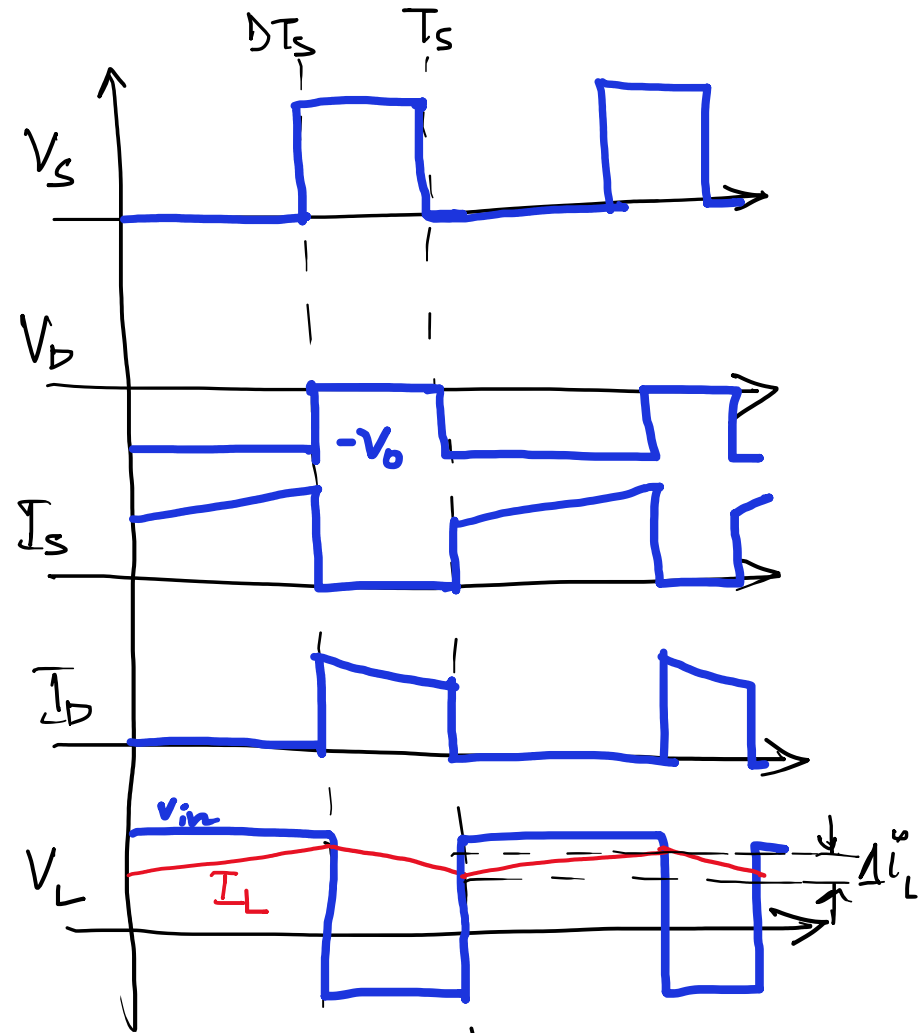


$$L \frac{\Delta i_L}{DT_s} = V_{in}$$

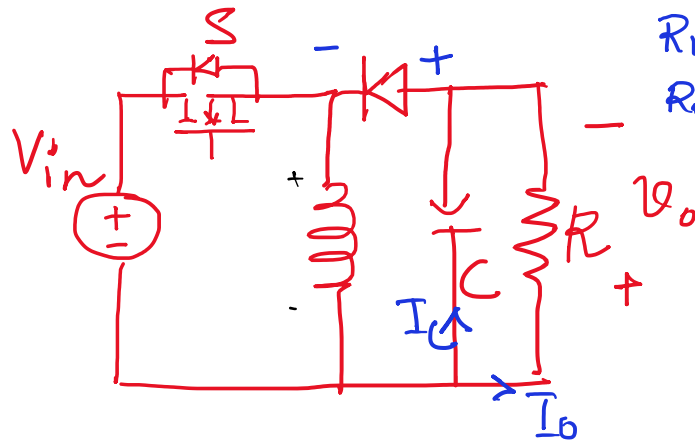
$$C \Delta V_o = I_o DT_s$$

$$L = \frac{V_{in} D}{\Delta i_L f_s}$$

$$C = \frac{I_o D}{\Delta V_o f_s}$$



Buck-Boost [Steady State Equivalent Circuit]



R_L = series resistance of L
 R_{on} = On state resistance of switch

V_D = Diode forward voltage
 R_D = On state diode resistance

$$\begin{aligned}\bar{v}_L &= (v_{in} - \bar{i}_L R_{on} - \bar{i}_L R_L)D - (1-D)(v_o + \bar{i}_L R_L + \bar{i}_L R_D + V_D) \\ &= Dv_{in} - \bar{i}_L (DR_{on} + R_L + D'R_D) - D'v_o - D'V_D = 0\end{aligned}$$

$$\bar{I}_L = D\left(-\frac{v_o}{R}\right) + D'(\bar{I}_L - v_o/R) = D\bar{I}_L - v_o/R$$

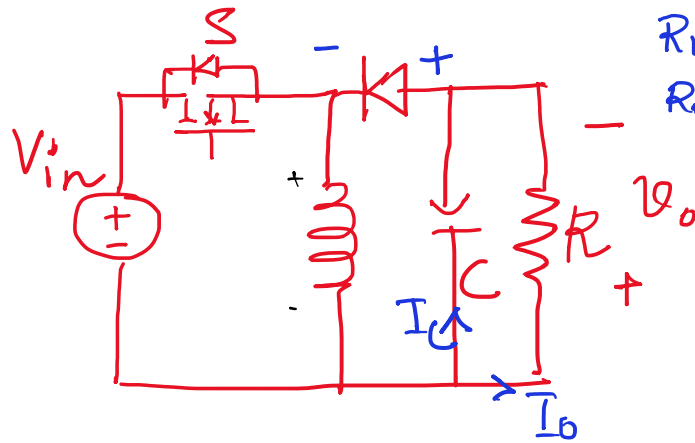
$$\bar{I}_L = \frac{v_o}{D'R}$$

$$Dv_{in} - \frac{v_o}{D'R} R_{eq} - D'v_o - D'V_D = 0$$

$$\Rightarrow v_o \left(D + \frac{R_{eq}}{D'R} \right) = Dv_{in} - D'V_D$$

$$\Rightarrow v_o = \frac{(D/D)v_{in}}{1 + \frac{R_{eq}}{D'^2 R}} - \frac{V_D}{1 + \frac{R_{eq}}{D'^2 R}}$$

Buck-Boost [Steady State Equivalent Circuit]



R_L = series resistance of L
 R_{on} = On state resistance of switch

V_D = Diode forward voltage
 R_D = On state diode resistance

$$\bar{v}_L = (v_{in} - \bar{i}_L R_{on} - \bar{i}_L R_L)D - (1-D)(v_o + \bar{i}_L R_L + \bar{i}_L R_D + V_D)$$

$$= Dv_{in} - \bar{i}_L (DR_{on} + R_L + D'R_D) - D'v_o - D'V_D = 0$$

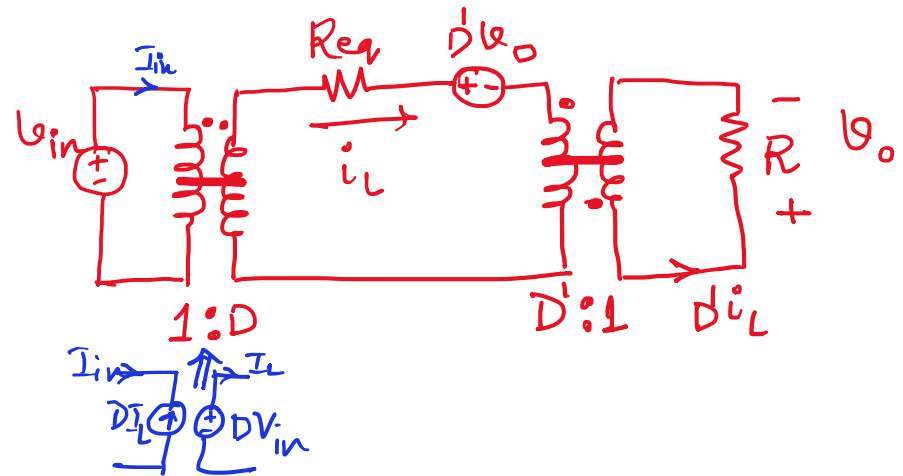
$$\bar{I}_L = D\left(-\frac{v_o}{R}\right) + D'(\bar{I}_L - v_o/R) = D\bar{I}_L - v_o/R$$

$$\bar{I}_L = \frac{v_o}{D'R}$$

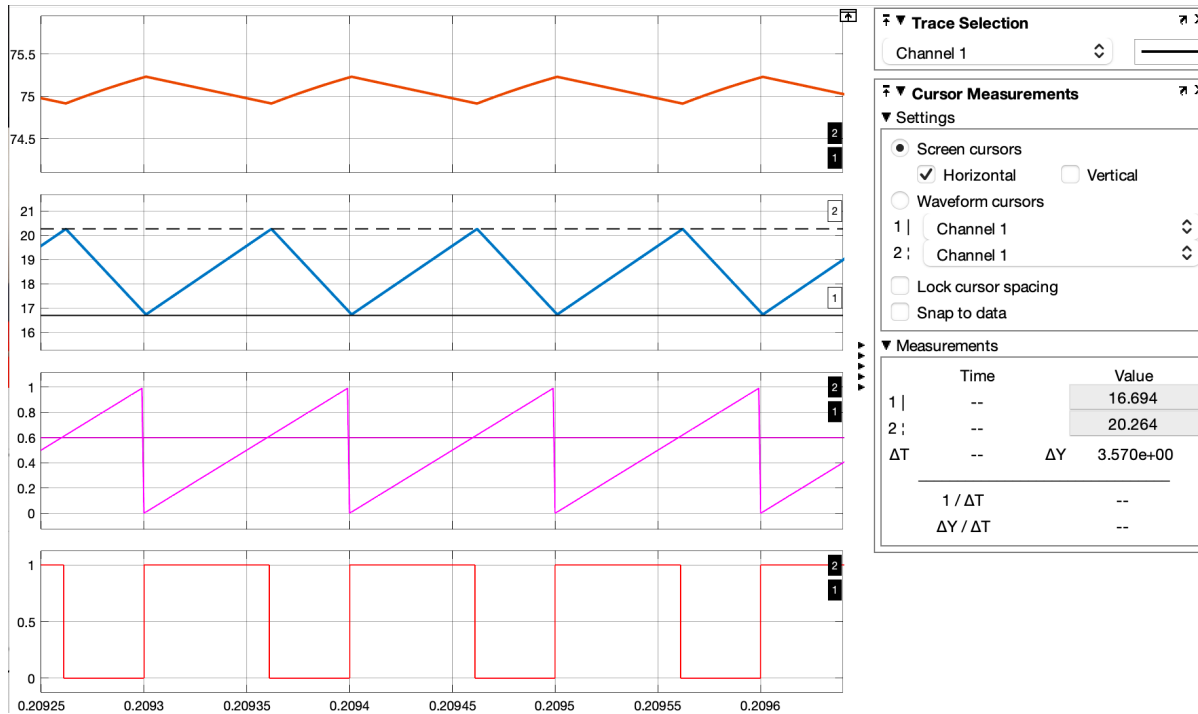
$$Dv_{in} - \frac{v_o}{D'R} R_{eq} - D'v_o - D'V_D = 0$$

$$\Rightarrow v_o \left(D + \frac{R_{eq}}{D'R} \right) = Dv_{in} - D'V_D$$

$$\Rightarrow v_o = \frac{(D/D')v_{in}}{1 + \frac{R_{eq}}{D'^2 R}} - \frac{V_D}{1 + \frac{R_{eq}}{D'^2 R}}$$



Buck-Boost [Steady State]



$$P = 500W, V_{in} = 48V$$

$$V_o = 12V - 72V$$

$$f_{sw} = 10kHz$$

$$\Delta i_L = 20\% \text{ of max. } I_L$$

$$\Delta V_o = 5\% \text{ of max voltage}$$

$$D_{min} = \frac{V_{o min}}{V_{in} + V_{o min}} \quad D_{max} = \frac{V_{o max}}{V_{in} + V_{o max}}$$

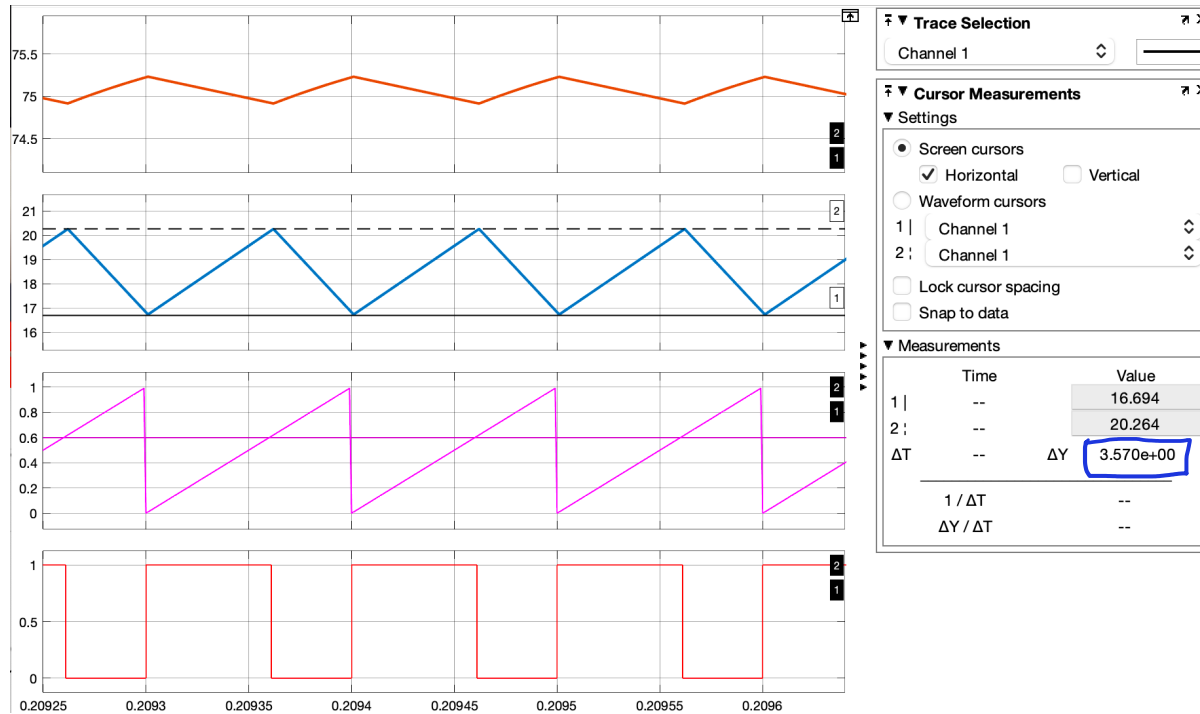
$$L = \frac{V_{in} D}{\Delta i_L f_{sw}}$$

$$= \frac{V_{in} D}{(\Delta i_L \%) I_L f_{sw}}$$

$$= \frac{V_{in} D^2}{(\Delta i_L \%) I_{in} f_{sw}}$$

$$I_{in} = D I_L$$

Buck-Boost [Steady State]



$$D_{max} = 0.6$$

$$P = 500W, V_{in} = 48V$$

$$V_o = 12V - 72V$$

$$f_{sw} = 10kHz$$

$$\Delta i_L = 20\% \text{ of max. } I_L$$

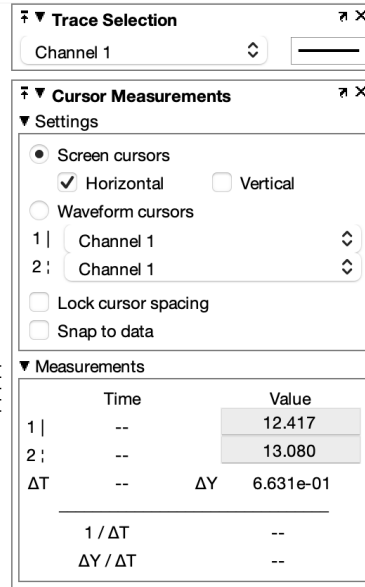
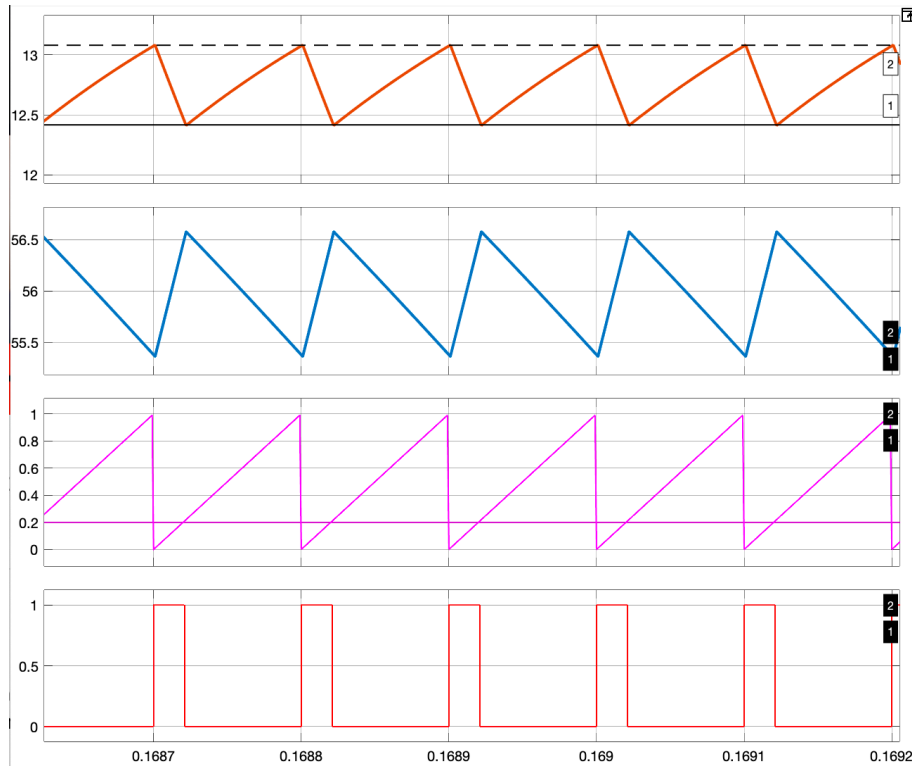
$$\Delta V_o = 5\% \text{ of max voltage}$$

$$D_{min} = \frac{V_{o min}}{V_{in} + V_{o min}} \quad D_{max} = \frac{V_{o max}}{V_{in} + V_{o max}}$$

$$L = \frac{V_{in} D_{max}^2}{(\Delta i_L) I_{in} f_{sw}} = \underline{\underline{0.83mH}}$$

$$\Delta i_L = 0.2 \times \frac{I_{in}}{D_{max}} = \underline{\underline{3.47A}}$$

Buck-Boost [Steady State]



$$P = 500W, V_{in} = 48V$$

$$V_o = 12V - 72V$$

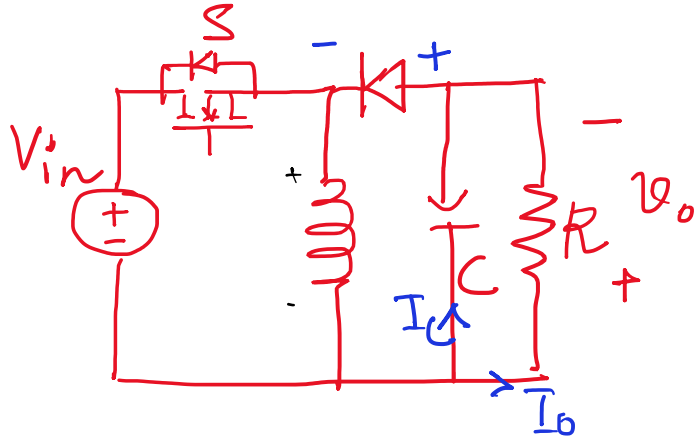
$$f_{sw} = 10kHz$$

$$\Delta i_L = 20\% \text{ of max. } I_L$$

$$\Delta V_o = 5\% \text{ of max voltage}$$

$$\begin{aligned}
 C &= \frac{I_o D}{\Delta V_o f_{sw}} \\
 &= \frac{PD}{\Delta V_o V_o f_{sw}} \\
 &= \frac{PD}{(\Delta V_o \%) V_o^2 f_{sw}} \\
 &= \frac{P(1-D)^2}{(\Delta V_o \%) D f_{sw} V_{in}^2}
 \end{aligned}$$

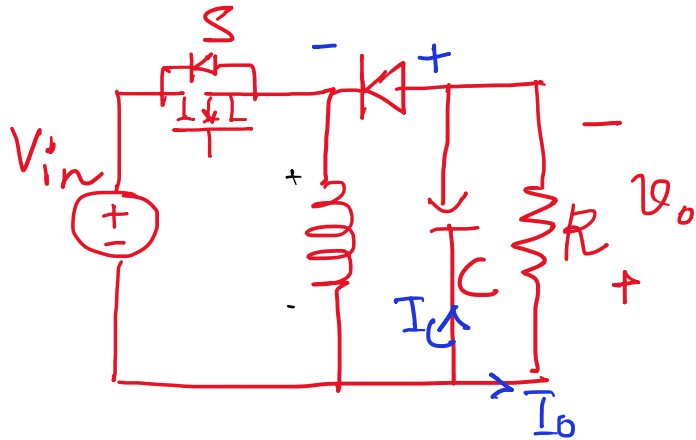
Buck-Boost Small signal Model



$$\bar{v}_L = \bar{v}_{in} \bar{D} - (1 - \bar{D}) \bar{v}_o$$

$$\bar{i}_c = (1 - \bar{D}) \bar{i}_L - \frac{1}{R} \bar{v}_o$$

Buck-Boost Small signal Model



$$\bar{v}_L = \bar{v}_{in} \bar{D} - (1 - \bar{D}) \bar{v}_o = L \frac{d\bar{i}_L}{dt}$$

$$\bar{i}_C = (1 - \bar{D}) \bar{i}_L - \frac{1}{R} \bar{v}_o = C \frac{d\bar{v}_C}{dt}$$

$$v_C = v_o$$

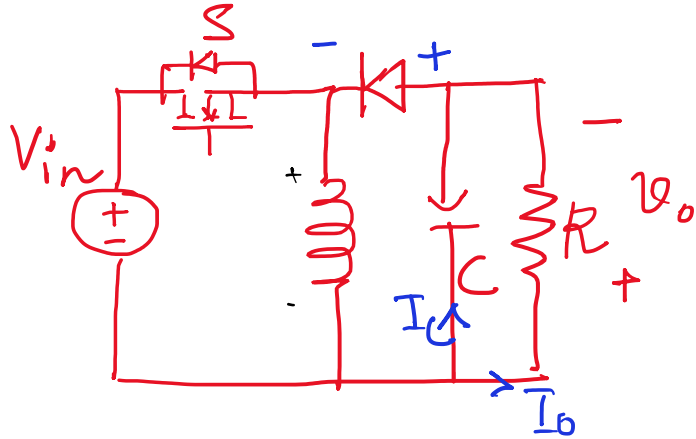
$$\bar{i}_{in} = \bar{D} \bar{i}_L$$

Perturbation and linearizing:

$$\begin{aligned} L \frac{d\hat{i}_L}{dt} &= \bar{D} \hat{v}_{in} + \bar{v}_{in} \hat{d} - \bar{D}' \hat{v}_o + \bar{v}_o \hat{d} \\ &= \bar{D} \hat{v}_{in} + \bar{v}_{in} \left(1 + \frac{\bar{D}}{1 - \bar{D}}\right) \hat{d} - \bar{D}' \hat{v}_o \\ &= \bar{D} \hat{v}_{in} + \frac{\bar{v}_{in}}{\bar{D}'} \hat{d} - \bar{D}' \hat{v}_o \end{aligned}$$

$$C \frac{d\hat{v}_C}{dt} = \bar{D}' \hat{i}_L - \bar{i}_L \hat{d} - \frac{\hat{v}_o}{R}$$

Buck-Boost Small signal Model



$$\bar{v}_L = \bar{v}_{in} \bar{D} - (1 - \bar{D}) \bar{v}_o = L \frac{d\bar{i}_L}{dt}$$

$$\bar{i}_C = (1 - \bar{D}) \bar{i}_L - \frac{1}{R} \bar{v}_o = C \frac{d\bar{v}_C}{dt}$$

$$v_C = v_o$$

$$\bar{i}_{in} = \bar{D} \bar{i}_L$$

Perturbation and linearizing:

$$L \frac{d\hat{i}_L}{dt} = \bar{D} \hat{v}_{in} + \bar{v}_{in} \hat{d} - \bar{D}' \hat{v}_o + \bar{v}_o \hat{d}$$

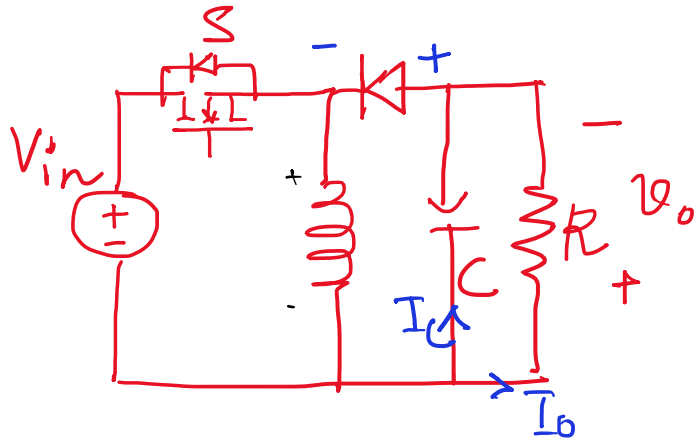
$$= \bar{D} \hat{v}_{in} + \bar{v}_{in} \left(1 + \frac{\bar{D}}{1 - \bar{D}}\right) \hat{d} - \bar{D}' \hat{v}_o$$

$$= \bar{D} \hat{v}_{in} + \frac{\bar{v}_{in}}{\bar{D}'} \hat{d} - \bar{D}' \hat{v}_o$$

$$C \frac{d\hat{v}_C}{dt} = \bar{D}' \hat{i}_L - \bar{i}_L \hat{d} - \frac{\hat{v}_o}{R}$$

$$\hat{i}_{in} = \hat{d} \bar{i}_L + \bar{D} \hat{i}_L$$

Buck-Boost Small signal Model



$$\bar{v}_L = \bar{v}_{in} \bar{D} - (1 - \bar{D}) \bar{v}_o = L \frac{d\bar{i}_L}{dt}$$

$$\bar{i}_C = (1 - \bar{D}) \bar{i}_L - \frac{1}{R} \bar{v}_o = C \frac{d\bar{v}_C}{dt}$$

$$v_C = v_o$$

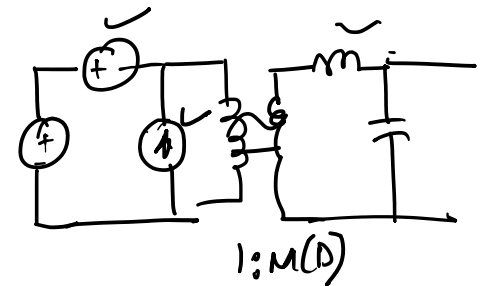
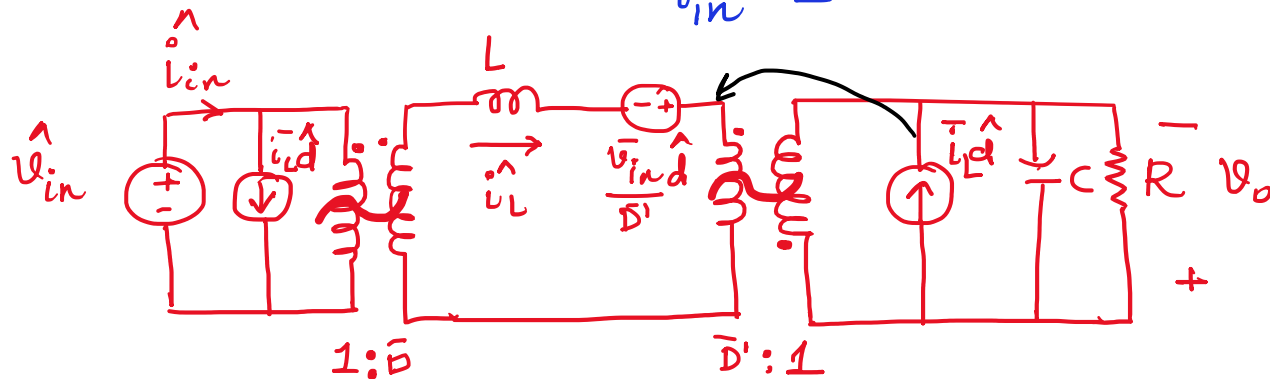
$$\bar{i}_{in} = \bar{D} \bar{i}_L$$

Perturbation and linearizing:

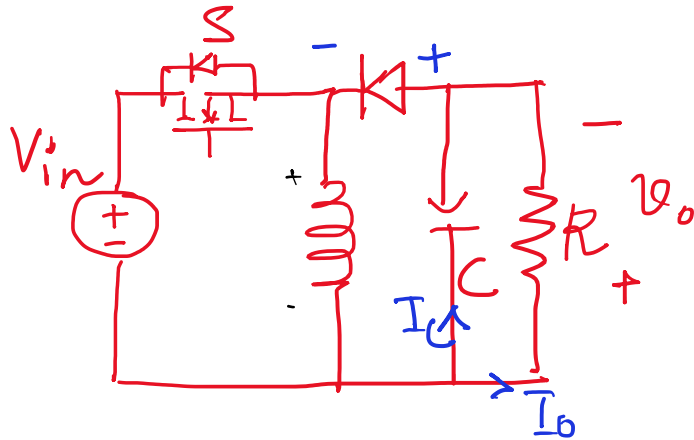
$$L \frac{d\hat{i}_L}{dt} = \bar{D} \hat{v}_{in} + \frac{\bar{v}_{in}}{\bar{D}'} \hat{d} - \bar{D}' \hat{v}_o$$

$$C \frac{d\hat{v}_C}{dt} = \bar{D}' \hat{i}_L - \bar{i}_L \hat{d} - \frac{\hat{v}_o}{R}$$

$$\hat{i}_{in} = \hat{d} \bar{i}_L + \bar{D} \hat{i}_L$$



Buck-Boost Small signal Model



$$\bar{v}_L = \bar{v}_{in} \bar{D} - (1 - \bar{D}) \bar{v}_o = L \frac{d\bar{i}_L}{dt}$$

$$\bar{i}_c = (1 - \bar{D}) \bar{i}_L - \frac{1}{R} \bar{v}_o = C \frac{d\bar{v}_c}{dt}$$

$$v_c = v_o$$

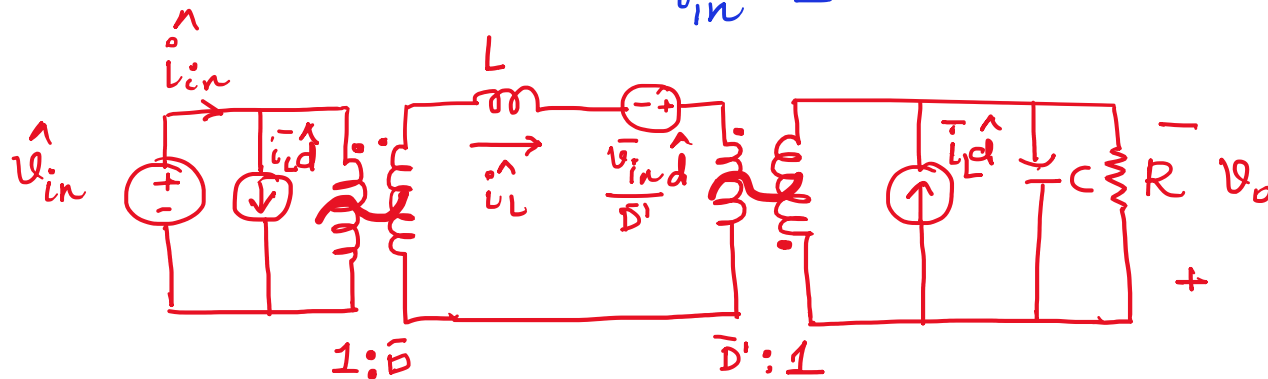
$$i_{in} = \bar{D} \bar{i}_L$$

Perturbation and linearizing:

$$L \frac{d\hat{i}_L}{dt} = \bar{D} \hat{v}_{in} + \frac{\bar{v}_{in}}{\bar{D}'} \hat{d} - \bar{D}' \hat{v}_o$$

$$C \frac{d\hat{v}_c}{dt} = \bar{D}' \hat{i}_L - \bar{i}_L \hat{d} - \frac{\hat{v}_o}{R}$$

$$\hat{i}_{in} = \hat{d} \bar{i}_L + \bar{D} \hat{i}_L$$



Buck-Boost Small signal Model

$$L \frac{d \hat{i}_L}{dt} = \bar{D} \hat{v}_{in} + \frac{\bar{v}_{in}}{\bar{D}'} \hat{d} - \bar{D}' \hat{v}_o$$

$$C \frac{d \hat{v}_o}{dt} = \bar{D}' \hat{i}_L - \bar{i}_L \hat{d} - \frac{\hat{v}_o}{R}$$

$$sC \hat{v}_o(s) + \frac{\hat{v}_o(s)}{R} + \bar{i}_L \hat{d}(s) = \bar{D}' \hat{i}_L(s)$$

$$\Rightarrow \hat{i}_L(s) = \frac{1}{\bar{D}'} \left[\left(\frac{sCR+1}{R} \right) \hat{v}_o + \bar{i}_L \hat{d} \right]$$

Buck-Boost Small signal Model

$$L \frac{d\hat{i}_L}{dt} = \bar{D} \hat{v}_{in} + \frac{\bar{v}_{in}}{\bar{D}'} \hat{d} - \bar{D}' \hat{v}_o$$

$$C \frac{d\hat{v}_o}{dt} = \bar{D}' \hat{i}_L - \bar{i}_L \hat{d} - \frac{\hat{v}_o}{R}$$

$$sC \hat{v}_o(s) + \frac{\hat{v}_o(s)}{R} + \bar{i}_L \hat{d}(s) = \bar{D}' \hat{i}_L(s)$$

$$\Rightarrow \hat{i}_L(s) = \frac{1}{\bar{D}'} \left[\left(\frac{sCR+1}{R} \right) \hat{v}_o + \bar{i}_L \hat{d} \right]$$

$$\frac{SL}{\bar{D}'} \left[\frac{sCR+1}{R} \hat{v}_o + \bar{i}_L \hat{d} \right] = \bar{D} \hat{v}_{in} + \frac{\bar{v}_{in}}{\bar{D}'} \hat{d} - \bar{D}' \hat{v}_o$$

$$\Rightarrow \hat{v}_o \left[\frac{s^2 LCR + SL}{\bar{D}' R} + \bar{D}' \right] = \bar{D} \hat{v}_{in} + \frac{\bar{v}_{in} - SL \bar{i}_L}{\bar{D}'} \hat{d}$$

$$\hat{v}_o \left[\frac{s^2 LCR + SL + \bar{D}'^2}{\bar{D}' R} \right] = \bar{D} \hat{v}_{in} + \frac{\bar{v}_{in}}{\bar{D}'} \left(1 - \frac{SL \bar{D}}{R \bar{D}'^2} \right) \hat{d}$$

$$\Rightarrow \hat{v}_o = \frac{\bar{D} \hat{v}_{in}}{\bar{D}' \left(s^2 \frac{LC}{\bar{D}'^2} + s \frac{L}{R \bar{D}'^2} + 1 \right)} + \frac{\bar{v}_{in}}{\bar{D}'^2} \frac{\left(1 - SL \frac{\bar{D}}{R \bar{D}'^2} \right) \hat{d}}{\left(s^2 \frac{LC}{\bar{D}'^2} + s \frac{L}{R \bar{D}'^2} + 1 \right)}$$

Buck-Boost Small signal Model

$$L \frac{d\hat{i}_L}{dt} = \bar{D} \hat{v}_{in} + \frac{\bar{v}_{in}}{\bar{D}'} \hat{d} - \bar{D}' \hat{v}_o$$

$$C \frac{d\hat{v}_o}{dt} = \bar{D}' \hat{i}_L - \bar{i}_L \hat{d} - \frac{\hat{v}_o}{R}$$

$$sC \hat{v}_o(s) + \frac{\hat{v}_o(s)}{R} + \bar{i}_L \hat{d}(s) = \bar{D}' \hat{i}_L(s)$$

$$\Rightarrow \hat{i}_L(s) = \frac{1}{\bar{D}'} \left[\left(\frac{sCR+1}{R} \right) \hat{v}_o + \bar{i}_L \hat{d} \right]$$

$$\frac{\hat{i}_L}{\hat{d}} = \frac{1}{R \bar{D}'^2} \frac{(1+sCR)}{\left(s^2 \frac{LC}{\bar{D}'^2} + s \frac{L}{R \bar{D}'^2} + 1 \right)}$$

$$\frac{SL}{\bar{D}'} \left[\frac{sCR+1}{R} \hat{v}_o + \bar{i}_L \hat{d} \right] = \bar{D} \hat{v}_{in} + \frac{\bar{v}_{in}}{\bar{D}'} \hat{d} - \bar{D}' \hat{v}_o$$

$$\Rightarrow \hat{v}_o \left[\frac{s^2 LC R + sL}{\bar{D}' R} + \bar{D} \right] = \bar{D} \hat{v}_{in} + \frac{\bar{v}_{in} - sL \bar{i}_L}{\bar{D}'} \hat{d}$$

$$\Rightarrow \hat{v}_o \left[\frac{s^2 LC R + sL + \bar{D}'^2}{\bar{D}' R} \right] = \bar{D} \hat{v}_{in} + \frac{\bar{v}_{in}}{\bar{D}'} \left(1 - \frac{sL \bar{D}}{R \bar{D}'^2} \right) \hat{d}$$

$$\Rightarrow \hat{v}_o = \underbrace{\frac{\bar{D}}{\bar{D}' \left(s^2 \frac{LC}{\bar{D}'^2} + s \frac{L}{R \bar{D}'^2} + 1 \right)}}_{\hat{v}_o / \hat{v}_{in}} + \underbrace{\frac{\bar{v}_{in}}{\bar{D}'^2} \frac{\left(1 - sL \frac{\bar{D}}{\bar{D}'^2} \right)}{\left(s^2 \frac{LC}{\bar{D}'^2} + s \frac{L}{R \bar{D}'^2} + 1 \right)}}_{\hat{v}_o / \hat{d}} \hat{d}$$

Buck-Boost Small signal Model

$$L \frac{d\hat{i}_L}{dt} = \bar{D} \hat{v}_{in} + \frac{\bar{v}_{in}}{\bar{D}'} \hat{d} - \bar{D}' \hat{v}_o$$

$$C \frac{d\hat{v}_o}{dt} = \bar{D}' \hat{i}_L - \bar{i}_L \hat{d} - \frac{\hat{v}_o}{R}$$

$$sC \hat{v}_o(s) + \frac{\hat{v}_o(s)}{R} + \bar{i}_L \hat{d}(s) = \bar{D}' \hat{i}_L(s)$$

$$\Rightarrow \hat{i}_L(s) = \frac{1}{\bar{D}'} \left[\left(\frac{sCR+1}{R} \right) \hat{v}_o + \bar{i}_L \hat{d} \right]$$

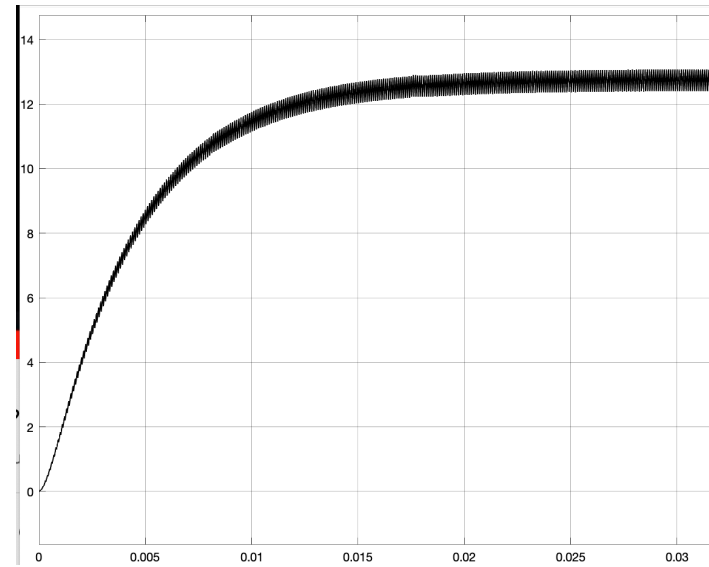
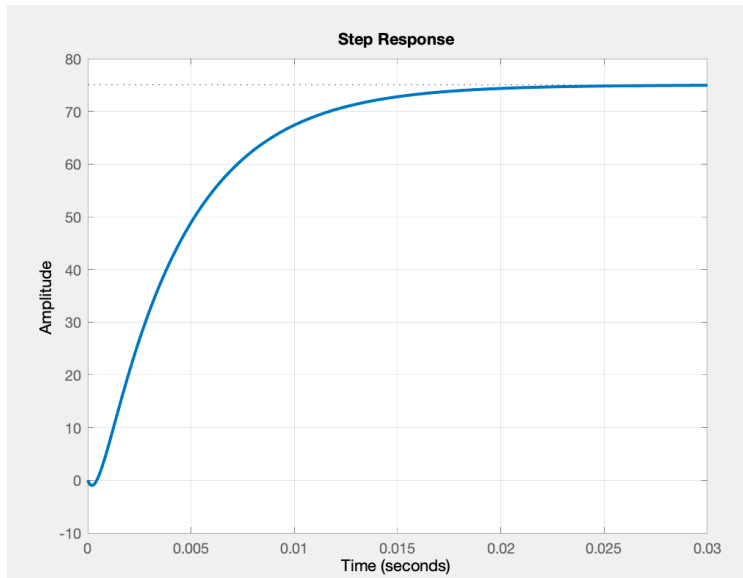
$$\frac{\hat{i}_L}{\hat{d}} = \frac{\bar{v}_{in}(1+\bar{D})}{R(1-\bar{D})^3} \left(\frac{1+sC\frac{R}{1+\bar{D}}}{s\frac{LC}{\bar{D}'^2} + s\frac{L}{R\bar{D}'^2} + 1} \right)$$

$$\frac{SL}{\bar{D}'} \left[\frac{sCR+1}{R} \hat{v}_o + \bar{i}_L \hat{d} \right] = \bar{D} \hat{v}_{in} + \frac{\bar{v}_{in}}{\bar{D}'} \hat{d} - \bar{D}' \hat{v}_o$$

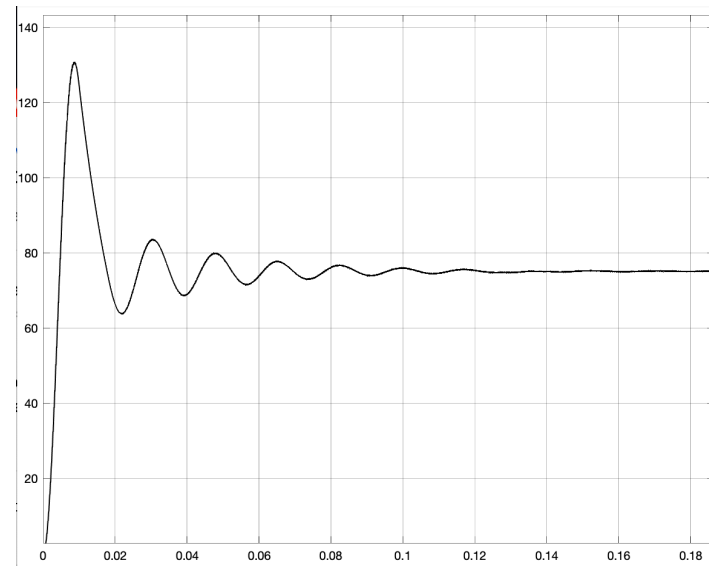
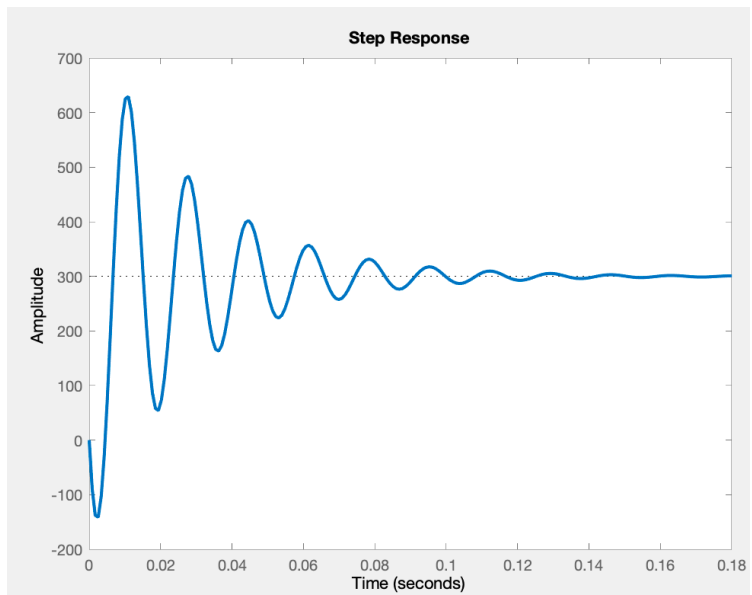
$$\Rightarrow \hat{v}_o \left[\frac{s^2LCR+SL}{\bar{D}'R} + \bar{D}' \right] = \bar{D} \hat{v}_{in} + \frac{\bar{v}_{in}-SL\bar{i}_L}{\bar{D}'} \hat{d}$$

$$\Rightarrow \hat{v}_o \left[\frac{s^2LCR+SL+\bar{D}'^2}{\bar{D}'R} \right] = \bar{D} \hat{v}_{in} + \frac{\bar{v}_{in}}{\bar{D}'} \left(1 - \frac{SL\bar{D}}{R\bar{D}'^2} \right) \hat{d}$$

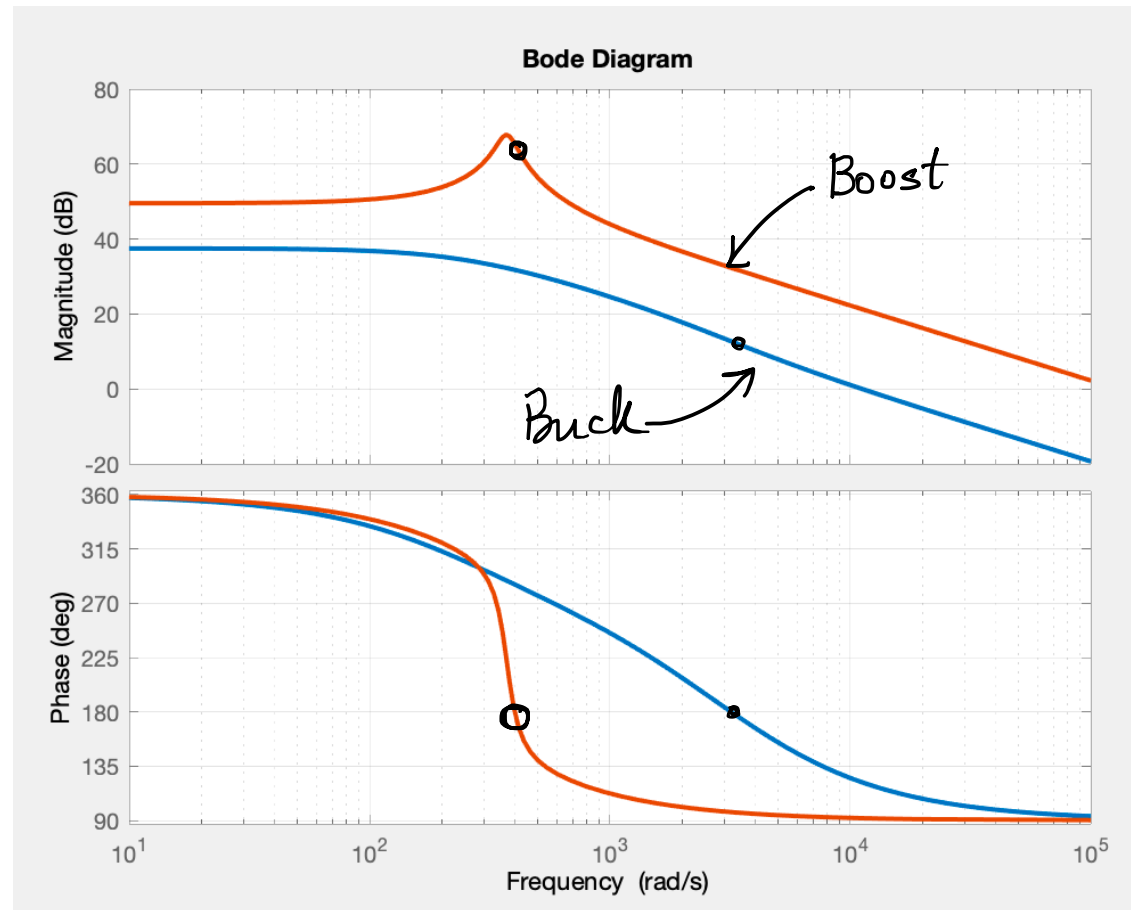
$$\Rightarrow \hat{v}_o = \underbrace{\frac{\bar{D}}{\bar{D}' \left(s^2 \frac{LC}{\bar{D}'^2} + s \frac{L}{R\bar{D}'^2} + 1 \right)}}_{\hat{v}_o / \hat{v}_{in}} + \underbrace{\frac{\bar{v}_{in}}{\bar{D}'^2} \frac{\left(1 - SL \frac{\bar{D}}{\bar{D}'^2} \right)}{\left(s^2 \frac{LC}{\bar{D}'^2} + s \frac{L}{R\bar{D}'^2} + 1 \right)}}_{\hat{v}_o / \hat{d}} \hat{d}$$



Buck



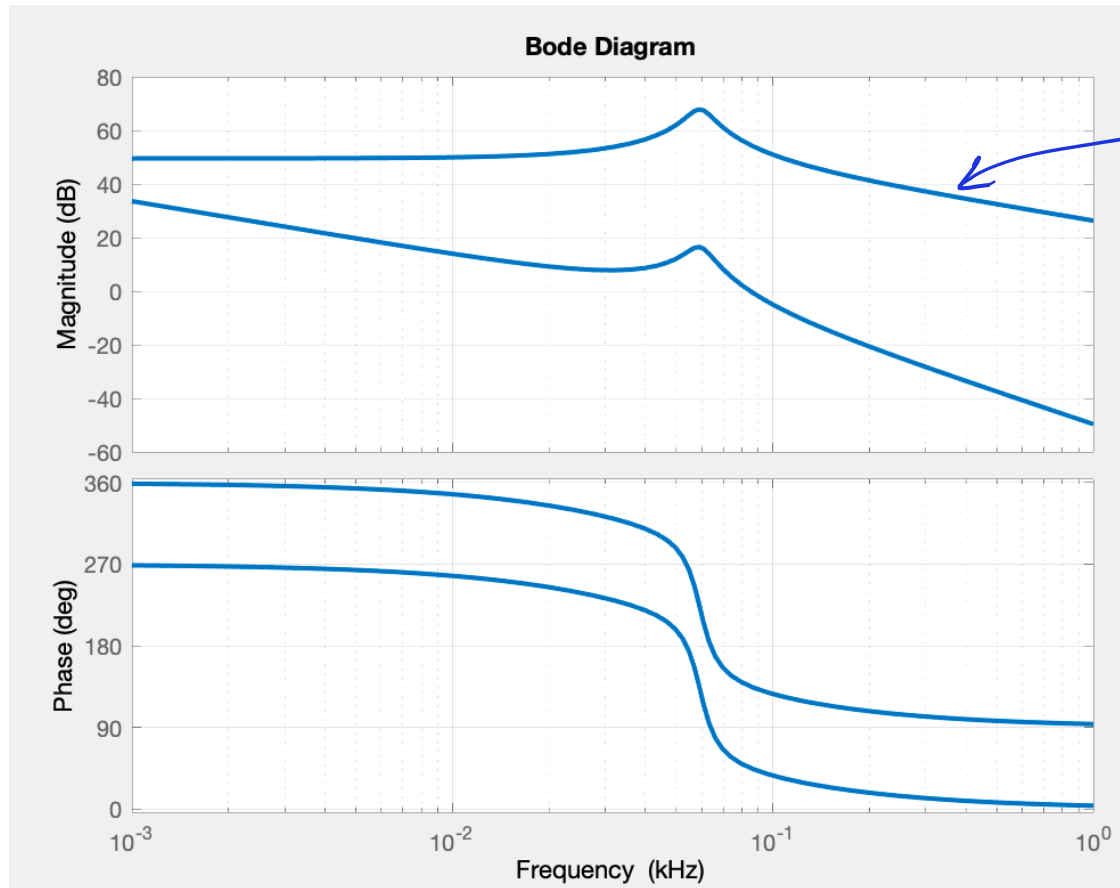
Boost



RHP zero

-90°

Voltage Control



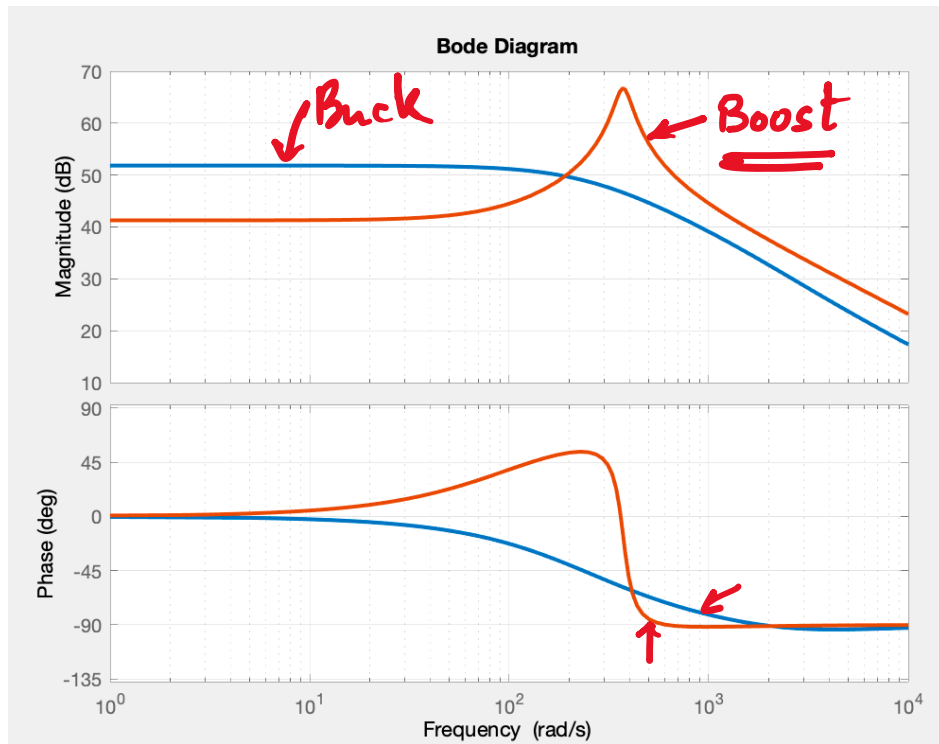
$\hat{v}_o/d$

$$c(s) = 1/s$$

Restriction on B/w
that can be achieved
due to RHP zero

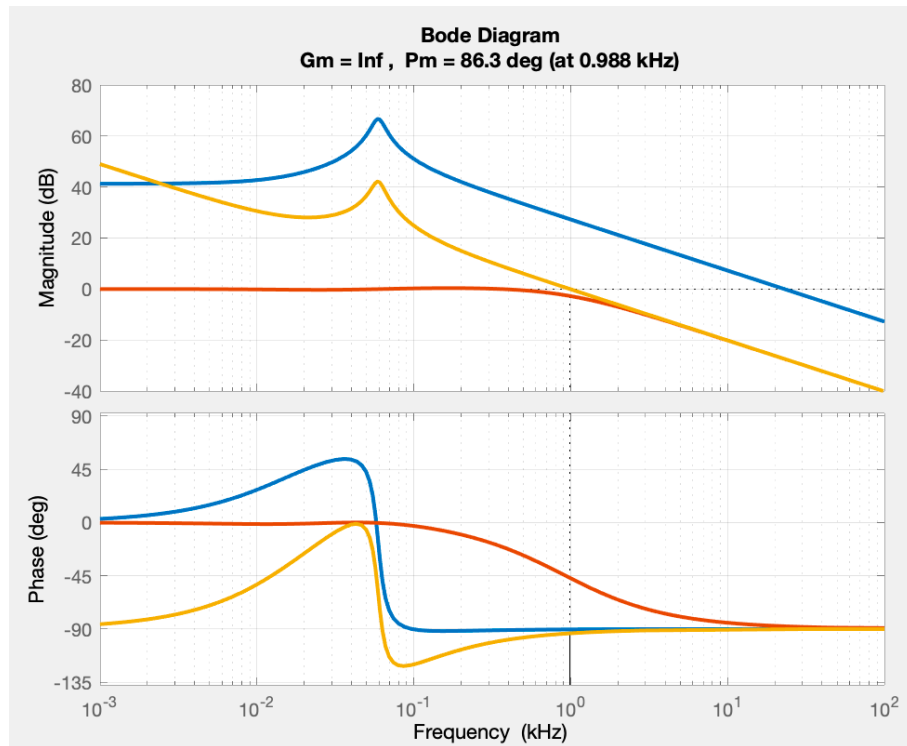
Current Control

$$\frac{\hat{i}_L}{\hat{d}} = \frac{\bar{v}_{in}(1+\bar{D}) \left(1 + sC \frac{R}{1+\bar{D}}\right)}{R(1-\bar{D})^3 \left(s^2 \frac{LC}{\bar{D}'^2} + s \frac{L}{R\bar{D}'^2} + 1\right)}$$



Current Control

$$\frac{\hat{i}_L}{\hat{d}} = \frac{\bar{v}_{in}(1+\bar{D}) \left(1 + sC \frac{R}{1+\bar{D}}\right)}{R(1-\bar{D})^3 \left(s^2 \frac{LC}{\bar{D}^2} + s \frac{L}{R\bar{D}^2} + 1\right)}$$

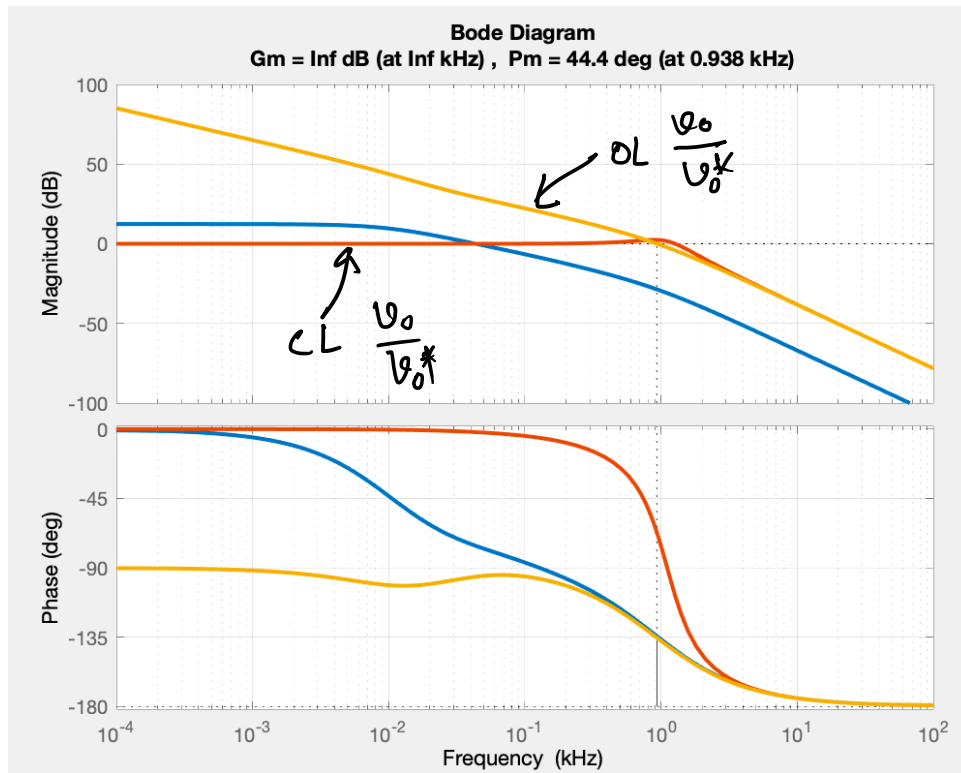


$$C_i(s) = \frac{0.0427(s + 357)}{s}$$

Ouler Voltage Control

$$\frac{\hat{V}_o}{\hat{I}_L} = \frac{\bar{D}'R}{1+sCR}$$

Boost



$$\underline{\underline{C_v(s) = \frac{27 \cdot 23(s + 100)}{s}}}$$

Buck

