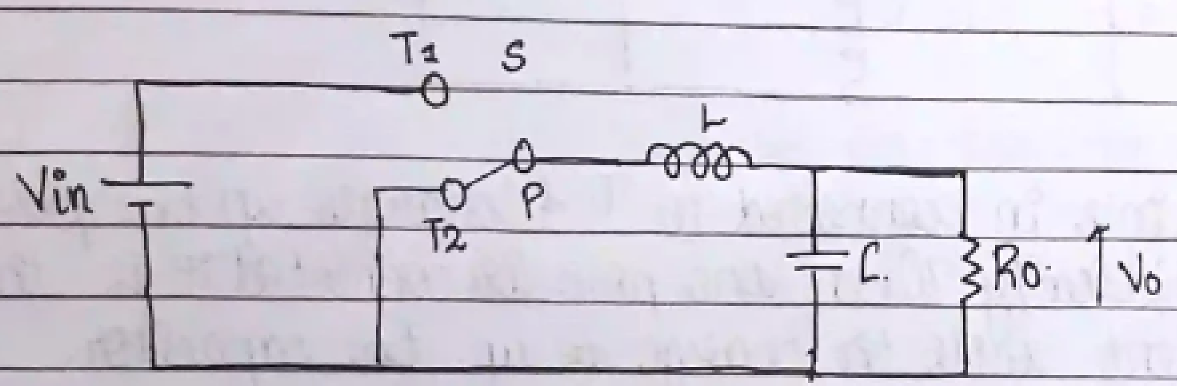
POWER CONVERTORS:-

BUCK CONVERTORS

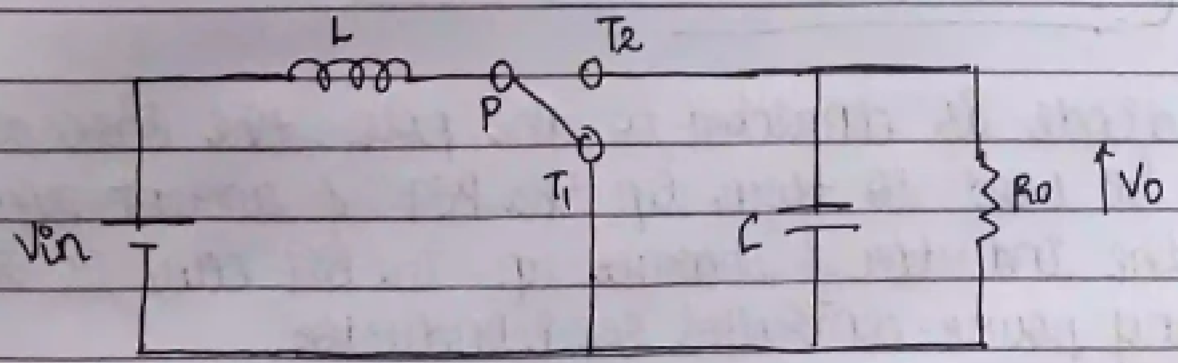
→ Ckt diagram:

Buck convertors



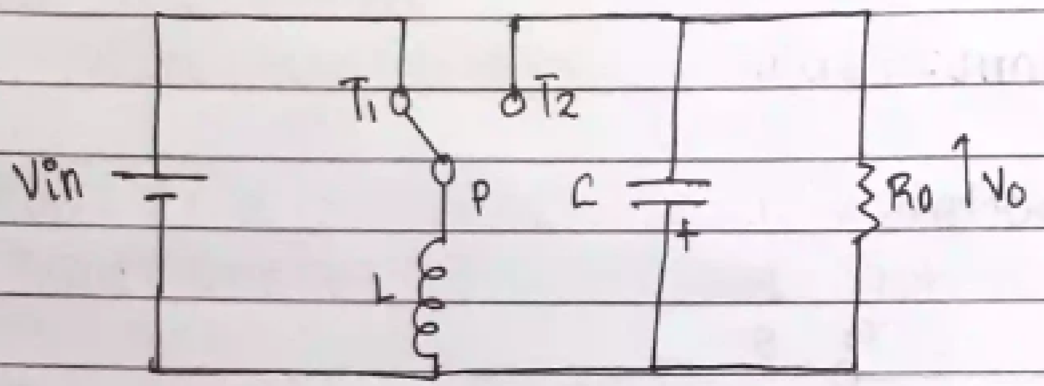
The energy is flowing from Vin to Vo. Vin is the higher voltage side, and Vo is lower.

Boost convertors



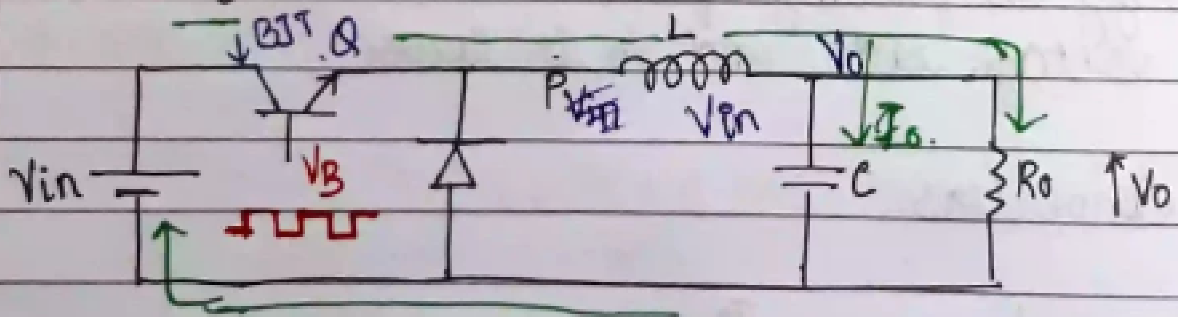
When pole is connected to T_1, the inductor charges up. Pole is at 0 poten. When pole is switched to T_2, the inductor current cannot go to 0. The induc will discharge the magnetized current. Inductor current can't change suddenly ∴ It is always connected to the pole.

Buck-boost convertors



The pole in connected to T_1 & charges up the ~~pole~~ induc magnetically. When the pole is connected to T_2 the current will ~~the~~ charge ~~to~~ up the capacitor.

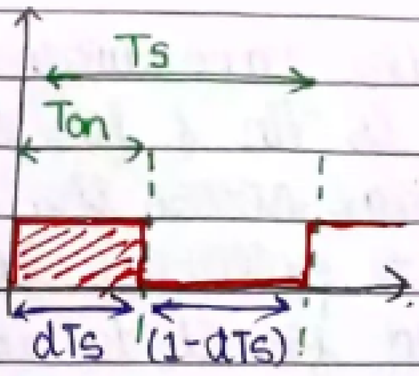
→ Buck converter.



The diode is connected to the pole. the base drive will be used to turn up the BJT, & current flows thr the inductor & charges up. The BJT can be replaced by any power-controlled semiconductor.

$d \Rightarrow$ duty ratio $= \dfrac{T_{on}}{T_{on} + T_{off}}$

$d = \frac{T_{on}}{T_S}$



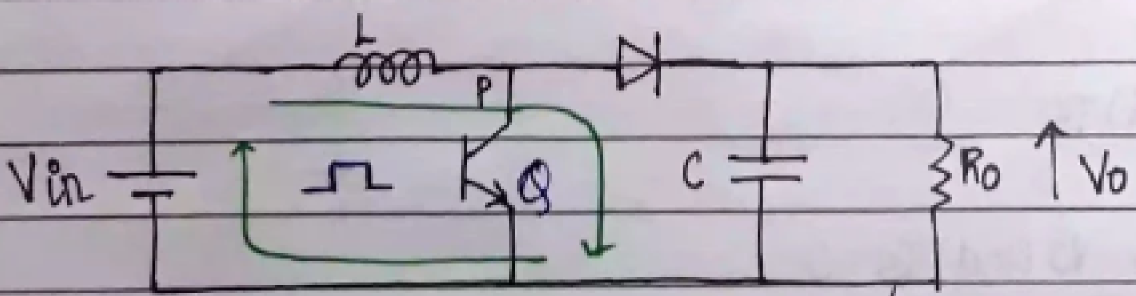
When $V_B \uparrow$ - Transistor on
When $V_B \downarrow$ - Transistor off

When Q ON: $(V_{in} - V_o)\, dT_s$
When Q OFF: $-V_o(1-d)T_s$

※ These 2 must be balanced for inductor to work properly

$$(V_{in} - V_o)\,dT_S + -V_o(1-d)T_S = 0$$
$$V_{in} \cdot d = V_o(d+1-d)$$
$$\boxed{V_o = V_{in} \cdot d}$$

→ Boost converter



$Q_{on}\,(dT_S) = V_{in} \cdot dT_S$
$Q_{off}\,(1-d)T_S = (V_{in} - V_o)(1-d)\,T_S = 0$

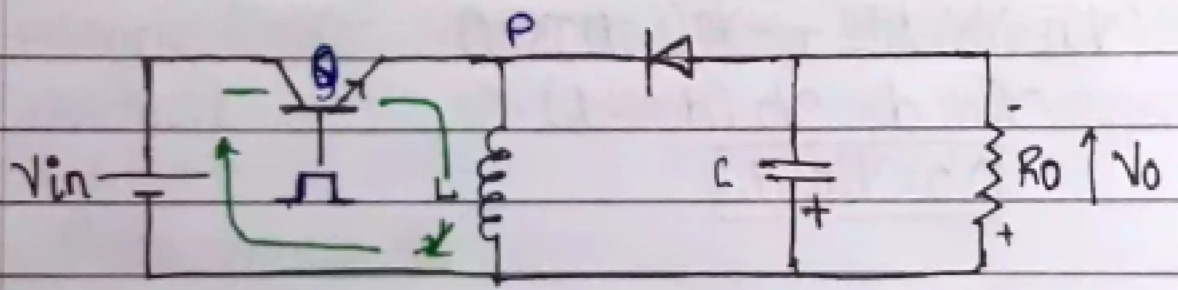
$$V_{in} = V_o(1-d)$$
$$\boxed{V_o = \frac{V_{in}}{1-d}}$$

at $d = 0$, Q is never on
at $d \to 1$, $V_o \uparrow$

During the time when Q is on, the potential across the inductor is Vin & for the whole second balance the voltage or potential across the inductor must change sign. As the ~~#~~ potential becomes V_0, as the diode is conducting, for it to be change sign V_0 > Vin.

$V_0 = \frac{V_{in}}{1-d}$. when $d=1$, transistor is not switching & it is continuously on. The diode is off. The capacitor is decoupled from the ckt & eventually discharge from ckt. ∴ $d=1$ we should not take, but $d \to 1$

→ Buck- Boost converter.



$Q_{ON} : dT_s$

$Q_{OFF} : (1-d)T_s$

$V_{in} \cdot dT_s + V_0(1-d)T_s = 0$

$\boxed{V_0 = -\frac{V_{in} \cdot d}{1-d}}$

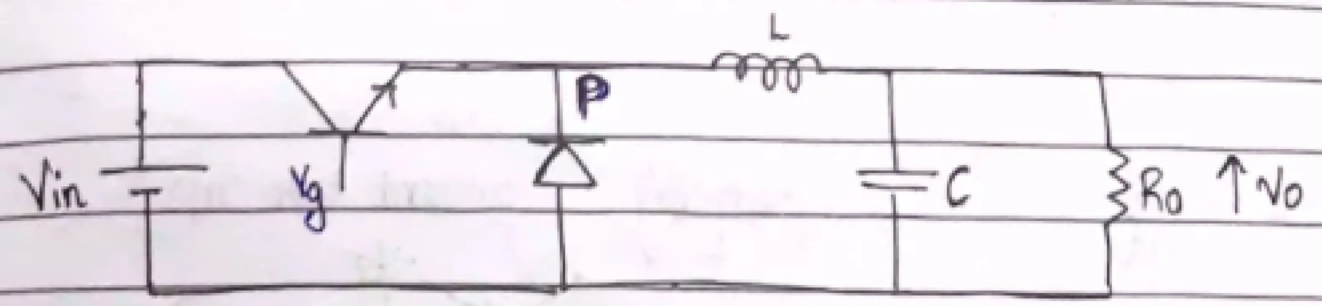
at $d=0$, $V_0 = 0$

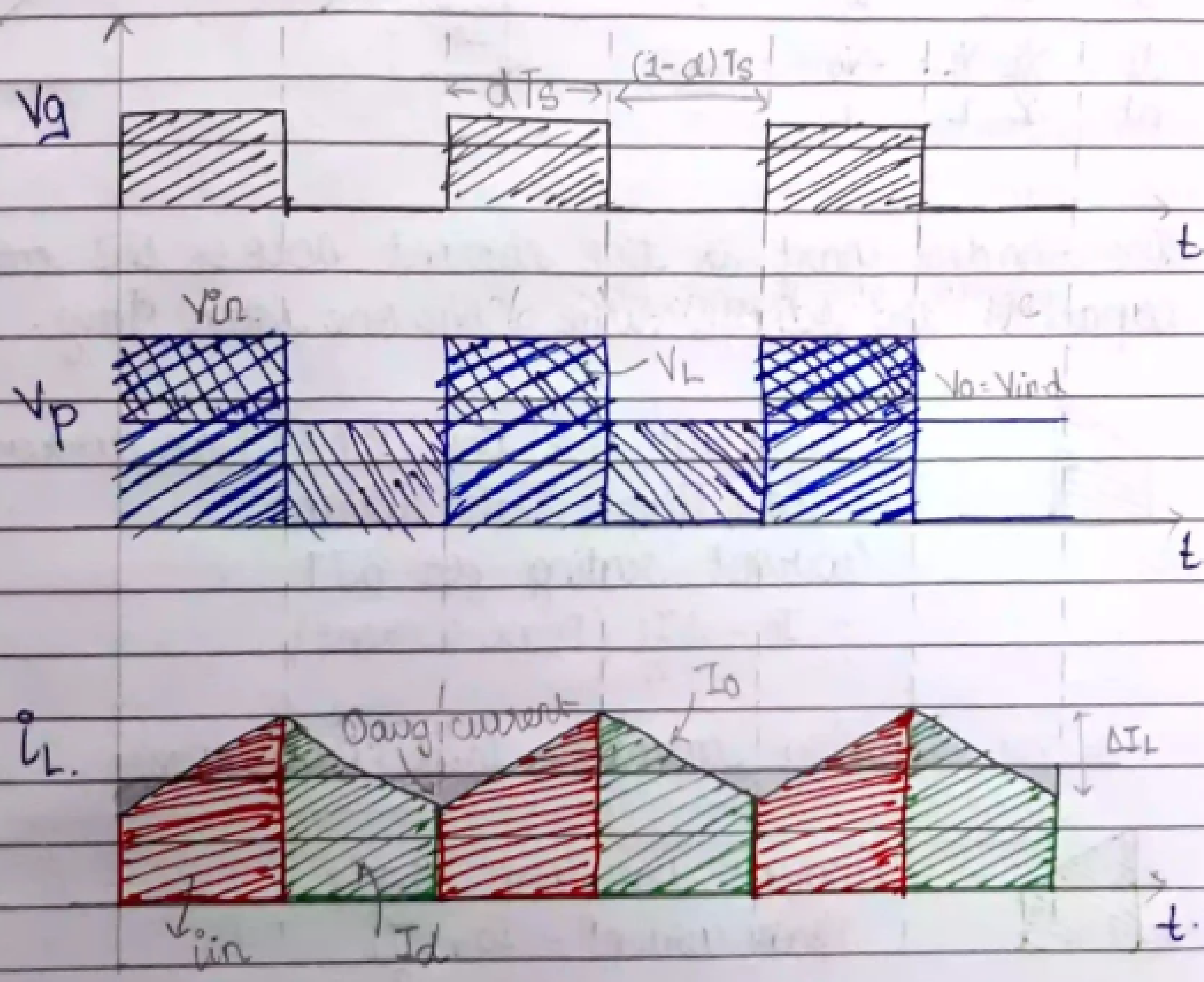
at $d = 0.5$, $V_0 = -V_{in}$

at $d > 0.5$, $V_0 > |V_{in}|$ — Boost

at $d < 0.5$. $V_0 < |V_{in}|$ — Buck

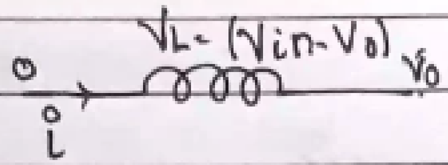
⇒ BUCK- CONVERTOR





When Vg is on. Vp will be Vin.. When diode is off ⇒ 0
When diode is on, the rest of ckt is free-wheeling & the P is connected to grd. ∴ The power withstanding capacity of BJT or any power-controlled semi is Vin

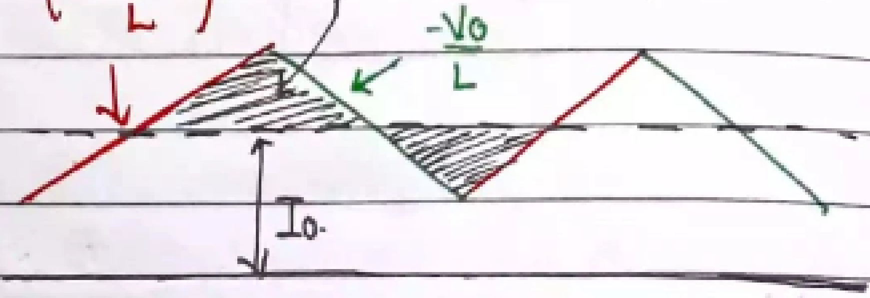
on time



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

$\frac{di}{dt} = \frac{V_L}{L} = \frac{V_{in}-V_0}{L}$

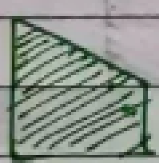
$\frac{di}{dt} = \frac{\cancel{V_L}}{\cancel{L}} \frac{V_L}{L} = \frac{-V_0}{L}$



The shaded part is the current across the ~~current~~ capacitor; the ripple value .. the one with Q_{avg}.

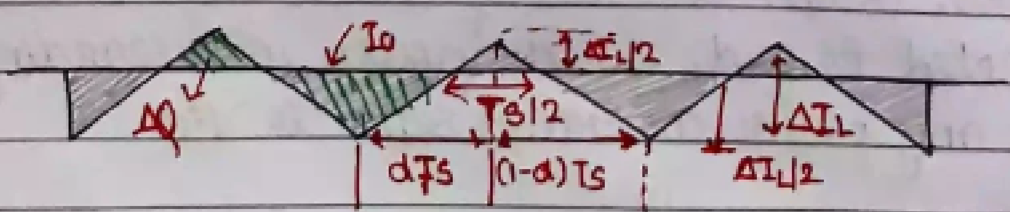
- current thr the BJT: Peak current
  I_0 + Ripple Peak current
  Current rating for BJT
  $= I_0 + \frac{\Delta I_L}{2}$ (Peak current)

  Avg current: $I_0 \cdot d$ (Duty cycle)



- Current thr. the diode.
  Peak current $= I_0 + \frac{\Delta I_L}{2}$

  Average value: $I_0 \cdot (1-d)$



Current thr the capacitor

Green shaded parts should be equal

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Area of Δ = charge

$$\Delta Q = \frac{1}{2} \times b \times h$$

$$= \frac{1}{2} \times \frac{T_S}{2} \times \frac{\Delta I_L}{2}$$

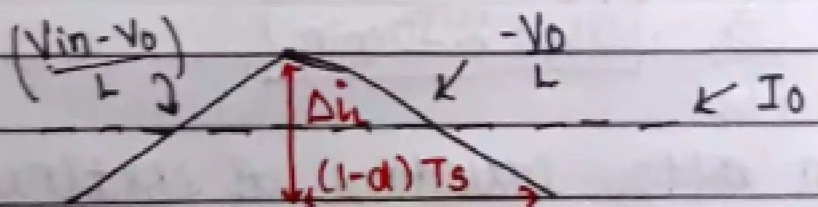
$$= \frac{T_S \cdot \Delta I_L}{8} \Rightarrow \frac{\Delta I_L}{8 f_S}$$

$$\Delta Q = C \cdot \Delta V$$

$$= \frac{\Delta i_L}{8 f_S} \Rightarrow \boxed{C = \frac{\Delta i_L}{8 f_S \cdot \Delta V}}$$

ΔV = Ripple across capacitance
Δi_L = assumed in designing
10% of I_{omax} (known)
f_S = designing aspect (known)

Inductor : L.



$$V_L = L \cdot \frac{di}{dt} \qquad \left|\frac{V_0}{L}\right| = \frac{di_L}{dt} = \frac{\Delta i_L}{\Delta T} = \frac{\Delta i_L}{(1-d)T_S}$$

$$\frac{V_0}{L} = \frac{\Delta i_L}{(1-d)T_S} \quad \text{OR} \quad \boxed{L = \frac{V_0(1-d)}{\Delta i_L \cdot f_S}}$$

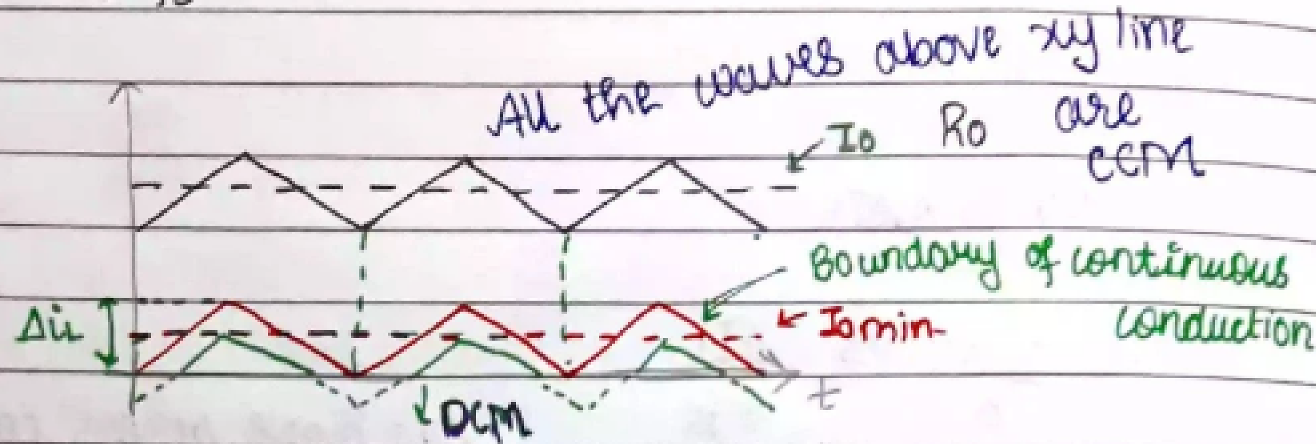
$$L_{max} = \frac{V_0(1-d_{min})}{\Delta i_L \cdot f_S}$$

10% of I_{omax}

$$V_0 = V_{in} \cdot d \qquad d = \frac{V_0}{V_{in}} = \overset{d_{min}}{\frac{V_0}{V_{in\,max}}} \text{ or } \overset{d_{max}}{\frac{V_0}{V_{in\,min}}}$$

These are the limiting values of d.

$$L = \frac{V_o(1-d)}{\Delta i_L \cdot f_s}$$

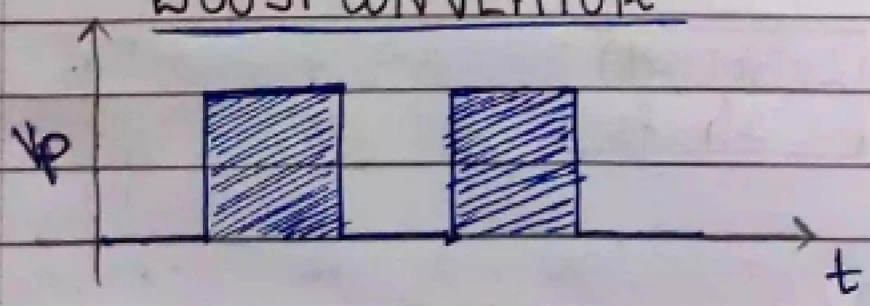


If Ro ↑ then Io (↓). But Δi_L & fs ~~will~~ will not change i.e. the slopes will not change as they are dependent on $\frac{V_{in}-V_o}{L}$ & $\frac{-V_o}{L}$ & independent of Ro. During limit, it will just touch the t-axis

$\frac{\Delta i_L}{2} = I_{o\,min}$ ⇒ $\boxed{\Delta i_L = 2 I_{o\,min}}$

Any wave form after boundary of continuous conduction, appear like the green waveform. They are called discontinuous conduction mode, or DCM. We should ensure that the inductor operates in CCM. All the analysis are for CCM

⇒ BOOST CONVERTOR



During time dTs, diode is off, transistor is conducting
Diode conducting capability = Vo.
When BJT is off, diode conducting.
∴ BJT conducting capability = Vo (during off time)

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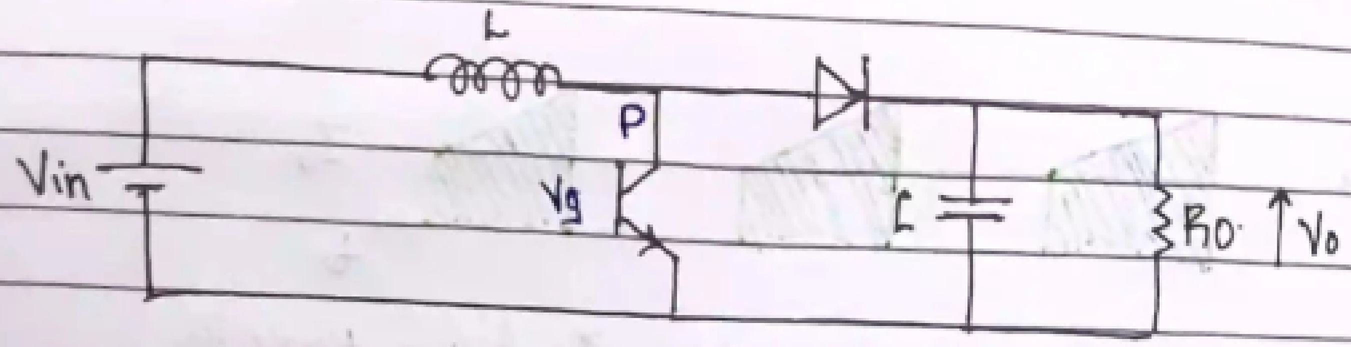
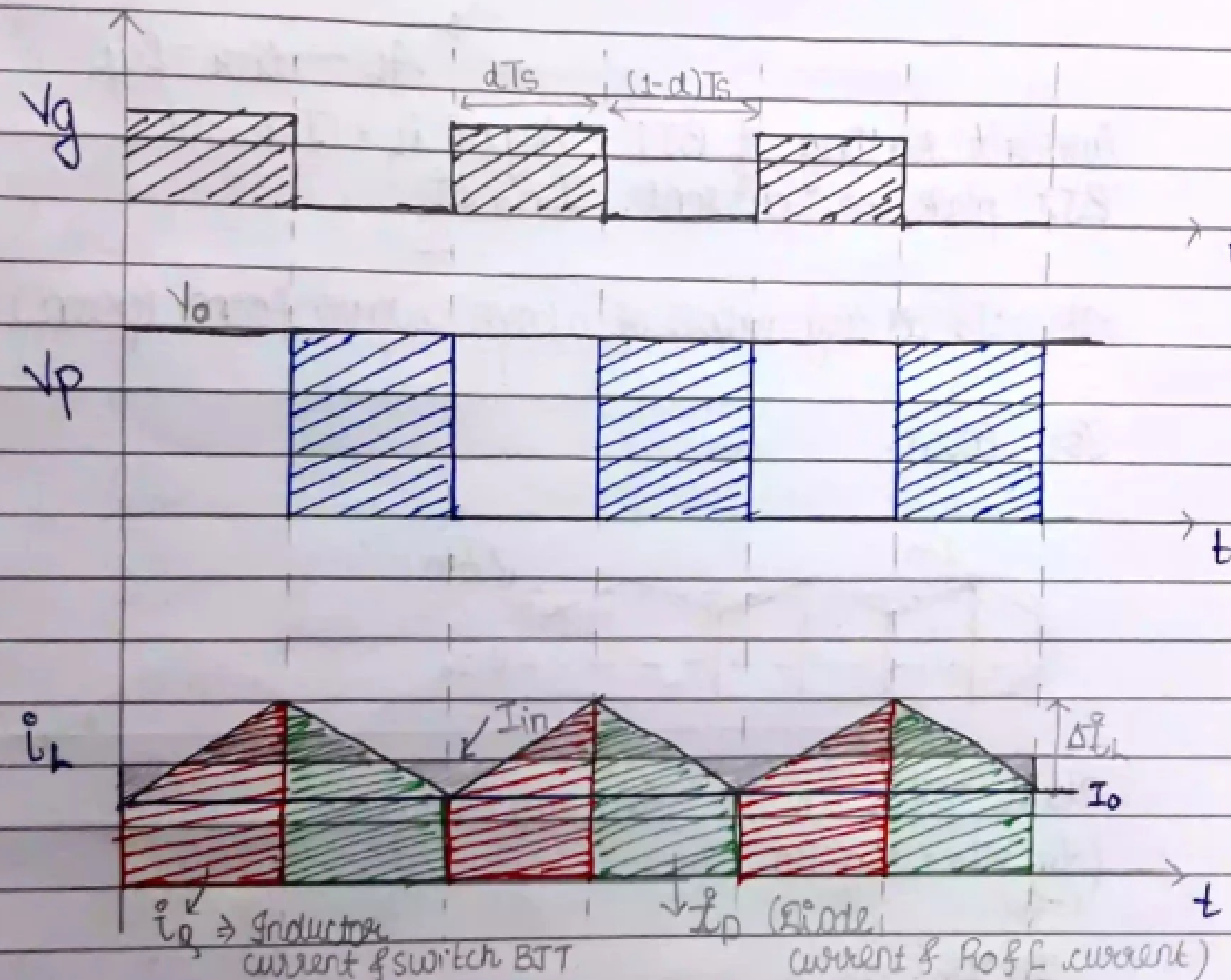
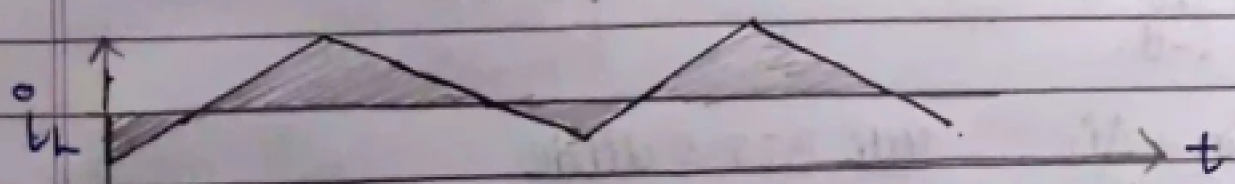
⇒ BOOST - CONVERTOR.







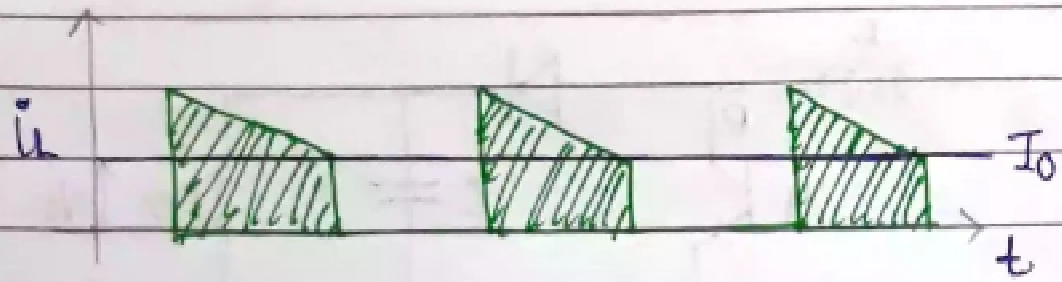
Rise in slope in slope is when transistor = ON. $\left(\frac{V_{in}}{L}\right)$

Fall in slope diode = ON $\left(\frac{V_{in}-V_o}{L}\right)$.

(output vol > input voltage)

Here the average current is indicating source current or I_{in} and not I_o as in buck convertor.

~~Input current~~ I_{in}

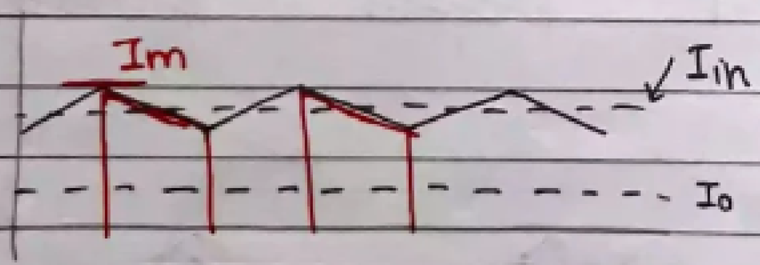


This will have 2 parts $\begin{cases} \text{Avg - thr } R_0 \\ \text{AC - thr Cap.} \end{cases}$

Current rating of BJT : Avg of i_L = I_{in}
BJT peak ~~cu~~ current: $I_{in} + \frac{\Delta i_L}{2}$

~~At~~ I_0 is avg value of above wave form (green).

For BOOST:



$V_0 I_0 = V_{in} I_{in}$ ∴ For any convertor

$\left(\frac{V_{in}}{1-d}\right) I_0 = V_{in} \cdot I_{in}$

∴ ~~In~~ $I_{in} = \frac{I_0}{1-d}$.

$I_{max} = I_{in} + \frac{\Delta i_L}{2}$ rate BJT & diode

Diode ⇒ peak inverse rating > V_0 } V_P.
BJT ⇒ $V_{CEO} > V_0$.

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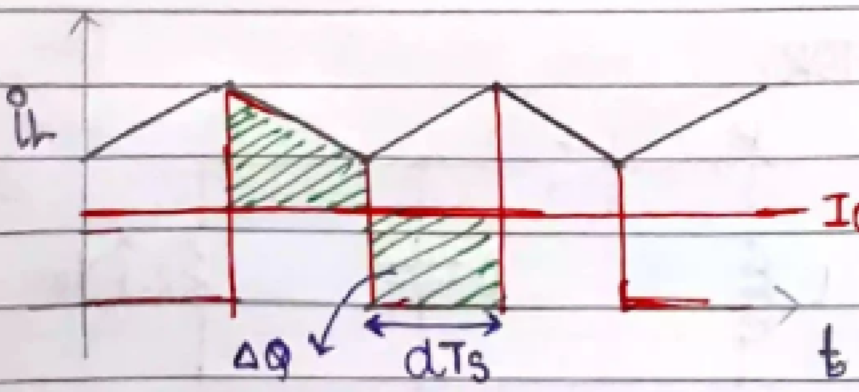
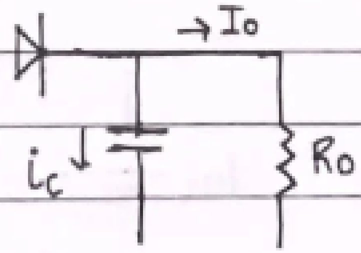
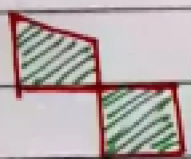




- current thr. diode



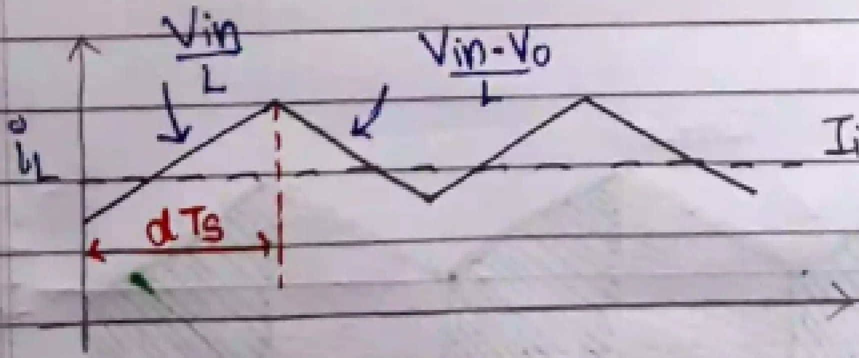
- current thr. cap.

green areas should be equal

Area $= \Delta Q = I_o \cdot dT_s = C\Delta V$

$$\boxed{C = \frac{I_o \cdot d}{\Delta V \cdot f_s}}$$

Normally 10% V is used for ΔV.



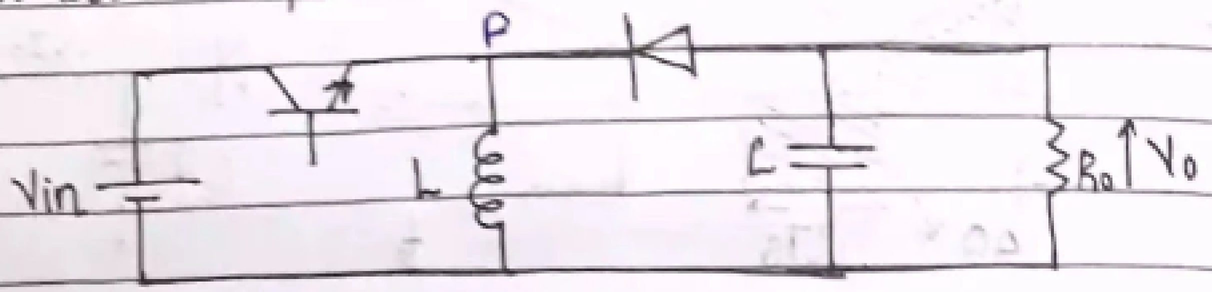
$I_{in} = \frac{I_o}{1-d}$.

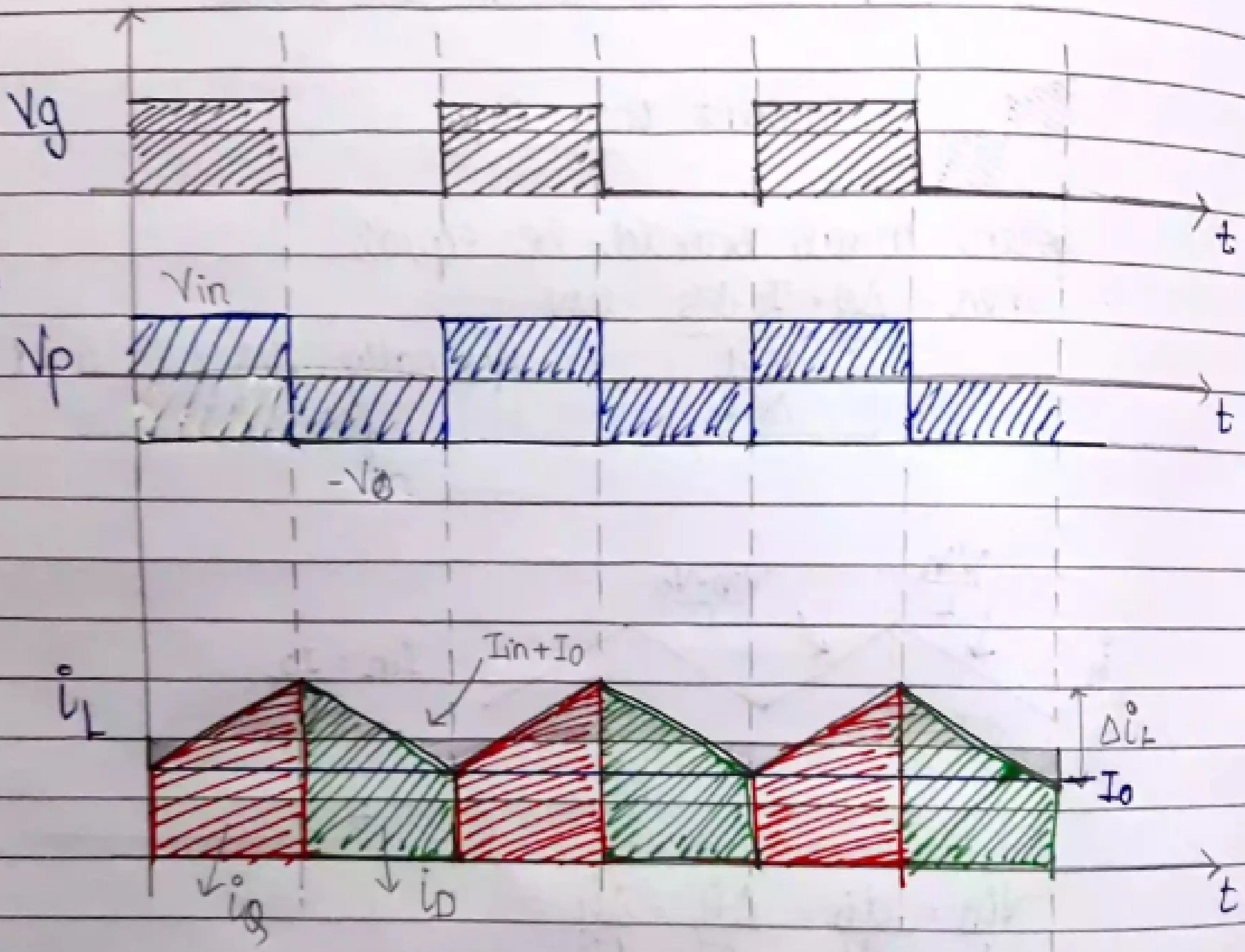
$$\frac{V_{in}}{L} = \frac{di_L}{dt} = \frac{\Delta i_L}{\Delta T} = \frac{\Delta i_L}{dT_s}$$

$$\therefore \boxed{L = \frac{V_{in} \cdot d}{\Delta i_L \cdot f_s}}$$

$$V_o = \frac{V_{in}}{1-d} \doteq \text{If } \frac{V_{in\,max}}{1-d_{min}} \text{ OR } \frac{V_{in\,min}}{1-d_{max}}$$

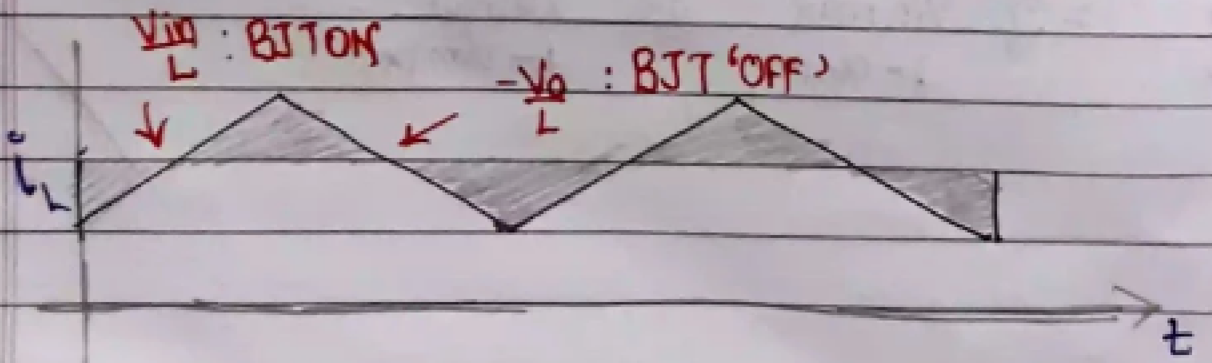
→ BUCK-BOOST CONVERTOR.

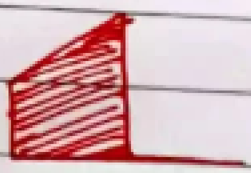




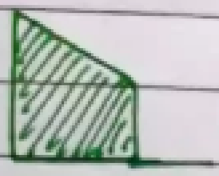
V_{in} → BJT on, $-V_0$ ~~→ Vin~~ = Diode conducting

Diode withstanding cap :- $V_{in} + V_0$. (Max rating)





- Current thr BJT
  Avg value: I_{in}.
  Peak: $I_{in} + I_o + \frac{\Delta i_L}{2}$



- Current thr the diode
  Avg:- I_o
  Rating:- Peak:- $I_{in} + I_o + \frac{\Delta i_L}{2}$

The value ~~ss~~ ~~so~~ of C is same as boost convertor i.e.

$$\boxed{C = \frac{I_o \cdot d}{\Delta V \cdot f_s}}$$

⇒ IMP FORMULAE & EQNs

V_{in} = Input voltage
V_{out} = Output voltage.
I_{out} = Output load current
$V_{in\,(max)}$ = Max input voltage
$V_{in\,(min)}$ = Min input voltage.
ΔI_L = Peak to Peak inductor / output current ripple
ΔV_{out} = Output peak-Peak voltage ripple.
L = Inductance (Filter)
C = Capacitance (Filter)

→ BUCK:

1. D_{min} = Min duty cycle
η = Efficiency = 0.9 ... assume

$$D_{min} = \frac{V_{out}}{V_{in(max)}} \times \eta$$

2. $\Delta i_L = 0.1 \times I_{out}$

$$L = \frac{V_{out}(V_{in(max)} - V_{out})}{\Delta i_L \times f_s \times V_{in(max)}}$$, f_s = Switching frequency (Hz)

Δi_L = 10% of I_{out} ⇒ $0.1 \cdot I_{out}$

3. ΔV_{out} = 2% of V_{out}
$= 0.02 \cdot V_{out}$

$$C_{out(min)} = \frac{\Delta I_L}{8 \cdot f_s \times \Delta V_{out}}$$

4. $D_{min} = \frac{V_{out}}{V_{in\,max}}$ - Min value of D when $V_{in(max)}$

$D_{max} = \frac{V_{out}}{V_{in(min)}}$ - Max value of D when $V_{in(min)}$

→ BOOST:

1. $$\frac{V_{out}}{V_{in}} = \frac{I_{in}}{I_{out}} = \frac{1}{1-D}$$

$$D = 1 - \frac{V_{in(min)}}{V_{out}} \times \eta$$

$\Delta i_L = 10\% \times I_{out} \times \frac{V_{out}}{V_{in}}$ ... Induct current ripple.

$$I_{SW(max)} = \frac{\Delta I_L}{2} + \frac{I_{out}}{1-D}$$

$$L = \frac{V_{in} \times (V_{out} - V_{in})}{\Delta I_L \times f_s \times V_{out}}$$. ΔV_{out} - output voltage ripple.

$$C_{out(min)} = \frac{I_{out} \times D}{f_s \times \Delta V_{out}}$$

→ BUCK - BOOST

1. $$\frac{V_o}{V_{in}} = \frac{-D}{1-D}$$. $$D_{min} = \frac{V_o}{V_o + V_{in(max)}}$$

2. $$L = \frac{V_{in(max)} \times D_{min}}{\Delta I_L \times f_s}$$. ΔI_L - current ripple

3. $$D_{max} = \frac{V_o}{V_{in(min)} + V_o}$$

∴ $$C_{out} = \frac{2 \times D_{max}}{f_s \cdot \Delta V_{out}}$$. $\Delta V_{out} = 2\% \cdot V_{out} = 0.02 \times V_{out}$