BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

# PROJECT REPORT

## Course No: EEE 316
## Power Electronics Laboratory

**Project Title: Designing Regulated DC-DC (Boost) Converter (Simulation)**

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Department: EEE
Section: C1
Level: 3 Term: 2

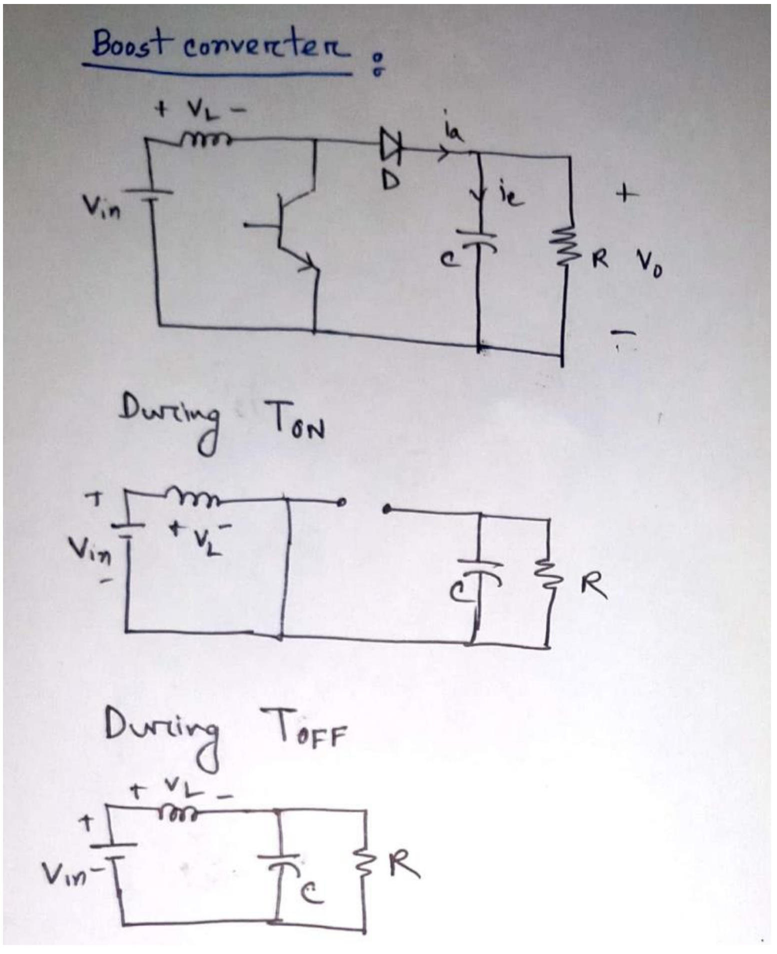
## Problem Statement

**Design Using Boost Converter**

| | |
|---|---|
| Input Voltage Range | 10-15 V |
| Output Voltage | 20V |
| Output Voltage Ripple | ±0.2V |
| Maximum Load | 5A, 100W |
| Switching Frequency | 80 KHz |
| Maximum Inductor Ripple Current | ±10% |

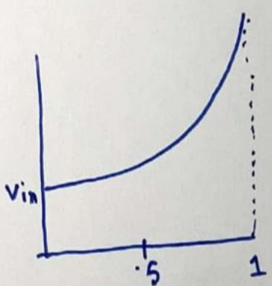
## Solutions:

## Steady State analysis for Boost converter



Now,

$$\int_0^{T_{ON}} V_{in}\,dt + \int_{T_{ON}}^{T} (V_{in}-V_o)\,dt = 0$$




$$\Rightarrow V_{in} T_{ON} + (V_{in}-V_o)(T-T_{ON}) = 0$$

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$$\Rightarrow V_{in} T_{ON} + V_{in} T - V_{in} T_{on} - V_o T + V_o T_{ON} = 0$$

$$\Rightarrow V_{in} T_{ON} + V_{in} \frac{T_{ON}}{D} - V_{in} T_{on} - V_D \frac{T_{ON}}{D} + V_o T_{ON} = 0$$

$$\Rightarrow V_{in} (D+1-D) = V_o (1-D)$$

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

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

$$\Rightarrow V_{in} = L \frac{\Delta I}{T_{ON}}$$

$$\Rightarrow \Delta I = \frac{V_{in} T_{ON}}{L} = \frac{V_{in} D}{fL}$$

again,

$$\Delta V_c = \frac{\Delta Q}{C\,T_{ON}}$$

here,

$$\Delta Q = \int_0^{T_{ON}} I_o\,dt = I_o T_{ON}$$

$$\Delta V_c = \frac{I_o T_{ON}}{C\,T_{ON}} = \frac{I_o D}{fC}$$

# Calculation of Passive elements:

when $V_{in} = 10V$

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

$$= 1 - \frac{10}{20}$$

$$= .5$$

$$R = \frac{100}{5^2} = 4\Omega$$

$$I_L = \frac{V_{in}}{(1-D)^2 R}$$

$$= \frac{10}{(1-.5)^2 4}$$

$$= 10A$$

$$\Delta I_L = 10\% \text{ of } I_L$$

$$= 1A$$

$$L = \frac{D V_{in}}{f\, 2 \Delta i_L}$$

$$= \frac{.5 \times 10}{80 \times 10^3 \times 2 \times 1}$$

$$= \cancel{62.5\,\mu H}\ 31.25\,\mu H$$

$$C = \frac{V_o D}{f_s R\, 2\Delta V_o}$$

$$= \frac{20 \times .5}{80 \times 10^3 \times 4 \times 2 \times .2}$$

$$= 78\,\mu F$$

when $V_{in} = 15V$

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

$$= 1 - \frac{15}{20}$$

$$= .25$$

$$I_L = \frac{V_{in}}{(1-D)^2 R}$$

$$= 20/3\, A$$

$$= 6.667\, A$$

$$\Delta I_L = 10\% \text{ of } I_L$$

$$= .667\, A$$

$$L = \frac{D V_{in}}{f\, 2 \Delta i_L}$$

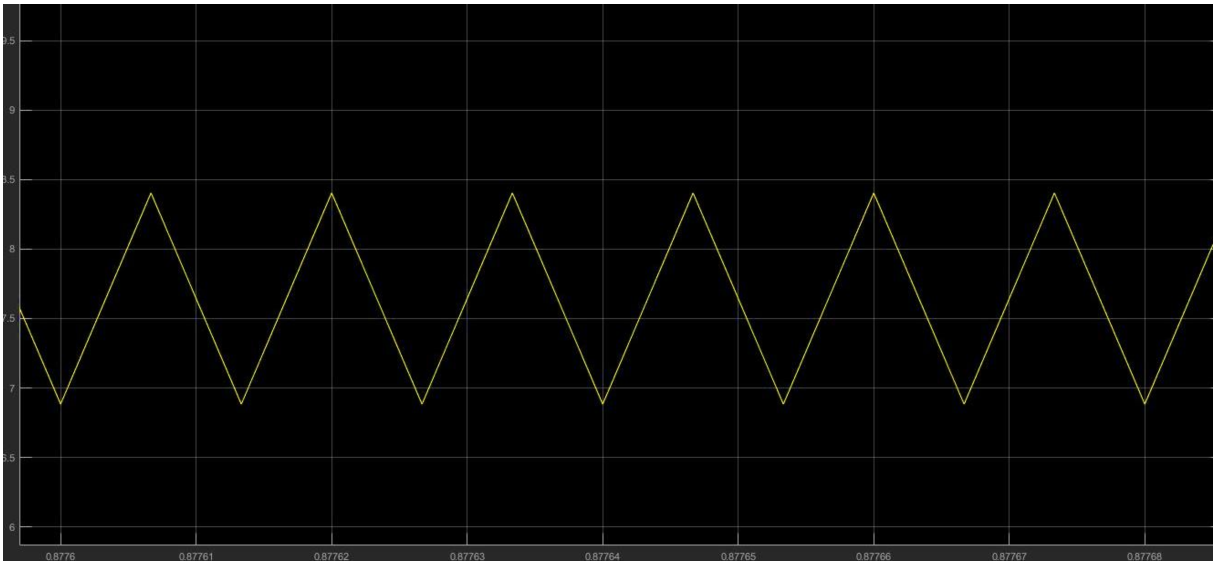
$$= \frac{.25 \times 15}{80 \times 10^3 \times 2 \times .667}$$

$$= 35.13\,\mu H$$

∴ Inductor has to be of 35 μH to satisfy given specifications for total range of input voltage and minimum value of Capacitance in 78 μF

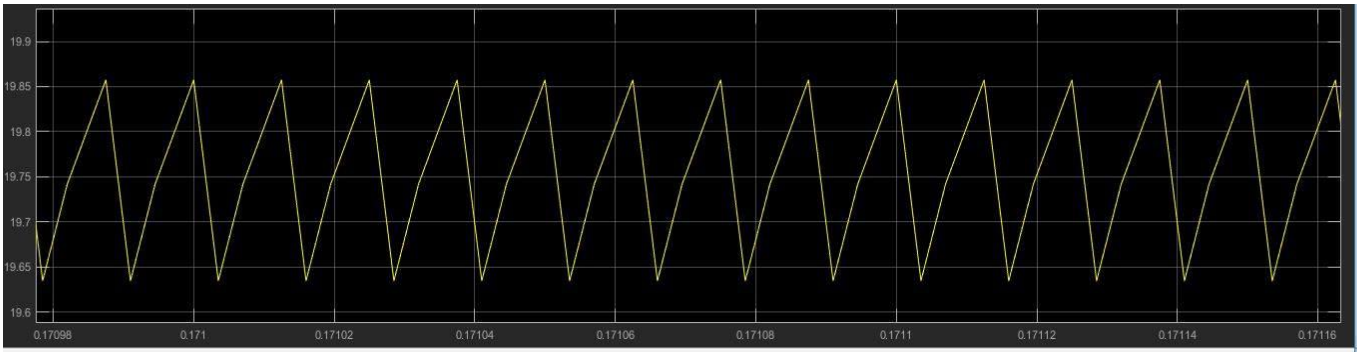
**Inductor value is L= 35μH**
**Capacitor value is C = 78μF**

## Verification of ripple inductor current:




**From this graph we find that Average inductor current 8.15 amp and ∆IL = 0.8 amp**

## Verification of ripple in output voltage:




**From this graph we find that peak to peak voltage is .2V**

## Switch Selection

Maximum blocking voltage is $V_{o,max} = V_o + \Delta V$
$= 20.2V$

Maximum switch current $= I_L + \Delta I_L = (10+1) = 11A$

MOSFET switching capability = 80KHz X 150% = 120 KHz

Once blocking voltage and peak current is determined, a safety margin is preffered. For conservative design, we may have a safety margin of 50%.

For maximum blocking voltage of 20.2V, we would choose a switch with blocking capacity of at least 20.2 X 150% = 30.3V

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## Derivation of Transfer function

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

Taking laplace transform on both side,

$$sLI_L = V_L$$

$$\Rightarrow sLI_L = V_{in}D + (V_{in} - V_o)(1-D)$$

$$\Rightarrow sLI_L = V_{in} - V_o + V_oD$$

$$\Rightarrow I_L = \frac{V_{in} - V_o + V_oD}{sL}$$

Now, $i_c = C\frac{dV_o}{dt}$

Taking Laplace transform on both side,

$$sCV_o = i_c$$

$$\Rightarrow sCV_o = I_D - I_o$$

$$\Rightarrow sCV_o = I_L(1-D) - I_o$$

$$\Rightarrow sC\Delta V_o = \Delta i_L(1-D) - I_L\Delta D - \frac{\Delta V_o}{R}$$

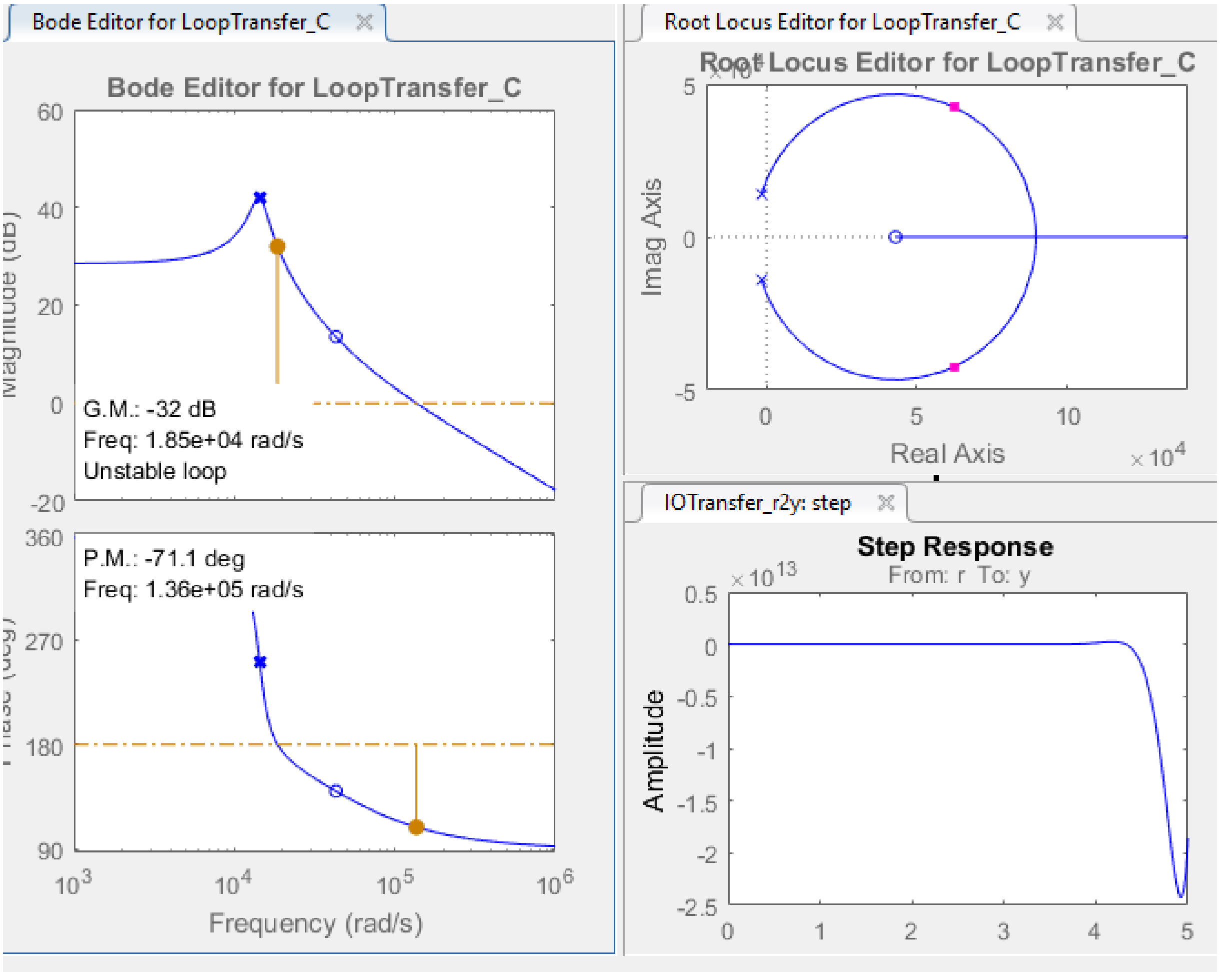
$$\Rightarrow \left[s^2LC + (1-D)^2 + \frac{sL}{R}\right]\Delta V_o = \left[V_o(1-D) - sLI_L\right]\Delta D$$

$$\therefore T(s) = \frac{\Delta V_o}{\Delta D} = \frac{V_{in} - sLI_L}{s^2LC + s\frac{L}{R} + (1-D)^2}$$

## Using the value of components of our designed circuit

$$T(s) = \frac{15 - (2.333\times10^{-4})s}{(2.73\times10^{-9})s^2 + (8.75\times10^{-6})s + .5625}$$

# Bode plot Root locus and Step response for uncompensated system:

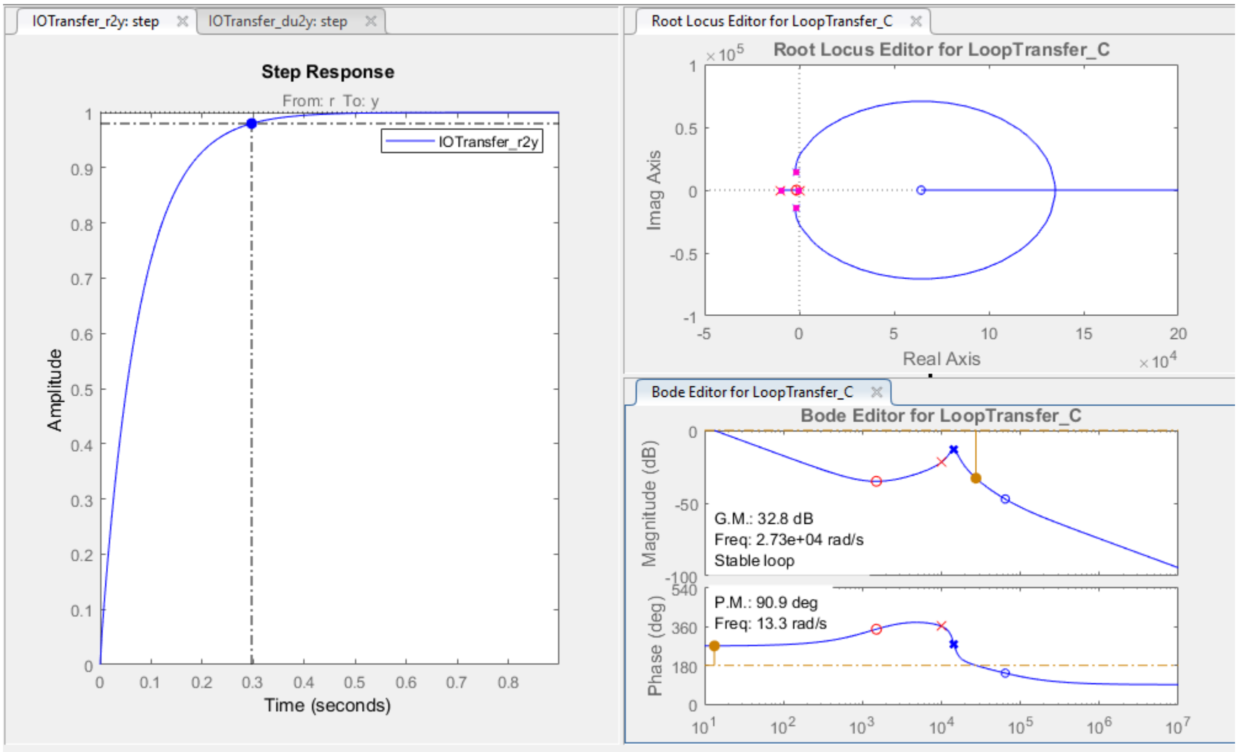



# Compensator Designing:

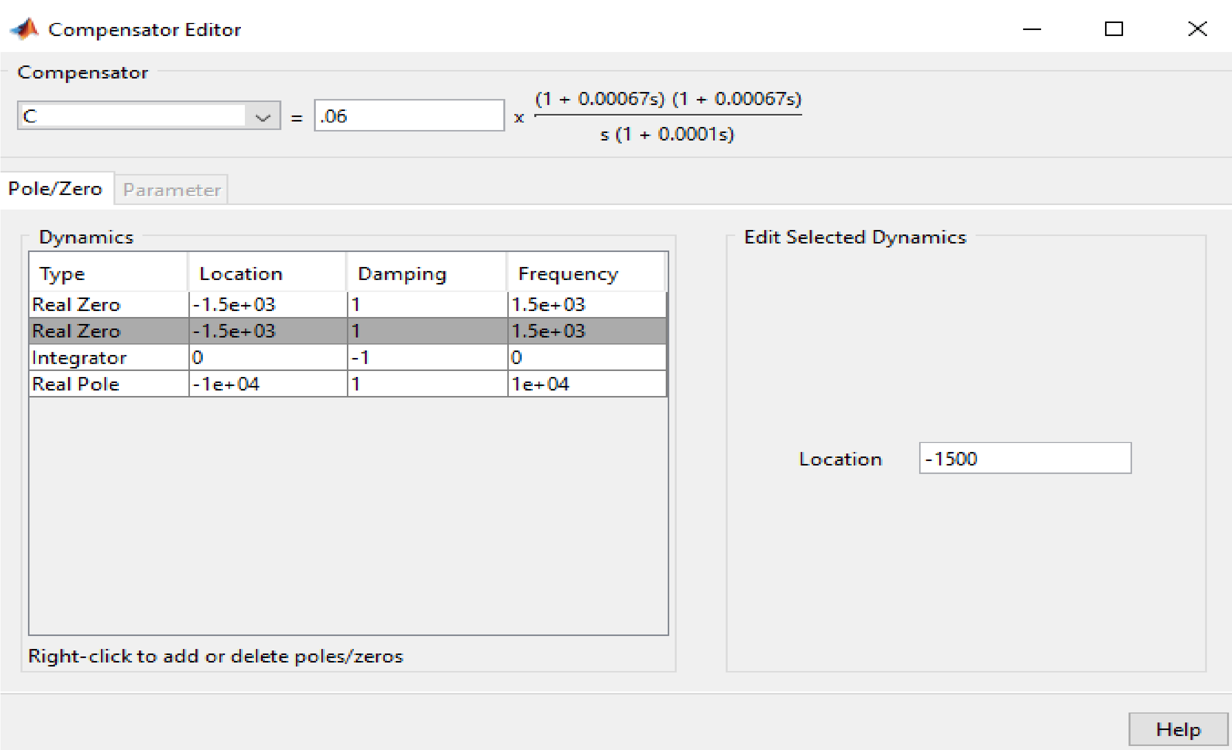
One of the main purpose of this project is that we have to design a compensator for our designed boost converter so that the output and specification will remain constant though input changes value in a fixed range. In our project our input will vary from **10V to 15V.**

To design the compensator we took help of MATLAB and sisotool. At first
We designed a PID controller by sisotool's automatic PID tuning method.
Then we adjusted some parameters by moving the poles and zeros in sisotool.
By trial and error method we found our desired Compensator.

# Bode plot Root locus and Step response for desired compensator:



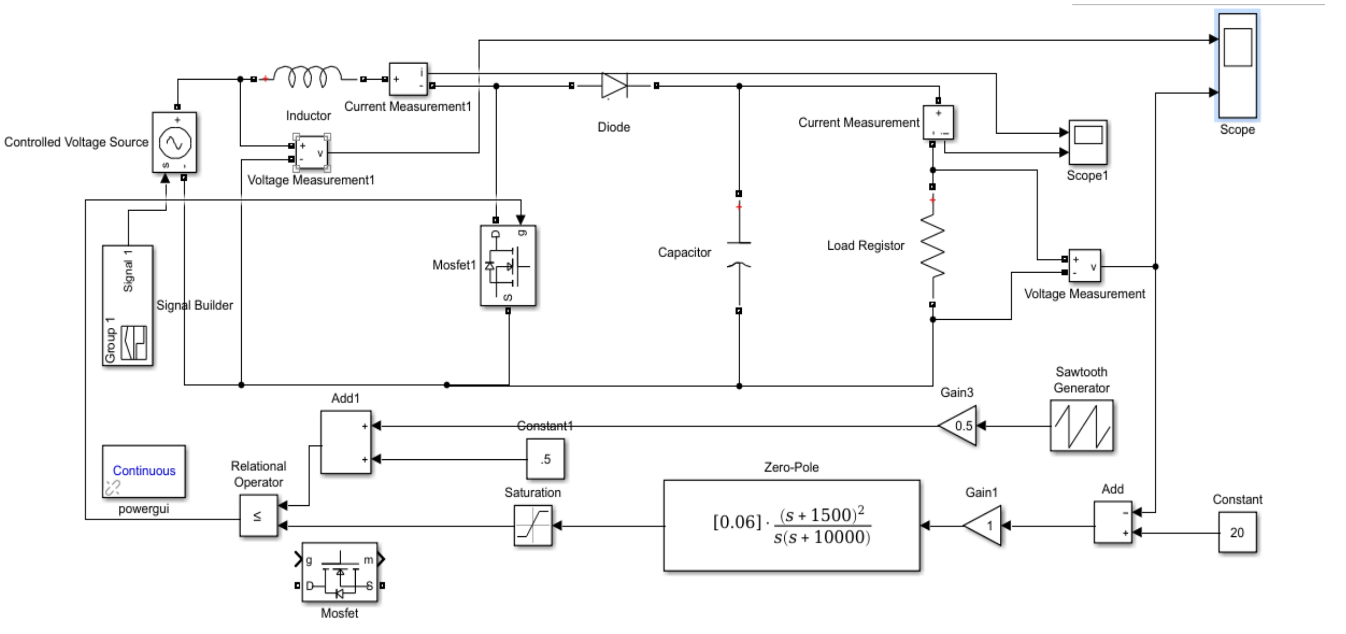

# Position of pole and zeros in our desired compensator as follows:



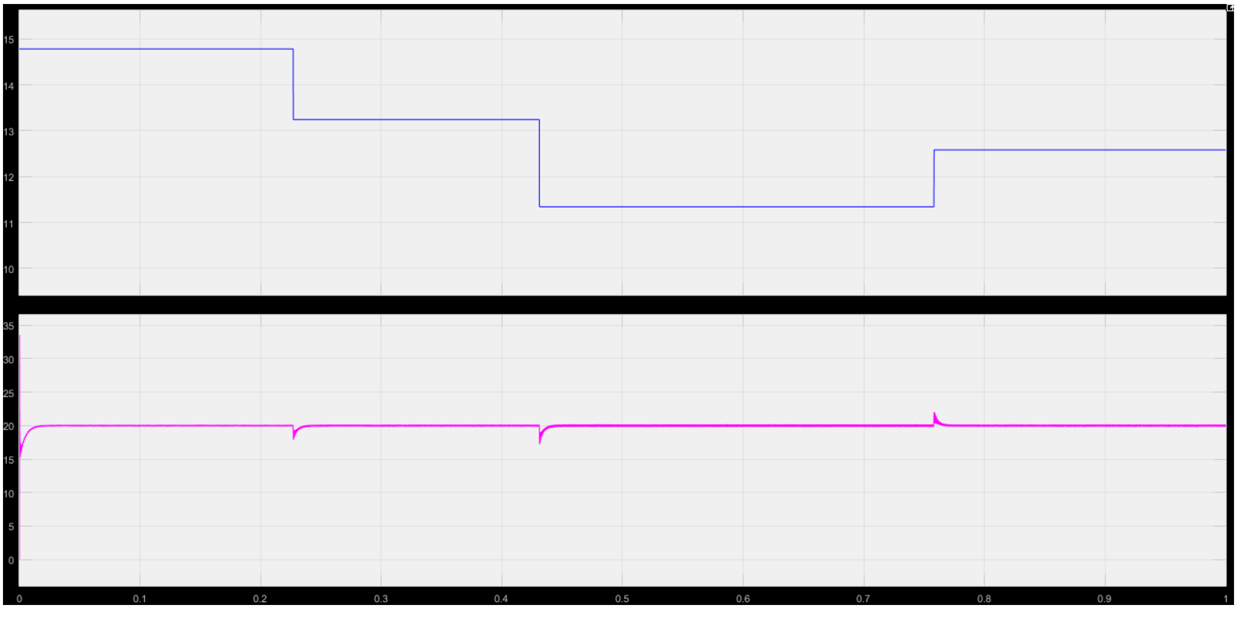

**Our designed PID controller H(s) is**

$$\frac{0.06\,(s+1500)(s+1500)}{s(s+10000)}$$

# Implementation of Compensator:



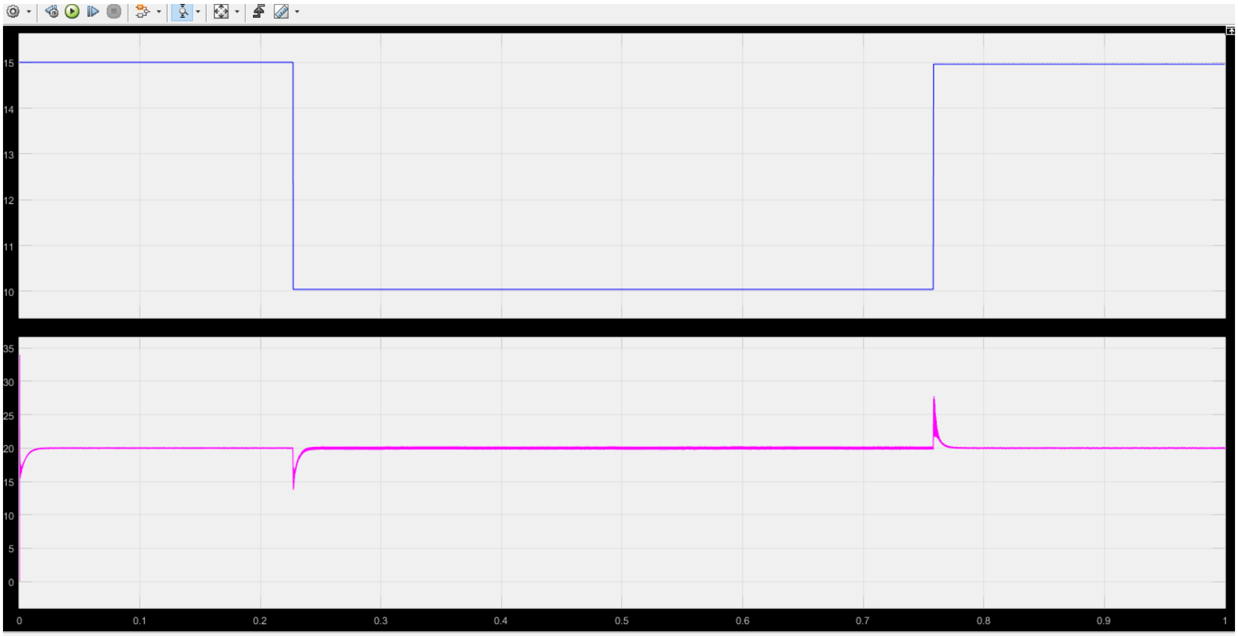

Here, we have changed our input from 10v to 15v step by step



At steady state output voltage remains at 20v. But at transient we get Overshoot of approximately 2v.

## Critical Case:

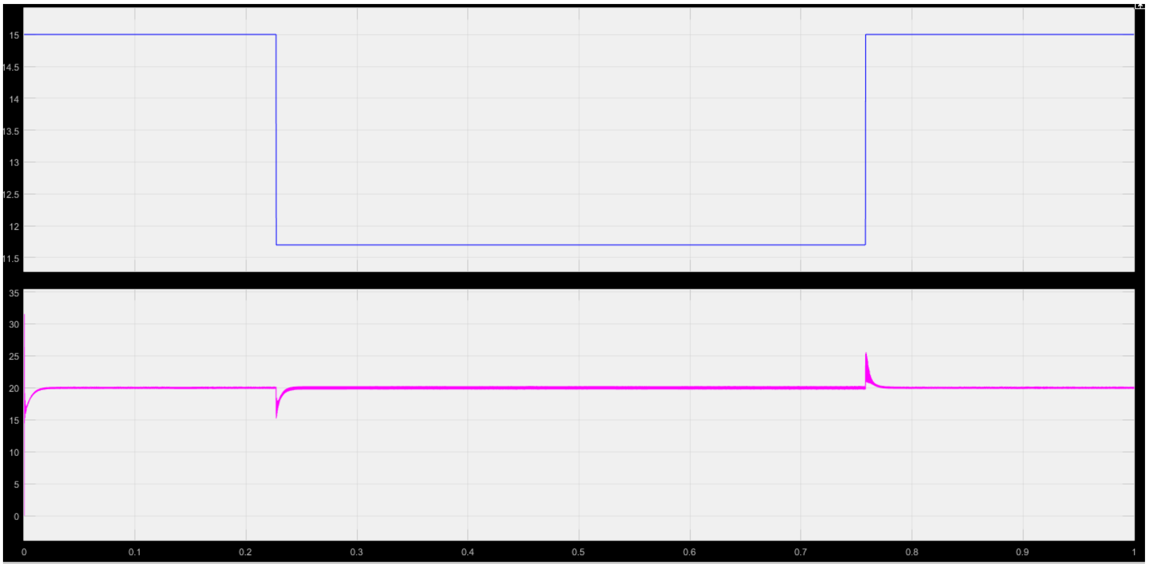
System response for step change in input from 10V to 15V and from 15V to 10V is as the following:



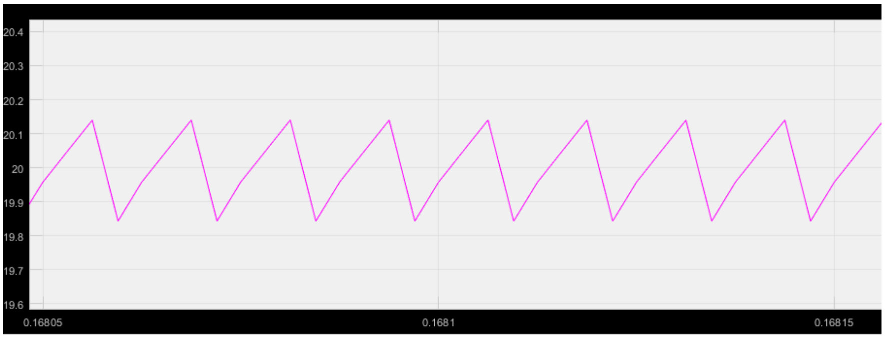
We get overshoot of approximately 4V

If we want to see the response for step change **outside the given range**, for example from 10V to
20V, then we will get the following result:

Now, if we change the load value to full load to its 70%, then R= 4 ohm, the system response for output voltage remains same, ripples tends to increase:




Zoomed view of output voltage at 70% load



## Additional Tasks for Bonus Points

Design of the compensator

$$C(s) = \frac{.06\,(s+1500)^2}{s(s+10000)}$$

$$= .06\,\frac{s+1500}{s} \times \frac{s+1500}{s+10000}$$

PI controller $T.F = \frac{R_2}{R_1}\,\frac{s+\frac{1}{R_2C}}{s}$

Lead Compensation $T.F = \frac{C_1}{C_2}\,\frac{s+\frac{1}{R_1C_1}}{s+\frac{1}{R_2C_2}}$ , where $R_1C_1 > R_2C_2$

For PI controller,

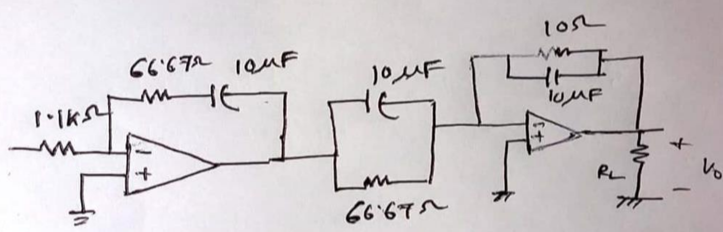
$$\frac{R_2}{R_1} = .06$$

$$\frac{1}{R_2C} = 1500$$

let, $C = 10\mu F$

$\therefore R_2 = 66.67\Omega$

$R_1 = 1.1K\Omega$




For Lead compensator,

$$\frac{C_1}{C_2} = 1$$

$\Rightarrow C_1 = C_2$

let, $C_1 = C_2 = C = 10\mu F$

$$\frac{1}{R_1C_1} = 1500$$

$\Rightarrow R_1 = 66.67\Omega$

$$\frac{1}{R_2C_2} = 10000$$

$R_2 = 10\Omega$

- We will use **IRFR1018E** MOSFET
- We will use iron powder toroid core of core size **T50-6 (yellow).** the required inductance is 35uH. For this inductance required turns is 84. electromagnetic permeability of the core is 35
- We will use A **1N5817** is a 30V 1A Schottky diode.
  1N5818 - 30 V 550 mV drop at 1A