Self Project

PCB Design of Clsoed Loop Control of Flyback Converter

Name : - GHANSHYAM DAS GUPTA
Roll no . 224102109

1 Objective:

PCB Design of Flyback converter which is type of isolated converter, while we are using flyback converter as open loop configuration we will get the output voltage more than we required , so we use Type - II Compensator to regulate the output Voltage as per are requirement; Desired Gain Cross Over Frequency of Compensated System : 100Hz ; Desired Phase Margin : 120 degree

2 Given Parameter:

There are the parameter that we are going to use design of flyback converter

Input Voltage = 24 V , Duty Ratio= 0.33 , Capacitor = 220μF , Turn Ratio = 1 : 5 , Inductor = 22μH , Resistor = 5Ω , Inductor Resistance = 1Ω, D'=1 − 0.33 = 0.67,Switching Frequency = 10 KHz

3 Flyback Converter Design:

3.1 Derivation of Transfer function using small signal analysis:

The transfer function is derived using small signal analysis comes as:

$$G_{vd}(s) = \frac{V_o(s)}{D(s)} = \frac{V_{in} + \frac{V_O}{n} - \frac{n*V_O}{R*D'} - \frac{V_O}{R*D'} * (L_S + D*r)}{\frac{n}{D'} * \frac{RCS+1}{R} * (LS + D*r) + \frac{D'}{n}}$$

(1)

3.2 MATLAB CODE

```
Vin = 24;
n = 5;
R = 5;
L= 22.22e-6;
C = 220e-6;
D = 0.33;
r= 1;
% Converter Transfer Function ----------------------------------
A = ((R*L*C*n)/(R*0.67));
B = ((R*C*D*r*n)/(R*0.67)+(n*L)/(R*0.67));
C = ((D*R*n)/(R*0.67)+0.67/5);
D = (24+11.82/5-((5*11.82)/(0.67*5))*1);
E  = (11.82*L)/(5*0.67) ;
F = (11.82*D*r)/(5*0.67) ;
J = [E 39.5473];
K = [A B C];
M= tf(J,K);
% Compensator  Transfer Function ----------------------------------
N = [84.8772  26029.29534];
P = [1 1286.0184 0];
Q= tf(N,P);
bode(M,Q)
```

Fig. 1: Matlab Code

3.3 Uncompensated Flyback Converter

Substituting the values a the in Eqn.1 the open loop transfer function of FlyBuck Converter

$$G_{vd}(s) = \frac{7.84e^{-}5 * S + 39.55}{3.648e^{-}8 * S^2 + 0.000575 * S + 2.597}$$

(2)

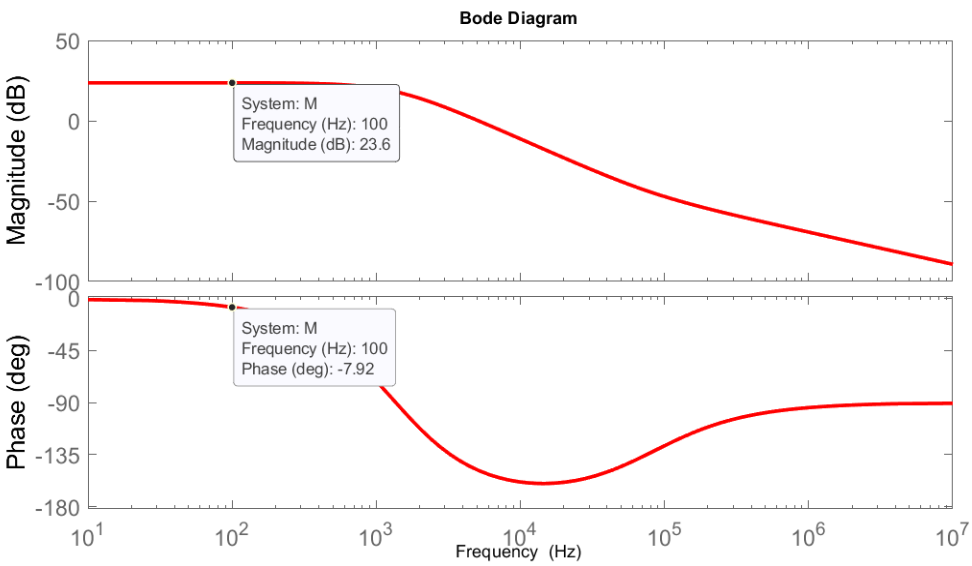


Fig. 2: Bode Plot of Uncompensated Flyback Converter

For the uncompensated Flyback converter, phase margin (PM) is $-7.92°$ and GM is 23.6 cross-over frequency is 100 Hz

3.4 Design of TYPE- II Compensator

- Since Desired the gain cross-over frequency 100 Hz. value of G_{MB} is Given by

$$\begin{aligned} 20 * \log 10_K &= 23.6 \\ k &= 15.1356 \\ G_{MB} = \frac{1}{K} &= 0.0660 \end{aligned} \tag{3}$$

- Phase Margin (P.M.) is given 120° the phase margin of uncompensated Buck converter at W_{gc} is $-7.94°$ by the help of this we can easily find the phase boost for that given system

$$\begin{aligned} \phi_b &= \phi_m \text{ - } \phi_p \text{ -90°} \\ \phi_b &= 120° \; +0.907° \text{ -90°} \\ \phi_b &= 37.94° \end{aligned} \tag{4}$$

- Transfer Function of TYPE -II compensator is given by

$$a(s) = \frac{G_{MB} * (1 + \frac{\omega_z}{s})}{(1 + \frac{s}{\omega_p})} \tag{5}$$

$$\begin{aligned} k &= \tan(45° + \phi_b/\overline{2)} \\ k &= 1.732 \\ \omega_z &= (\omega_c)/\text{k} \\ \omega_p &= (\omega_c)\text{*k} \end{aligned}$$

On putting these two conditions, $G_{MB} = 0.0660$, ω_z =306.670 rad/sec and ω_p =1286.0184 rad/sec are obtained.

- The Transfer Function of TYPE- II Compensater is given by

$$a(s) = \frac{84.8772 * S + 26029.29534}{S^2 + 1286.0184 * S}$$

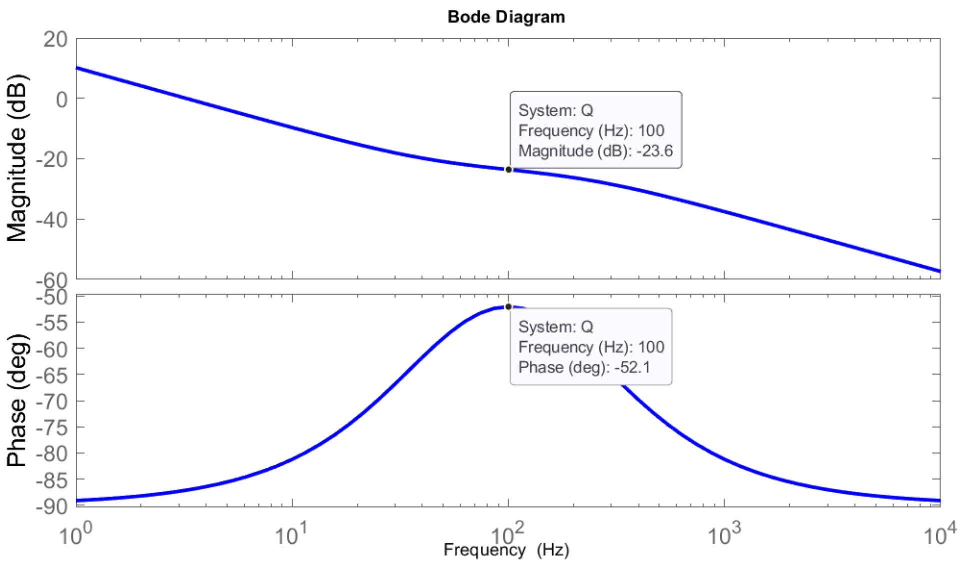


Fig. 3: Bode Plot of TYPE-II Compeansator

3.5 Flyback Converter with TYPE-II compensater

Total plant transfer function using compensator

$$a(s)G_{vd}(s) = \frac{0.006654s^2 + 3359s + 1.029e06}{3.648e-08s^4 + 0.0006219s^3 + 3.336s^2 + 3339s}$$

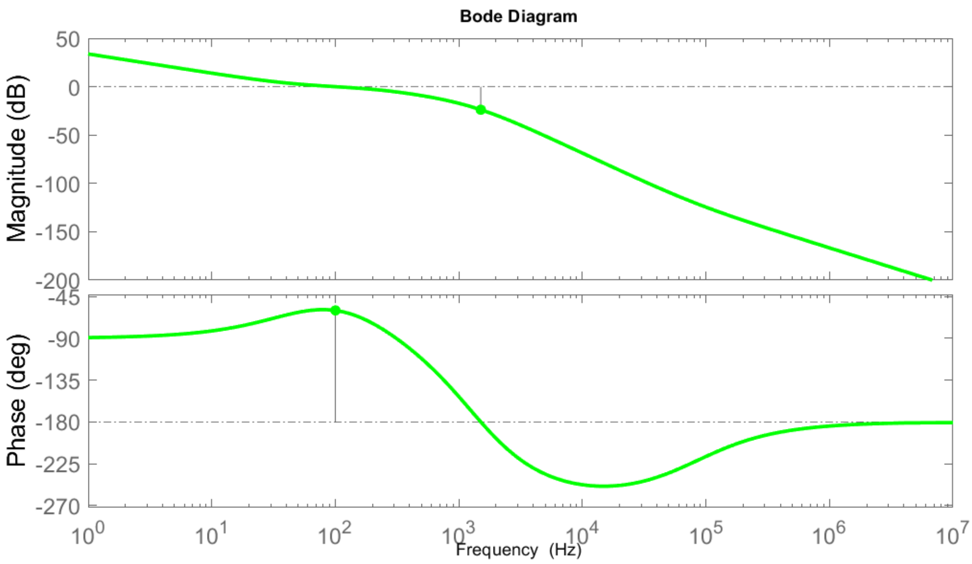


Fig. 4: Bode Plot of Compensated Flyback Converter

4 WAVEFORM

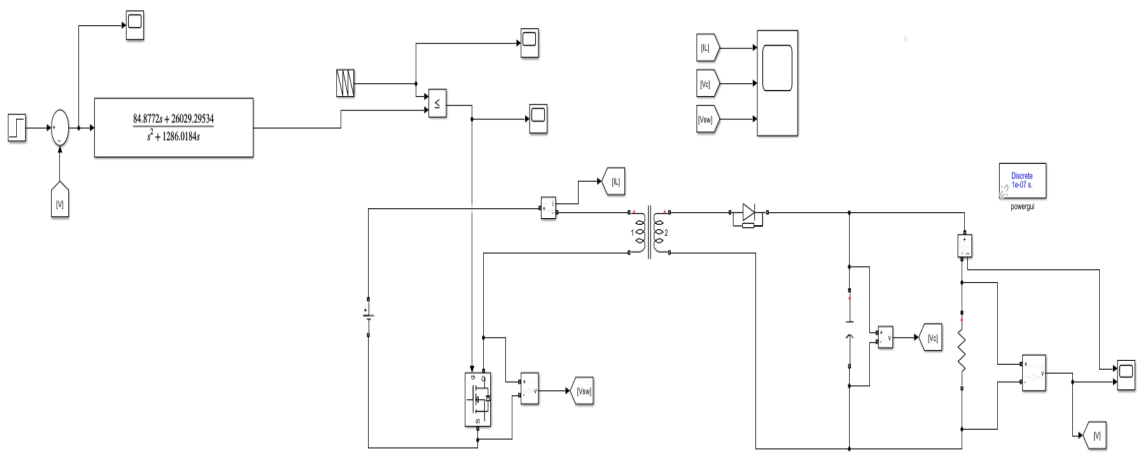
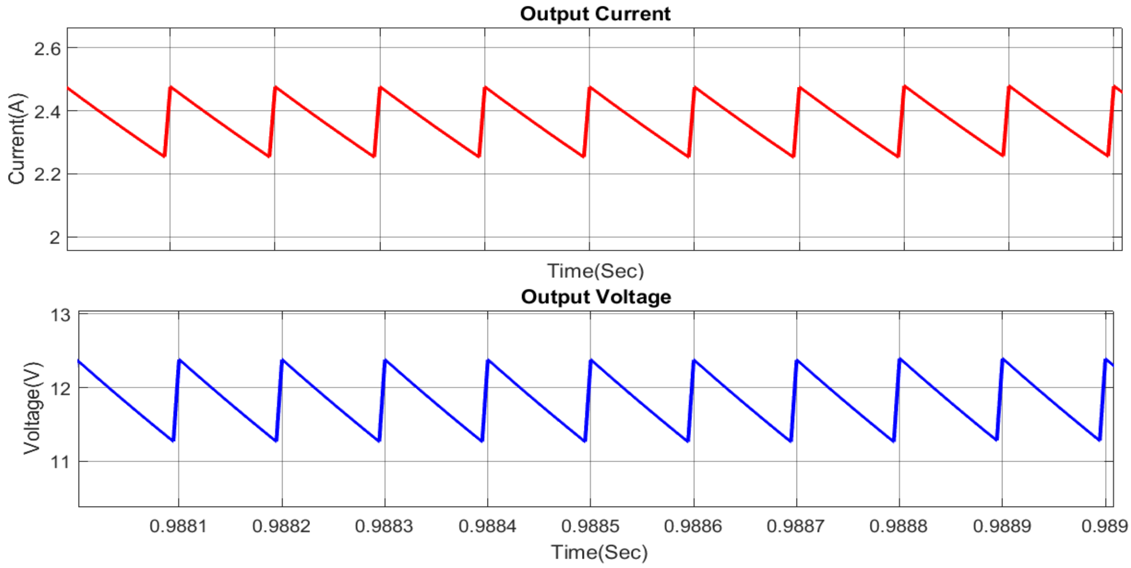
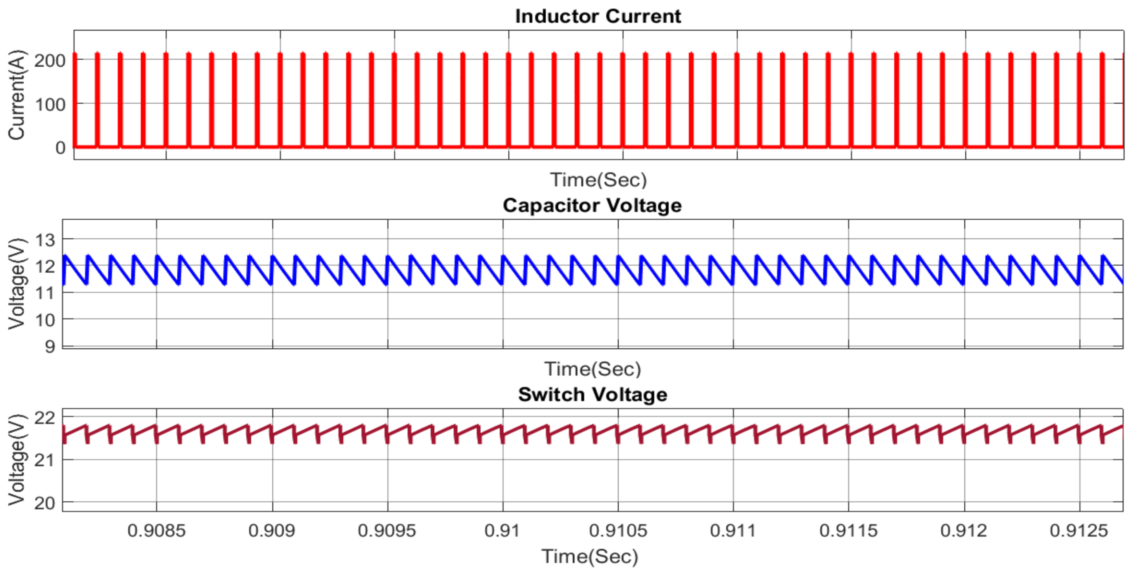
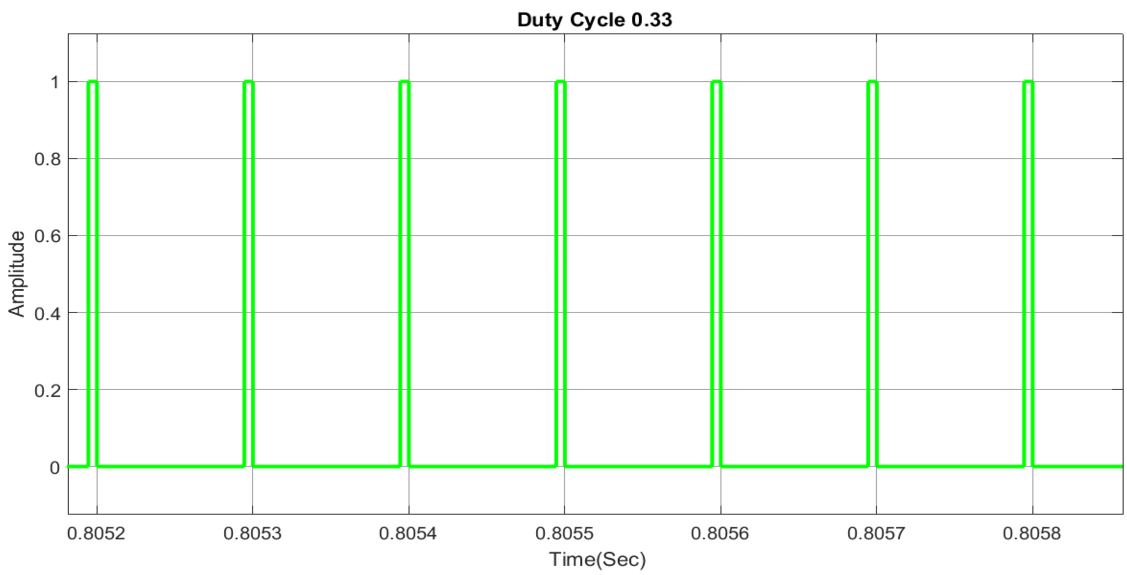


Fig. 5: Simulated Diagram of Compensated Flyback Converter


Output Current
Current(A)
2.6
2.4
2.2
2
Time(Sec)
Output Voltage
Voltage(V)
13
12
11
0.9881
0.9882
0.9883
0.9884
0.9885
0.9886
0.9887
0.9888
0.9889
0.989
Time(Sec)


Inductor Current
Current(A)
200
100
0
Time(Sec)
Capacitor Voltage
Voltage(V)
13
12
11
10
9
Time(Sec)
Switch Voltage
Voltage(V)
22
21
20
0.9085
0.909
0.9095
0.91
0.9105
0.911
0.9115
0.912
0.9125
Time(Sec)


Duty Cycle 0.33
Amplitude
1
0.8
0.6
0.4
0.2
0
0.8052
0.8053
0.8054
0.8055
0.8056
0.8057
0.8058
Time(Sec)

5 LTspice Circuit Diagram

5.1 Triangular wave generator

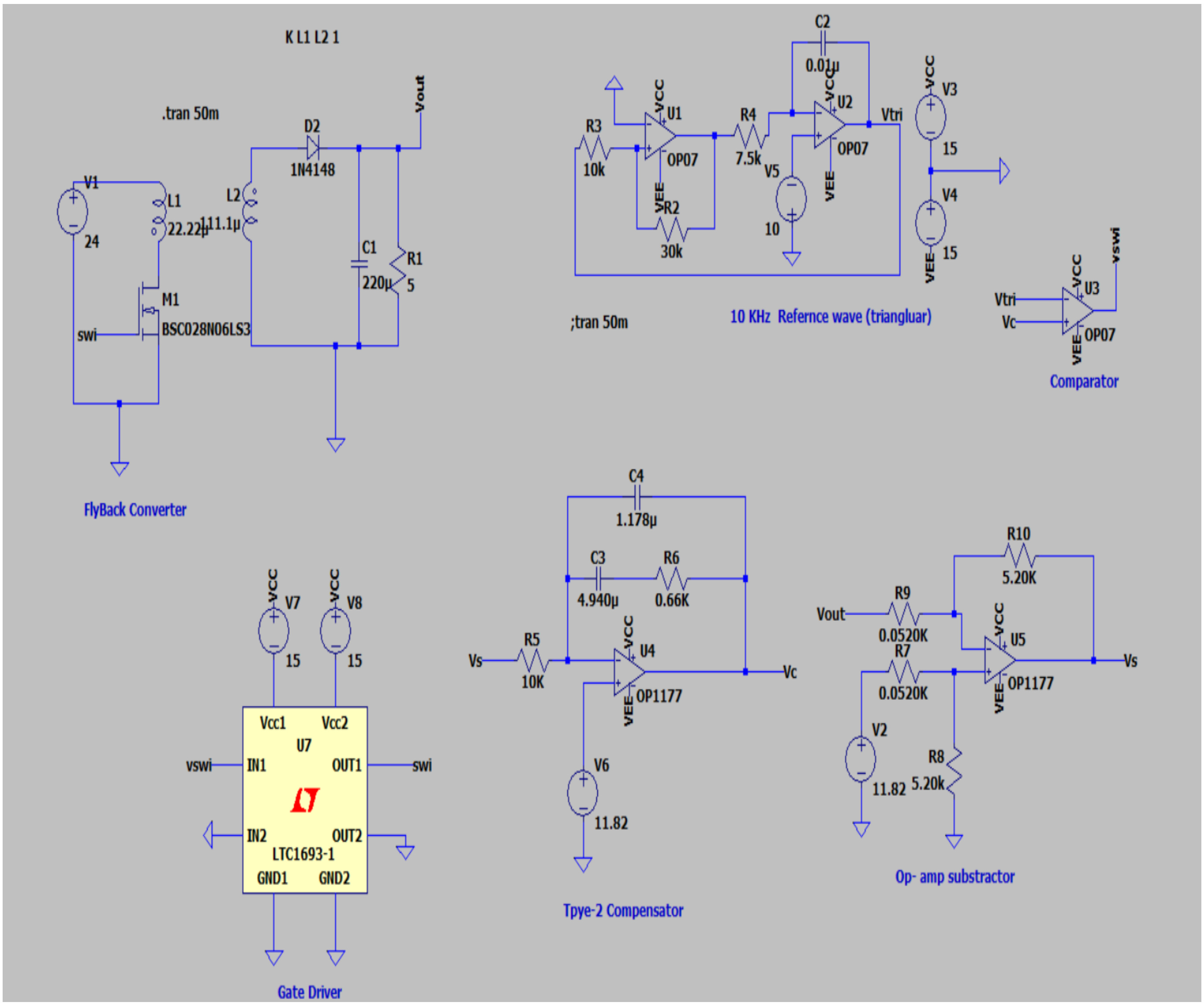
Here we are generating triangular wave using op-amp and the switching frequency of MOSFET is 10 KHz whose peak to peak output voltage is 10 V , here we are considering resistance R1 =10Ω and capacitor c= 0.01μ F. Saturation voltage of op-amp is 15V

$$V(P-P) = 2 * \frac{R_2}{R_1} * V_{sat}$$
$$f = \frac{R_1}{4 * R_3 * R_2 * C_1}$$

5.2 Op-amp Subtractor

we design op-amp subs tractor to generate error and given it to the signal compansator then switching using gate driver. The output of the substractor must vary form 0 to 1, we take error value 0.5.so the calculted output value 11.82 and reference are given from the flyback output

$$V_o = \frac{R_2}{R_1} * (11.82 - V_{out})$$
$$R_1 = 0.0520K, R_2 = 5.20K$$



6 PCB module

MOSFET rating = 40 v , 30A BSCO28N06LS3

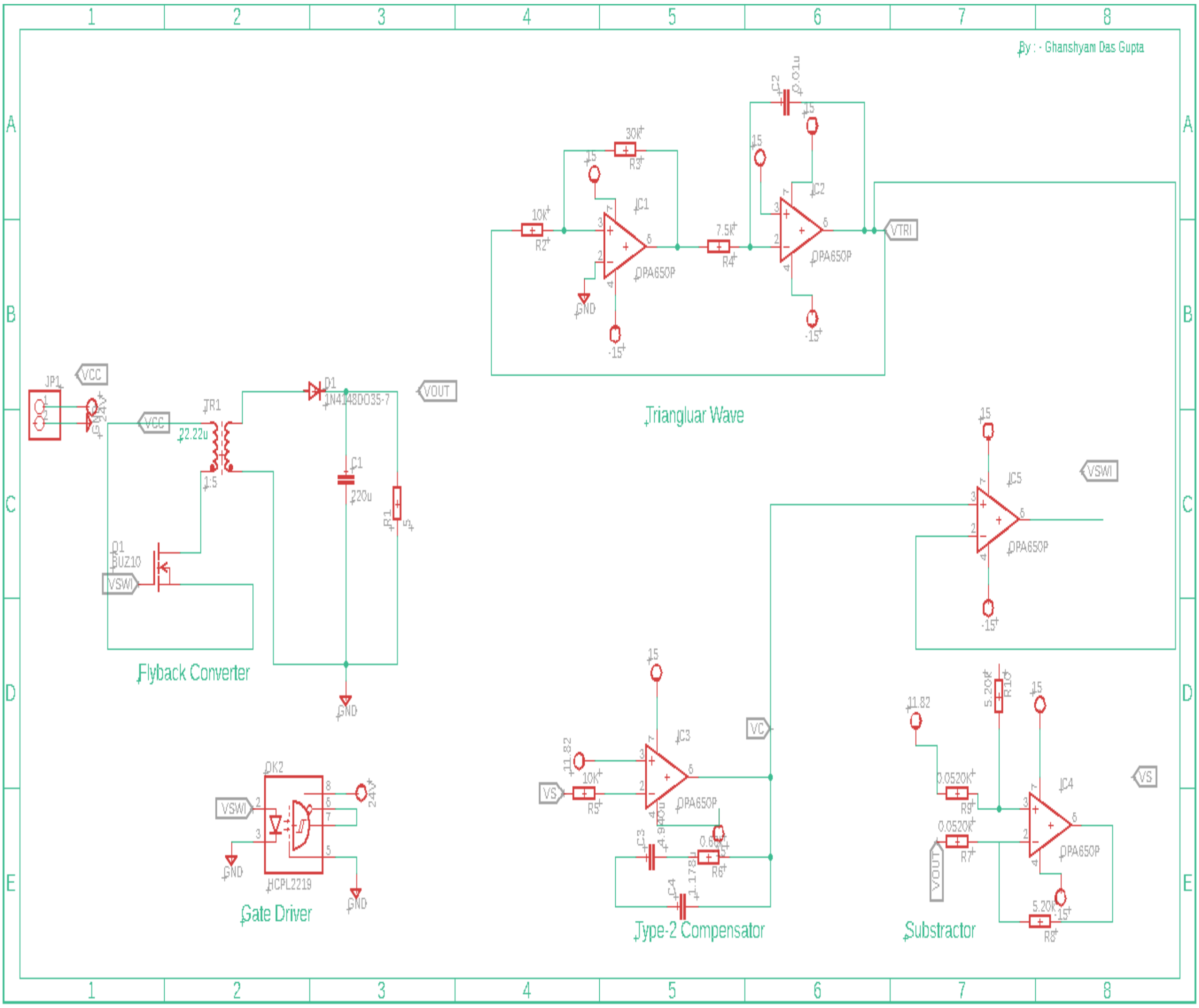
Diode Rating = 75V (Breakdown Voltage) , 1N4148

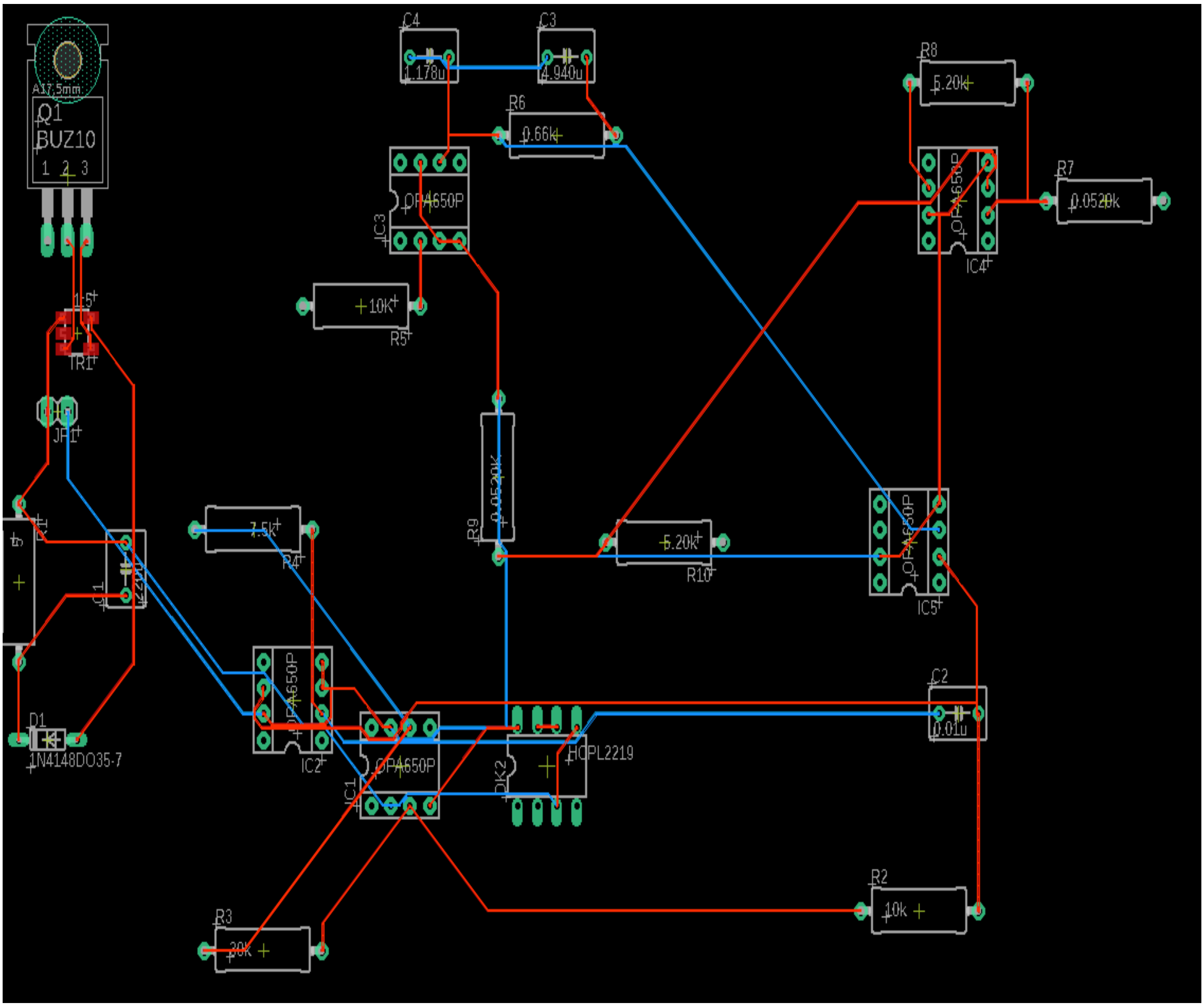
Opretional Amplifier = OP1177

Gate Driver = HCPL2219

Resistor and Capacitor = Electrolite

Rating and name of the switch that is used in the circuit.




Q1
BUZ10
A17,5mm
C4
1.178u
C3
4.940u
R6
0.66k
R8
5.20k
R7
0.0520k
OPA650P
IC3
10K
R5
TR1
JP1
IC4
IC5
R9
0.0520K
7.5k
R4
5.20k
R10
IC2
IC1
OK2
HCPL2219
C2
0.01u
D1
1N4148DO35-7
R3
20k
R2
10k