Objective:

Design, fabrication, implementation of a 150 W, 100 V to 230 V and 100 V to 50V, 20 kHz Buck-Boost converter.

Vin = 100V

Vo = (Vin x D)/(1-D)

Step up from 100 V to 230 V ➔ D=23/33=69.7%

Step down from 100V to 50V ➔ D=1/3=33.33%

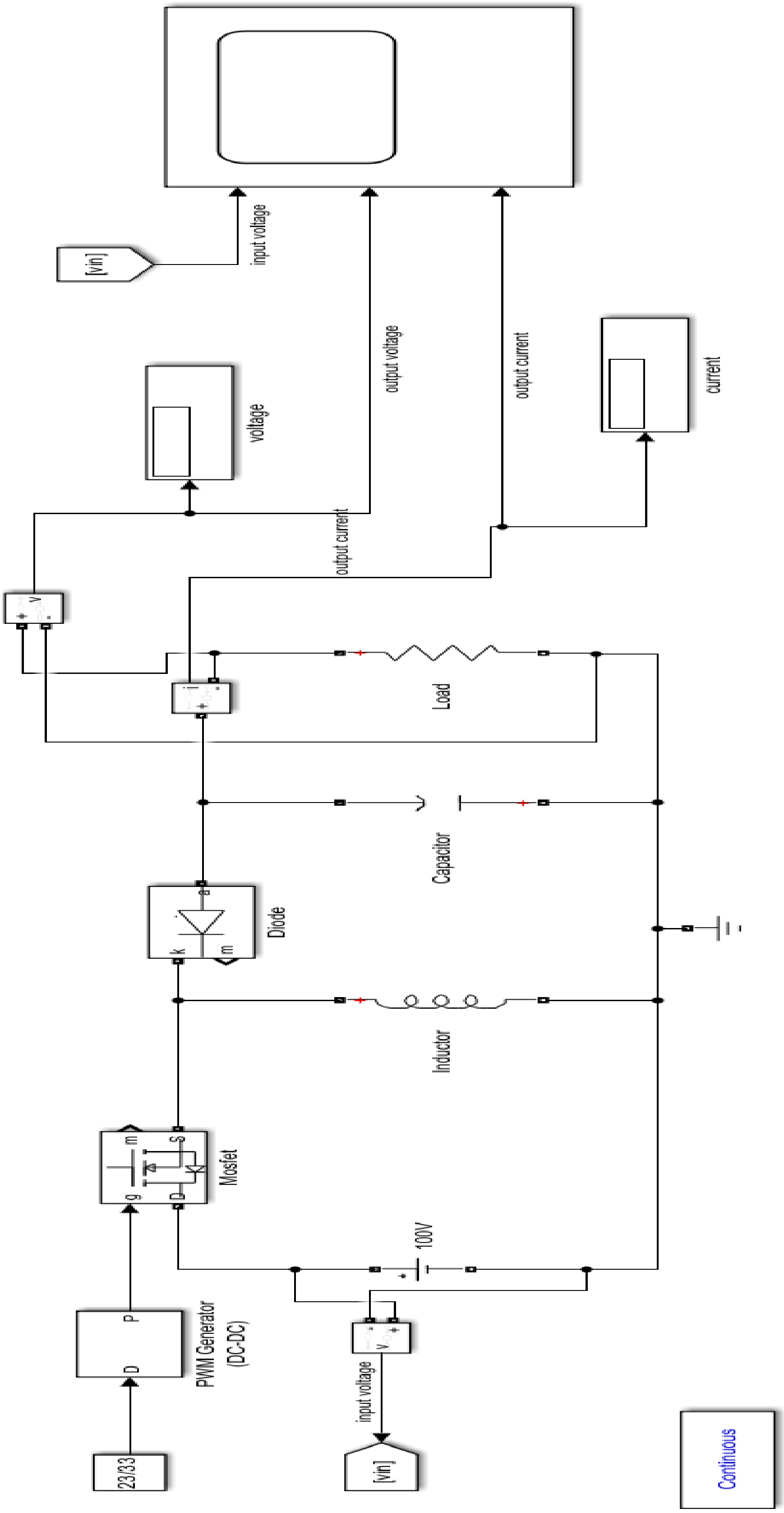
Component Design

Component	Value	Voltage rating	Current rating
Inductor	4 mH		5A
Capacitor	20uF	250V	
Switch	MOSFET IRF740	400V	10A
Diode	MUR860	Vr=600V, Vf=1.5V	If=8A, Ir=10uA

Simulation and component selection:

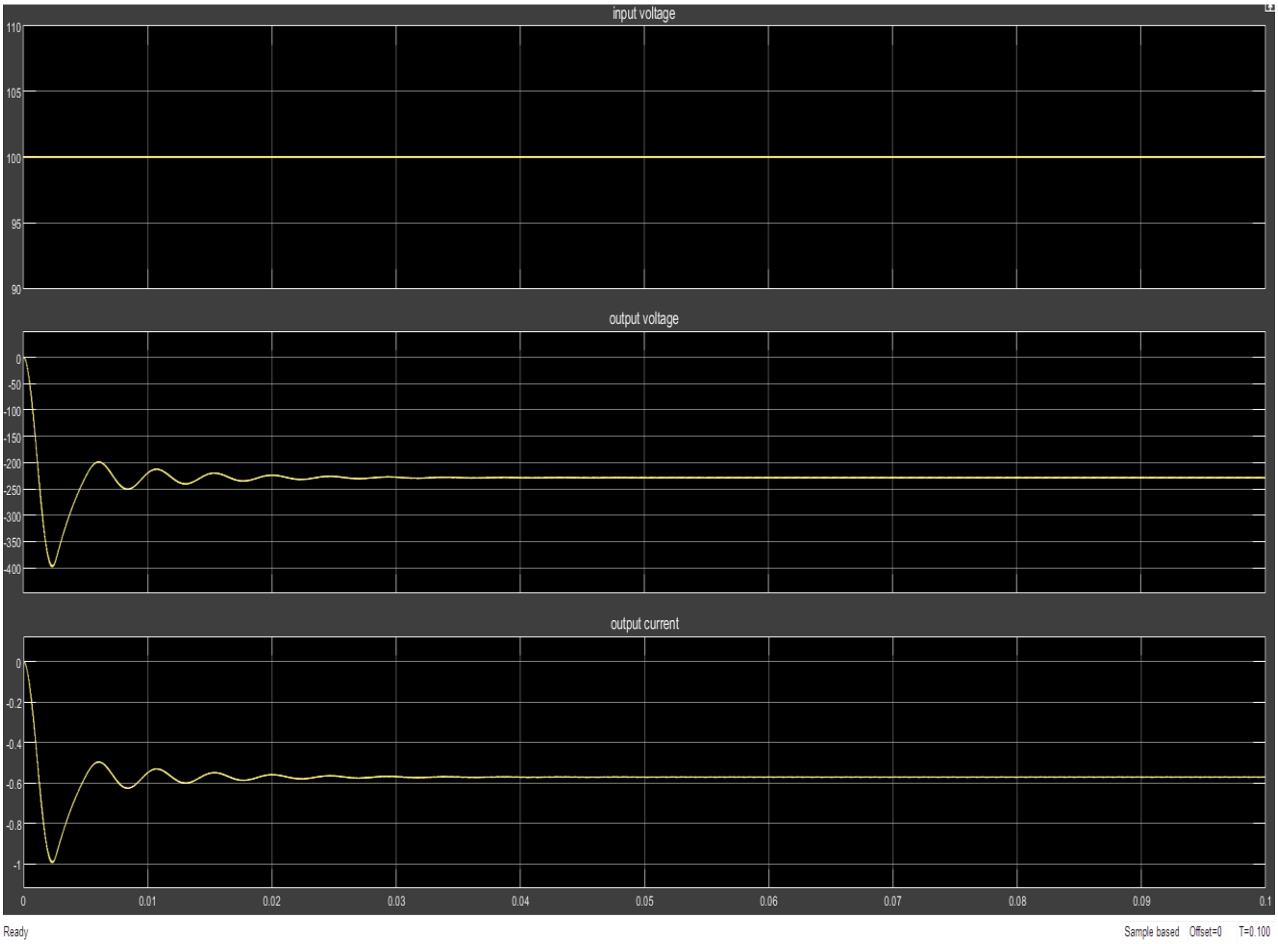
- Simulation-based verification of the component ratings is **done** to ensure feasibility before fabrication.
- identified key components, including **MOSFETs, Diodes, Inductors, and Capacitors**, based on **desired voltage and current ratings**.
- Circuit layout using MATLAB feasibility before fabrication

MATLAB SIMULATION

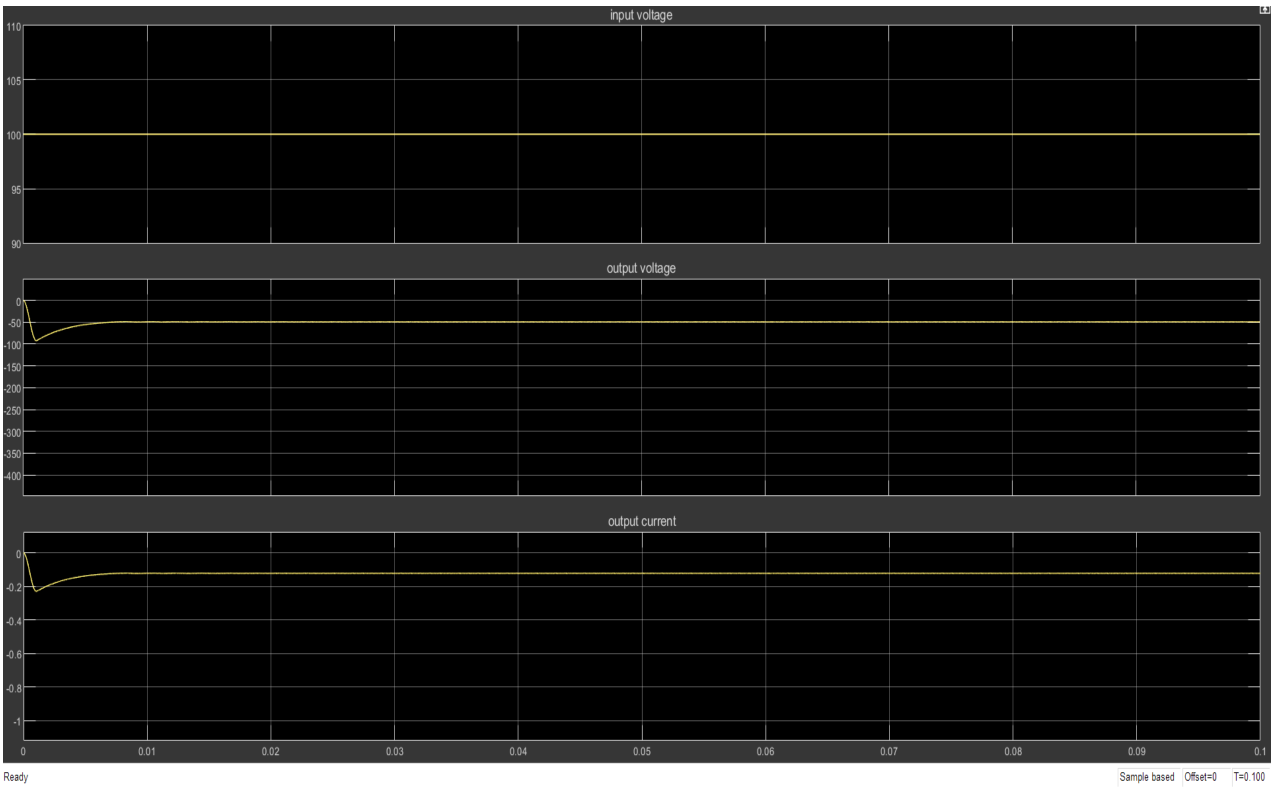


Analytical waveforms

Boost operation--

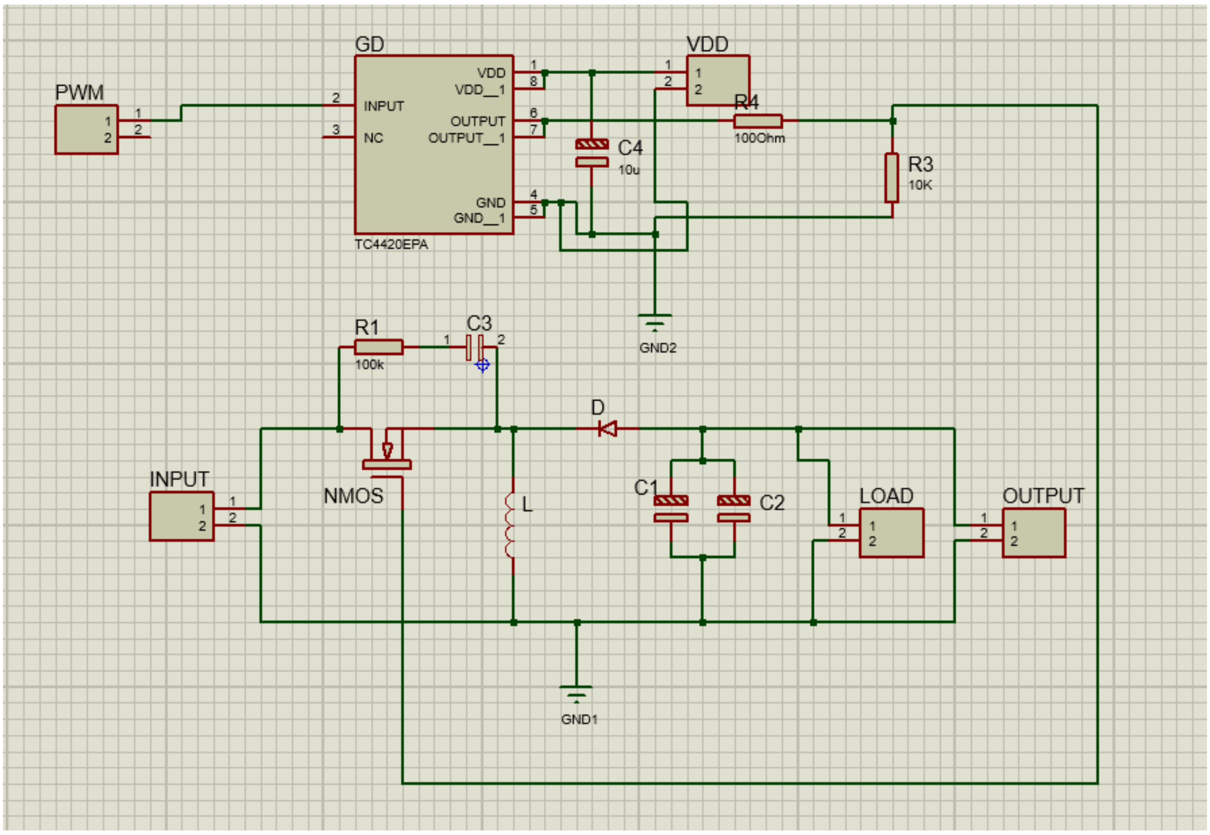


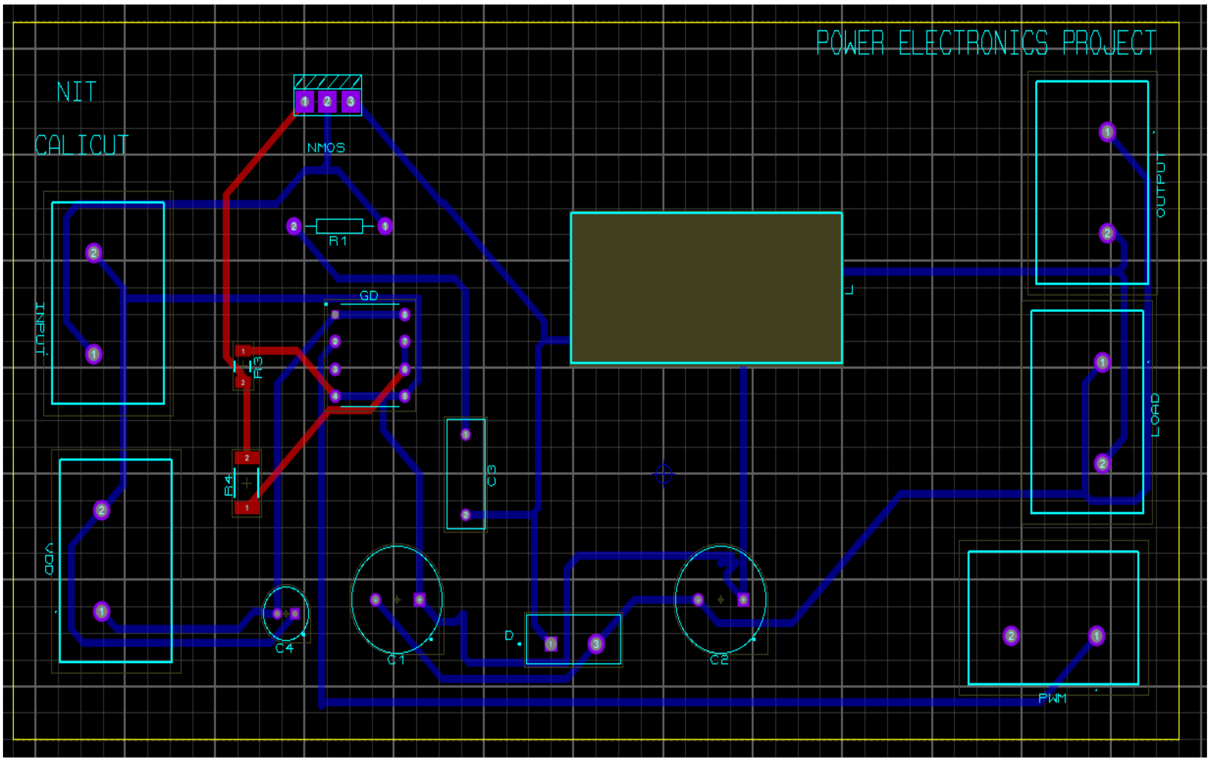
Buck operation—

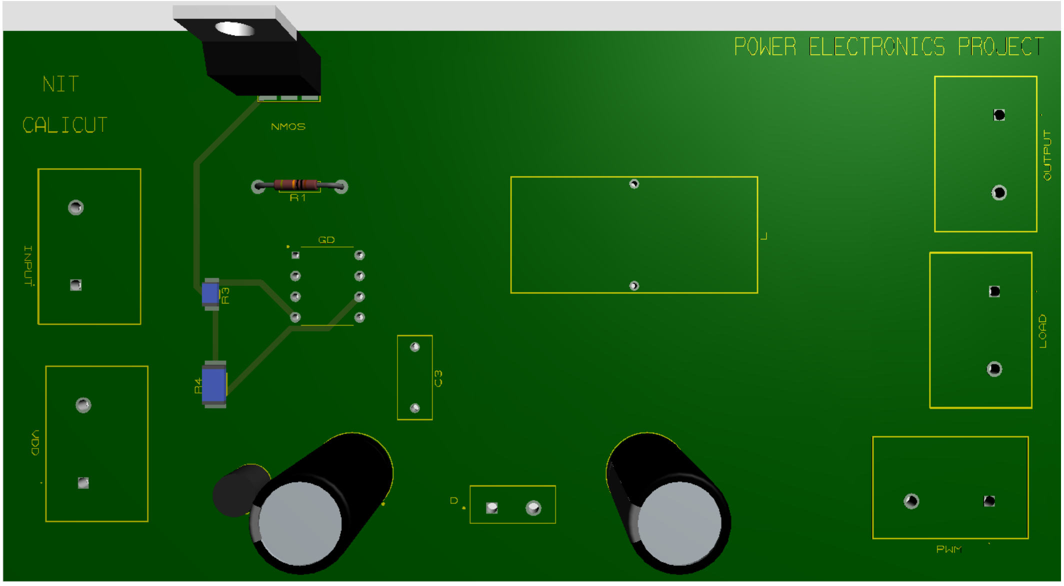


PCB layout and design

Designed PCB Layout using Proteus







PCB Specifications

PCB Bare Board Specifications

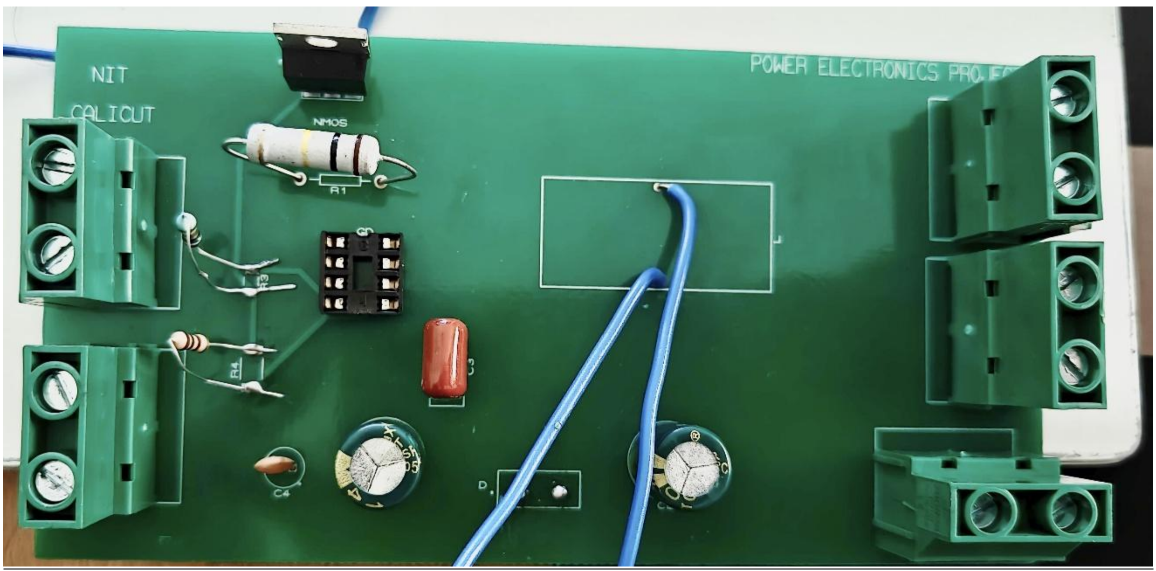
- Updated Specifications

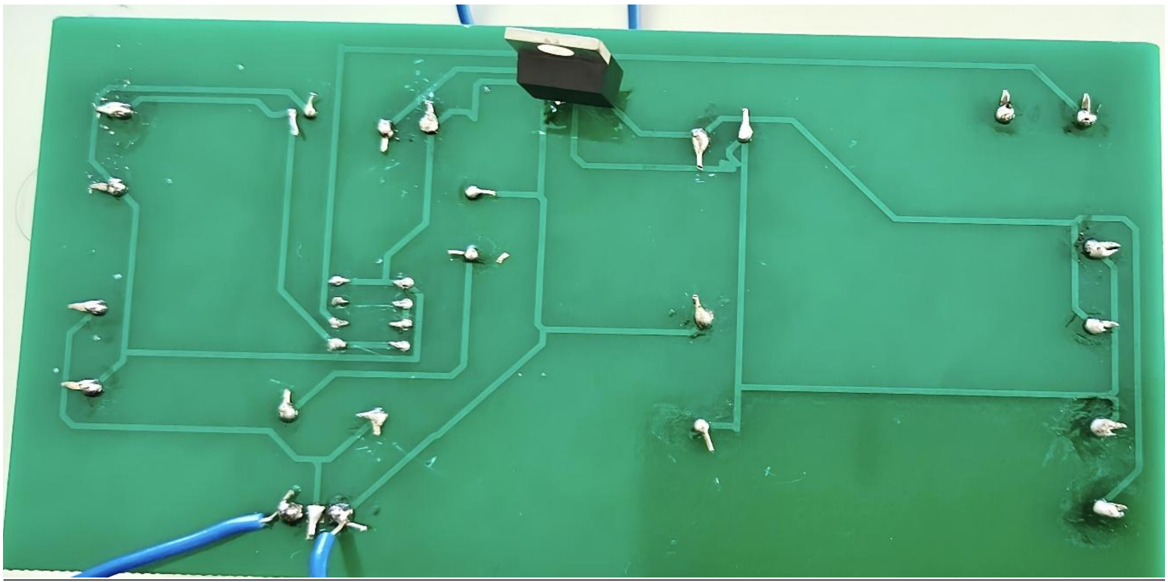
Dispatch Unit	Single Board
Board Size	130.00 x 67.50 mm
Repeat X	-
PCB Per Panel	0
Distance b/w PCBs	-
Panel Dim	-
Material	FR4
Board Thickness	0.063 inch/1.6 mm
Surface Finish	HASL (SnPb)
Solder Mask Bottom	Green
Solder Mask Top	Green
Legend Bottom	White
Peel Off	No
Carbon Contacts	No
Manufacturing Logo	No
Impedance Control	No
ET Symbol	No
Round Edge Platting	No
UL Sign	No
Data Approval	No
Electrical Testing	Yes
Date Code	No

Panel By	-
Panel Qty	-
Repeat Y	-
Different Design Per Panel	-
Board Seperation	-
Panel Border	-
Layers	2 L
TG	Std. Tg (130-140 °)
Finish Cu Thickness	70 μ/2 oz
Inner Cu Thickness	0 μ/0 oz
Legend Top	White
Blind & Buried via	No
Countersunk	No
Hard Gold(Gold Tabs)	0.00
Serialization For PCB	No
Viafill	No
Special BuildUp	No
Bevelling	No
Quality Standard	IPC-600A-CLASS-II
Microsection Report	No
Gold Area Top	0 %
Gold Area Bottom	0 %
Depth routing	No

Buildup Image
Core-1.50 (0.035/0.035)
Total thickness - 1.640

Pcb assembly :





Calculations:

- Boost: D=230/230+100=0.697D
- Buck: D=50/50+100=0.
- ΔiI = 30% of max current
- Δ Vo = 1% of the output voltage

Critical inductance:

$$L_{\text{crit}} = \frac{(1-D)^2 \cdot R}{2f_s}$$

a) For Boost (D = 0.697)

$$L_{\text{crit}} = \frac{(1-0.697)^2 \cdot 350}{2 \cdot 20000} = \frac{(0.303)^2 \cdot 350}{40000} \approx \frac{32.17}{40000} = 0.804\,\text{mH}$$

b) For Buck (D = 0.333)

$$L_{\text{crit}} = \frac{(1-0.333)^2 \cdot 350}{2 \cdot 20000} = \frac{(0.667)^2 \cdot 350}{40000} \approx \frac{155.7}{40000} = 3.89\,\text{mH}$$

Conclusion:
Using **4 mH > L_crit in both modes**, so the converter operates in **Continuous Conduction Mode (CCM)**

Capacitance calculation :

Capacitance is calculated from below formula

C= (Io x D)/(ΔVo x fs)

Critical capacitance Cc =D/(2 x f x Rl)

After the calculation, it is found to be 10uF, but through simulation it is chosen to be 20uF for better accuracy

Component Ordering:

NMOS -IRF740

Diode -MUR860

Gate Driver -TLP250

RC snubber -100kΩ(carbon film) + 0.1uF (ceramic capacitor)

Inductor - 4mH

Capacitor - 20uf, 400v(electrolytic capacitors)

Load resistor - 350Ω

Micro Controller for gate pulse:

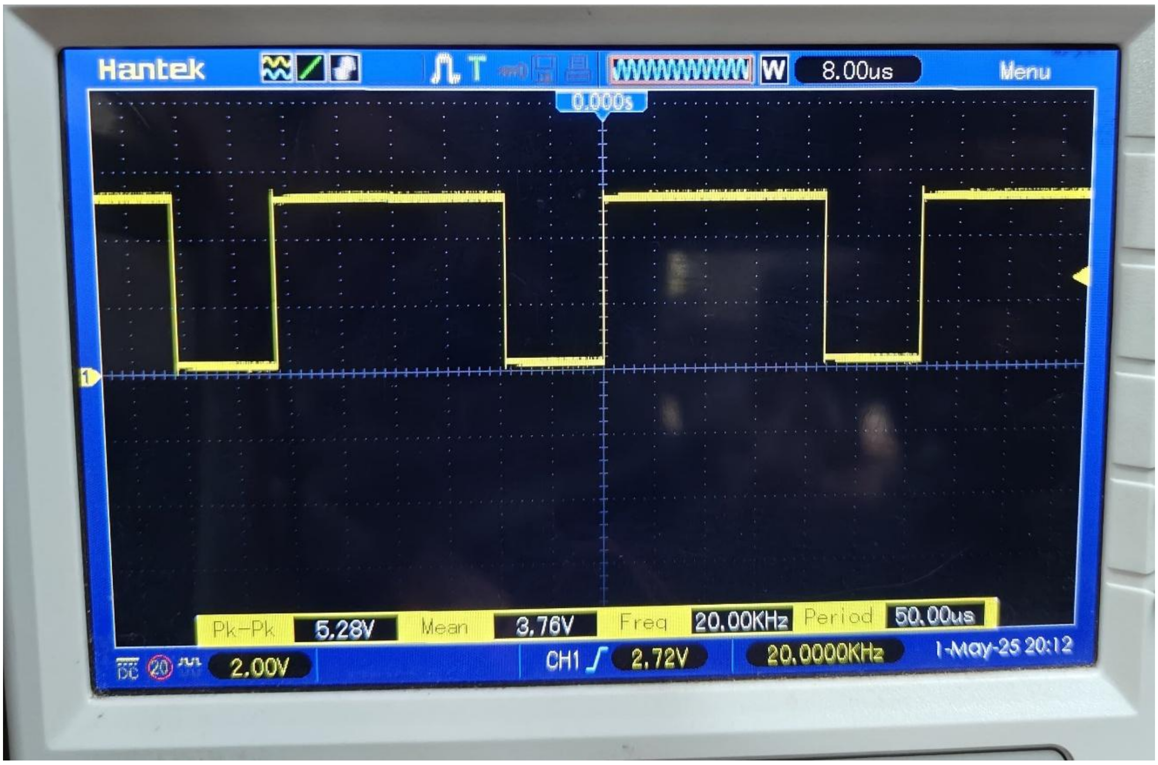
Arduino Uno R3:

- Used Timer1 in Phase Correct PWM mode.
- PWM frequency ~20 kHz.
- Oscilloscope used to verify PWM pulse width and frequency.
- Generated pulses at output pins 9 and 10

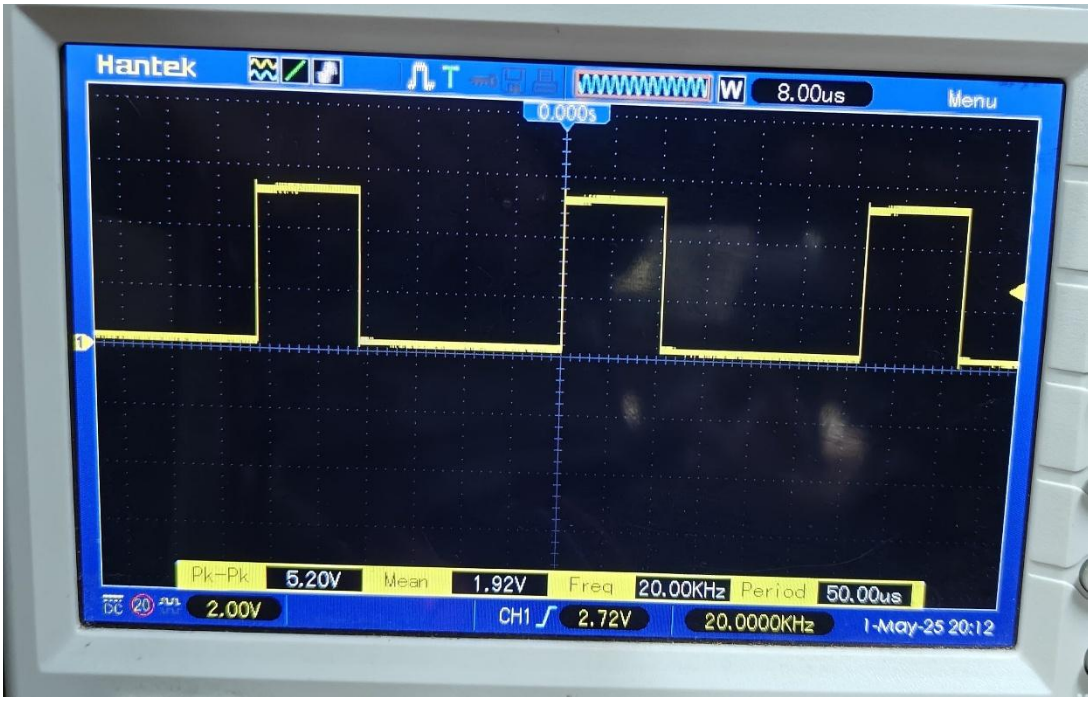
Code for pulse generation:

```
void setup() {
 // Set D9 and D10 as output
 pinMode(9, OUTPUT);
 pinMode(10, OUTPUT);

 // Stop Timer1
 TCCR1A = 0;
 TCCR1B = 0;
 TCNT1 = 0;

 // Set Fast PWM mode with ICR1 as TOP
 // WGM13:WGM10 = 14 => Fast PWM with ICR1 as TOP
 TCCR1A |= (1 << COM1A1) | (1 << COM1B1); // Non-inverting mode
 TCCR1A |= (1 << WGM11);
 TCCR1B |= (1 << WGM12) | (1 << WGM13);

 // No prescaling (prescaler = 1)
 TCCR1B |= (1 << CS10);

 // TOP value for 20kHz PWM frequency
 ICR1 = 799; // f_PWM = 16MHz / (1 * (1 + 799)) = 20kHz

 // Set duty cycles
 OCR1A = (ICR1 * 23) / 33; // BOOST duty on D9
 OCR1B = (ICR1 * 5) / 15;       // BUCK duty on D10

}
void loop() {
}
```

For 69.7% duty cycle, i.e for boost operation.

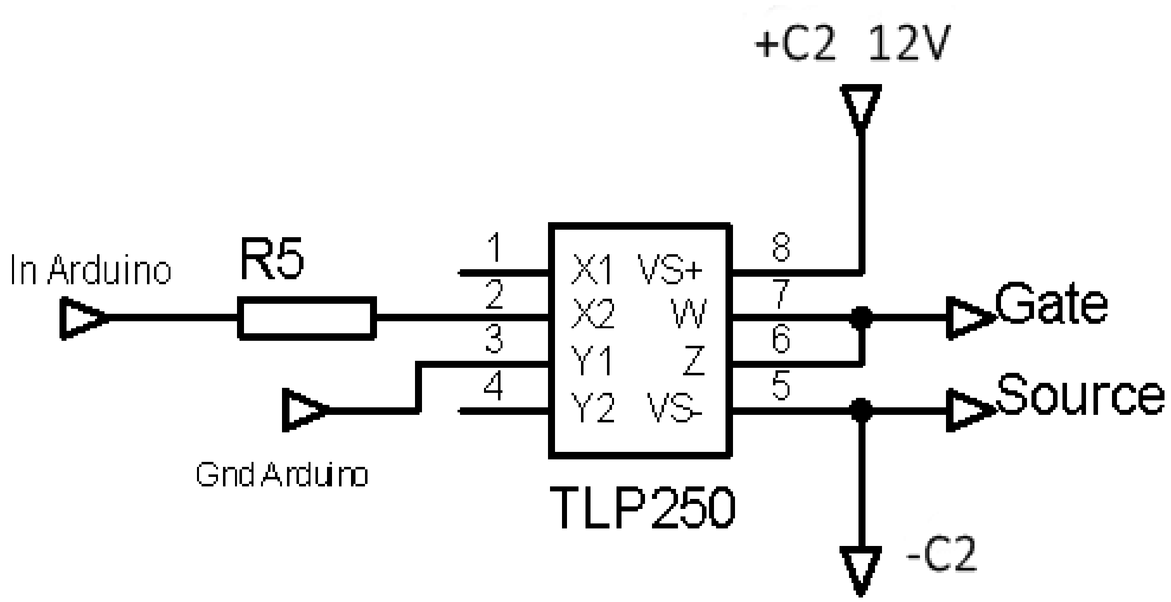


For 33.3% duty cycle, i.e for buck operation



Gate driver design

To drive the IRF740 as a high-side MOSFET, a 15 V gate signal was required—beyond the 5 V logic level provided by the Arduino. The **TLP250**, an opto-isolated gate driver, was chosen to safely translate 5 V logic to 15 V while providing necessary isolation between the control and power circuits, making it ideal for this high-voltage application.



Gate Resistor (Rg)

Usually **1 resistor per gate** – used between the TLP250 output and the MOSFET gate.

Rg=Vdrive/Igate

It is chose to be 100 **Ω** for reduced EMI losses and proper switching speed

Pull-Down Resistor (Rpd)

Connected between the **Gate and Source** of the MOSFET.

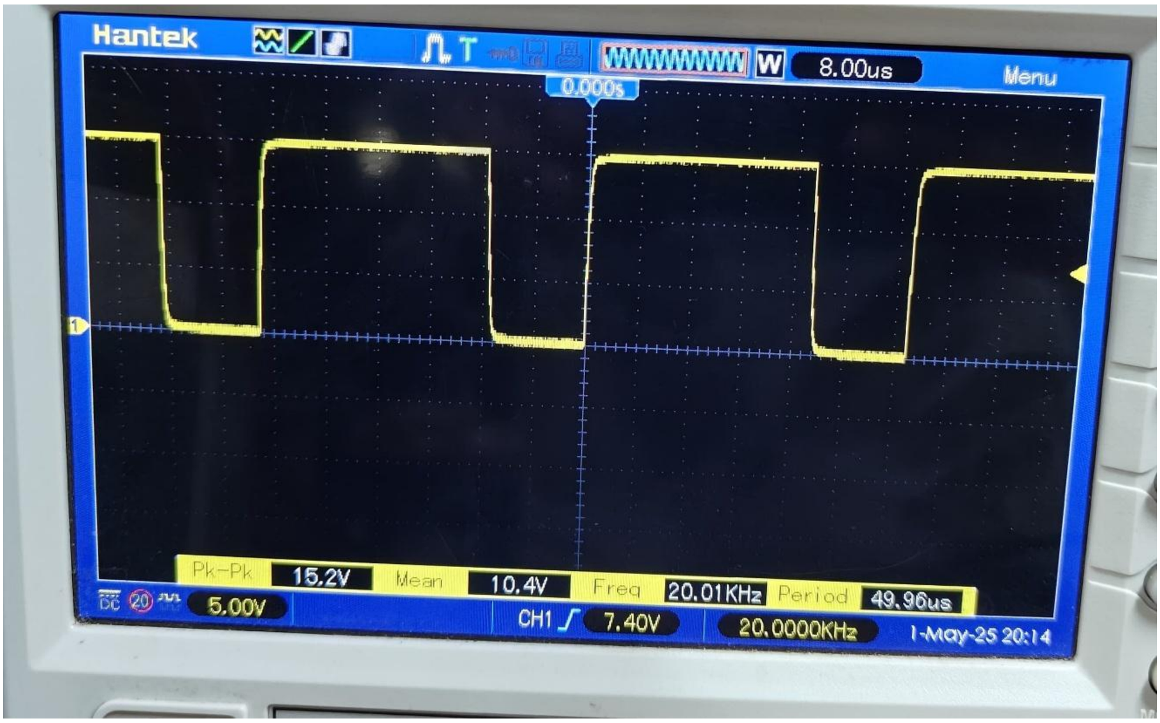
Typically 10k**Ω is used**

Bootstrap Capacitor (Cb)

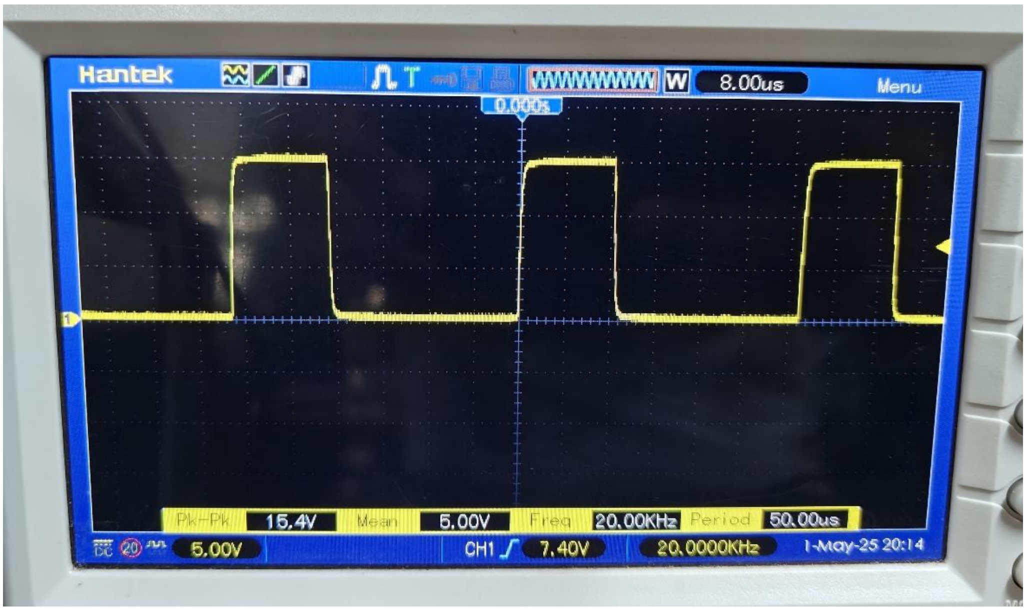
If you're driving a **high-side MOSFET** (like in a half-bridge), the **bootstrap capacitor** is used to provide gate voltage above the source.

But for TLP250, which is **not bootstrap-based**, the **capacitor is usually a bypass capacitor** between **Vcc and GND**

Output from the gate driver for 69.7% duty cycle



Output from the gate driver for 33.3% duty cycle



Inductor Design and Fabrication :

Objective:

Design and fabricate a 4 mH inductor suitable for use in a buck-boost converter operating around 100V input, with capability for both step-up and step-down modes.

$L=(\mu_0 \cdot \mu_r \cdot A \cdot N^2)/l$

1. Core Selection:

Core Type: EE55 ferrite core (MnZn material) chosen for high-frequency performance and minimal core losses.

- **Core Parameters:**
  - **A(Effective Area):** ~1.5 cm^2
  - **L(Magnetic Path Length):** ~8.5 cm
  - **B:** ~0.35 T
  - **μr:** ~2000 (assumed for gapped ferrite)

2. Inductance Calculation:

- **Target Inductance (L):** 4 mH
- **Frequency:** ~20 kHz
- **Estimated Turns (N):** ~85–100 turns (adjusted empirically based on actual inductance measured using LCR meter)
- **Wire:** AWG 20 enameled copper wire (current rating ~1.5–2A continuous)

3. Saturation Current Check:

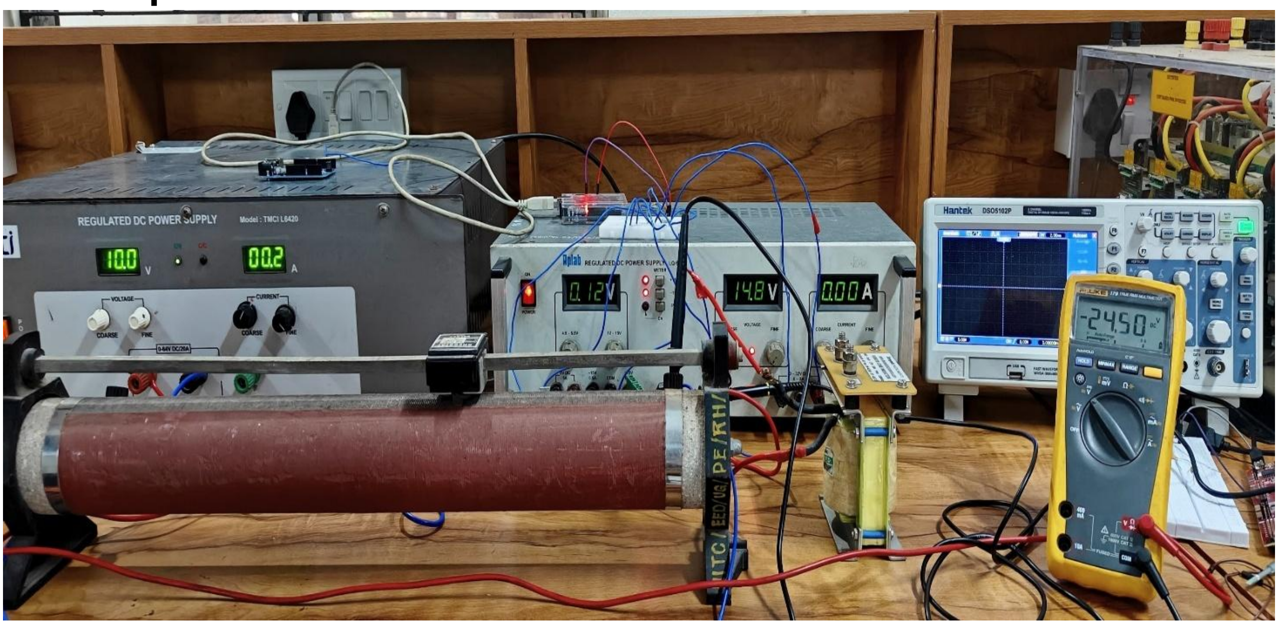
With the gapped core, a saturation current of around **1.5–2 A** was achieved, which was within expected limits for the converter's operation.

4. Fabrication:

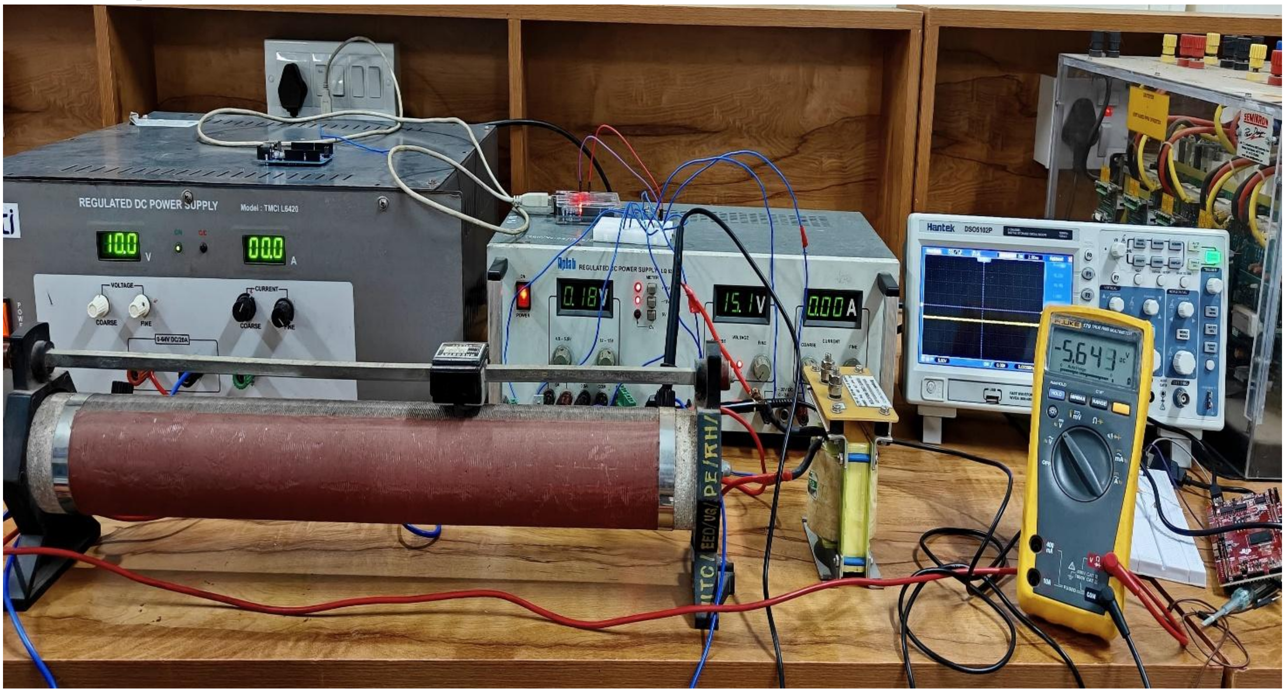
- **Winding:** 90 turns of AWG20 wire.

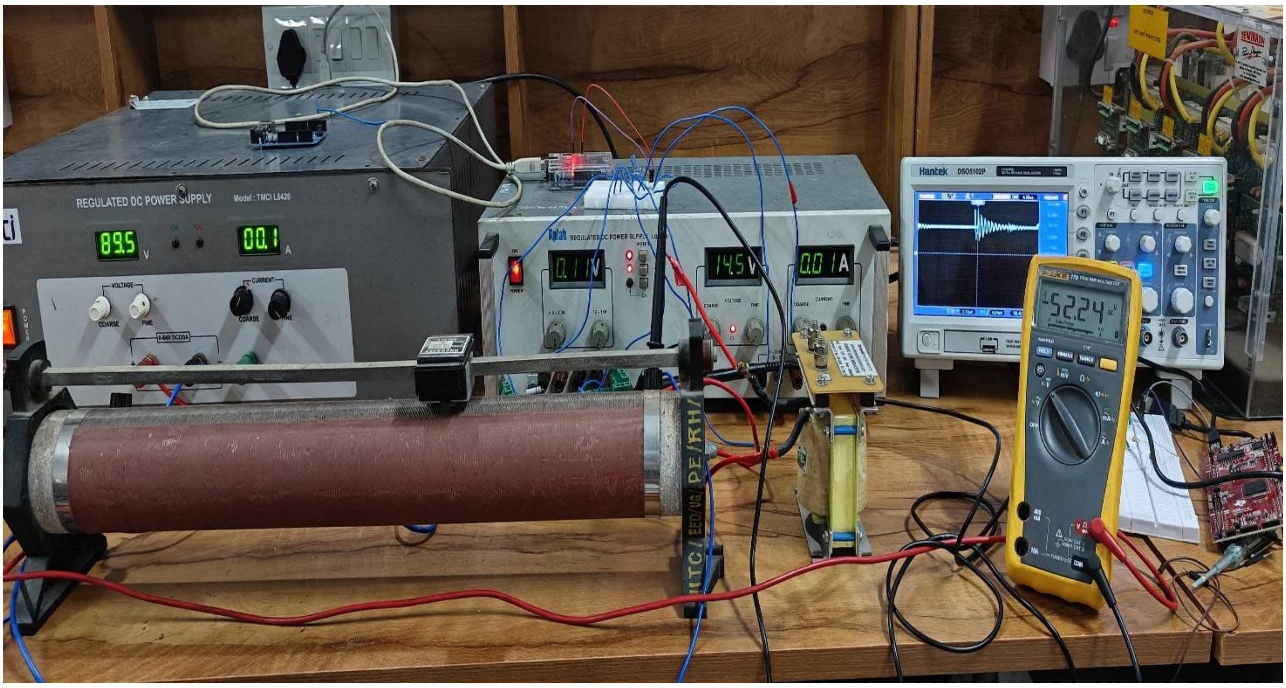
Result:

Boost operation



Buck operation





Application:

A buck-boost converter is ideal in **UPS (Uninterruptible Power Supply) systems**. In **buck mode**, it steps down rectified AC (~100 V DC) to charge a **48 V battery bank**. In **boost mode**, during a power outage, it steps up the battery voltage (~100 V) to **230 V DC**, which is then inverted to AC to power connected devices. This dual functionality ensures reliable charging and uninterrupted power delivery in a single compact design.

Conclusion:

This project successfully demonstrates a buck-boost converter capable of regulating output voltage under varying input conditions using an IRF740 MOSFET driven by the isolated TLP250 gate driver. The converter design, including calculated inductor and capacitor values, ensures efficient energy conversion with acceptable ripple levels. Its practical relevance is evident in renewable energy systems and other applications requiring stable voltage from variable power sources.

-----------------------------------THE END---