# Solar Charging Control System

Peter Kolok, Peter Ševčík

***Abstract***— The result of the work is the creation of an energy-efficient device based on the WIO RP2040 module from the Seeed Studio company, which can effectively search for the angle under which the highest measured intensity of solar radiation is found and then ensure positioning to this angle. By achieving such a state, we can charge the Li-ion battery, which also powers this device. It was necessary to achieve the smallest possible losses and therefore it was important to save energy wherever possible, for the best possible result.

***Keywords***— Wio, RP2040, Li-ion

## I. INTRODUCTION

Solar energy harnessed from the sun can be utilized almost anywhere sunlight reaches the Earth's surface. Solar panels, made up of numerous solar cells, offer an efficient method for converting sunlight into electricity. These panels are employed across various levels, including the commercial sector, in mini-grid systems, and for individual use. They have proven to be an ideal energy source for powering mini-grids, particularly in areas lacking access to mains electricity. This is especially crucial for developing countries that have a high potential for solar radiation.

### *A. Advantages of Solar Charging*

Solar charging offers several significant advantages that contribute to its growing relevance and popularity. First, solar energy is a renewable resource available in any location that receives sufficient sunlight. Additionally, it is environmentally friendly; using solar panels does not contribute to pollution and helps reduce the overall carbon footprint. While the initial investment in solar panels may be higher, they prove to be economically beneficial in the long term because they do not require a continuous supply of fuel.

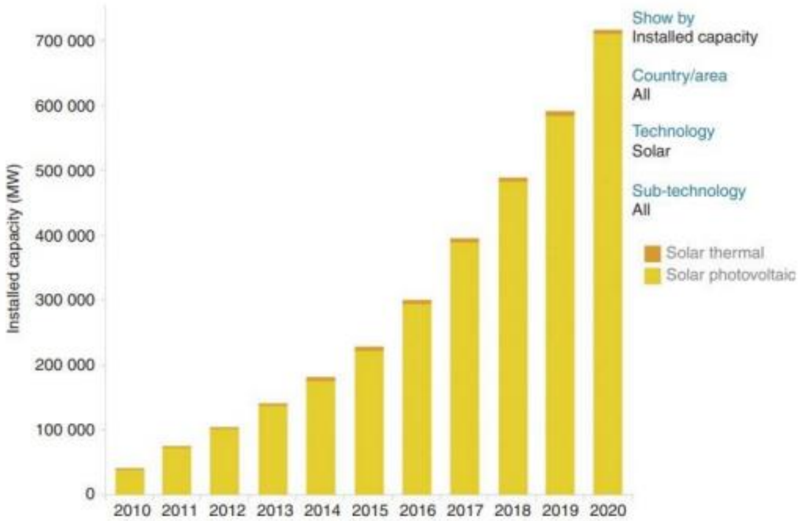


**Figure 1** *Increase in solar panel installation over time*

Furthermore, the increasing availability and decreasing solar technology costs support these advantages.

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### *B. Applications of Solar Charging in Practice*

Solar charging is widely used in areas without reliable access to electricity, such as remote regions, developing countries, and rural areas. It powers portable devices like mobile phones, tablets, and GPS units, and serves as a backup energy source for home battery systems, ensuring operation during power outages.

### *C. Enhancing Energy Harvesting Efficiency*

Optimal positioning of solar panels enhances energy generation by ensuring consistent alignment with the sun. A dual-motor system can adjust the panel's angle and orientation for effective energy harvesting. To conserve energy, repositioning can be programmed at intervals, such as every three hours. Fast and precise adjustments further improve efficiency by minimizing energy consumption during realignment.

## II. CONTROL SYSTEM SOLUTION

To enhance charging efficiency by repositioning devices, choosing suitable components and creating an effective algorithm for managing their placement is vital.

### *A. Selection of suitable components*

Initially, the ESP32 processor was considered for this project due to its wide range of capabilities. However, the RP2040 was ultimately selected for its high energy efficiency in low-power modes. To enhance power management, the Wio RP2040 module, which features the RP2040 processor, was chosen.

The project also includes components such as a solar cell, two servomotors, step-up modules, a charging module, and a Li-ion battery. A solar cell measuring 70x90 mm, capable of generating 5V and 160mA, was more than sufficient for our needs. For the servomotors, we used a 180-degree (SG90) motor and a 360-degree (DS04-NFC) motor. The device is powered by a standard rechargeable Li-ion battery with a voltage of 3.7V and a capacity of 2500 mAh.

To drive the servomotors, we employed a step-up module (SX1308) to efficiently convert the battery voltage to 5V at 2A, ensuring adequate power for both motors. For efficient charging, we selected the TP4056 charging module, specifically designed for charging Li-ion batteries.

### *B. Selection of suitable algorithm*

To create an effective algorithm, it is essential first to establish a clear objective. In this case, the objective is to charge the Li-ion battery as efficiently as possible by optimizing the positioning of the solar cell. The positioning should be adjusted at regular intervals, such as every hour, to maintain optimal energy collection. Additionally, it would be practical to monitor the battery voltage levels, providing the user with insight into the charging status. It is also important to consider possible events, such as an unknown object obstructing the sunlight reaching the solar cell. For simplicity of implementation, the MicroPython programming language was selected.

### *C. Implementation of the device*

After selecting the components, a printed circuit board (PCB) was designed, on which all the components were assembled. The design of the PCB and the interconnection of the components were based on the structure of the block diagram.

According to the block diagram, the device was designed to include a mechanical switch. This switch allows the user to choose between charging the battery directly from the solar cell or, if the device is connected to a computer (or another peripheral), charging from that source. The device also features three buttons: the first button restarts the search for the highest radiation intensity, the second button serves as a RESET, and the third button is used for BOOT.

An RGB LED was added to indicate errors or to display the device's status.

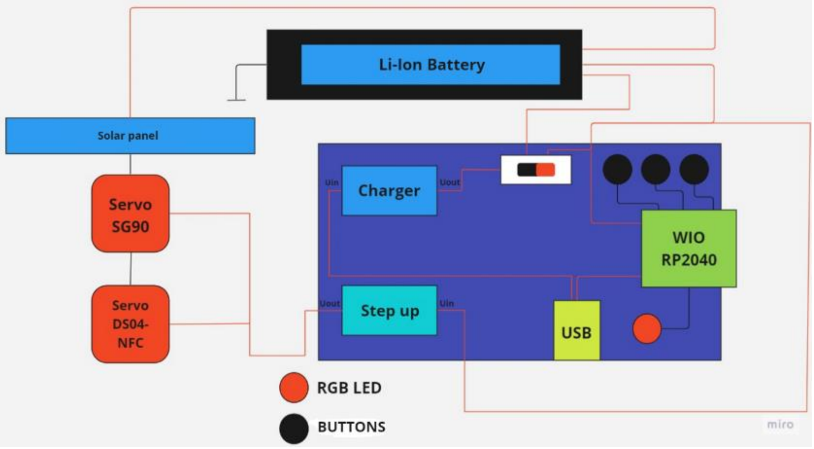


*Figure 2 Device block diagram*

## III. Use in practice

The device must work with efficiency, energy management, and precise placement to increase the efficiency of solar charging.

### A. *Principle of operation of the device*

At the beginning, when the button is pressed, the device initializes, setting the upper servo motor (SG90) to a 40-degree angle. Subsequently, the lower servo motor (plate_number_1) begins to rotate the structure through 360 degrees. During this rotation, the voltage of the solar cell is measured using a voltage divider. Once the scanning process is complete, the device adjusts its position to the angle that recorded the highest light intensity. After this adjustment, the upper servo motor (SG90) activates again to reposition the solar cell, aiming to achieve maximum light intensity.

### B. *Signaling and Sleep Mode*

After identifying the optimal position, the RGB LED indicates the system's status. If the solar cell generates enough voltage to charge the battery, the green LED will flash. If the voltage is insufficient, the red LED will flash instead. Following the green LED signal, the blue LED blinks 20 milliseconds later to indicate that the charging process has begun. Once the charging is complete, the Wio RP2040 enters sleep mode to conserve energy.

### C. *Periodic Repositioning Using RTC Timers*

The device uses a Real-Time Clock (RTC) timer to wake up every hour and automatically adjust its position to the angle with the highest light intensity. In addition, a secondary RTC timer activates the device every 10 minutes for a duration of 1 millisecond to check if any object, such as a cloud, is obstructing the solar cell.

If shading is detected, the device will attempt to reposition itself to find a new optimal angle. If it is unable to achieve sufficient light intensity to charge the battery, it will revert to its previous position and stop further attempts to reposition. However, the 10-minute RTC timer will remain active to continue periodic checks.

### D. *Obstruction Handling and Extended Sleep Mode*

If the shading clears and the solar cell receives sufficient light intensity, the system will return to its normal operation. However, if the obstruction continues for more than an hour, the Real-Time Clock (RTC) timer will stop any further wakeups to prevent unnecessary battery drain. This approach ensures energy efficiency and extends the device's operational lifespan under limited power conditions.

## IV. Work result

With the selected components and the chosen programming approach, several key outcomes were achieved.

### *A. Device consumption*

The device was designed with a strong emphasis on maximizing energy efficiency. In sleep mode, the device consumes an average of 180 µA, while in positioning mode, the power consumption can increase to as much as 200 mA. Due to this significant difference, it is crucial to execute the positioning process as quickly as possible to minimize energy usage.

### *B. Charging time*

The device was tested on a bright, cloudless day and fully charged within 11 hours. Although this result is not entirely satisfactory, it is important to note that the solar cell used in this project was not very efficient. In the future, the charging performance could be significantly improved by using a more efficient solar cell.

### *C. Final result*

The outcome of this project was a functional solar charging control system that successfully met its objectives. However, some minor issues arose during operation, particularly with inconsistent control between the servo motors. The SG90 servo was controlled by position, while the DS04-NFC was controlled by speed. To improve consistency in the future, it would be beneficial to replace the DS04-NFC with the SG90-HV, a 360-degree position-controlled servo.

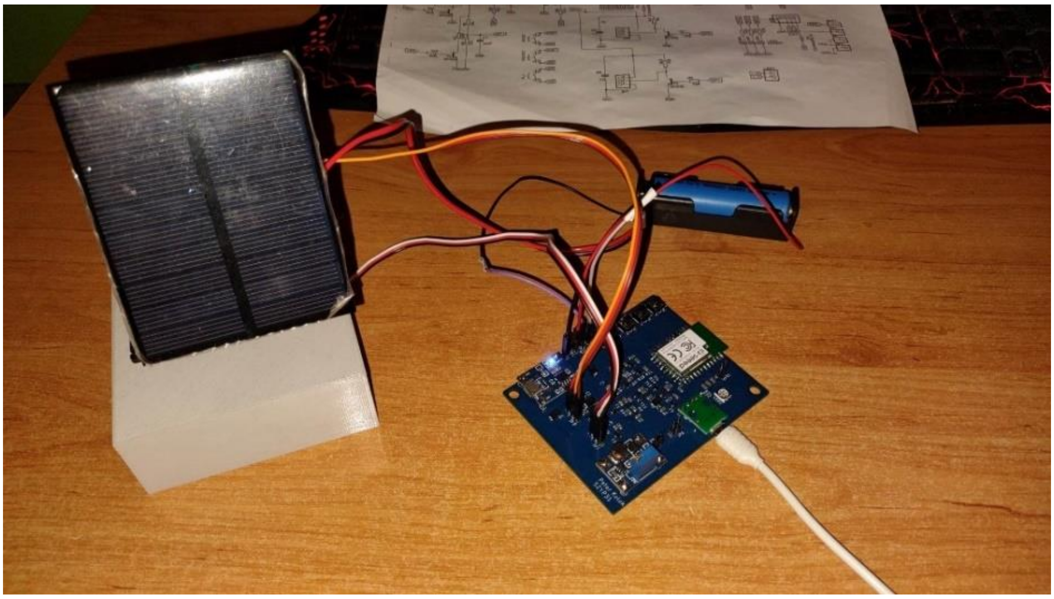

*Figure 3. Final application*

Additionally, using a more efficient solar cell and programming in a low-level language like C or C++ could enhance both performance and efficiency. Despite these considerations, the project successfully demonstrated the feasibility of positioning a solar cell effectively while charging a Li-ion battery, providing a practical solution for efficient solar charging.

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