[PROJECT REPORT]

ON

Arduino Control Solar Charger

Submitted by

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<u>Approval Sheet</u>

This project report entitled " **Arduino Control Solar Charger**" by SHUVA BISWAS, SOUMYADIP PAUL ,SURAJ KUNDU & DEEP KARMAKAR is approved for the degree of B.Tech. (ECE) submitted to the Department of Electronics and Communication Engineering at KALYANI GOVERNMENT ENGINEERING COLLEGE, KALYANI under MAKAUT.

Examiners

DECLARATION

We certify that

1. The work contained in the project is original and has been done by us under the general supervision of our supervisor.
2. The work has not been submitted to any other institute for any degree or diploma.
3. We have followed the guidelines provided by the institute in writing of the project.
4. We have conformed to the norms and guidelines given in the Ethical Code of Conduct of the Institute and University.

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Thanking You

Abstract

The Arduino Controlled Solar Charger project represents a sophisticated and sustainable energy solution designed to harness solar power efficiently for charging Li-ion batteries. With a foundation built on the NodeMCU ESP8266 microcontroller, Buck-Boost converter XL6009, solar panels, Li-ion batteries, a display module, INA 219 current sensor, and various supporting components, the system aims to achieve optimal energy conversion, storage, and user-friendly control.

The project's objectives include the design of a comprehensive solar charging system with Arduino control, the implementation of advanced voltage regulation, meticulous monitoring and control through the NodeMCU ESP8266, and the integration of a user-friendly display module. The INA 219 current sensor ensures precise current monitoring, contributing to the overall optimization of the charging process.

The components work together seamlessly in a well-defined system architecture, where solar panels interface with the Buck-Boost converter XL6009 to regulate voltage for efficient battery charging. Li-ion batteries are managed through the Buck-Boost converter, with the NodeMCU ESP8266 serving as the control hub. Users interact with the system through the display module, gaining real-time insights and control capabilities.

Challenges, including voltage and temperature regulation, are addressed with the Buck-Boost converter XL6009, thermistor, and Mosfet (IRF9540N), ensuring stable charging conditions and safeguarding against overheating.

Results indicate exceptional charging capabilities, with the system providing optimal voltage regulation and precise current monitoring. The user-friendly display module enhances the overall experience, offering real-time status updates and control options.

Future improvements may involve the implementation of advanced control algorithms, integration of additional environmental sensors, and enhanced connectivity options for remote monitoring and control.

1.Introduction:

In an era where sustainability and energy efficiency are at the forefront of technological advancements, the integration of Arduino microcontrollers with solar charging systems stands as a beacon of innovation. The Arduino-controlled solar charger represents a harmonious marriage of renewable energy and intelligent control, offering a dynamic and eco-friendly solution to power challenges. This report explores the intricate synergy between Arduino technology and solar charging, delving into the components, working principles, and the myriad applications that make this system a pivotal player in the realm of sustainable energy. As the world grapples with the imperative shift towards greener technologies, understanding the capabilities and implications of Arduino-controlled solar chargers becomes not only pertinent but a catalyst for a more sustainable future.

2.Proposed System:

The proposed system, an advanced Arduino Controlled Solar Charger, aims to enhance the efficiency and usability of solar energy harvesting and storage. Building upon the success of the current system, the proposed enhancements focus on increasing energy conversion rates, implementing advanced monitoring and control features, and ensuring adaptability to future technological developments.

3.System Architecture:

The system architecture is designed to convert solar energy into electrical power, regulate the voltage, and charge the Li-ion battery. The NodeMCU ESP8266 acts as the central control unit, monitoring and regulating various parameters. The Buck-Boost converter adjusts the voltage from the solar panels to meet the battery charging requirements.

4.Hardwire Requirements:

The proposed system includes the following components.

[1] NodeMCU ESP8266

[2] Buck boost converter XL6009

[3] Solar panels

[4] Li-ion Batteries

[5] Oled Display Module

[6] INA 219 Current sensor

[7] Thermistor 10k ohm

[8] Some Resistors, Capacitors, Inductor, Wires, Breadboard, & MOSFET (IRF9540N)

4.1. NodeMCU ESP8266

NodeMCU is an open-source firmware and development kit based on the ESP8266 Wi-Fi SoC (System-on-a-Chip). The ESP8266 is a low-cost Wi-Fi chip that is used for Internet of Things (IoT) projects, and is capable of connecting to a Wi-Fi network and transmitting data over the internet.

The NodeMCU firmware is based on the Lua scripting language, which is easy to learn and can be used to program the ESP8266. The NodeMCU development kit includes a USB-to-serial converter and a voltage regulator, making it easy to connect to a computer and power the ESP8266.

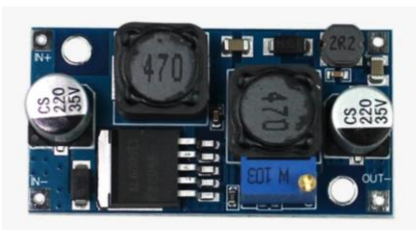
NodeMCU can be used for a wide range of projects, including home automation, sensor networks, and smart devices. It is compatible with a variety of sensors and actuators, and can be programmed using the Arduino IDE as well as the Lua programming language.

One of the advantages of NodeMCU is its low cost and ease of use, making it an ideal platform for hobbyists and DIY enthusiasts who want to experiment with IoT projects without investing a lot of money or time. Additionally, the large and active NodeMCU community provides ample support and resources for beginners and experts alike.

NodeMCU ESP8266

4.2. Buck boost converter (XL6009)

The XL6009 is a versatile DC-DC buck-boost voltage regulator module designed for efficiently converting input voltages between 3V and 32V to adjustable higher or lower output voltages. Operating as both a buck (step-down) and boost (step-up) converter, it accommodates diverse power supply requirements. With adjustable output voltage and relatively high efficiency, the XL6009 is employed in various applications, including LED drivers, battery-powered devices, and electronics requiring stable voltage levels. Users can fine-tune output voltages using external resistors, making it a popular choice for projects where power flexibility and efficiency are paramount.



Buck boost converter (XL6009)

4.3. Solar Panel

A solar cell, also known as a photovoltaic cell, is a semiconductor device that converts sunlight directly into electrical energy through the photovoltaic effect. When exposed to sunlight, the cell generates an electric current as photons in sunlight excite electrons in the semiconductor material, creating a flow of electricity. Solar cells are fundamental components of solar panels, harnessing renewable energy for applications ranging from powering small electronic devices to generating electricity for residential and commercial purposes.

Solar Panel

4.4. Li-ion Batteries:

A Lithium-Ion (Li-ion) battery is a rechargeable energy storage device widely used in electronic devices. Known for its high energy density, lightweight design, and long cycle life, Li-ion batteries power smartphones, laptops, and electric vehicles. They operate on the movement of lithium ions between positive and negative electrodes, allowing for efficient energy storage and release. Despite their advantages, proper charging and discharging management are crucial to prevent safety issues, such as overheating and capacity degradation.

Li-ion Batteries

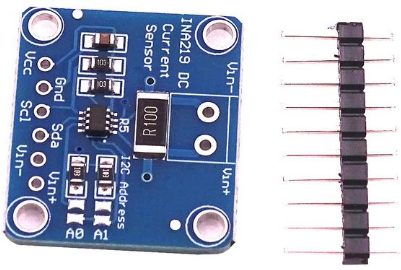
4.5. Oled Display Module:

An OLED (Organic Light-Emitting Diode) display is a type of flat-panel display technology that uses organic compounds to emit light when an electric current is applied. OLEDs offer vibrant colors, high contrast ratios, and fast response times. These displays are known for their thin and flexible nature, allowing for curved screens. Commonly used in electronic devices such as smartphones, TVs, and wearable gadgets, OLEDs provide a visually appealing and energy-efficient means of displaying information.

Oled display module:

4.6. INA 219 Current sensor

The INA219 is a high-side DC current sensor with voltage measurement capabilities. With its integrated precision amplifier and analog-to-digital converter, the INA219 accurately measures current up to 3.2A and voltage up to 26V. Ideal for power monitoring in electronic systems, it provides digital output over I2C, allowing precise monitoring and control. Its small form factor and high accuracy make the INA219 a popular choice for applications such as energy monitoring, battery management, and power supply characterization in various electronic projects.



INA 219 Current sensor

4.7. Thermistor:

A thermistor is a temperature-sensitive resistor that exhibits a change in resistance with variations in temperature. Divided into two types, NTC (Negative Temperature Coefficient) and PTC (Positive Temperature Coefficient), its resistance decreases with rising temperature in NTC thermistors and increases in PTC thermistors. Commonly used in temperature measurement and control applications, thermistors find extensive use in electronics, automotive systems, and industrial equipment due to their precision and sensitivity to temperature changes.

Thermistor

4.8. Other Components

Resistors, capacitors, and inductors are used for filtering and regulating electrical signals. Wires connect the components on the breadboard, providing the necessary electrical connections. and the MOSFET (IRF9540N) may serve as a switch or a control element in the circuit.

5. Implementation:

Software Implementation:

1. Proteus
    - Proteus is a software package used for electronic design automation (EDA). It is widely employed for designing and simulating microcontroller-based systems, including both hardware and software components. Proteus is particularly useful for its ability to simulate the entire microcontroller-based system before it is physically implemented.
2. **Arduino Programming:**
    - Write an Arduino program to read the voltage and current data from the sensors.
    - Implement the MPPT algorithm in the Arduino code to determine the optimal duty cycle for the DC-DC converter.
    - Using library :
        1. LiquidCrystal.h
        2. Wire.h
        3. Adafruit_INA219.h
        4. TimerOne.
3. **Control DC-DC Converter:**
    - Use the Arduino PWM output to control the duty cycle of the DC-DC converter.
4. **Battery Charging Control:**

- Implement battery charging control in the Arduino code to ensure the battery is charged safely.

5. **Communication:**
    - If desired, implement communication protocols (e.g., UART, I2C) for monitoring and controlling the system.

Circuit Design Steps:

1. **Voltage and Current Sensing:**
    - Connect voltage and current sensors to measure the solar panel's output. Use these sensors to provide feedback to the Arduino about the panel's operating conditions.
2. **MPPT Algorithm Circuit:**
    - Design an MPPT algorithm circuit. This typically involves comparing the actual power output with the maximum possible power at different voltage and current levels. The algorithm adjusts the operating point to maximize power.
3. **Arduino Interface:**
    - Connect the output of the MPPT algorithm circuit to the Arduino Uno. The Arduino reads the voltage and current data from the sensors and implements the MPPT algorithm to determine the optimal operating point.
4. **Control DC-DC Buck Converter:**
    - Connect the output of the Arduino to control the DC-DC buck converter. The Arduino adjusts the duty cycle of the buck converter based on the MPPT algorithm's output to maintain the maximum power point.
5. **Battery Charging and Protection:**
    - Connect the output of the buck converter to charge the battery. Implement battery charging and protection circuitry to ensure safe and efficient charging.
6. **Diodes for Protection:**
    - Use diodes to prevent reverse current flow from the battery to the solar panel during low-light or nighttime conditions.

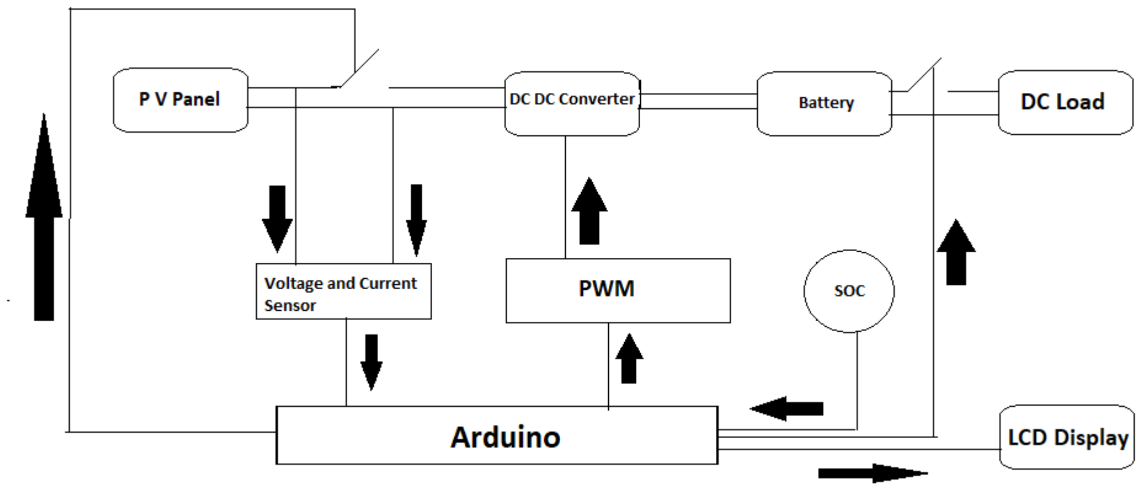


Figure- Block Diagram[1]

Code -

```
#include <TimerOne.h>
#include <Adafruit_INA219.h>
#include <Wire.h>
#include <LiquidCrystal.h>
//Adafruit_INA219 ina219;
LiquidCrystal lcd(12, 11, 5, 4, 3, 2);
Adafruit_INA219 ina219;
float sensorValue1 = 0;
float sensorValue2 = 0;
float voltageValue = 0;
float currentValue = 0;
float Power_now = 0, Power_anc = 0, voltage_anc = 0;
float delta = 3;
float pwm = 128;
void setup()
{
  pinMode(6, OUTPUT);
```

```
  lcd.begin(16, 2);
  uint32_t currentFrequency;
  if (! ina219.begin())
  {
  lcd.display();
  lcd.setCursor(0, 0); // top left
  lcd.print("Failed to find INA219 chip");

    while (1) { delay(10); }
  }
}

void loop()
{
  sensorValue1 = analogRead(A0);
  //sensorValue2 = analogRead(A1);
  voltageValue = (sensorValue1 * 5.0 / 1023.0) * 5;
  //currentValue = (sensorValue2 * 5.0 / 1023.0);
  currentValue = ina219.getCurrent_mA()/1000;
  Power_now=voltageValue*currentValue;

  lcd.display();
  lcd.setCursor(0, 0);
  lcd.print("P=");
  lcd.print(Power_now);
  lcd.print("W PWM=");
  lcd.print(pwm);
  lcd.setCursor(0, 1);
  lcd.print("V=");
  lcd.print(voltageValue);
  lcd.print("V I=");

  lcd.print(currentValue);
  lcd.print("A");
  //Serial.print("Current:       ");
  //Serial.print(currentValue);
  //Serial.println(" mA");




  if (Power_now > Power_anc)
  { if (voltageValue > voltage_anc)
      pwm = pwm - delta;
    else
      pwm = pwm + delta;
  }
```

```
else
{
  if (voltageValue > voltage_anc)
    pwm = pwm + delta;
  else
    pwm = pwm - delta;
}

Power_anc = Power_now;
voltage_anc = voltageValue;
if (pwm < 20)
  pwm = 20;
if (pwm > 150)
  pwm = 150;

analogWrite(6, pwm);
}
```

Circuit Diagram:

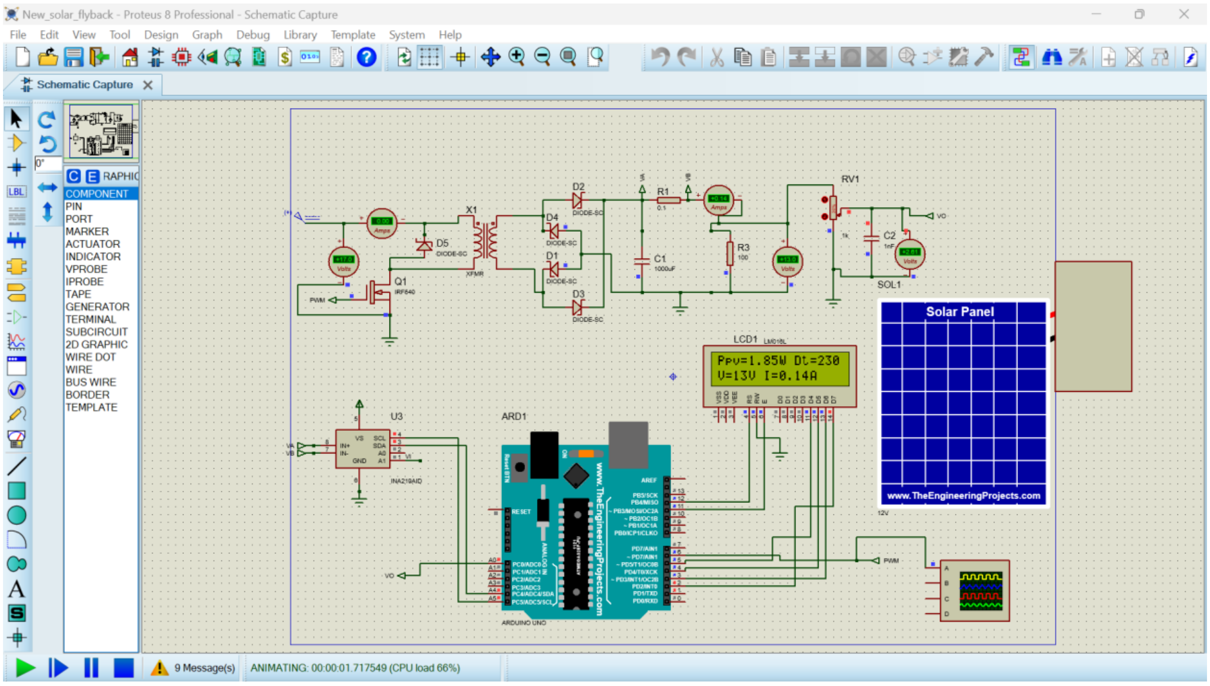


Figure- Circuit Diagram [2]

Output [Output Power]:

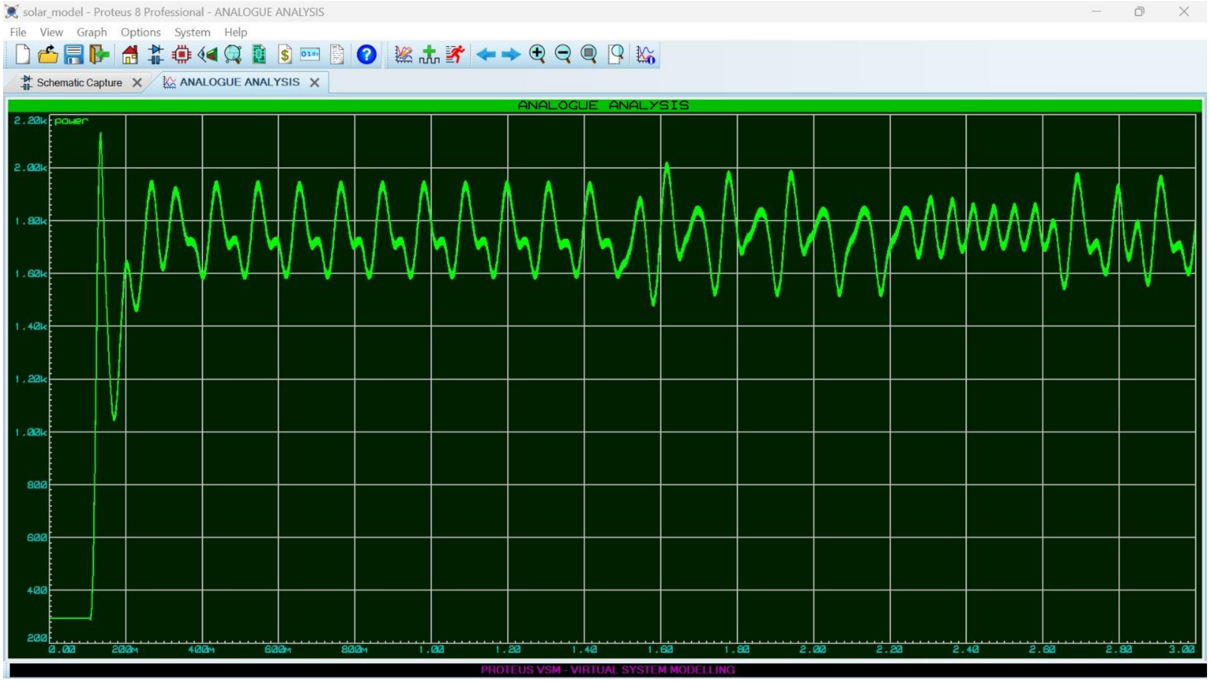


Figure- Output [Output Power][3]:

Output [Input Power]:

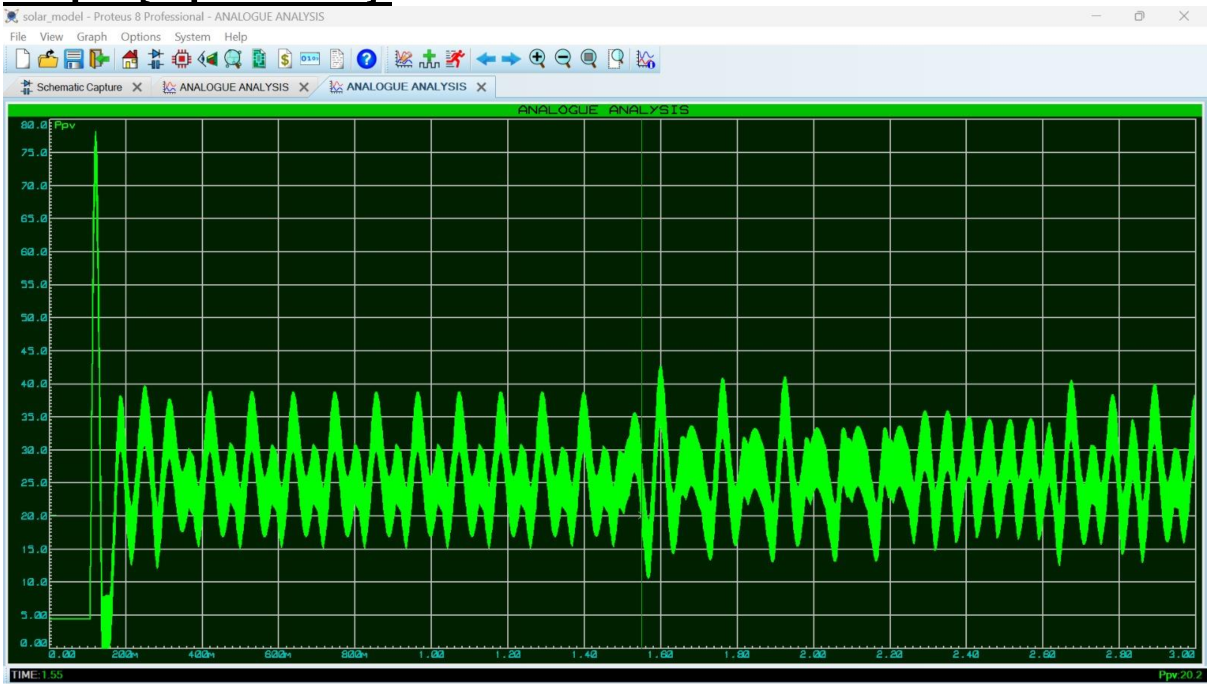
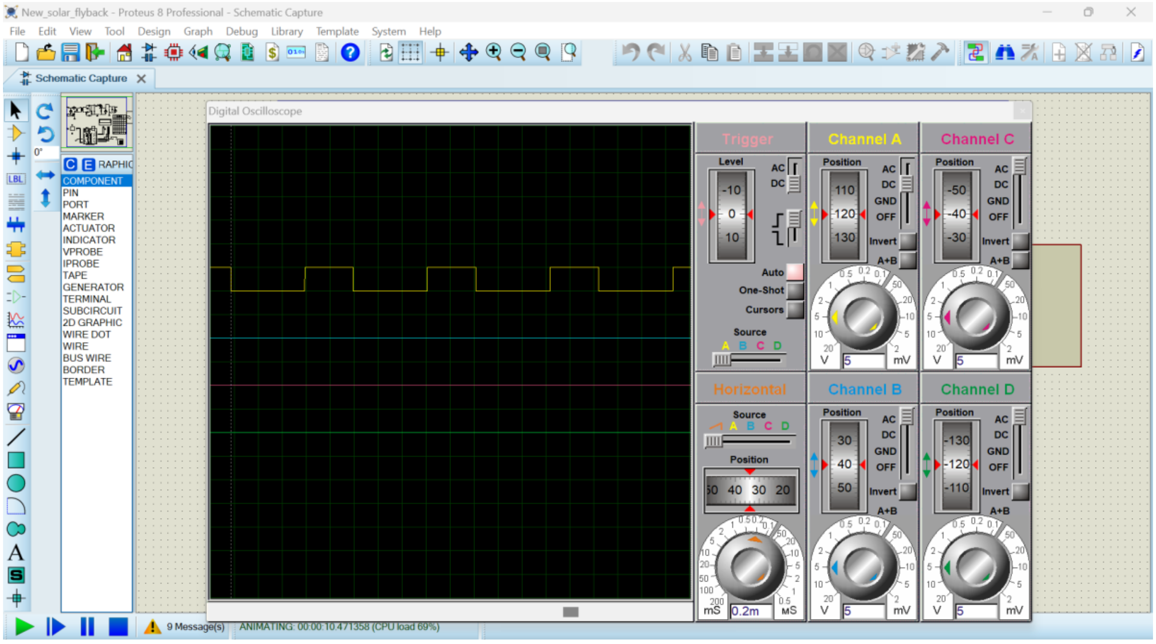


Figure- Output [Input Power] [4]:

6.Result : A prototype was built using various electronic components, this prototype was tested block by block before the realization of the global circuit. The DC-DC converter is the most critical part, the experimental results are presented in figure 1. The LCD screen was used to display the results obtained. The observations ahead show the results of the Software implementation. The PWM signal was generated with Arduino Uno board. The output voltage can be controlled by the duty cycle with the following expression - $x = \frac{Vout}{Vin}$



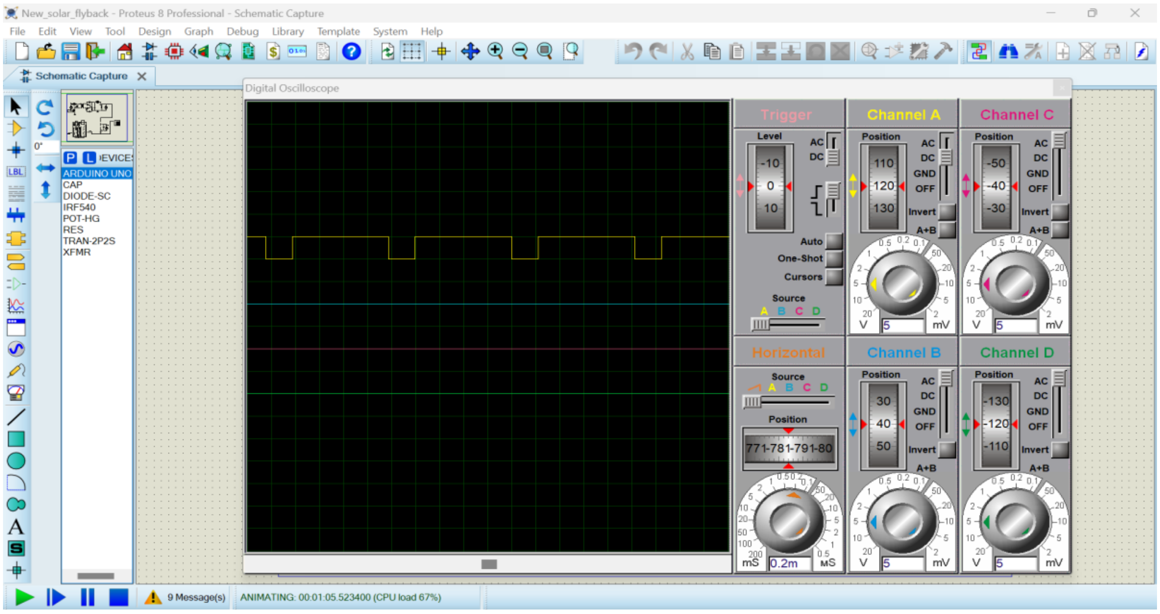


Figure 5 shows the PWM signal and the output voltage of the DC-DC converter for the different Duty cycle.

7.Benefits

The proposed system offers several key benefits:

- ➔ Optimized Energy Harvesting: Improved algorithms lead to increased energy conversion rates, ensuring more efficient use of available solar power.
- ➔ Intelligent Adaptability: The system adapts to changing environmental conditions and learns from historical data, optimizing charging patterns for increased battery lifespan.
- ➔ Remote Monitoring and Control: Cloud connectivity allows users to access and control the system remotely, enhancing convenience and accessibility.
- ➔ Future-Ready Design: The modular and expandable architecture ensures that the system can easily incorporate advancements in technology and additional sensors for evolving needs.
- ➔ User-Friendly Interface: The inclusion of a display module and cloud connectivity provides users with a convenient and accessible interface for monitoring and controlling the system.

8.Disadvantages

- ➔ Complex Implementation: The integration of advanced features, such as machine learning and cloud connectivity, may increase the complexity of system implementation, requiring advanced technical expertise.
- ➔ Cost: The addition of sophisticated components and features may lead to an increase in the overall cost of the system, potentially limiting its affordability for certain applications.
- ➔ Power Dependency: The system's effectiveness heavily relies on the availability of sunlight for efficient energy harvesting, making it less suitable for locations with limited sunlight.
- ➔ Maintenance Challenges: Advanced features may introduce additional points of failure or require more frequent maintenance, increasing the complexity of system upkeep.
- ➔ Environmental Factors: The system's performance may be influenced by environmental factors such as extreme weather conditions, which could impact solar panel efficiency and overall system reliability.

9.Future Enhancements:

- **Smart Charging Algorithms:** Implement intelligent charging algorithms that consider battery health, usage patterns, and weather conditions. This ensures dynamic optimization of charging parameters for improved efficiency and battery longevity.
- **MPPT Integration:** Incorporate Maximum Power Point Tracking (MPPT) algorithms to dynamically adjust the solar panel's operating point, optimizing energy harvesting under varying sunlight conditions. This enhances overall system efficiency.

- **IoT Connectivity:** Integrate Internet of Things (IoT) capabilities for remote monitoring and control. This enables users to access real-time data, receive notifications, and adjust settings through a web or mobile interface, enhancing system accessibility and user convenience.
- **Enhanced Safety Features:** Strengthen safety mechanisms by adding overcurrent protection, reverse polarity protection, and short-circuit detection. Implement fail-safe measures to automatically halt the charging process in the event of critical faults, ensuring user and system safety.
- **Integration with Electric Vehicles:** The rise of electric vehicles presents an opportunity for integrating solar charging solutions into the transportation sector. Solar panels on the roof or body of vehicles could contribute to the overall charging capacity, extending the range of electric vehicles.

10.Our Next Target

- Use of DC-DC Converter in Circuit
- Battery & Temperature monitoring using Mobile App
    - Battery Status
    - Battery Percentage
    - Temperature
    - Battery Usage graph

11.Conclusion

The Arduino-controlled solar charger provides an efficient and intelligent solution for harnessing solar energy and charging Li-ion batteries. The integration of various components ensures precise control, monitoring, and user feedback, making it a reliable and sustainable energy management system. Employing Arduino for solar charger control proves to be a judicious choice, bringing efficiency and adaptability to solar energy systems. Arduino's programmability enables precise regulation of charging processes, ensuring optimal energy utilization. The platform's compatibility with an array of sensors enhances real-time monitoring, allowing for dynamic adjustments based on environmental factors. This adaptability is crucial for maximizing energy capture and storage in diverse conditions. Furthermore, Arduino's open-source nature fosters a collaborative community, facilitating knowledge exchange and continuous improvement. The integration of Arduino in solar chargers not only offers a customizable and intelligent solution but also promotes accessibility in the realm of sustainable energy. Its versatility accommodates various setups, from off-grid installations to portable applications. As technology progresses, Arduino's role in enhancing solar energy solutions is poised to expand, contributing to the development of efficient, eco-friendly power systems. In summary, Arduino's control in solar chargers stands as a pivotal advancement, offering a scalable, adaptable, and community-supported approach to harnessing solar energy for a more sustainable future.

12.Reference

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