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# Self Project

## PCB Design of Clsoed Loop Control of Flyback Converter

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### 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 = 220 $\mu$ F , Turn Ratio = 1 : 5 , Inductor = 22 $\mu$ H , Resistor = 5 $\Omega$  , Inductor Resistance = 1 $\Omega$ , 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

```

1  Vin = 24;
2  n = 5;
3  R = 5;
4  L= 22.22e-6;
5  C = 220e-6;
6  D = 0.33;
7  r= 1;
8  % Converter Transfer Function -----
9  A = ((R*L*C*n)/(R*0.67));
10 B = ((R*C*D*r*n)/(R*0.67)+(n*L)/(R*0.67));
11 C = ((D*R*n)/(R*0.67)+0.67/5);
12 D = (24+11.82/5-((5*11.82)/(0.67*5))*1);
13 E = (11.82*L)/(5*0.67) ;
14 F = (11.82*D*r)/(5*0.67) ;
15 J = [E 39.5473];
16 K = [A B C];
17 M= tf(J,K);
18 % Compensator Transfer Function -----
19 N = [84.8772 26029.29534];
20 P = [1 1286.0184 0];
21 Q= tf(N,P);
22 bode(M,Q)
23

```

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

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

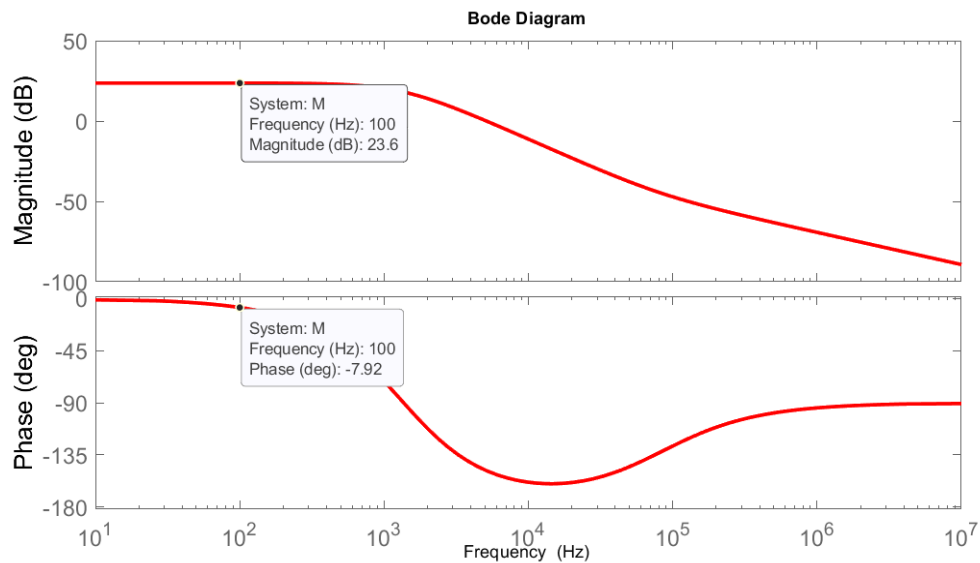


Fig. 2: Bode Plot of Uncompensated Flyback Converter

For the uncompensated Flyback converter, phase margin (PM) is  $-7.92^\circ$  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

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

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

$$\begin{aligned} \phi_b &= \phi_m - \phi_p - 90^\circ \\ \phi_b &= 120^\circ + 0.907^\circ - 90^\circ \\ \phi_b &= 37.94^\circ \end{aligned} \quad (4)$$

- Transfer Function of TYPE -II compensator is given by

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

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

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

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

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

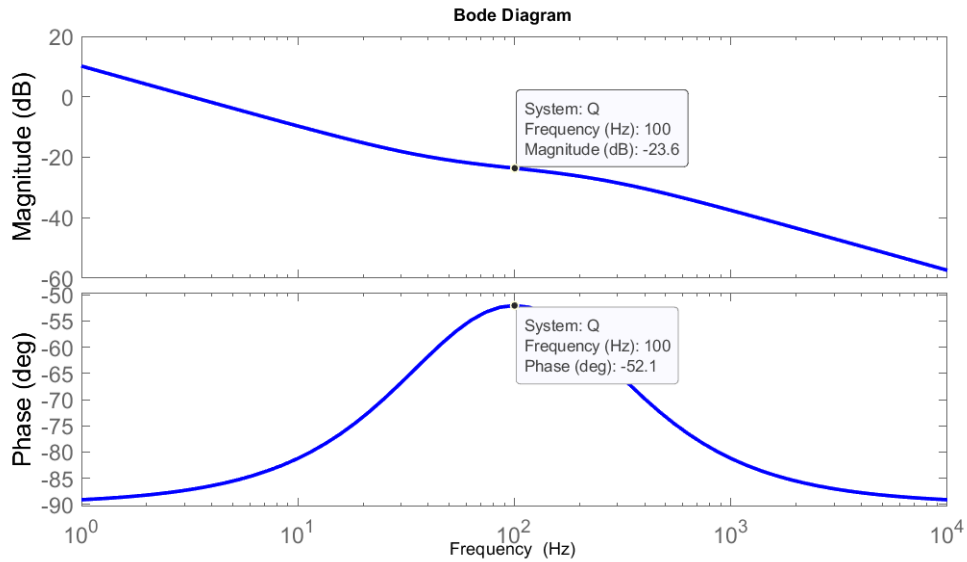


Fig. 3: Bode Plot of TYPE-II Compensator

### 3.5 Flyback Converter with TYPE-II compensator

Total plant transfer function using compensator

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

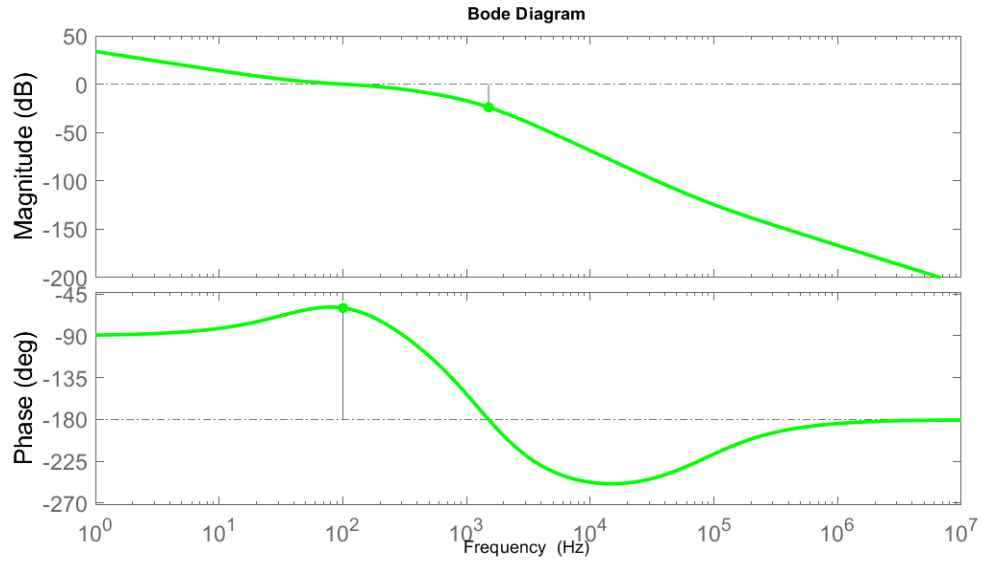


Fig. 4: Bode Plot of Compensated Flyback Converter

## 4 WAVEFORM

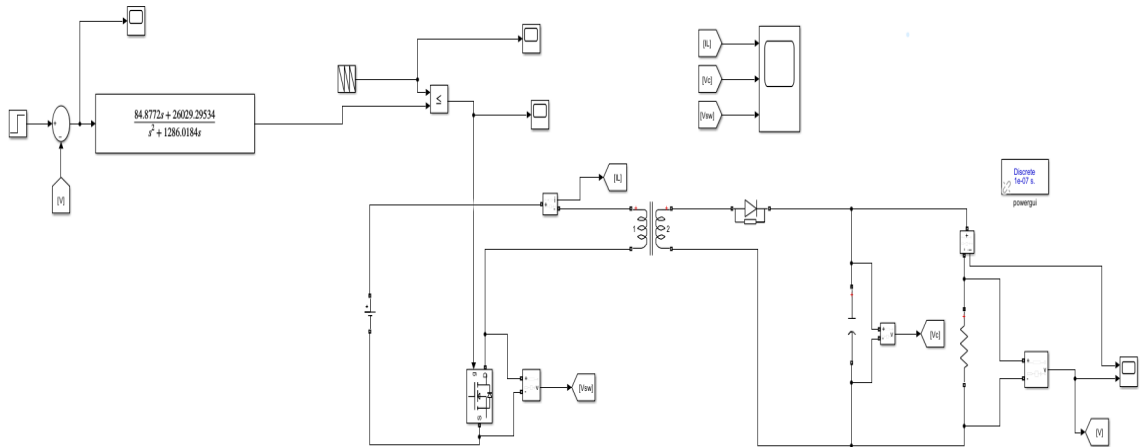
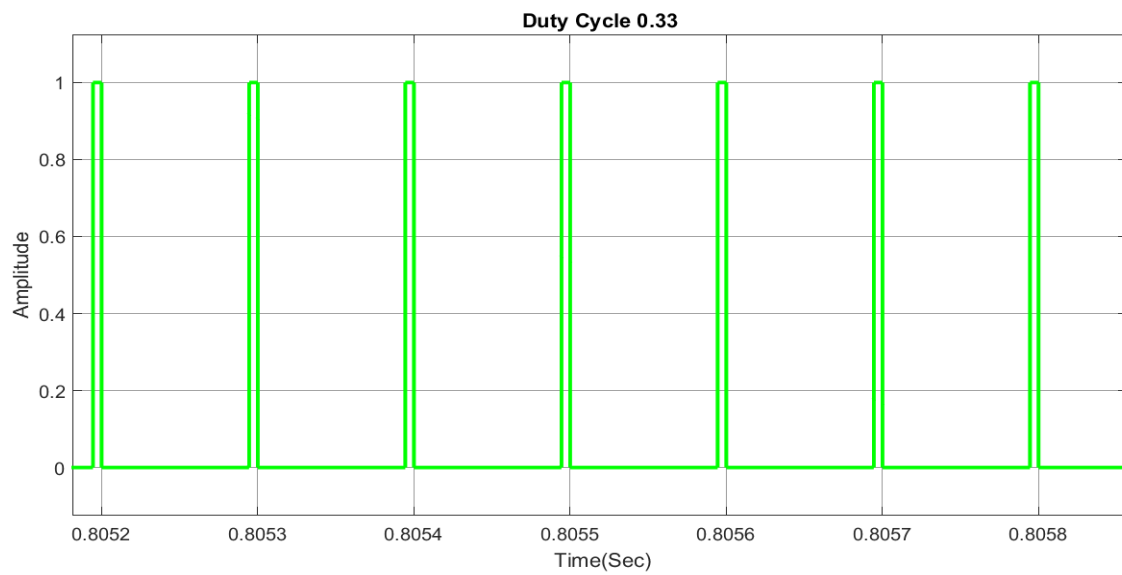
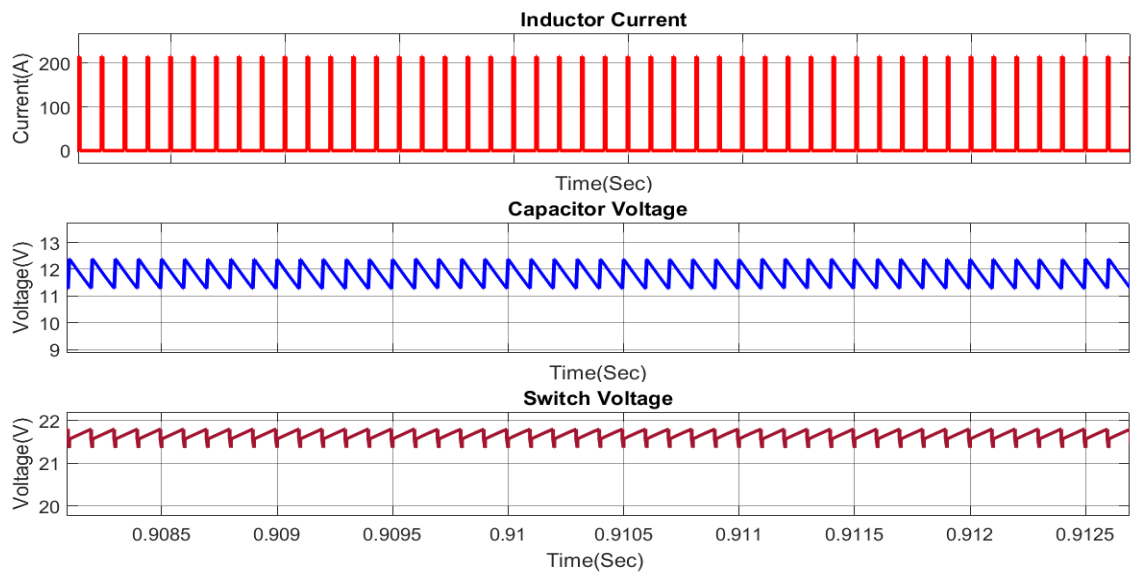
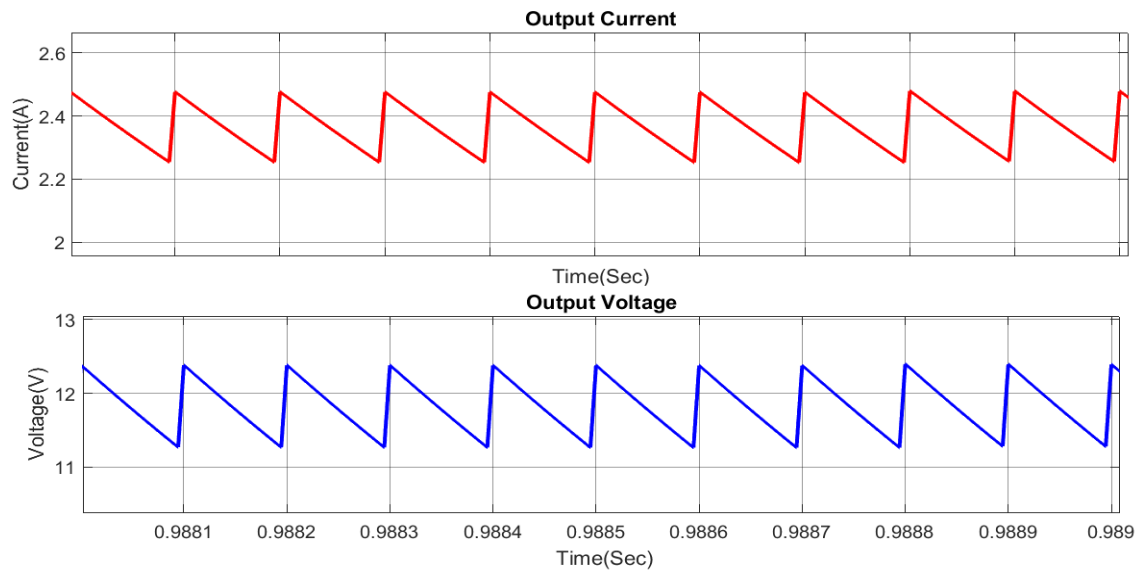


Fig. 5: Simulated Diagram of Compensated Flyback Converter



## 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  $R_1 = 10\Omega$  and capacitor  $c = 0.01\mu$  F. Saturation voltage of op-amp is 15V

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

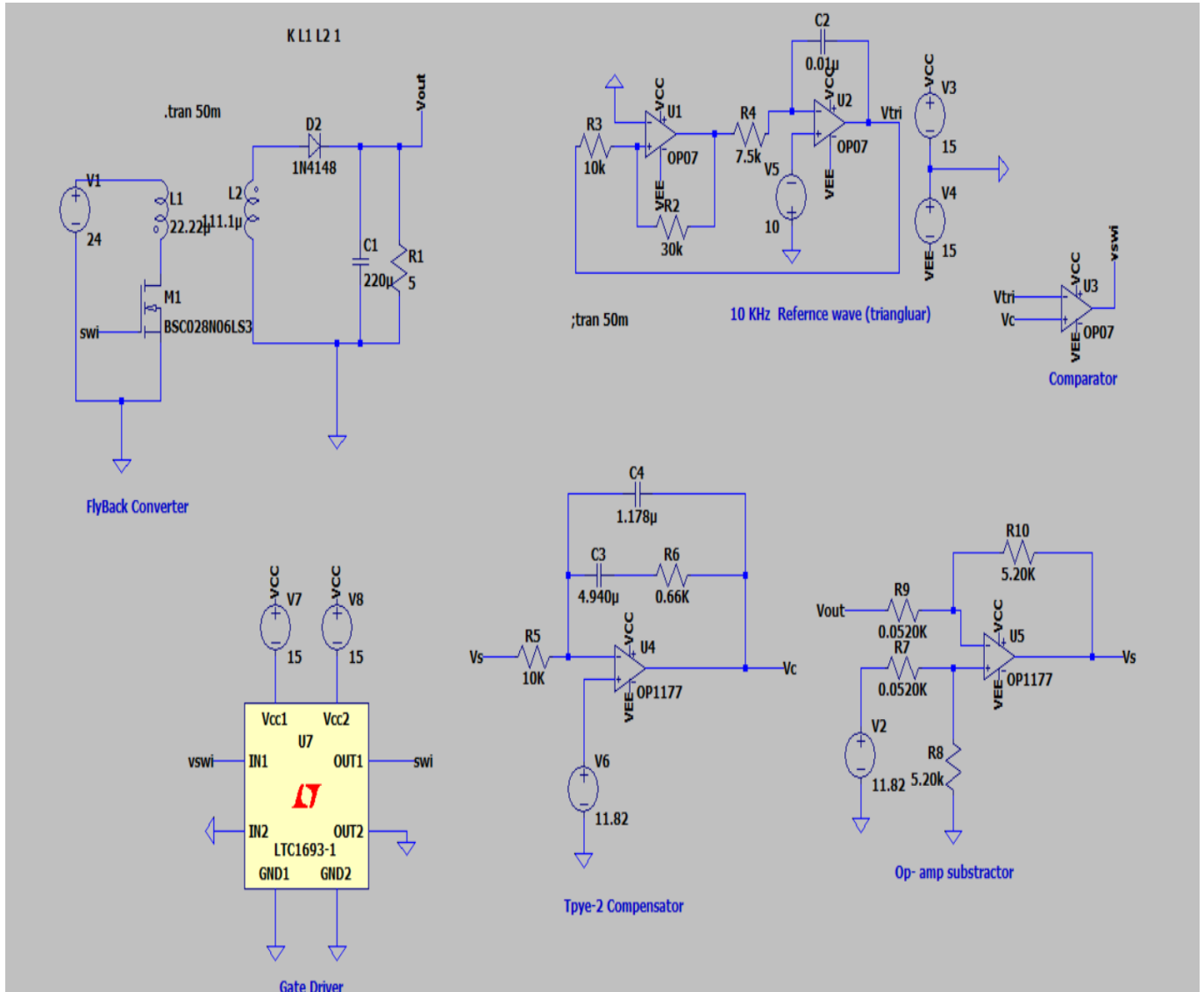
$$f = \frac{R_1}{4 * R_3 * R_2 * C_1}$$

### 5.2 Op-amp Subtractor

we design op-amp sub tractor to generate error and given it to the signal compensator then switching using gate driver. The output of the subtractor 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 BSC028N06LS3

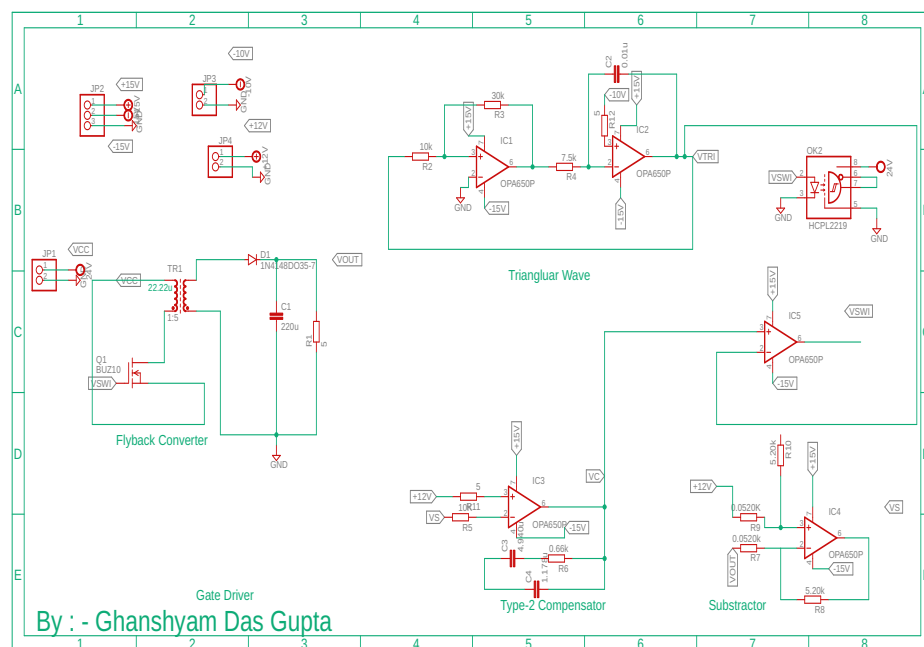
Diode Rating = 75V (Breakdown Voltage) , 1N4148

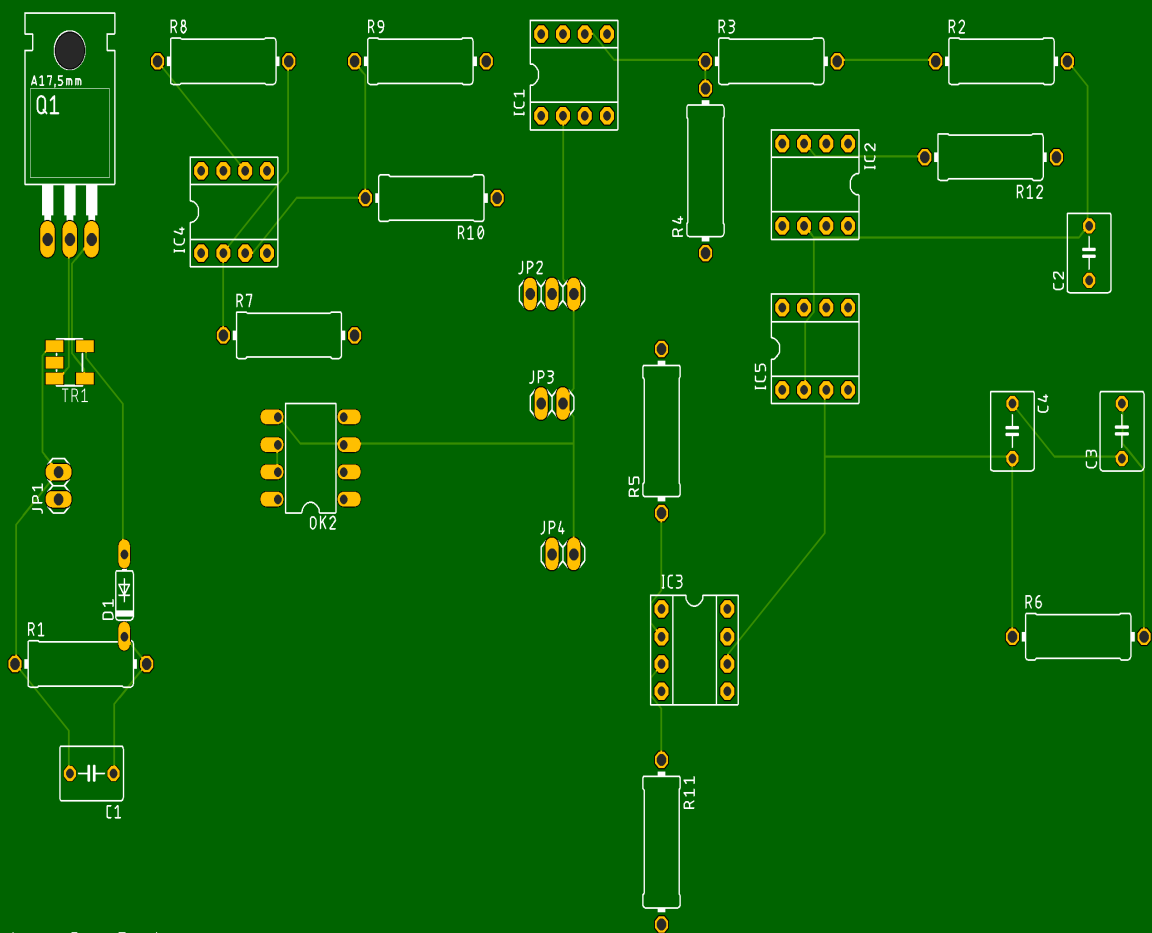
Operational Amplifier = OPA1177

Gate Driver = HCPL2219

Resistor and Capacitor = Electrolyte

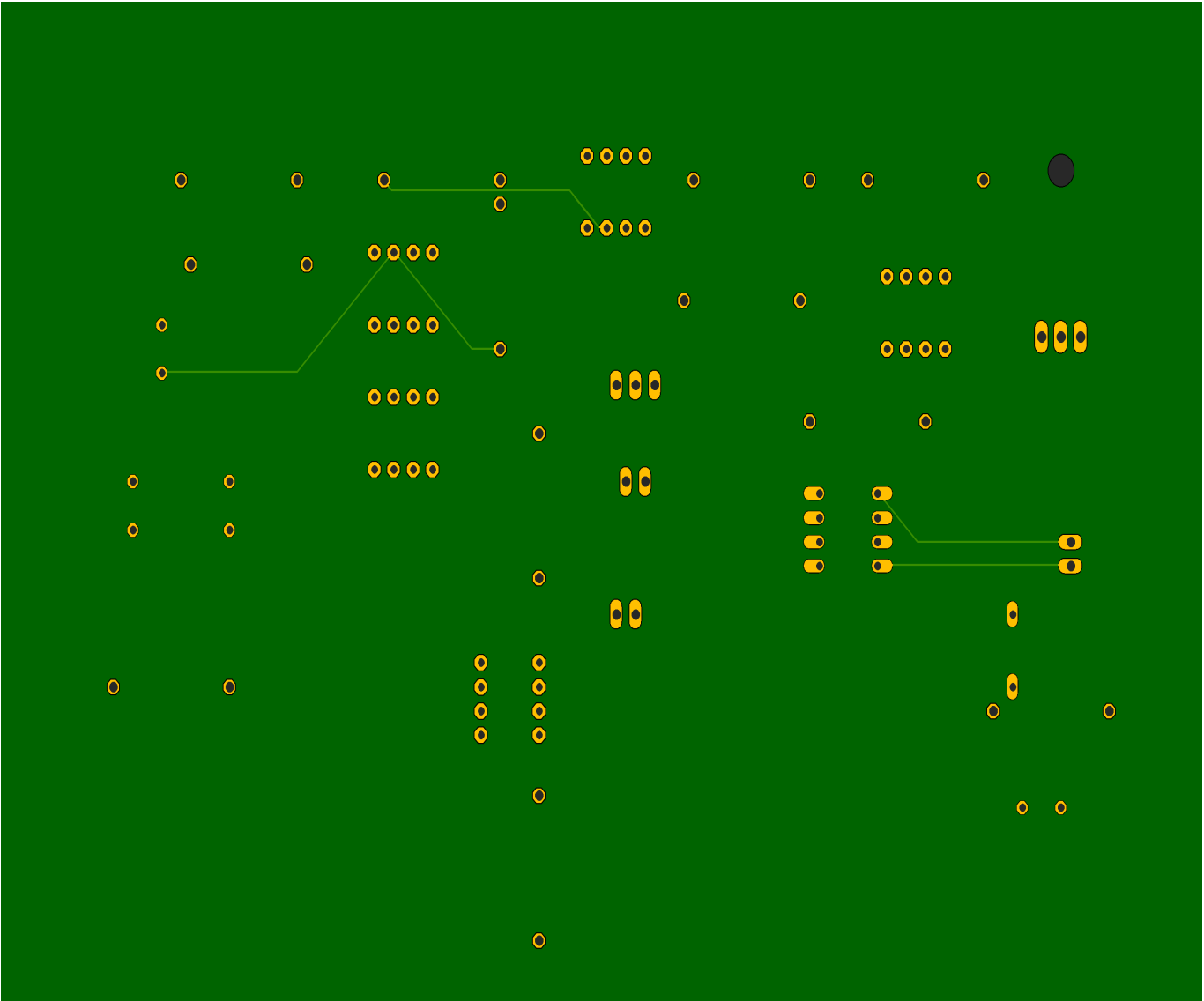
Rating and name of the switch that is used in the circuit.

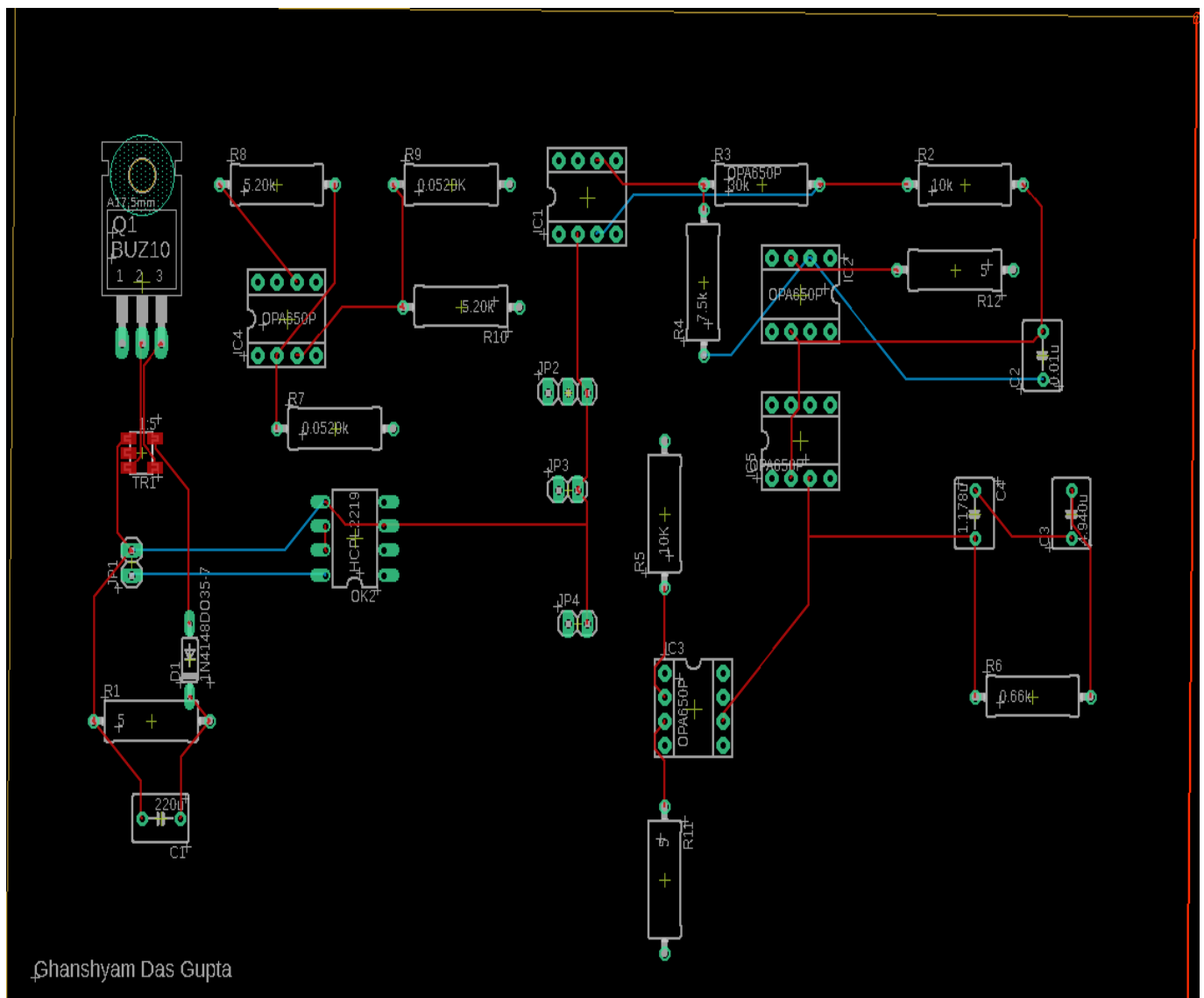




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