# A Self Project on

# Simulation and PCB Design of Close loop PI Controlled Boost Converter


Submitted by:

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# 1. Objective

Design a closed loop control of boost converter controlled by analogue PI controller. The specifications for the boost converter are given below.

Input Voltage ($V_{in}$): 24 V, Output Voltage ($V_o$): 48 V, Switching frequency: 20 kHz, Output Voltage Ripple ($\Delta V_o$): 5%, Inductor Current Ripple ($\Delta i_L$): 10%, Rated Power: 50 W.

# 2. Boost Converter Design:

## 2.1 Output current and Inductor current:

$$R = \frac{V_o{}^2}{P_o} = \frac{48^2}{50} = \mathbf{46.08\ \Omega}$$

$$I_o = \frac{P_o}{V_o} = 1.041 \text{ A}$$

For boost converter we know that,

$$\text{Duty ratio, } D = \frac{V_o - V_{in}}{V_o} = \frac{48-24}{48} = 0.5$$

Also we know the formula of Inductor current is given as,

$$I_L = \frac{I_o}{1-D} = \frac{1.041}{1-0.5} = 2.083\text{A}$$

## 2.2 Inductor:

It is given that, Inductor current ripple is 10% of $I_L$,

$$\Delta I_L = 0.1 * 2.083 = 0.208 \text{ A}$$

$$L = \frac{V_{in}\, D}{f * \Delta I_L} = \frac{24 * 0.5}{20000 * 0.208} = \mathbf{2.9\ mH}.$$

## 2.3 Capacitor:

It is given that, Capacitor voltage ripple is 5% of $V_o$,

$$\Delta V_c = 0.05 * 48 = 2.4 \text{ V}$$

Now by using the formula of output ripple voltage,

$$C = \frac{I_o\, D}{f * \Delta V_c} = \frac{1.041 * 0.5}{20000 * 2.4} = \mathbf{10.85\ \mu F}.$$

# 3. Power circuit component specification:

As per Formulas, values are calculated but there may be the case that these components are not available with the same exact values so one have to take the nearby values which are available in market. So values taken are as following:

| s.no | Component | Name | Voltage/Current Ratting | Specifications |
|---|---|---|---|---|
| 1 | Inductor (2.9mH) | SCF47B-200S1 | 20A | R_internal=0.0029Ω |
| 2 | Capacitor (10.85$\mu$F) | UVR2A101MPD | 100V, 2A | r=0.026Ω |
| 3 | Load (46.08Ω) | HCHJ355J22RJ | - | Power=500W, Tolerance=5% |
| 4 | MOSFET | DMN5040LSS-13 | 50V, 5.2A | Vgs=20V, R_ON=0.48Ω |
| 5 | Diode | IN5415 | 50V, 4.5A | Vf<1.1V, Trr<60ns |

Table.1 Power Component Specification

# 4. Controller Design:

## 4.1 Open loop analysis:

Transfer function of boost converter is derived by using small signal model of boost converter and it is given as,

$$\frac{V_o\hat{}(s)}{d\hat{}(s)} = \frac{(1-D)V_o - \frac{L * V_o}{(1-D)R} S}{L * C\, S^2 + \frac{L}{R} S + (1-D)^2}$$

After putting all the values we get,

$$\frac{V_o\hat{}(s)}{d\hat{}(s)} = \frac{-0.006\, S + 24}{3.125e{-8}\, S^2 + 6.25e{-5}\, S + 0.25}$$

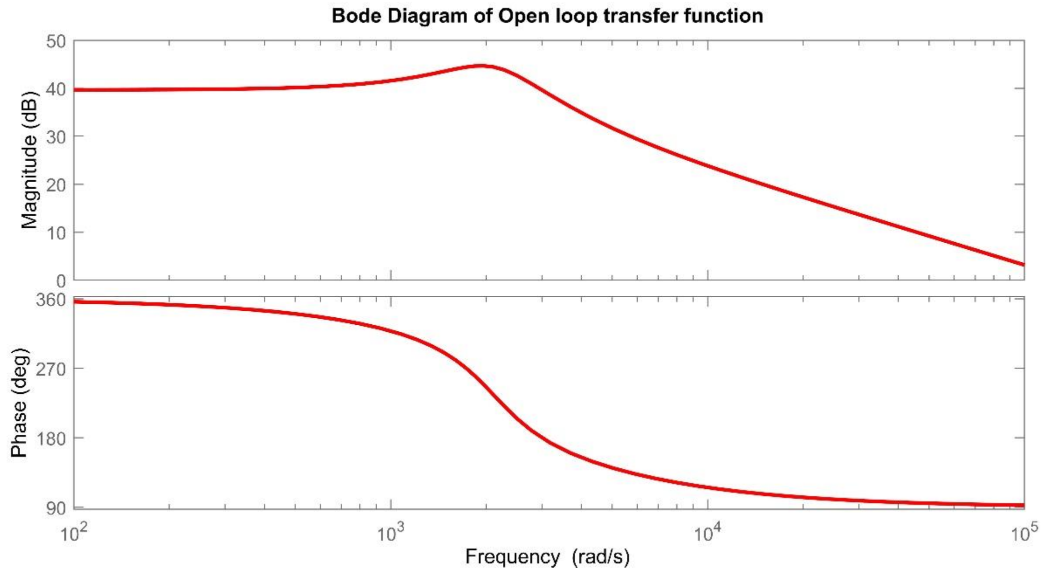



Fig.1: Bode plot of plant transfer function

System with above transfer function is not getting stable. It has one zero in right side of s-plane. So we need to design controller which can make this system stable.

## 4.2 Controller analysis:

Now controller is design to get phase margin (desired) of 30-degree at gain cross-over frequency of 2 kHz.

Transfer function of the controller is find out by using Ziggler-Nicolus technique and it is given as,

$$G_C(s) = 0.000119 + \frac{9.355}{s}$$

## 4.3 Close loop analysis:

This controller with unity feedback is implemented with the plant to make it close loop control system.

With the given value we got the close loop transfer function which is stable.

$$\frac{C(s)}{R(s)} = \frac{-1.233e{-5}\,S^2 - 0.000556\,S + 199.5}{3.125e{-8}\,S^3 + 6.25e{-5}\,S^2 + 0.25\,S}$$

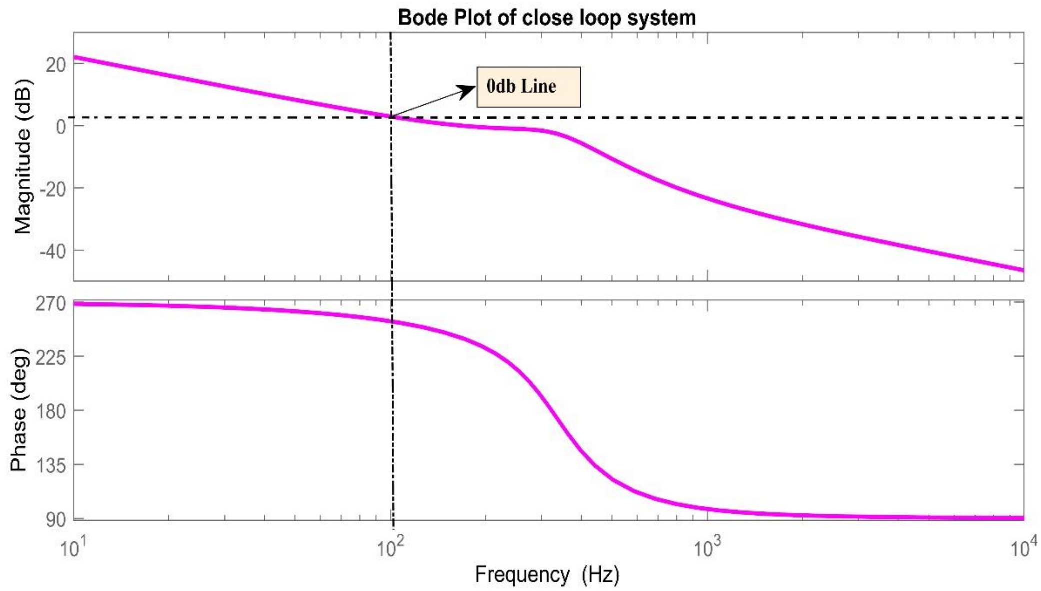



Fig.2: Bode plot of close loop transfer function

# 5. LTSpice Circuit Model:

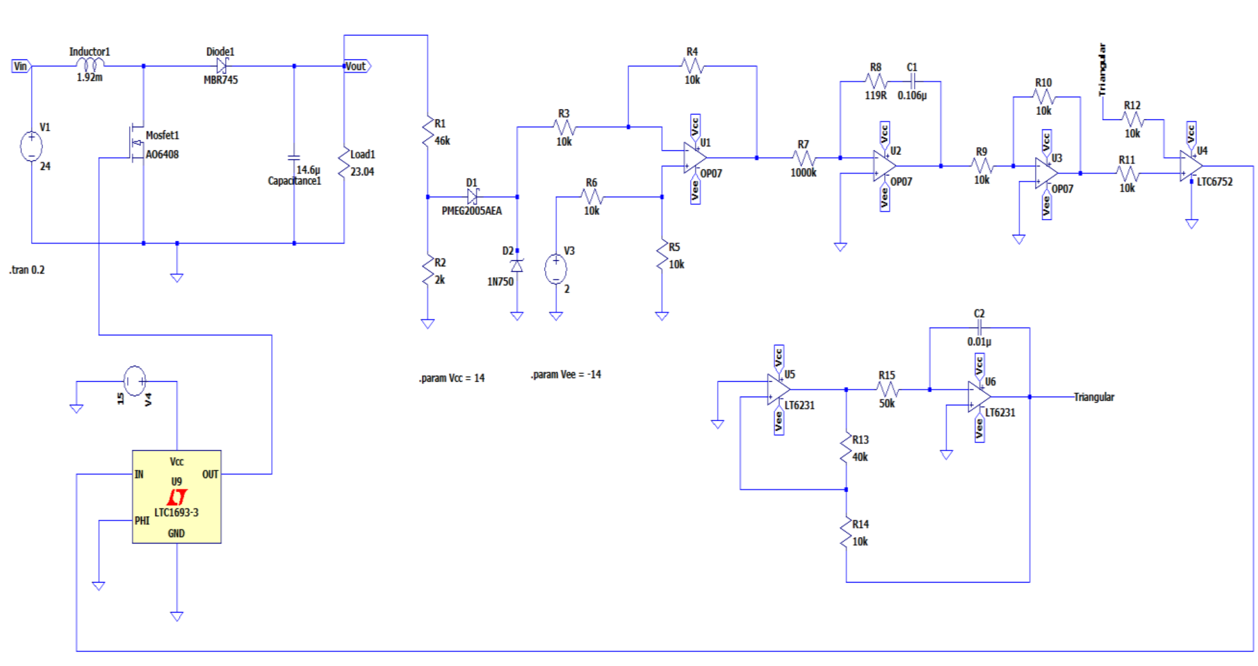



Fig.3: LTSpice Circuit Diagram

## 5.1 Sensor and Summer

Voltage divider Circuit is used to step down and sense output Voltage then diode configuration is to get steady voltage and to avoid any damage to the lower power ratting devices like Op-Amp. Error amplifier is having VOscaled and Vref as input and gives the scaled error at output. Circuitory for same is given in Fig.4

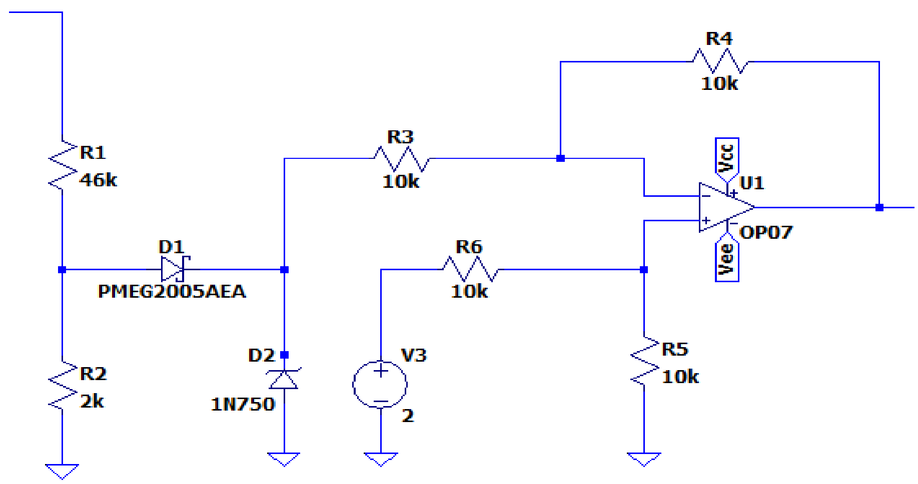



Fig.4: Sensor and summer block

## 5.2 PI controller and Comparator:

Scaled error is then given to the PI controller which is made using the OP-AMP as shown in Fig.5. Transfer function of PI controller can be found by simply taking ratio of feedback impedance to the input impedance. For fine tuning of PI controller it's input resistance is kept variable. Output of that is given to the inverting OPAMP because PI controller is acting as a inverting OP-AMP. Comparator IC LTC6752 is used to compare the output of PI controller with the 20kHz triangular signal and generate pulses. Output of comparator is given to the Driver IC which will generate gate pulses for MOSFET

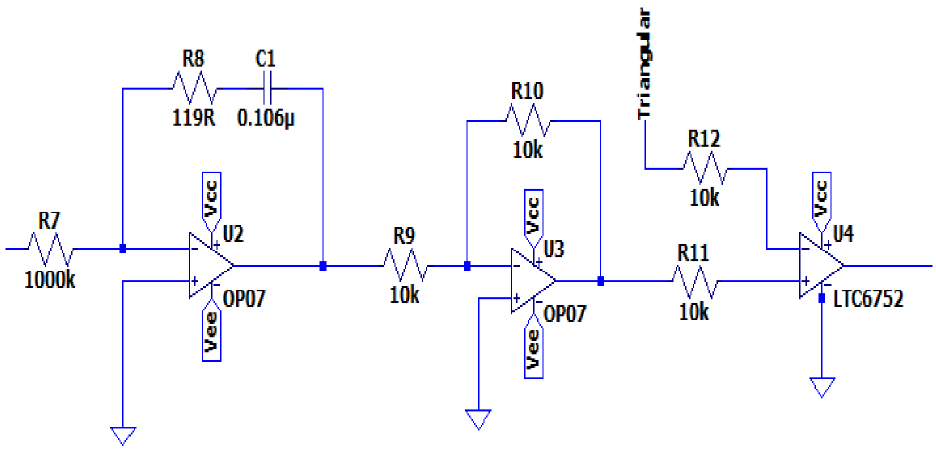



Fig.5: PI Controller and Comparator block

## 5.3 Triangular wave generator:

In Fig.6 Complete circuitory to generate triangular wave with amplitudw of 10V is given. This triangular wave generator is used as a carrier wave generator to compare with output of PI controller. First square wave with the desired frequency is obtained using positive feedback of LT6231 IC and then it is integrated simply using LT6231 as a integrator function. Then another OP-AMP is used to increase the magnitude of triangular signal to the +10V.(+VCC=10V and Vcc=-10V)

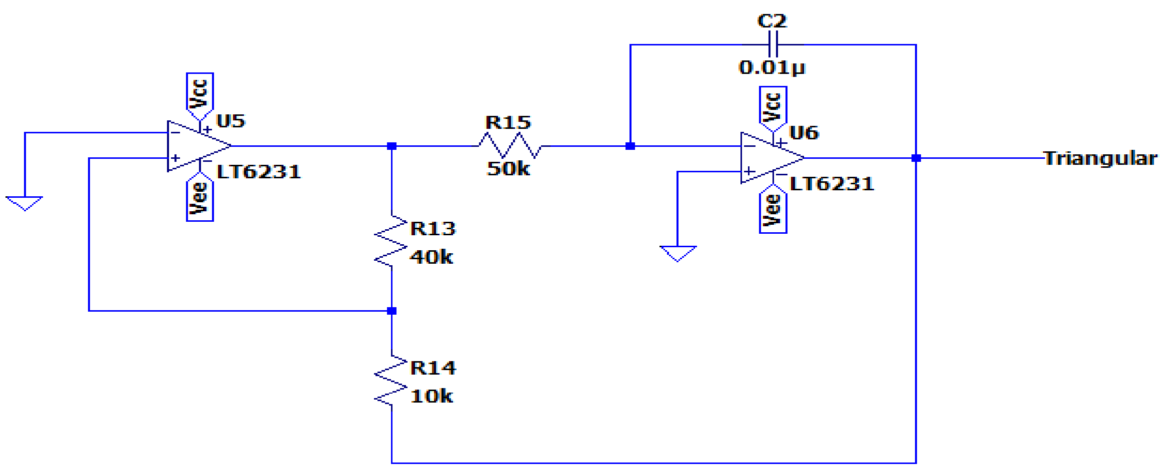
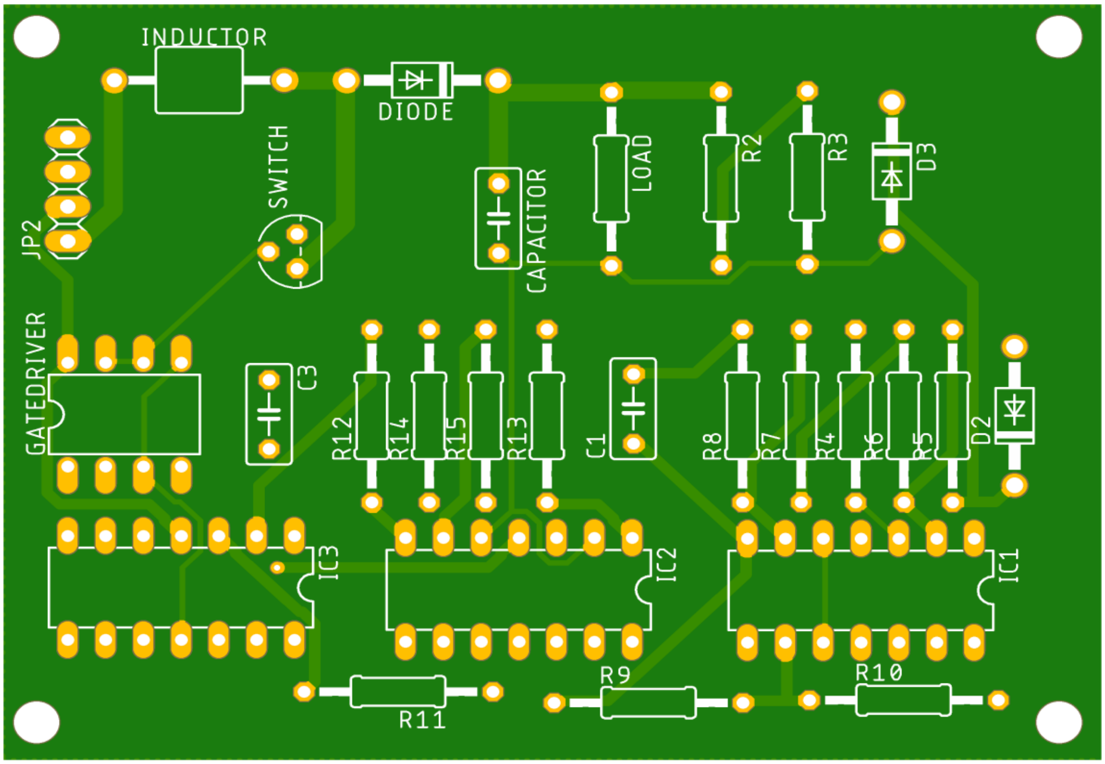



Fig.6: Triangular wave generator block

# 6. <u>PCB Design:</u>

## 6.1 Top View:




## 6.2 Buttom View: