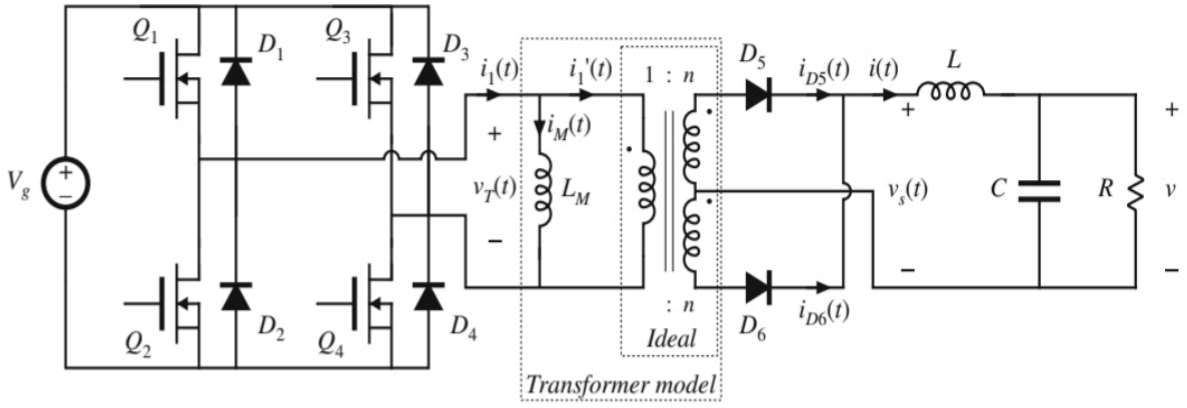
Objective: Close loop control of a 1kW Full bridge Isolated buck converter for EV battery charging with 400V input and 48V output.

Circuit diagram:



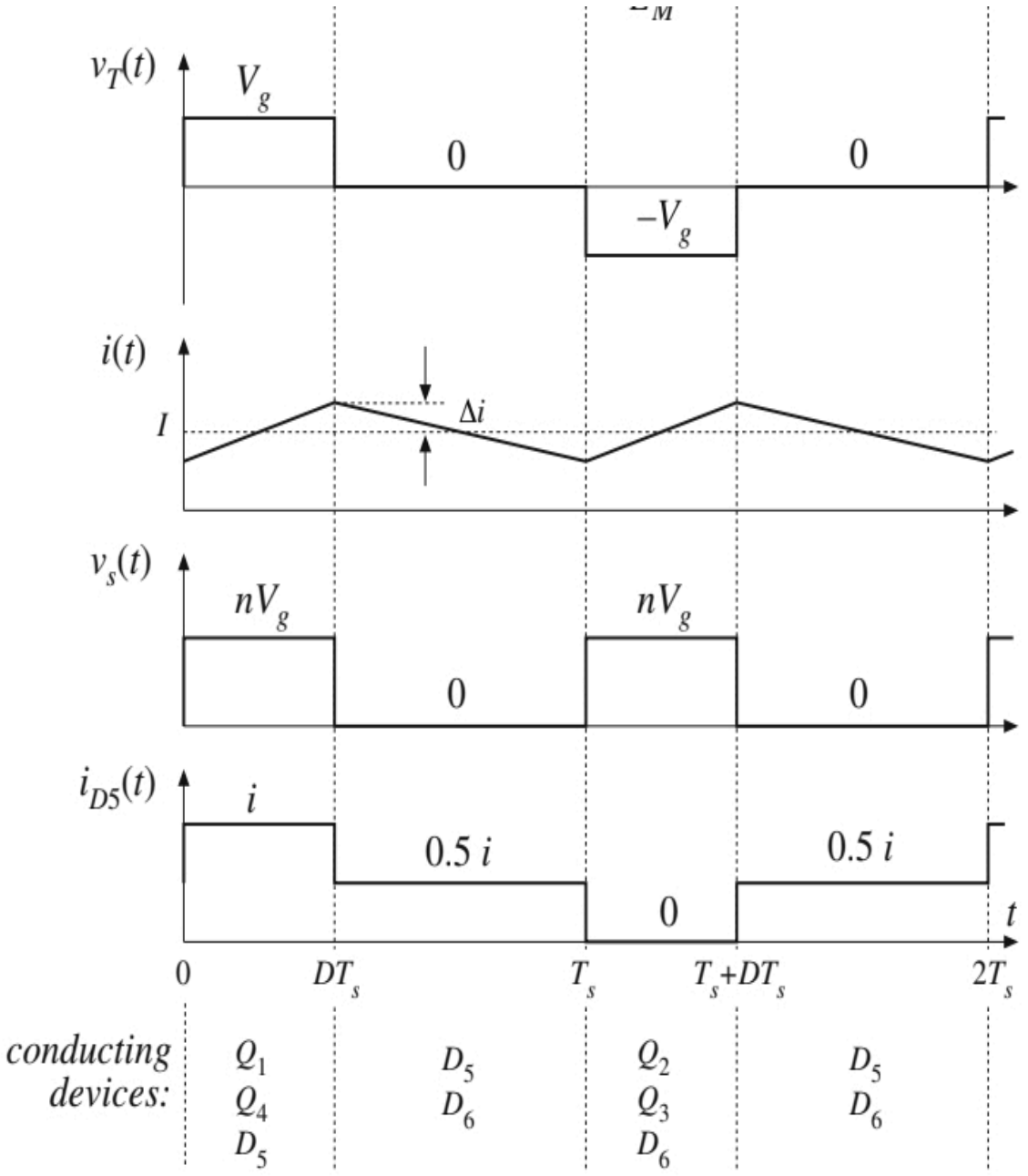
Assumptions:

- Transformer ratio 1:n = 1:1/2
- Switching frequency (fs) = 20kHz
- Inductor Current ripple = 10% of load current
- Output voltage ripple = 2% of load voltage
- Negligible leakage inductance

System is designed to achieve:

- phase margin >= 55°
- tss<= 5msec
- Steady state error for step input <=0.01%

Waveform:


$v_T(t)$
V_g
0
0
$-V_g$
$i(t)$
I
Δi
$v_s(t)$
nV_g
nV_g
0
0
$i_{D5}(t)$
i
0.5 i
0.5 i
0
t
0
DT_s
T_s
T_s+DT_s
$2T_s$
conducting devices:
Q_1 Q_4 D_5
D_5 D_6
Q_2 Q_3 D_6
D_5 D_6

Calculation of Capacitance and inductance:

Data given:

Vo= 48V, Vg= 400V, n=0.5, Io= 20.83A, ΔIL= 2.083A

ΔVo= 0.96V ,Ts= 1/fs

R=2.304Ω

Vo=n*D*Vg

D=0.24

- $\Delta IL = \frac{(nVg - Vo) * D(\frac{Ts}{2})}{(2L)}$ = 2.083A

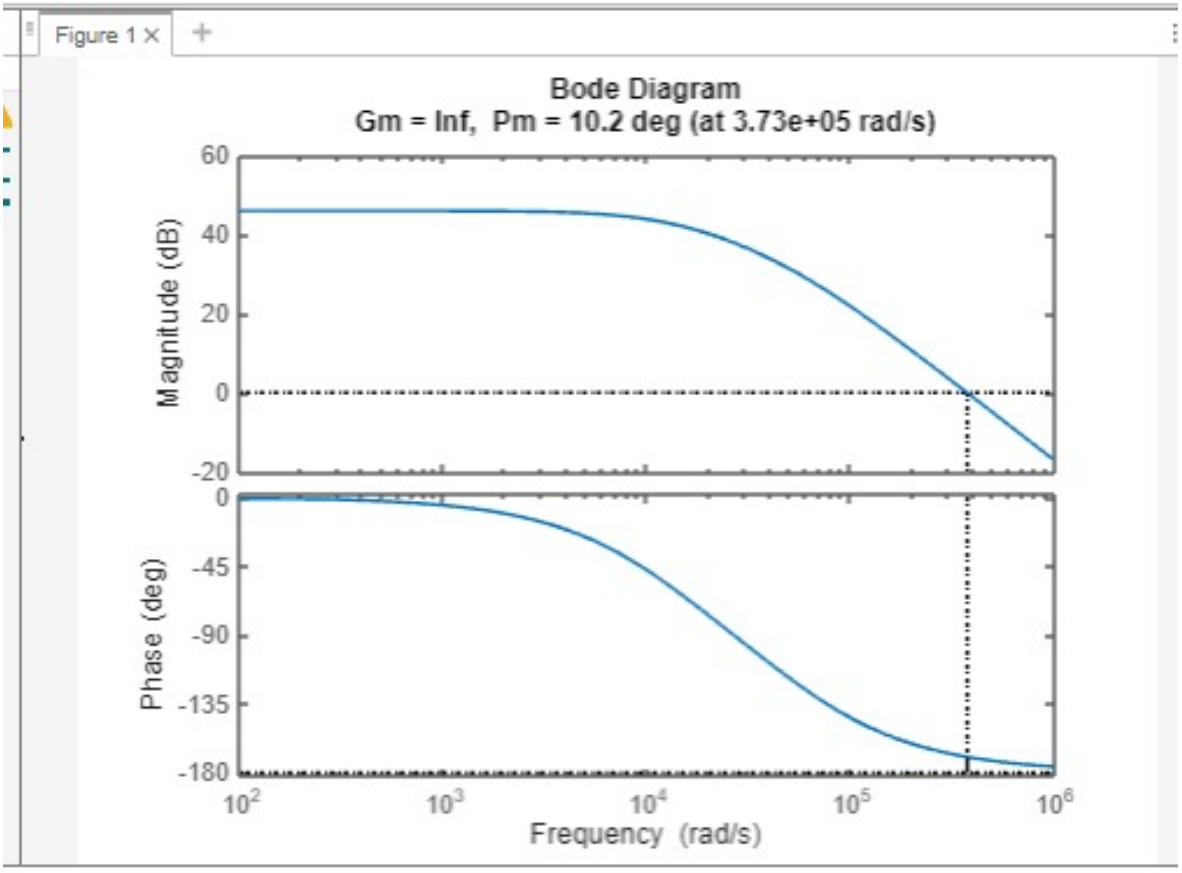
  L = 218.91μH

- $\Delta Vo = \frac{\Delta IL * \frac{Ts}{4}}{2C}$ = 0.96V

  C = 6.78μF

Open loop system transfer function:

$$\frac{v(s)}{d(s)} = \frac{nVg}{LCs^2+\frac{L}{R}s+1}$$



Bode plot of open loop system transfer function using MATLAB

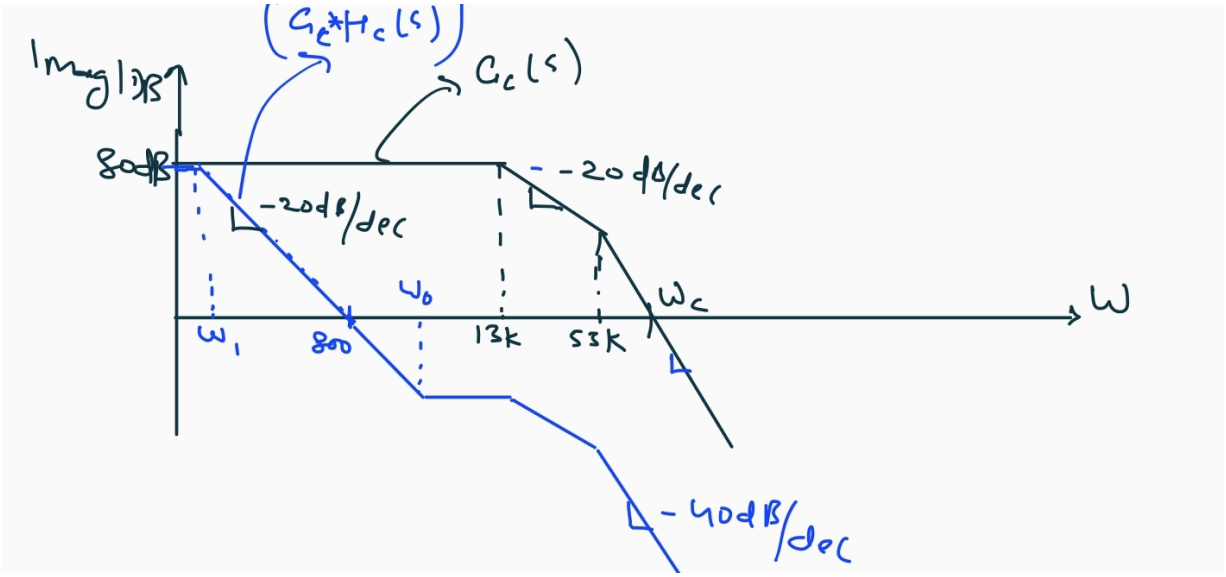
- phase margin is 10.5°
- Since phase margin is not as desired, compensator design is required

Compensator design of Full bridge Isolated Buck converter:

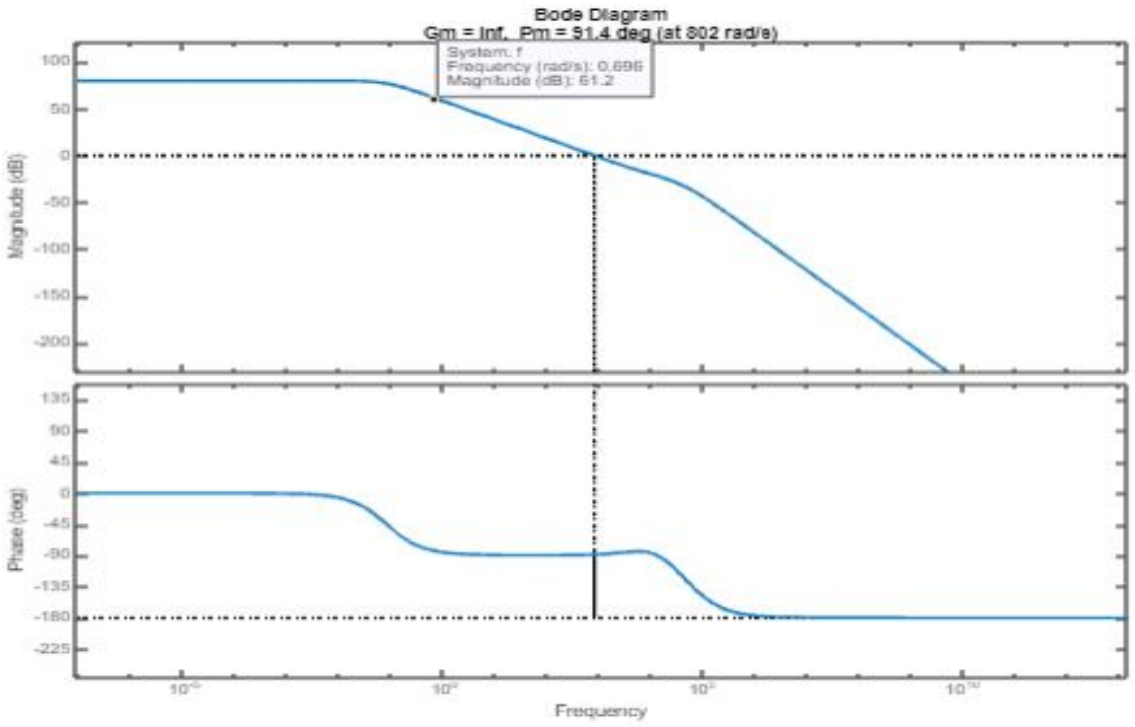
- error=$\frac{1}{Kreq} = \frac{0.01}{100}$

  Kreq = 10000
  Kcomp = 50
- tss= $\frac{4msec}{Wc}$, Wc >=800 rad/sec
- Let the Wc be at 800 rad/sec
- $Hc(s) = kcomp * \frac{1+\frac{s}{wz}}{1+\frac{s}{wp}}$

From bode plot analysis:
wp = 0.08 rad/sec
wz = 8000 rad/sec



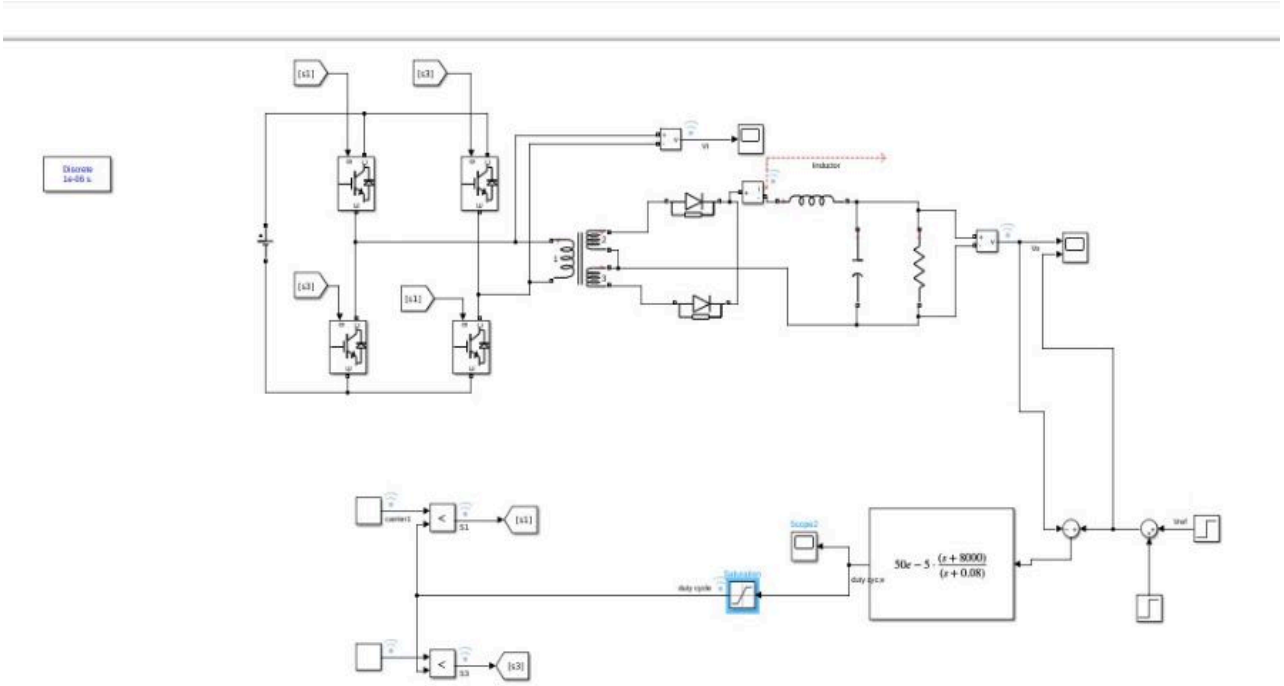
Bode plot of system with compensator:



Bode plot using MATLAB

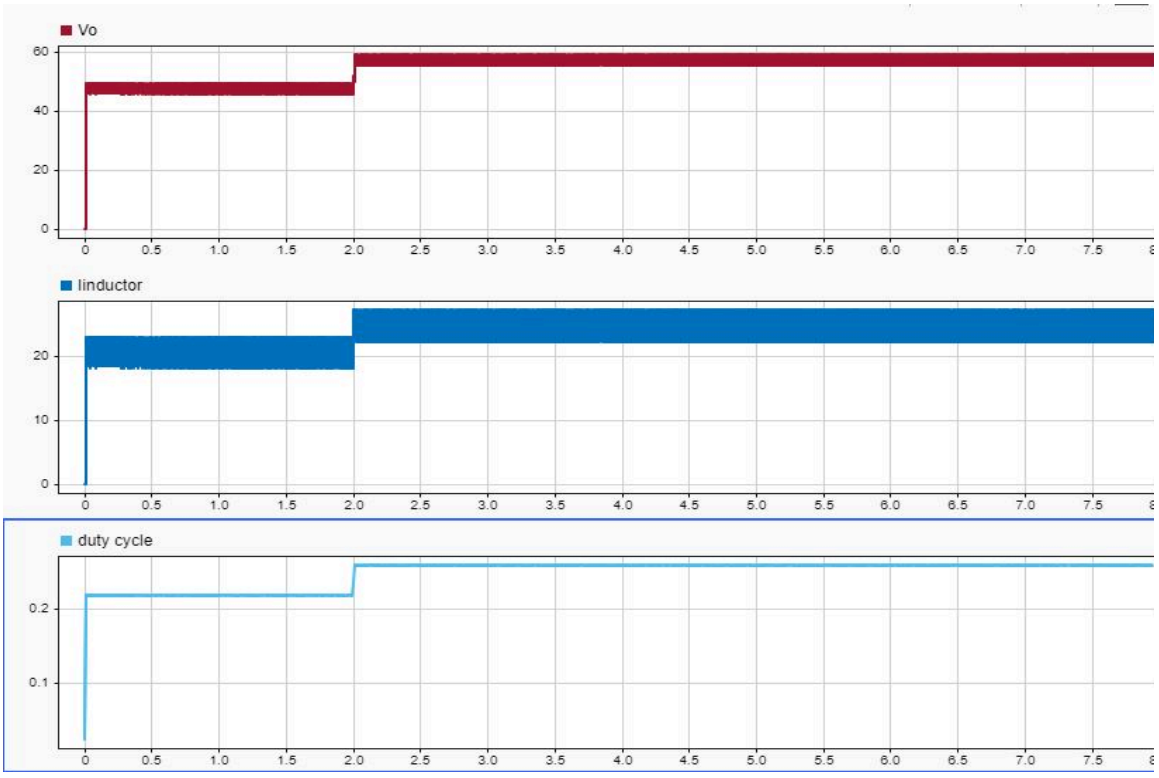
- phase margin is 91.4°
- Wc is 802 rad/sec, so time to reach steady state is 5 msec.
- Thus the compensator design meets the system specifications.

Schematic for simulation in MATLAB:

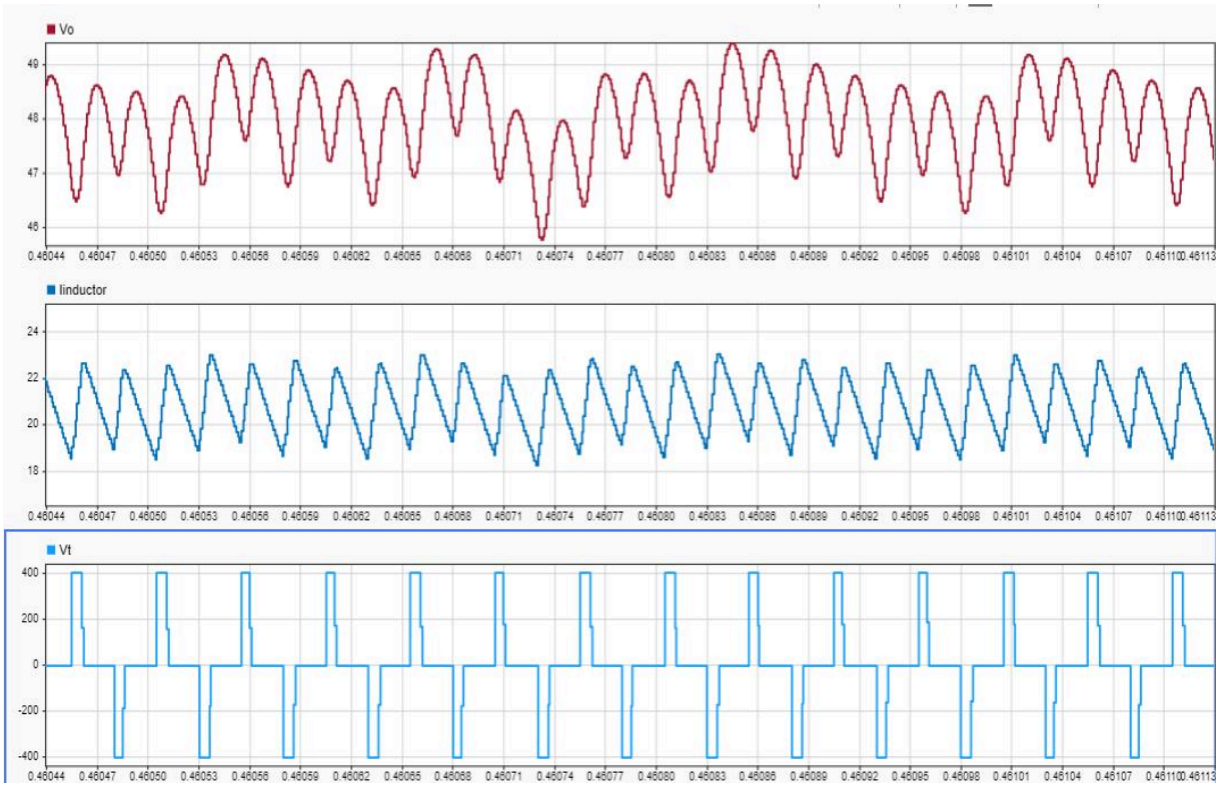


Simulation Results:

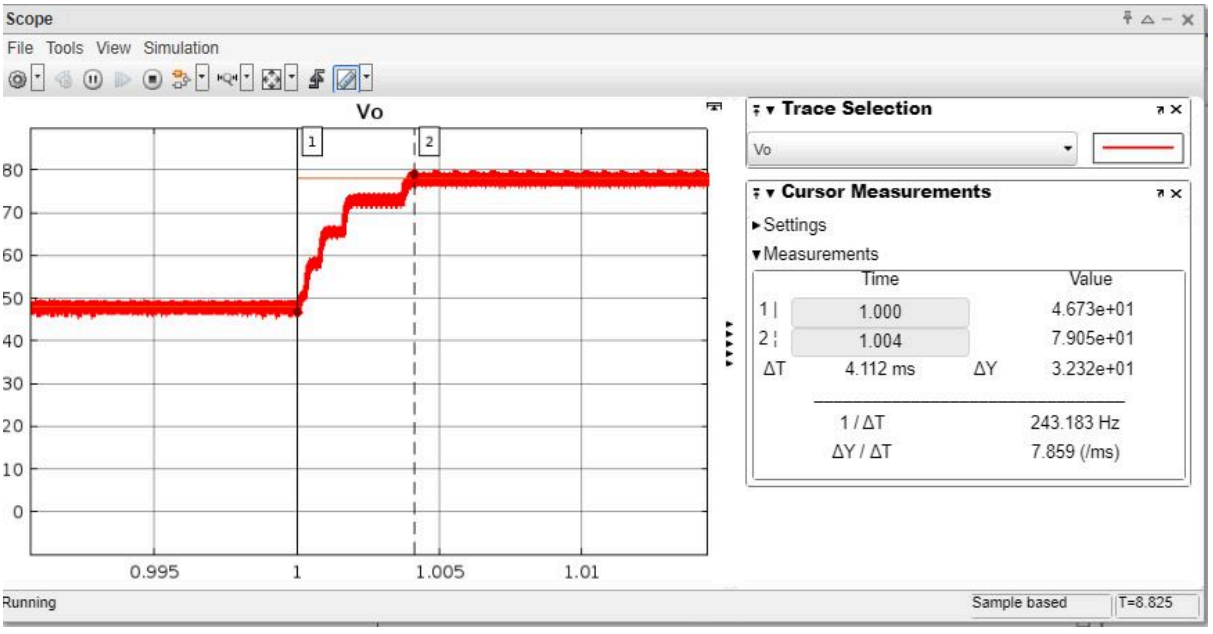
Output voltage, Inductor current, duty cycle



Voltage ripple,Current ripple,Transformer primary voltage



Step response:



Switch selection:

- Required blocking voltage of all the switches is 400V and conduction current rating is 11.45A .
- Selecting safety factor as 1.5.
- Voltage rating of switches =600V
- Current rating of switches = 18A
- Voltage rating of diode = 300V
- Current rating of diode = 35A

Selected IGBT's mfr part no.: STGD10HF60KD

STGD10HF60KD

Mouser No:	511-STGD10HF60KD
Mfr. No:	STGD10HF60KD
Mfr.:	STMicroelectronics
Customer No:	Customer No
Description:	IGBT Transistors Automotive-grade 10 A, 600 V short-circuit rugged IGBT Ultrafast diode

Unit price: 243 INR

Selected diode part no.:1N1187GN-ND

1N1187

DigiKey Part Number	1N1187GN-ND
Manufacturer	GeneSiC Semiconductor
Manufacturer Product Number	1N1187
Description	DIODE GEN PURP 300V 35A DO5

Unit price: 519 INR

Conclusion:

The system is well designed to meet the requirements.