BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

Department of Electrical and Electronic Engineering

Course No. : EEE 316 sessional
Course Title : Power Electronics Laboratory **Section :** B1

Project Title : NTELLIGENT BATTERY CHARGER WITH VARIABLE DC OUTPUT AND AUTO SHUTDOWN

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Abstract:

The project is about designing a battery charger with variable DC output using a Buck converter and an auto cutoff feature. The charger is designed to charge different types of batteries such as lead-acid, Li-ion etc. The charger is built using an AC-DC converter (uncontrolled full wave rectifier) circuit with LC filter that is capable of converting an input alternating voltage to a ripple free constant output voltage. The rectified output voltage is varied using a buck converter which switching frequency and duty cycle are controlled by a pulse generating circuit using IC SG3524 that enable the converter to vary the final output voltage for different type of battery using potentiometer.

The charger also includes an auto cutoff feature and auto charging that stops the charging process when the battery is fully charged. This is achieved by using 12 relays, a microcontroller and MOSFET. The charger is designed with safety features such as over-voltage protection, over-current protection, and reverse polarity current flow protection. These safety features ensure that the battery is not overcharged, and the charging process is halted in case of any faults.

List of Components:

- Step down transformer (220V/12V) 3000mA
- Silicon Diodes (1N4001)
- Capacitors (1000uF,3300uF, 220uF,0.01uF)
- Inductors (100mH)
- Resistors (10, 100, 220,4.7k,6.8k,15k,2k,1k, 10k)
- Lithium Ion Battery - 2 pieces (each rated 3.7V)
- SG3524
- 10k potentiometer
- Arduino UNO
- Voltage measurement IC
- MOSFET IRF 250
- Jumper Wires

Calculations:

Switching Pulse Generation Circuit

Switching pulses are generated by using SG3524 IC which is powered with a rectifier circuit. The frequency of the pulse is dependent on the values of R_T and C_T.

Switching frequency $f = \frac{1.3}{R_T C_T}$. We used R_T = 1k$\boldsymbol{\Omega}$ and C_T = 0.1μF. So, f = 13 kHz.

Buck Converter Circuit

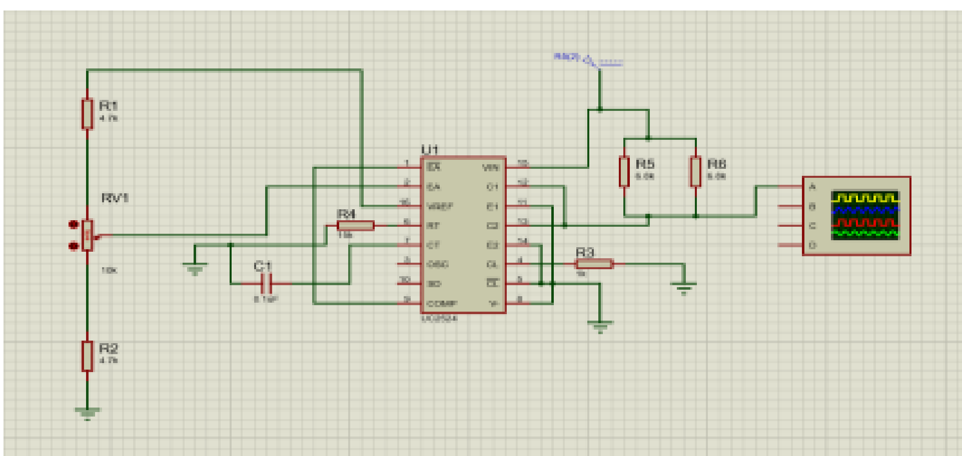
$$L_{min} = \frac{(1-k)R}{2f}$$

From the circuit, equivalent resistance R ≅ 200 $\boldsymbol{\Omega}$.
So, for k = 0.1, L_{min} = 6.92 mH
For k = 0.9, L_{min} = 0.7 mH
We used a 5mH inductor in buck converter, which is shorter than the L_{min} value. But it is okay as we would not increase our duty cycle absolute maximum and we needed to increase the output current by the ferrite core inductor we used.

$$C_{min} = \frac{1-k}{16Lf^2}$$

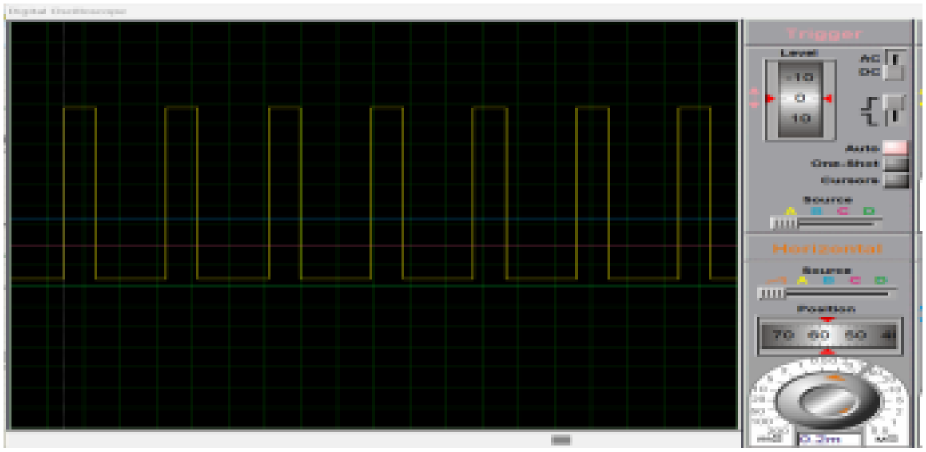
L = 5 mH.
So, for k = 0.1, C_{min} = 70nF
For k = 0.9, C_{min} = 7 nF.
We chose 1000 μF capacitor, which is way above the limiting value.

Proteus circuit simulation for Pulse Circuit:

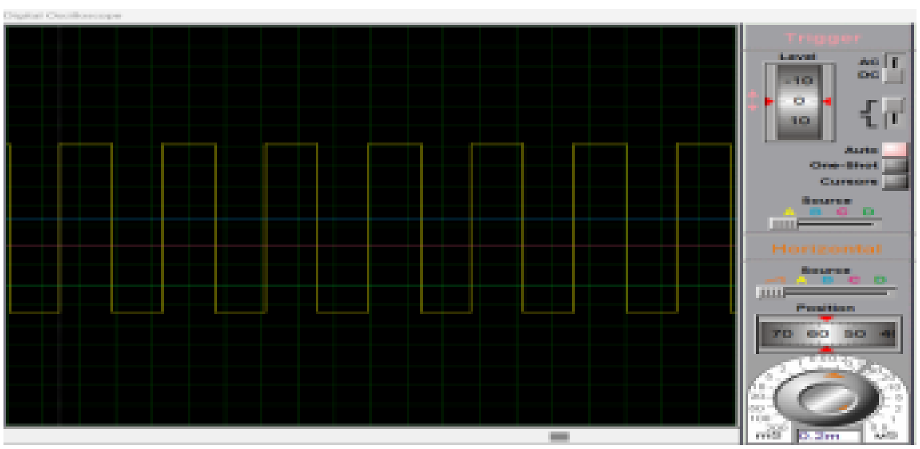


Pulse signal of proteus:

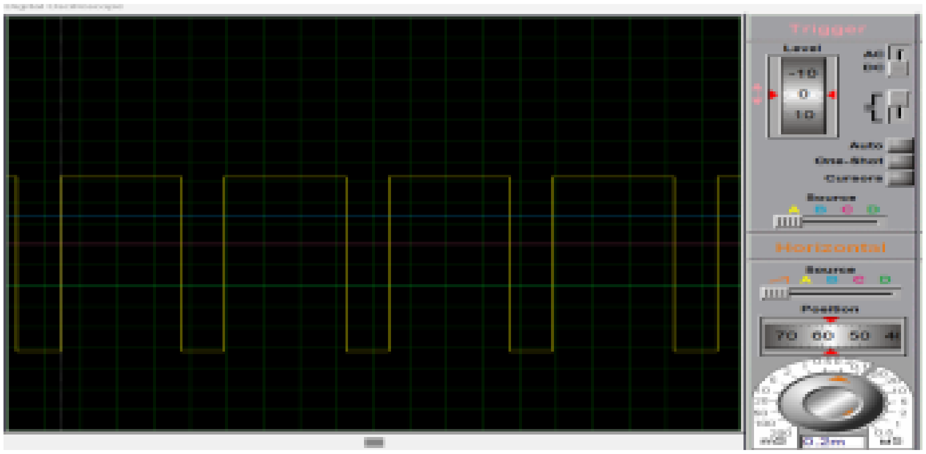
25% duty cycle:



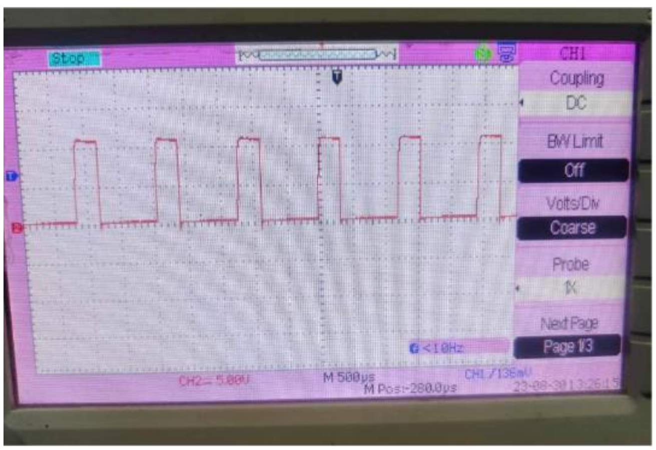
50% duty cycle:



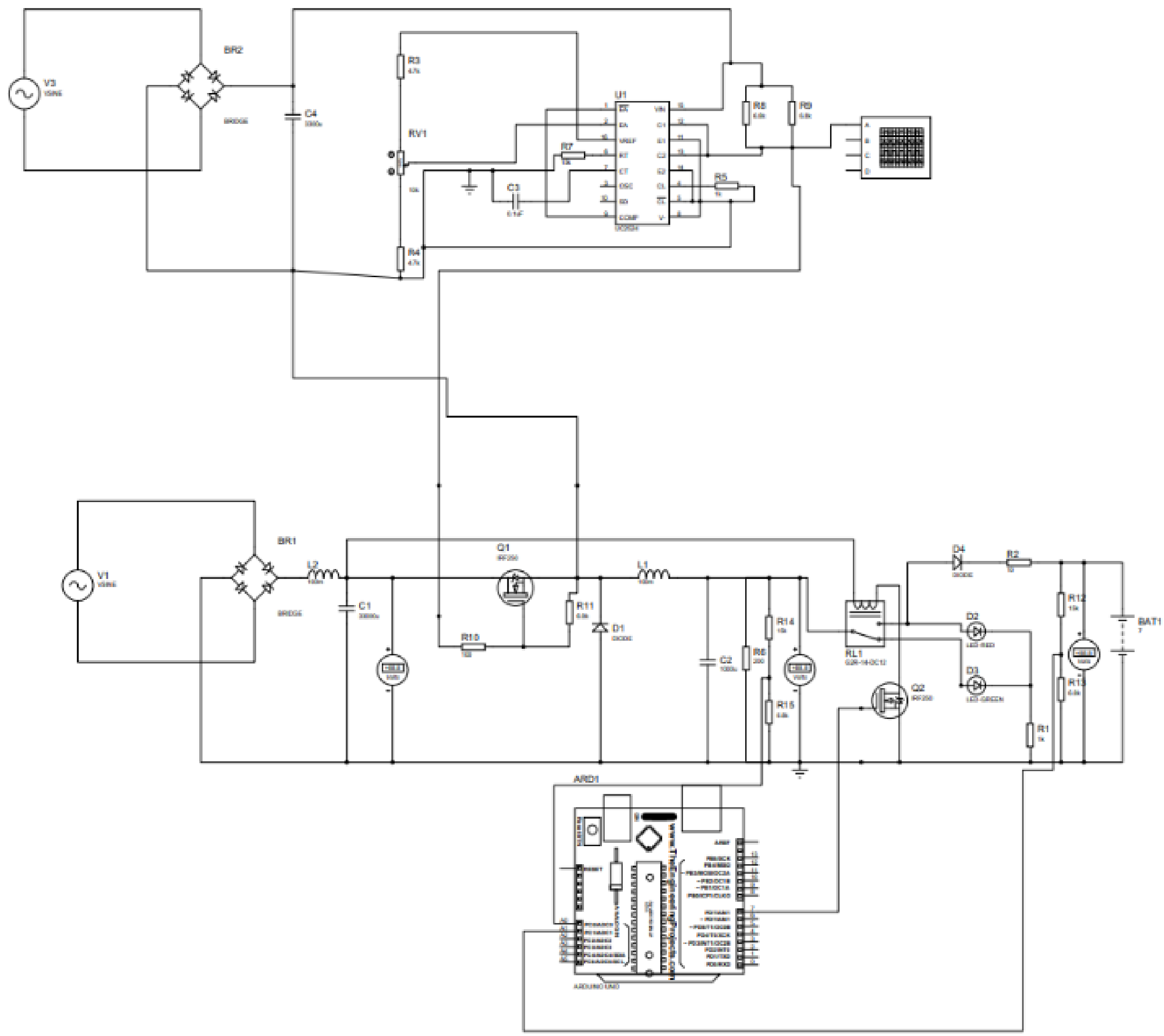
75 % duty cycle:



Oscilloscope output



Proteus circuit diagram for project:

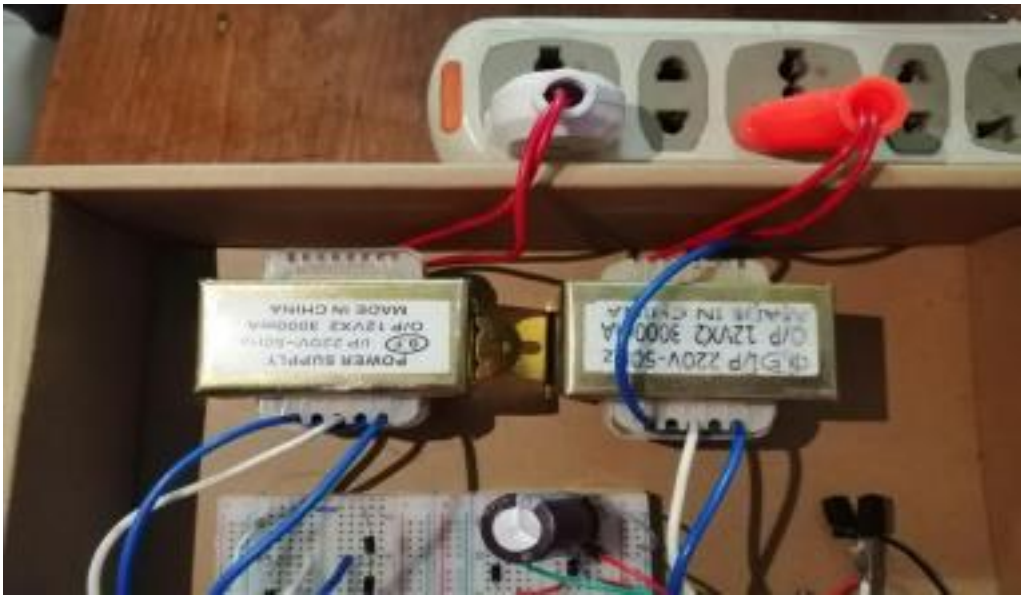


Hardware Implementation

Step down transformer:

We have used a 220V/12V transformer. It is a center tapped transformer. Input voltage is almost 220Vrms and the output voltage of the transformer is 12V rms. The current rating of the transformer is 3000 mA.

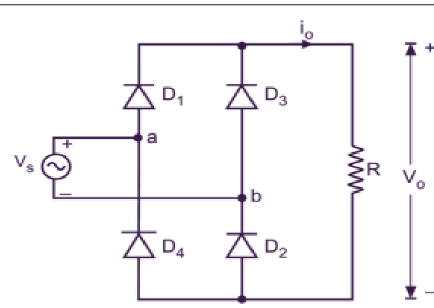
Turns ration = 220/12 = 18.33



Rectifier and filter:

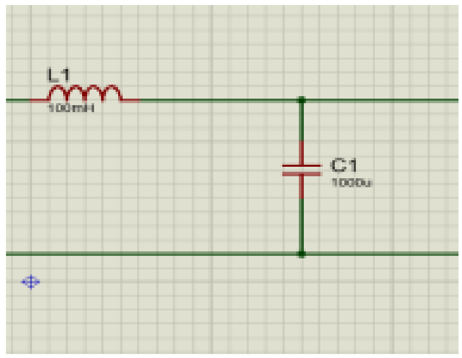
We have used bridge diode as full wave uncontrolled rectifier. The data table of the rectifier circuit are as follows.

Pulse Circuit	**Input Transformer**	**Output of the Transformer**
	198V	13.5V
	After rectification(Avg)	**After Filtering**
	16.8V	16.9V
	Ripple	
	0.2V	
Buck Circuit	**Input Transformer**	**Output of the Transformer**
	198V	13V
	After rectification(Avg)	**After Filtering**
	14.75V	14.5V
	Ripple	
	0.2V	

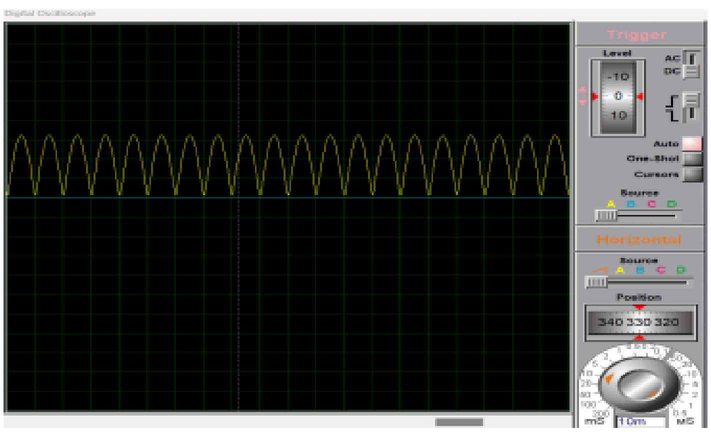


We have used a LC filter with 100mH inductor in series and 1000uF capacitor in parallel which acts as a filter by removing the high frequency ripple from the output voltage.

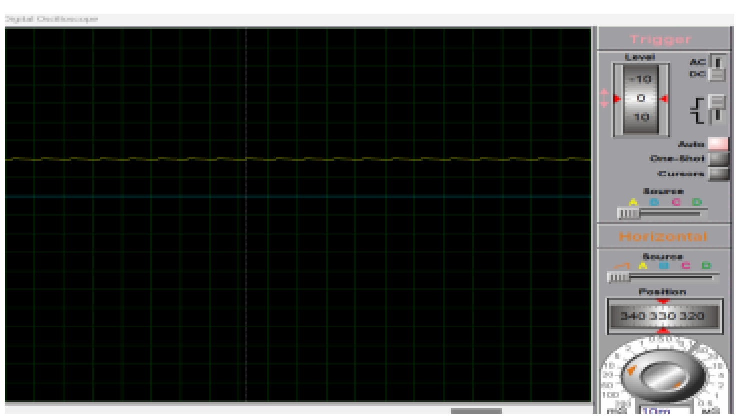
LC filter:



Output voltage of rectifier without capacitor:



Output voltage with capacitor:

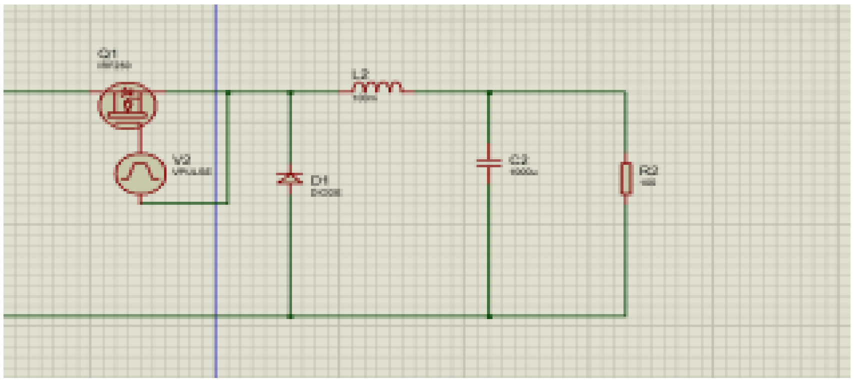


Buck converter:

Buck converter is a step-down converter. It can be controlled by changing the duty cycle of the switching pulse. We have used IRF 250 MOSFET as switch and gate pulse is applied between the gate and source of the MOSFET.

$V_o = k*V_{in}$. Here, k is the duty cycle.

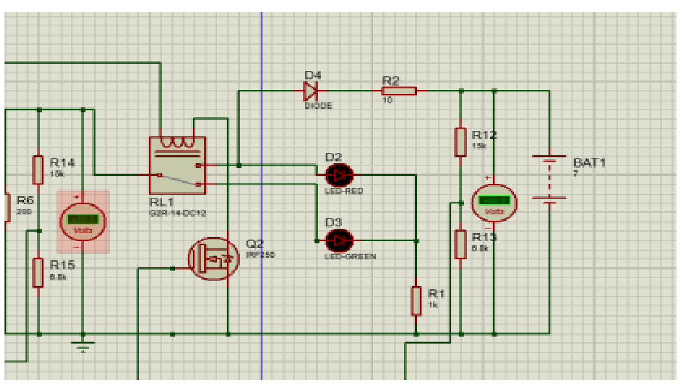
Buck converter Circuit diagram:



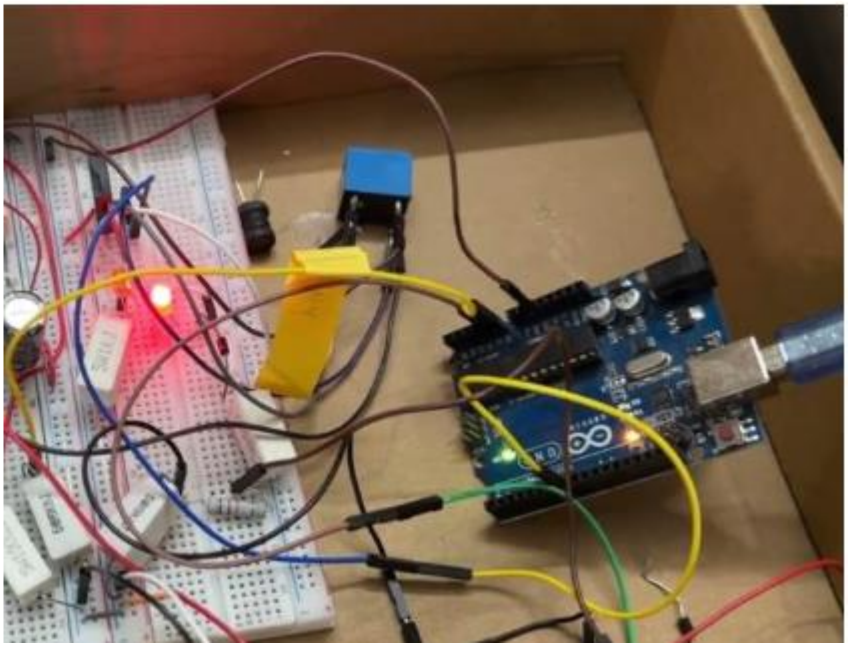
Auto cutoff circuit and auto charging circuit:

Relay coil is supplied with voltage form the rectifier output and the coil is connect to the ground through a MOSFET. Again, the MOSFET is driven by a microcontroller. When the MOSFET is on, the relay coil gets current and SPDT pole changes its position from the NO (Normally Open) position to NC (Normally Close) position. NO position is connected with the Green indicator which indicates the battery is not charging. NC is connected to the positive terminal of the battery through a series diode and 10-ohm series power resistor. The resistor limits the short circuit current and the diodes prevents the back flow of current form the battery.

Circuit diagram of Auto Cutoff Circuit:



Hardware implementation of auto cutoff circuit:

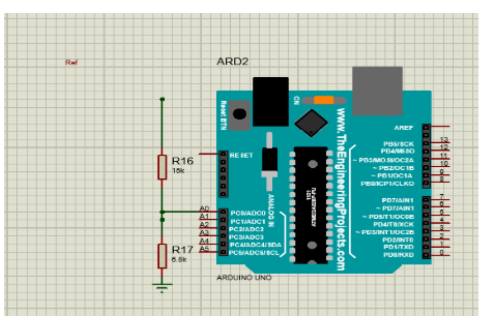


Necessary Codes for Auto Cutoff:

Arduino UNO has several analog pin (A0,A1,A2,A3,A4,A5).Arduino command converts the input voltage range, 0 to 5 volts, to a digital value between 0 and 1023. This is done by a circuit inside the microcontroller called an analog-to-digital converter or ADC which returns a number between 0 and 1023 that is proportional to the amount of voltage being applied to the pin. However, our voltage range is within 0V – 16V. For that reason, we have used voltage dividers of 15k and 6.8k to keep the output voltage within safe limit.

In Arduino code, for each voltage reading five values of the voltage are read and using this value average value is calculated. This method helps us to remove the adverse effect of ripple on auto cutoff and auto charging decision making. Again, we have defined two ratio 1.4 for auto cutoff and 2.2 ratio for auto charging decision.

Voltage divider for Arduino:



Codes:

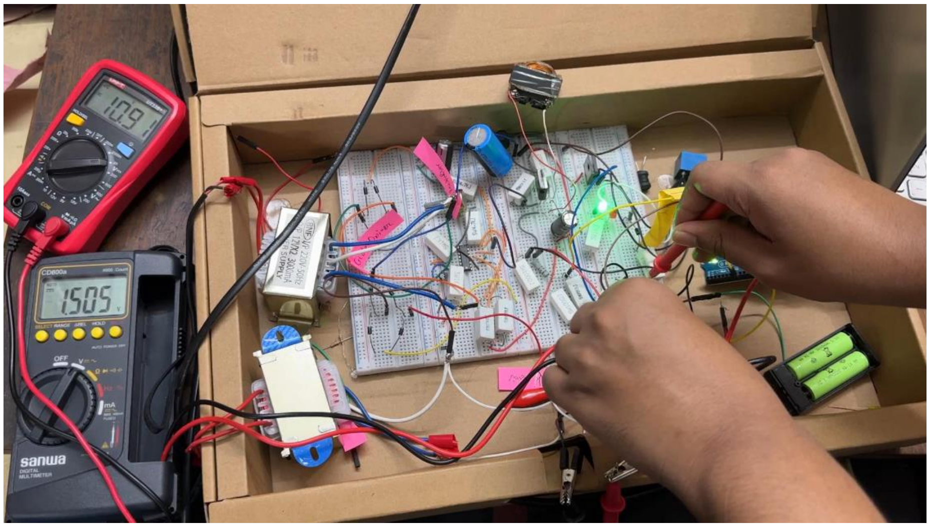
powerprojectautocutoff §

```
 int charging = 1;
float r_ref = 1.4;
void setup() {
  // initialize digital pin LED_BUILTIN as an output.
  pinMode(7, OUTPUT);
  pinMode(A0, INPUT);
  pinMode(A1, INPUT);
  Serial.begin(9600);
}
// the loop function runs over and over again forever
void loop() {
  delay(500);
  float r1 = analogRead(A0);
  delay(50);
  float b1 = analogRead(A1);
  delay(50);
  float r2 = analogRead(A0);
  delay(50);
  float b2 = analogRead(A1);
  delay(50);
  float r3 = analogRead(A0);
  delay(50);
  float b3 = analogRead(A1);
  delay(50);
  float r4 = analogRead(A0);
  delay(50);
  float b4 = analogRead(A1);
  delay(50);
  float r5 = analogRead(A0);
  delay(50);
  float b5 = analogRead(A1);
  delay(50);
  float reference=(r1+r2+r3+r4+r5)/5.0;
  float battery = (b1+b2+b3+b4+b5)/5.0;

  delay(100);
  float r = reference/(battery + 0.00001);

  if (charging == 1) {
    r_ref = 1.4;
  }
```

```
  float reference=(r1+r2+r3+r4+r5)/5.0;
  float battery = (b1+b2+b3+b4+b5)/5.0;

  delay(100);
  float r = reference/(battery + 0.00001);

  if (charging == 1) {
    r_ref = 1.4;
  }
  else if (charging == 0) {
    r_ref = 2.2;
  }

  if (r >= r_ref & r <= 4){
    digitalWrite(7, HIGH);
    charging = 1;
    delay(100);
  }
  else if (r < r_ref){
    digitalWrite(7, LOW);
    charging = 0;
    delay(100);
  }
  delay(500);
  Serial.println(reference);
  Serial.println(battery);
  Serial.println(r);
  Serial.println("end");
}
```

Complete hardware setup of our project:

Two voltage measurement IC are used to show the respective voltage across the battery and across the buck converter output. The range of voltage measurement is 3V – 30V. Our operating voltage range is within the safe voltage limit of voltage measurement IC limit. The left side of the display indicates the battery voltage and right side of the display indicates the buck converter output. Users must set the buck converter output by moving the 10k potentiometer according to the battery rating voltage.



Output Voltage:

The output voltage across output of buck converter can be seen in the red multimeter in the picture above. By changing the potentiometer, we can change output voltage.

Application

The project on Battery charger with variable DC output using converter with auto cutoff feature has various applications in different fields. We can adjust the reference voltage by rotating the knob and following the display of output voltage. User can set the output voltage according to their voltage. For example, a 4 V rated battery needs to be set 6V reference voltage to charge properly. Some of the significant applications are automotive industry, renewable energy, customer electronics, emergency power backup, hobbyist, and DIY Projects. In conclusion, the Battery charger with variable DC output using converter with auto cutoff feature has numerous applications in different fields. The charger's variable output voltage, safety features, and auto cutoff feature make it a versatile and efficient device for charging different types of batteries.

Challenges:

We have faced several challenges to implement our project. The inductor available in the market is not in very good quality and only a few inductance values are available in market. Charging state output voltage is lower than the no load output voltage. It indicates voltage regulation in our circuit is high as there are two series inductance, bridge diode and switch. For designing the control circuit, we have faced problems for this regulation. To solve this problem, we have set two different ratio one is 1.4 (used for Cut off) and other is 2.1 (used for auto charging).

Conclusion:

In conclusion, the project on Battery charger with variable DC output using converter with auto cutoff feature is a useful device for charging different types of batteries. The charger's variable output voltage, safety features, and auto cutoff feature make it an efficient and safe device for battery charging applications.

The project's DC-DC converter circuit is the heart of the battery charger, which converts a fixed input voltage to a variable output voltage. The variable output voltage feature allows charging of different types of batteries used in different applications.

The auto cutoff feature ensures that the battery is not overcharged, which increases the battery life and performance. The safety features such as over-voltage protection, over-current protection, and reverse polarity protection ensure safe charging of batteries.

The battery charger has various applications in different fields such as automotive, renewable energy, consumer electronics, emergency power backup, and hobbyist and DIY projects. The charger's versatility and efficiency make it an essential device for charging batteries in different applications.

In conclusion, the Battery charger with variable DC output using converter with auto cutoff feature is a useful device that provides a safe and efficient way of charging different types of batteries.