# MPPT Solar Charge Controller

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**ABSTRACT**

**Maximum Power Point Tracking (MPPT) solar charge controller utilizing a 5 V microprocessor , tailored for a 6 V lithium-ion battery system . The integration of an Optocoupler and MOSFET enhances the controller's efficiency and precision in tracking the solar panel's maximum power point . The microprocessor employs a sophisticated algorithm for dynamic adjustment of the operating point , ensuring optimal power extraction from the solar array . The use of an Optocoupler facilitates isolation , enhancing safety and reliability . The MOSFET component optimizes charge management , allowing for efficient energy transfer to the 6 V lithium-ion battery . This innovative MPPT solar charge controller design combines advanced microprocessor control with strategic component integration , presenting a robust solution for enhancing solar energy harvesting and storage systems. This MPPT solar charge controller, employing a PIC microprocessor, aims to enhance the efficiency of solar energy utilization. The project involves the integration of sophisticated MPPT algorithms into the microprocessor's control logic to dynamically track and extract maximum power from the solar panels. The PIC microprocessor facilitates real-time monitoring, allowing for precise control of charging parameters.**

## 1.INTRODUCTION

A Maximum Power Point Tracker, MPPT, is a high frequency DC to DC converter. It takes the DC input, from the solar panels in our case, and changes it to high frequency AC, and then rectifies it back down to a different DC voltage and current to exactly match the panels to the batteries. A MPPT controller "looks" for the point where the sharp peak occurs (below), and then performs a voltage/current conversion to change it to exact values that the battery requires. In reality, the peak will always vary due to changes in light conditions and weather.

## 2.LITERATURE REVIEW

The application of an MPPT, in the real world, is dependent on the array, climate, and seasonal load pattern. If we're looking for a current boost, we need a condition in which the Vpp is more than about 1V higher than the battery voltage.[1]. This is most effective when there is cold weather in the winter, because of the high energy use in residential areas, there
will be a substantial energy boost. In warmer weather, we might not be able to fulfill the Vpp condition unless the batteries are low in charge.[2].

The advantage of high frequency circuits can also contribute to it's disadvantage. These circuits can be designed with very high efficiency transformers and small components.[3]. Parts of the circuit work just like a radio transmitter and "broadcast" signals that cause radio and TV interference. Therefore, noise isolation and suppression becomes very important for a high frequency circuit.[4].Solar panel is an array of solar cells. The solar cell produces electrical energy when sunrays incident on the solar cells. maximum power point voltage.The purpose of a MPPT system is applying proper resistance after sampling output of PV cell in order to obtain maximum power.[5].The solar produces DC electricity as photons in sunlight hits on solar cells where semiconducting material (silicon) absorbs photons and generation of electricity takes place due to combinations of electron and holes pairs.[6]

An MPPT (Maximum Power Point Tracking) charge controller is an electronic device that regulates the charging of batteries from solar panels by maximizing the amount of power from the solar panel that is stored in the battery.[7].It does this by continuously adjusting the voltage and current of the solar panel to match the optimal charging voltage of the battery.[8] This allows the battery to charge more quickly and efficiently, and can also increase the overall power output of a solar system.[9] Normally a solar panel is able to convert only 30-40% of the total incident solar irradiation into electrical energy. Maximum Power Point Tracking (MPPT) is used to improve the efficiency of a particular solar panel.[10]

## 3.MAXIMUM POWER POINT TRACKING (MPPT)

### 3.1 INTRODUCTION

Maximum Power Point Tracking (MPPT) is an algorithm that is used to extract maximum power from PV under specific conditions. Maximum power of a PV panel depends on factors such as solar irradiation, ambient temperature and cell temperature. Normally a PV module produces maximum power voltage at cell temperature of 25°C. However depending on outside temperature it can fall or rise.MPPT checks the output of

a particular PV panel and after comparing it with battery voltage decides the most efficient voltage.
i.e. maximum power point voltage.The purpose of a MPPT system is applying proper resistance after sampling output of PV cell in order to obtain maximum power. It is also very effective when the battery is deeply discharged because more current can be extracted under low charge conditions. MPPT devices are integrated with power electronics creating an electric power converter system in form of solar inverters which convert DC power to AC power. Fig 3.1 shows the graph for MPPT VS NON-MPPT .

### 3.2. MPPT TECHNIQUES

There are different techniques used to track the maximum power point such as:

1. Perturb and observe (hill climbing method)
2. Incremental Conductance method
3. Current sweep
4. Constant voltage
5. Fuzzy Logic Control
6. Neural network

#### 3.2.1 Perturb and observe (hill climbing method)

Perturb and observe is one of the simplest methods due to its lower value of time complexity. This method uses one voltage sensor which senses the PV voltage and measures power. If power increases, the algorithm is designed to achieve constant power. However, this method can result in oscillations of power output because the algorithm continues to perturb recursively even after reaching MPP. This can be solve by setting an error limit to end the recursion. It is easy to implement and is known as hill climbing method because it depends on the rise and fall of power vs. voltage curve with respect to maximum power point.

#### 3.2.2. Incremental conductance

In this particular method, the controller measures incremental changes in voltage and current in the incremental conductance method. Even though it takes more number of computations it is better at tracking changes than perturb and observe method. Maximum power point is calculated by comparing incremental conductance (IΔ / VΔ) with PV array conductance (I / V). The output voltage is the voltage at which both ratios, i.e. conductance are same. The voltage is maintained till there are

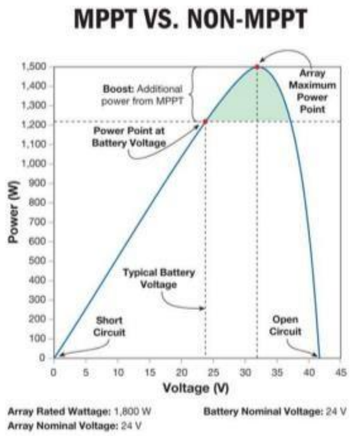


Fig 3.1 MPPT VS NON-MPPT

changes in irradiation levels upon which the process is repeated. Here both voltage and current are sensed simultaneously, therefore change due to irradiance does not cause in error. This method however is more complicated than perturb and observe method.

#### 3.2.3. Current sweep

This method helps in obtaining I-V characteristics by using a sweep waveform of the PV array current which is updated at fixed intervals of time. MPP is calculated from the curve at the same intervals of time.

#### 3.2.4 Constant voltage

In this method the operating point of PV array is maintained near Maximum Power Point. The PV array voltage is matched to a fixed reference voltage which is chosen to give optimal performance.

#### 3.2.5 Fuzzy Logic Control

Fuzzy logic is also used for implementing MPPT by the use of microcontrollers. Fuzzy logic controllers are not restricted with the need of accurate models. They have a distinct advantage of handling non linearity and imprecise inputs and have a fast rate of convergence. A fuzzy control system operates on the principle of fuzzy logic. It studies analog input values in context of logical variables having continuous values between zero and one.

#### 3.2.6 Neural Network

Neural networks are also used for implementing MPPT and they are also suitable for microcontrollers. They are a family of statistical learning algorithms used in estimation of approximate functions. They have three layers: input, output and hidden layers which have user dependent nodes whose number can be changed. Input variables such as open circuit voltage and short circuit current; temperature and solar irradiation can be used to find outputs such as duty cycle signal which in turn can be used to find maximum power point and make the converter operate around the point.

**4. MICROPROCESSOR**

The PIC microcontroller series, developed by industry leader Microchip Technology, represents a cornerstone in the realm of embedded systems. Renowned for its versatility and efficiency, the Peripheral Interface Controller (PIC) family has evolved over the years, catering to a myriad of applications across diverse industries.

At its core, a PIC microcontroller embodies a Reduced Instruction Set Computing (RISC) architecture, emphasizing streamlined instruction execution. This architectural choice contributes to the overall efficiency and performance of these microcontrollers. The PIC series is characterized by its integration of essential components, including Flash memory for program storage and RAM for data handling.

PIC microcontrollers come equipped with a spectrum of features. Notable among these are the integrated peripherals that enhance their functionality. Timers, communication ports such as UART, SPI, and I2C, as well as analog-to-digital converters (ADC), provide a comprehensive set of tools for interfacing and control tasks. Moreover, the inclusion of low-power modes makes PIC microcontrollers particularly suitable for applications where energy efficiency is paramount.

The versatility of PIC microcontrollers is reflected in their widespread applications. In industrial settings, they serve as the backbone of control systems, ensuring seamless automation processes. Automotive control units leverage PIC microcontrollers for their reliability and efficiency. Meanwhile, in consumer electronics, these microcontrollers power a range of devices, from smart gadgets to electronic toys. Educational institutions also utilize PIC microcontrollers as educational tools to teach microcontroller programming and interfacing.

The programming of PIC microcontrollers typically involves the use of assembly language or higher-level languages such as C. Microchip Technology provides a suite of development tools, including the MPLAB IDE, which encompasses compilers and simulators, facilitating the programming and debugging processes. While assembly language may pose a learning curve, the availability of high-level languages makes PIC microcontrollers accessible to a broader audience.

The PIC microcontroller series has undergone significant evolution, with successive generations catering to the evolving demands of technology. This adaptability ensures that PIC microcontrollers remain at the forefront of embedded systems development. The continual refinement of architecture and the introduction of advanced features contribute to their sustained relevance in the fast-paced world of electronics.

Despite their many advantages, PIC microcontrollers are not without challenges. Some models may have limited resources compared to more powerful microprocessors, and programming in assembly language might be considered more challenging for beginners. However, these challenges are often outweighed by the benefits and the extensive community and resources available for support.

In conclusion, PIC microcontrollers stand as a testament to Microchip Technology's commitment to providing robust solutions for embedded systems. Their widespread use across industries, coupled with their adaptability and feature-rich architecture, makes them indispensable in the world of electronics. Whether in industrial automation, automotive applications, consumer electronics, or educational settings, PIC microcontrollers continue to shape the landscape of embedded systems, driving innovation and progress.

**PROGRAM**

```
#include <pic_header_file.h>  // Replace with actual PIC header
file
// Define constants and variables
#define VREF 5.0  // Reference voltage
#define ADC_MAX 1023
#define SIMULATED_PANEL_VOLTAGE 3.0  // Replace with
desired simulated voltage for testing
#define SIMULATED_PANEL_CURRENT 1.0  // Replace with
desired simulated current for
testing // Function to initialize
ADC void initializeADC() {
   // Your ADC initialization code here
}
// Function to read simulated ADC value
unsigned int readSimulatedADC(float simulatedValue) {
// Convert simulated voltage/current to ADC value
   unsigned int simulatedADC = (unsigned int)((simulatedValue
/ VREF) * ADC_MAX);
   return simulatedADC;
} // Main
function void
main() {     //
Initialize ADC
initializeADC();
while (1) {
       // Simulate solar panel voltage and current readings
       unsigned int panelVoltage =
readSimulatedADC(SIMULATED_PANEL_VOLTAGE);
       unsigned int panelCurrent =
readSimulatedADC(SIMULATED_PANEL_CURRENT);
// Convert ADC values to actual voltage and current values
float voltage = (panelVoltage * VREF) / ADC_MAX;       float
```

```
current = (panelCurrent * VREF) / ADC_MAX // Your MPPT algorithm and charging control logic go here // Add appropriate delays or use interrupts based on your program structure
    }
}
```

**5. DESIGN**

Designing an MPPT (Maximum Power Point Tracking) solar charge controller using a microprocessor (like PIC), MOSFETs, optocouplers, presets, and a crystal oscillator involves several steps:

1.Microprocessor Selection:
- Choose a PIC microprocessor suitable for your project, considering factors like processing power, I/O capabilities, and power consumption.

2. MPPT Algorithm:
- Implement an MPPT algorithm in your microprocessor code to ensure the solar panels operate at their maximum power point.

3. MOSFETs for Power Switching:
- Select MOSFETs capable of handling the solar panel voltage and current. Ensure proper heatsinking for efficient operation.

4. Optocouplers:
- Use optocouplers to provide isolation between the microprocessor and high-power components. This protects the microprocessor from voltage spikes and enhances system reliability.

5. Presets for Calibration:
- Integrate presets (potentiometers) to calibrate and adjust parameters such as reference voltage and setpoints for the MPPT algorithm.

6. Crystal Oscillator:
- Employ a crystal oscillator to generate stable clock signals for the microprocessor, ensuring precise timing in your MPPT algorithm.

7. Battery Charging Control:
- Implement battery charging control logic to prevent overcharging and ensure optimal battery health.

8. PCB Design:
- Create a well-designed printed circuit board (PCB) layout, considering proper grounding, signal integrity, and thermal management. Fig 4.1 shows the design.

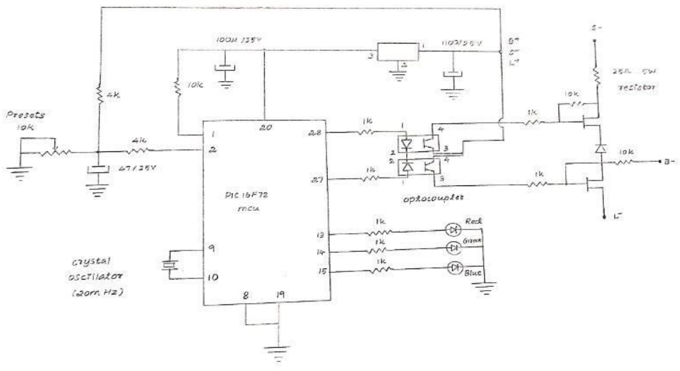


Fig 4.1. Design of MPPT solar charge controller

**6. HARDWARE IMPLEMENTATION**

Creating an effective hardware implementation of an MPPT (Maximum Power Point Tracking) solar charge controller using a PIC microprocessor involves a meticulous integration of various components. The design encompasses the selection of a suitable microprocessor, the establishment of a robust solar panel interface, implementation of MPPT algorithms, integration of MOSFETs for power switching, utilization of optocouplers for electrical isolation, inclusion of presets for calibration, addition of a crystal oscillator for precise timing, and incorporation of voltage regulation and protection mechanisms.

The first crucial step is the selection of an appropriate PIC microprocessor. This choice is contingent on factors such as the number of required I/O pins, processing power, and the presence of essential peripherals like ADC and PWM. The microprocessor serves as the brain of the system, orchestrating the entire charge control process and ensuring efficient energy harvesting from the solar panel.

Next, a robust interface for the solar panel is paramount. This involves implementing voltage and current sensing circuits to monitor the solar panel's output characteristics accurately. The interface acts as the gateway for the solar energy to enter the charge controller system, providing the necessary data for the MPPT algorithm.

The heart of the MPPT solar charge controller lies in the implementation of MPPT algorithms within the microprocessor's firmware. Leveraging the capabilities of the ADC, the microprocessor continuously monitors the solar panel's voltage and current, adjusting the duty cycle of the PWM signal to maximize power output. This iterative process ensures that the system operates at the maximum power point, optimizing energy conversion.

To efficiently manage the power flow between the solar panel and the battery, MOSFETs are employed for their fast switching capabilities and low power dissipation. Additionally, optocouplers are integrated to provide electrical isolation between the microprocessor and the high-power sections, enhancing safety and preventing potential damage by isolating control signals.

Calibration and customization are facilitated through the inclusion of presets. These resistors allow for fine-tuning the controller's parameters, enabling users to adjust settings based on different battery types and environmental conditions. This adaptability enhances the versatility of the charge controller, making it suitable for a wide range of applications.

Precise timing is ensured through the integration of a crystal oscillator. This component provides an accurate clock signal for the microprocessor, maintaining precision in the execution of control algorithms. Timing is crucial for synchronization and coordination within the system, enhancing overall efficiency.

Incorporating voltage regulation and protection mechanisms further enhances the charge controller's reliability. These include circuits to regulate output voltage and monitor conditions such as overcharge, over-discharge, and temperature. Such safeguards protect the battery and the overall system, ensuring longevity and safe operation. Efficient PCB layout design is crucial for minimizing signal interference and optimizing thermal management. Adequate heat dissipation measures, especially for components like MOSFETs, are essential to prevent overheating and ensure the stability of the system.

The final stage involves rigorous testing of the hardware under various conditions. This iterative process allows for refinement based on testing results and user feedback. The goal is to create a robust, reliable, and efficient MPPT solar charge controller capable of maximizing solar energy harvesting in diverse environmental scenarios. Fig 6.1 shows the hardware implementation.

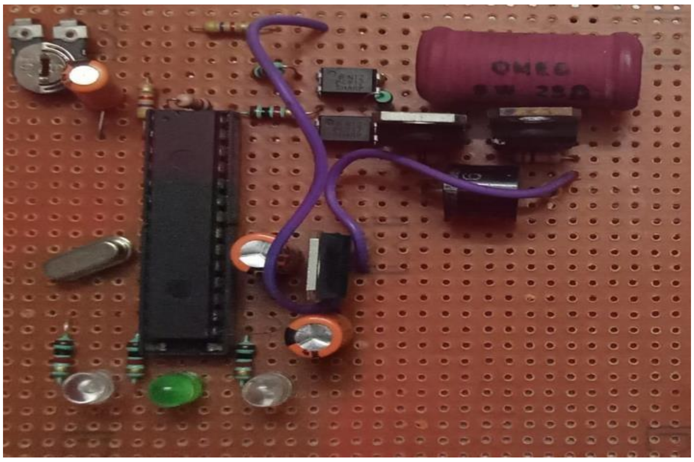

Fig 6.1. Hardware implementation

## 7. WORKING

The MPPT (Maximum Power Point Tracking) solar charge controller, employing a microprocessor such as the PIC (Peripheral Interface Controller), operates at the heart of optimizing energy conversion from solar panels to batteries. The microprocessor acts as the control center, orchestrating the entire process.

MOSFETs (Metal-Oxide-Semiconductor Field-Effect Transistors) are integrated into the system, serving as efficient switches that regulate the energy flow between solar panels and batteries.

An optocoupler plays a crucial role in electrical isolation, ensuring safety by separating the high-voltage components from the low-voltage microprocessor. This isolation is achieved through an LED and a photodetector, allowing signal transmission without direct electrical contact.

Presets, likely in the form of potentiometers, contribute to the controller's versatility. These adjustable resistors enable manual configuration of parameters such as voltage and current thresholds, providing a means to fine-tune the MPPT controller according to specific system requirements or environmental conditions.

The overall functioning involves the microprocessor continuously monitoring the solar panel output, calculating the optimal operating point for maximum power, and then dynamically adjusting the MOSFET to maintain this point.

This intricate interplay of components ensures that the MPPT solar charge controller maximizes the efficiency of solar energy harvesting, making it a pivotal component in solar power systems.

## 8. RESULT AND OUTPUT

Designing a Maximum Power Point Tracking (MPPT) solar charge controller using a microprocessor like PIC involves programming the microprocessor to continuously adjust the operating point of the solar panels for maximum power output. It requires sensor input for measuring solar panel voltage and current. The controller then adjusts the duty cycle of the charging circuit to maintain optimal power transfer. Specific code and circuit details would depend on the PIC model, solar panel specifications, and other design parameters.

Fig 7.1 shows the output . When it is charging , the red LED flashes.

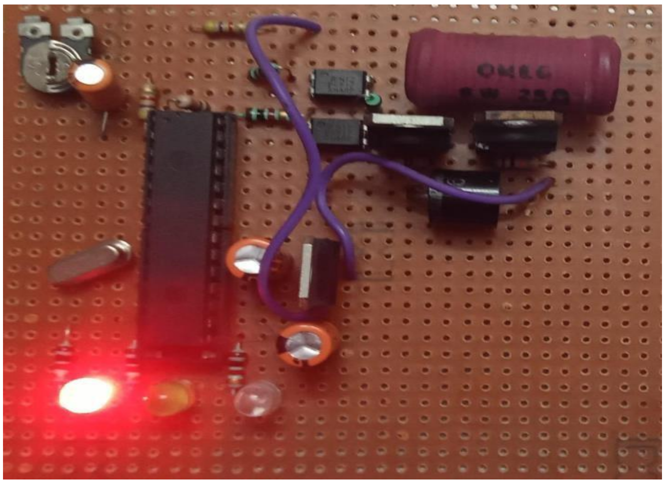

Fig 7.1 Output of MPPT Solar Charge Controller

**CONCLUSION**

The implementation of a Microprocessor PIC-based Maximum Power Point Tracking (MPPT) solar charge controller offers enhanced efficiency in solar energy harvesting. The intelligent control algorithm continuously adjusts the operating point of the solar panels to maximize power output, ensuring optima

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