UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

Automated Cleaning System For Solar Panels

Team #10

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Introduction

Introduction

Our Project

- Create system to autonomously:
    - Assess debris covering on a solar panel
    - Conduct cleaning if debris covering reaches a certain threshold
    - Charge battery and use battery power to operate the control system

Objective

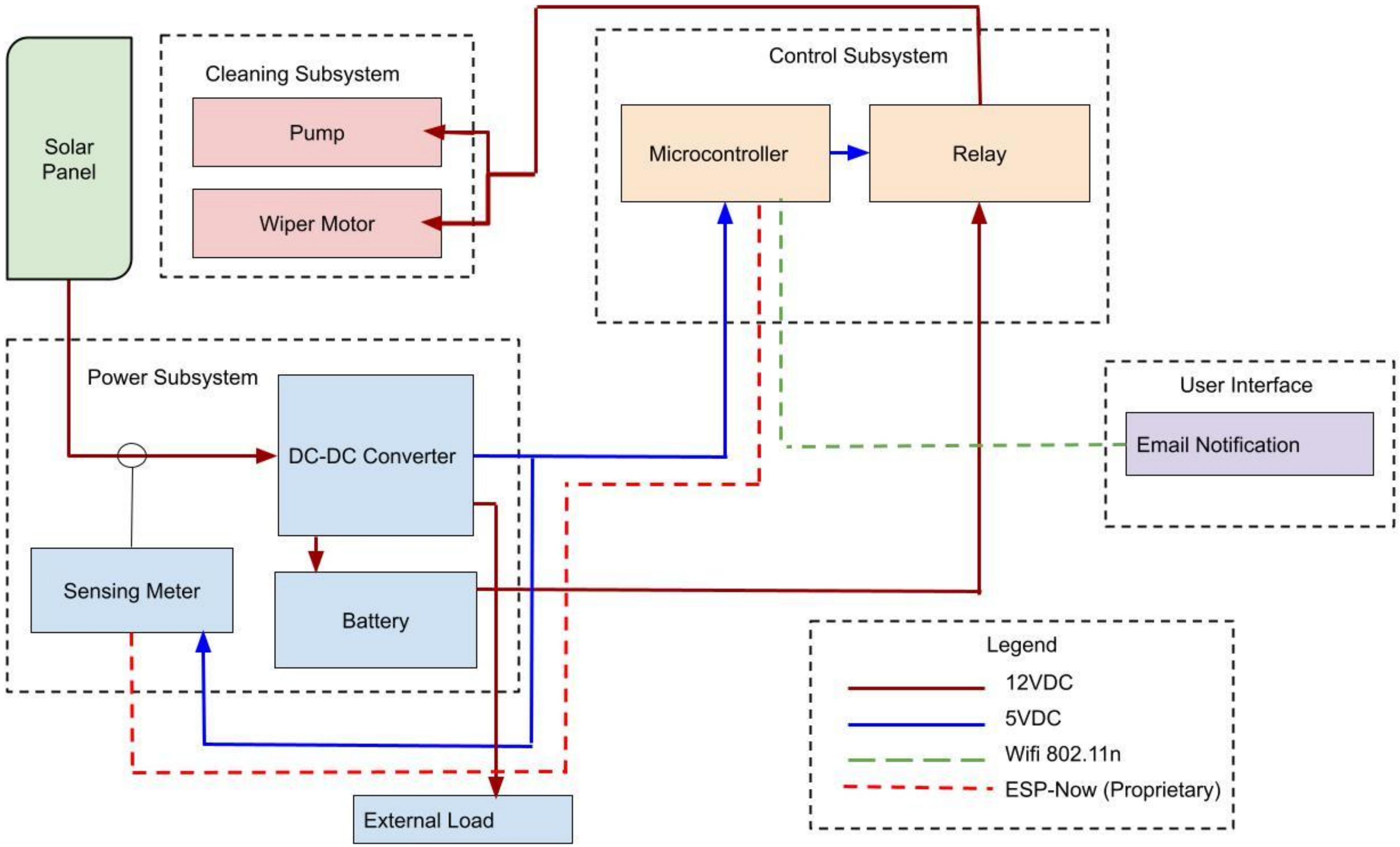
Objective

What we are solving

https://energypost.eu/solar-soiling-energy-loss-from-dust-on-panels-can-range-from-7-to-50/

Design Overview

Block Diagram

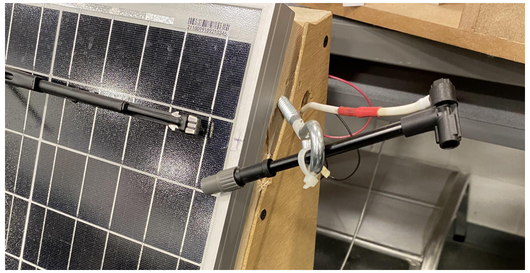


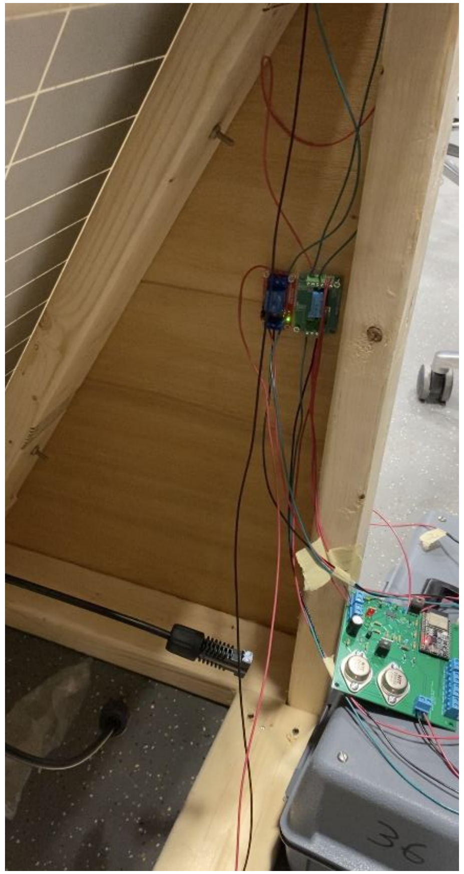
Cleaning Subsystem

Components

The System

The cleaning subsystem is made up of just a sprayer and motor that allows us to clean the panel when required.





The System

When determining the needs for the cleaning subsystem one thing needs to be taken into consideration, which is the power needed to clean the panel must be less than the power gained from cleaning the panel.

	Motor	Pump
Voltage	12VDC	5VDC
Current	≤200mA	≤700mA

- Motor Power Consumption : .6W-hours in a cleaning cycle.
- Sprayer Power Consumption : .004W-hours in a cleaning cycle.

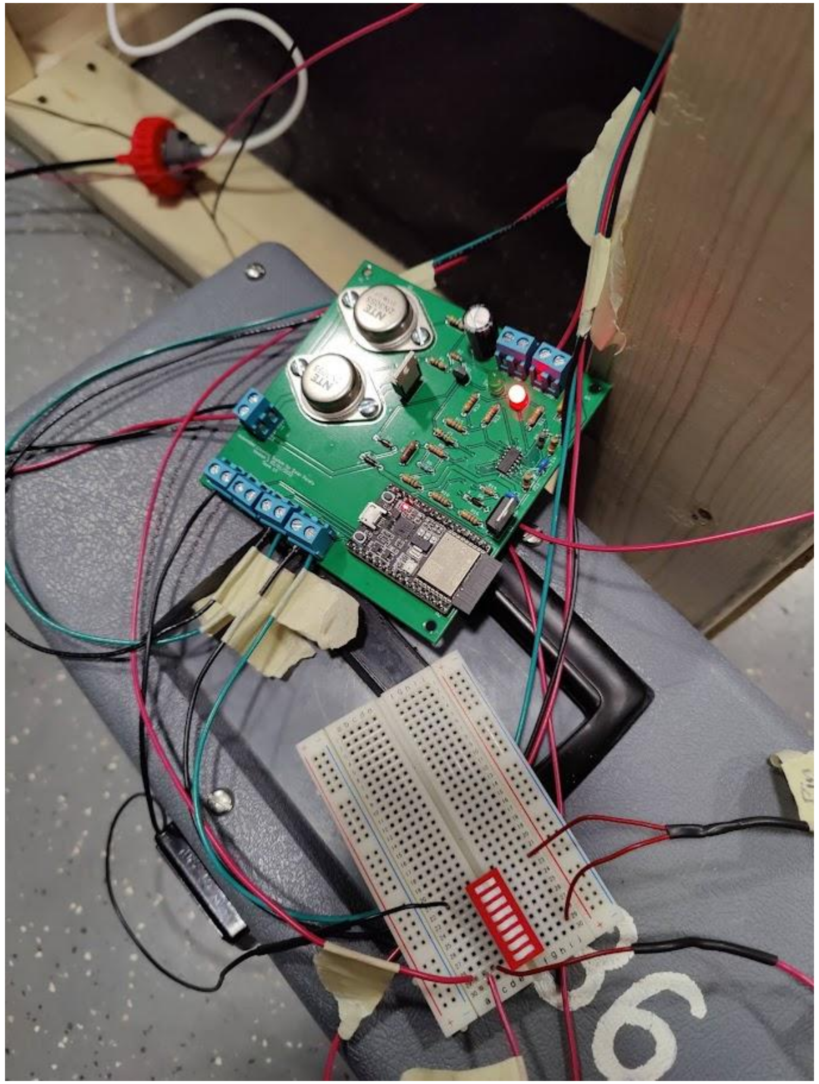
- Wanted 25%-35% power loss

(25W * time at power loss)

- With a 100W panel the cleaning power is less than the power gained

Power Subsystem

Components



Overview

The Power Subsystem is the electrical heart of the project as it takes in the solar panel output and converts it into useful levels for battery charging and running the other subsystems. It also monitors the solar panel input to determine if cleaning is necessary.

Parts

- Battery charging circuit
- Microcontroller supply circuit
- Cleaning subsystem supply circuit
- Sensing meter

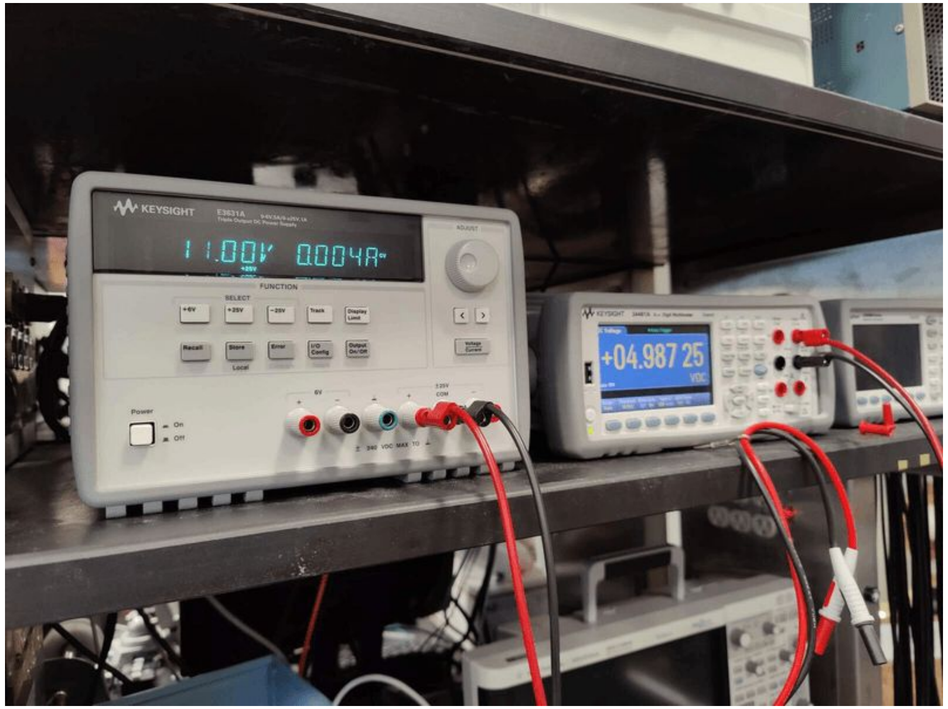
Microcontroller Supply

Design

The microcontroller and relay modules required a 5VDC supply for proper operation as well as the sprayer

Results

- Stable for voltage from 11-17VDC
- Able to provide up to 1.5A of current
- Tripped when running sprayer so had to use external source



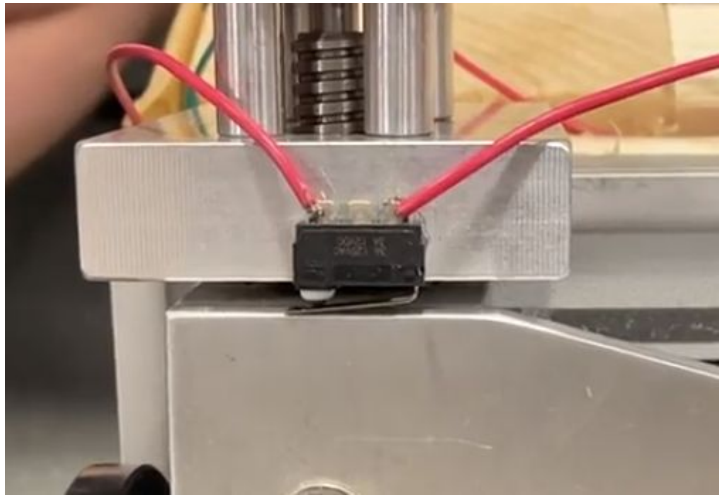
Cleaning Subsystem Supply

Design

The wiper motor required 12VDC to operate both directions and a DPDT relay will reverse polarity to return wiper to resting state

Results

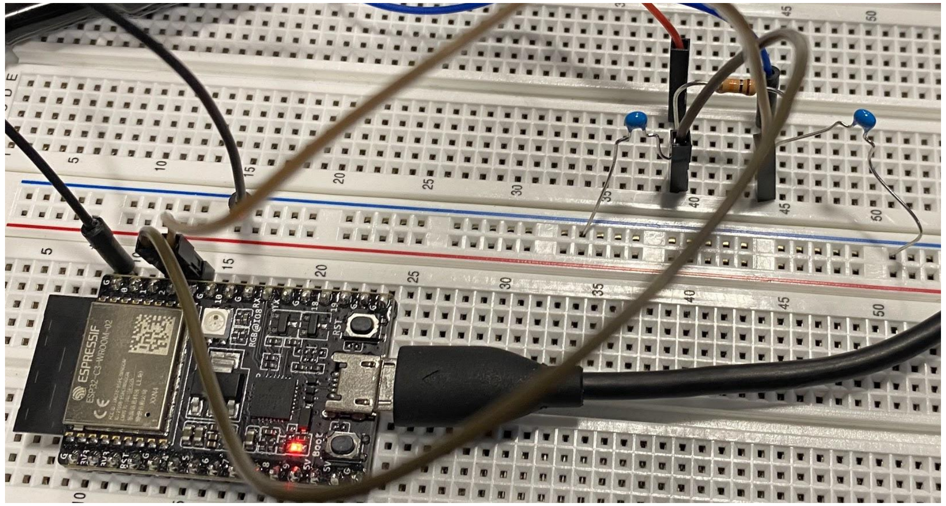
- PCB was able to output steady supply for motor
- Relay triggered on when initiated by microcontroller and reversed direction after wiping was done.
- Limit switch stopped wiper motion leaving system ready to clean again



The Sensing Meter

- Precision limited to be .3A
- Testing was done by measuring the voltage drop across 1k Ohm resistance

- 100nF bypass capacitors were needed when in combination with the esp microcontroller



Current (A)	Sensor Output (V)
0	1.664
0.3	1.6666
0.6	1.6702
0.9	1.6736
1.2	1.6772
1.5	1.6806
1.8	1.684
2.1	1.6875
2.4	1.691
2.7	1.694
3	1.6978
3.3	1.7012
3.6	1.7046
3.9	1.7082
4.2	1.7115

Control Subsystem

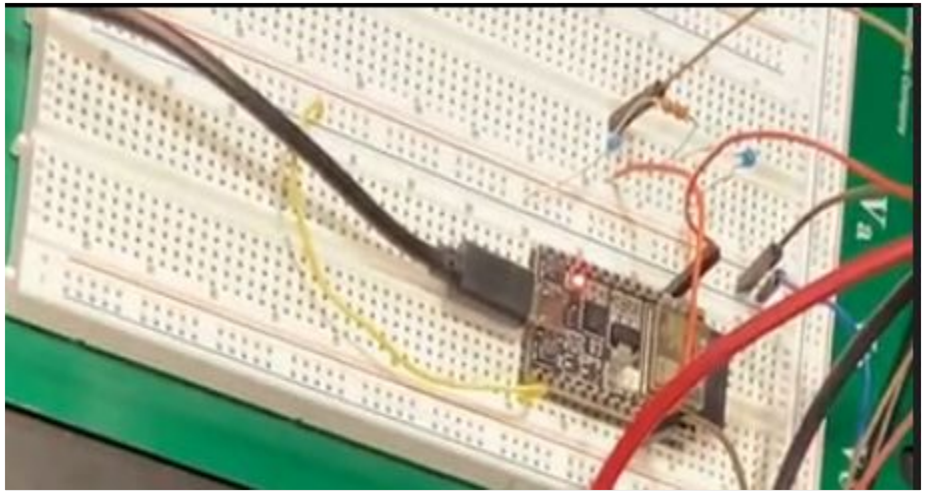
Overview

Design:

- Activate and Deactivate Relay Modules
- Send E-Mail notifications to clean
- Access Weather API:
  - temperature, cloud coverage, etc…
- Communication between Hall Sensor and PCB
- Hall Sensor readings and analysis

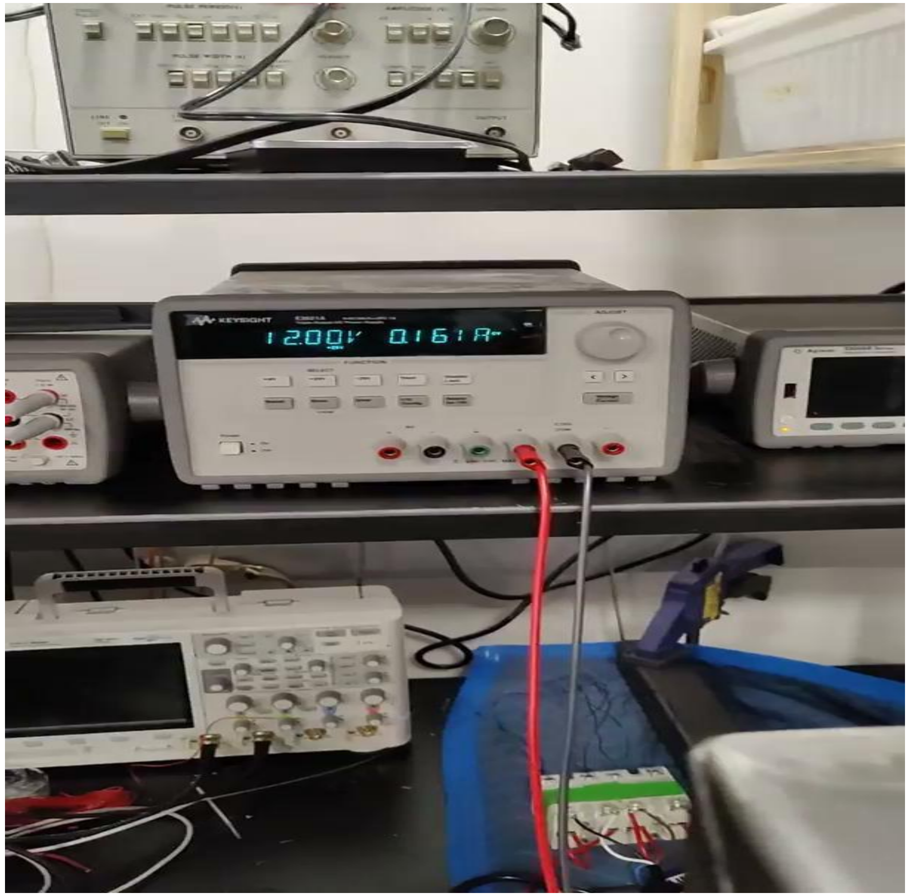
Requirements and Verifications:

Requirement	Verification
1. Controls relay and allows power to pump and motor when cleaning is wanted 2. Wirelessly transmit message to App or E-mail	1. Measure current and voltage, using an Oscilloscope, across resistive load from the output of the relay to be 0.25A amps and 12V for the motor. 2. Check if message is received by App or E-mail notification within a period of 3 minutes from when the data was processed on microcontroller



Results

Verification #1: 12V and 3A



Verification #2: E-mail Notification Speed

Trial Number	Time Taken (Seconds)
1	29.85
2	30.38
3	30.42
4	31.15
5	30.12
6	29.78
7	30.54
8	30.89
9	30.55
10	30.23

Data Collection and Analysis

- Hall Sensor continuously gave voltage output
  - Drops in voltage corresponded to proportional drops in current

- Used microcontroller onboard A/D converter to poll sensor readings at a steady rate
  - Fluctuations exist as A/D converter was not precise
  - Required tuning Reference voltage (Vref) and sampling speed

- Algorithm for degradation analysis:
  - Measured for voltage dip between adjacent samples
  - Dip held for long term → Potential cleaning
    - Comparison was based on max of the samples checked
  - Contact weather API for cloud coverage

Conclusion

Successes and Failures

Successes:

- Cleaning system actually cleans!
    - Sprayer will spray water
    - Wiper goes up and down the panel and removes material from the surface
- PCB outputs correct voltages for other subsystems
- Current sensor reads current outputted by panel
- Relays function as intended (SPDT and DPDT)
- Notifications are sent when panel is about to be cleaned

Failures:

- Battery does not charge (could not prove this since PCB died during final testing)
- Current hall sensor was not as accurate as we desired
    - Used averaging, faster sampling, and even taking max in a collection of data
- Data monitoring app not implemented (reach goal)

Possible Changes

Changes that could be made

Power Subsystem

- Look into more loop hall sensors that would allow us to read more accurate current readings

Control Subsystem

- Have the ability to remove snow with the least amount of power possible

- Perhaps use data structure such as a heap to maintain current readings
    - Beneficial for continuous stream of data analysis

Cleaning Subsystem

- Utilize faster motor to clean the panel at a faster rate

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