



UNIVERSITY OF
ILLINOIS
URBANA-CHAMPAIGN

SolarTrack

Team 7

5/01/2026

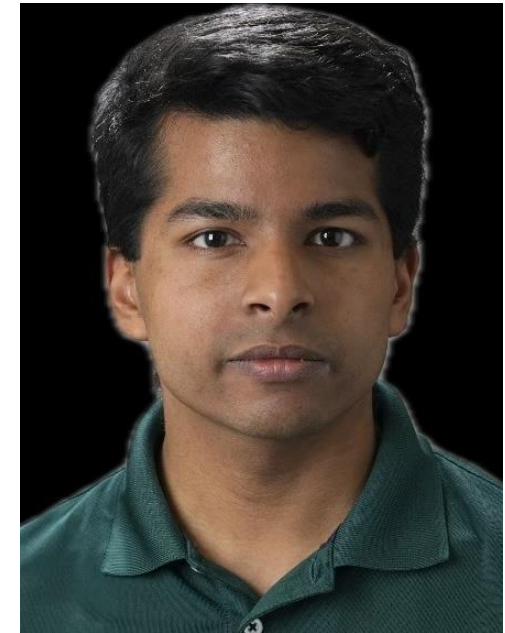
Meet the Team



Rahul Patel – Electrical



Rishikesh Balaji – Software



Siddhant Jain – Software

Inefficient Solar Energy Capture

- Global energy demand is increasing, creating a need for renewable solutions
- Solar power is growing rapidly, but efficiency is still limited
- Fixed solar panels only work best when sunlight hits them directly
- The sun's position changes throughout the day and across seasons
- This leads to significant unused energy potential



Inefficient Solar Energy Capture Means...

- Lower overall energy generation
- Continued reliance on fossil fuels
- Higher energy costs
- Limited effectiveness in rural or developing areas
- Missed opportunity to maximize renewable energy adoption



Core Challenges

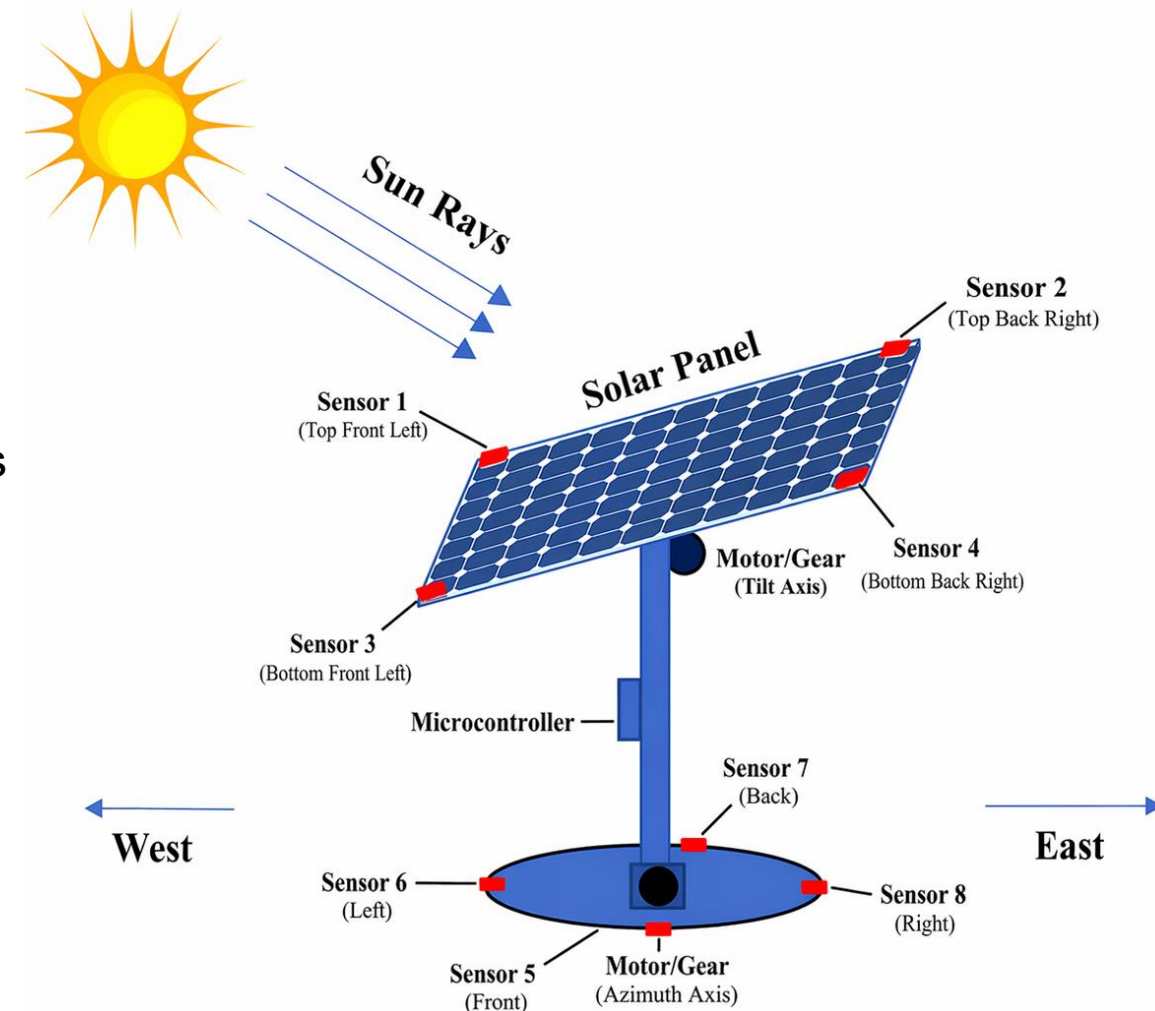
Existing solar tracking systems are expensive

Many designs are mechanically complex

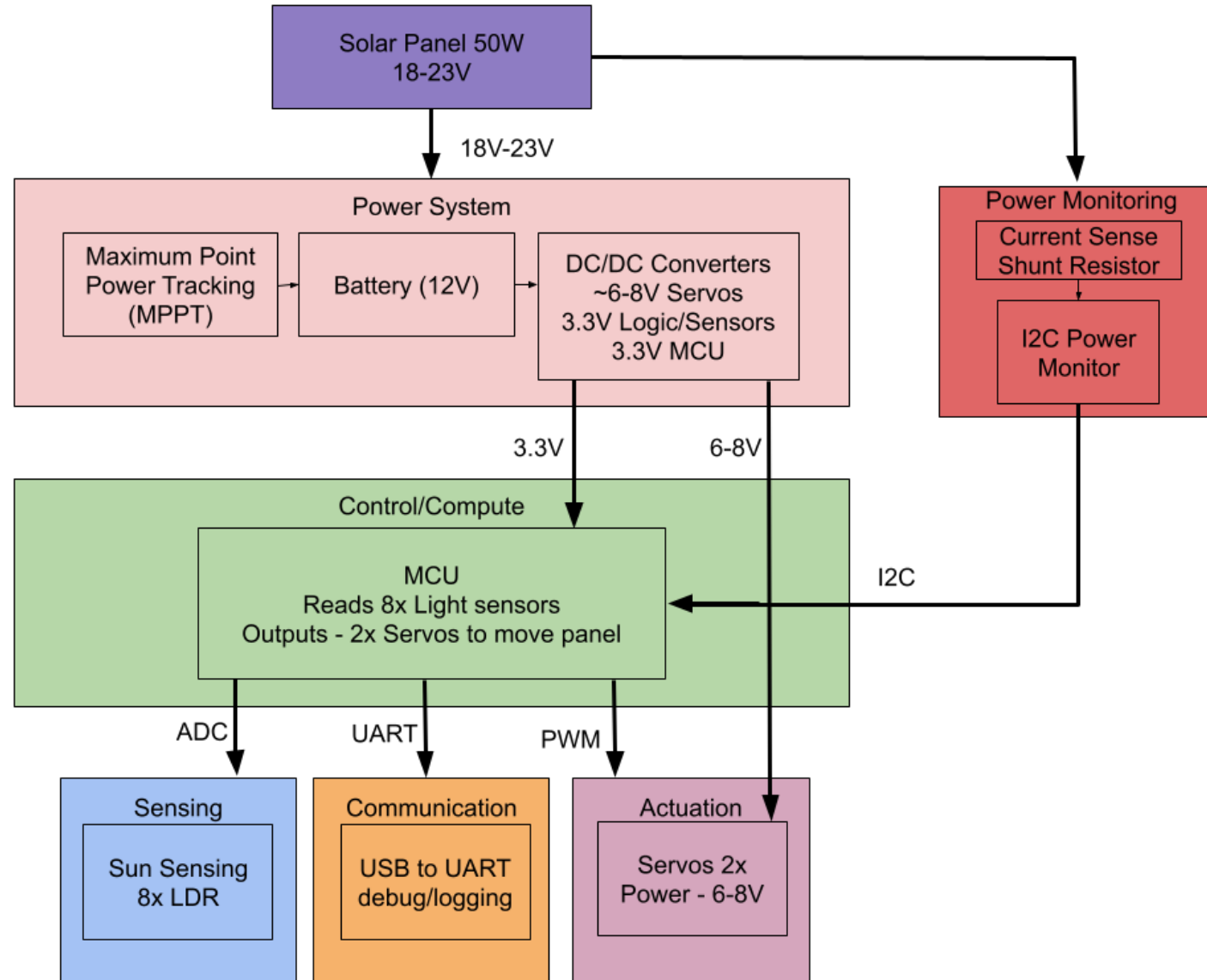
A better solution must be efficient, affordable, and reliable

SolarTrack

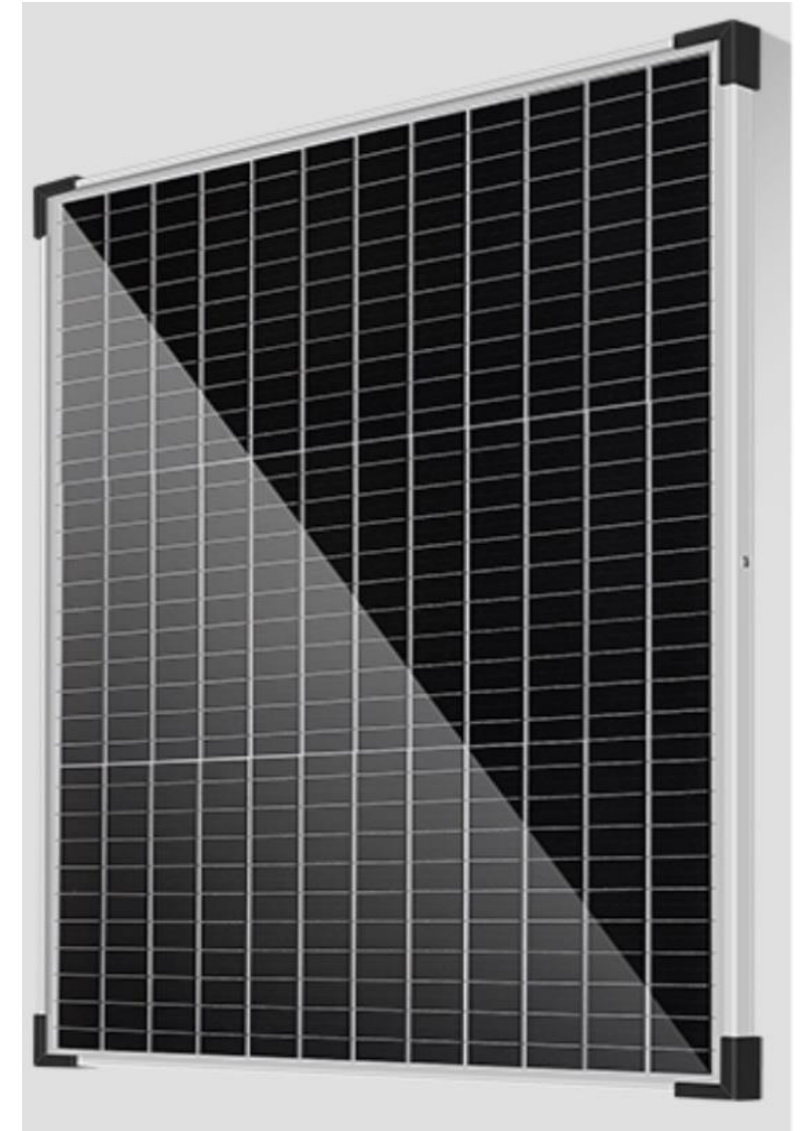
- Self positioning solar panel system for maximum energy capture
- Continuously adjusts based on sunlight direction
- Uses light sensors to detect intensity from different angles
- Repositions panel to stay aligned with the sun
- Designed to increase overall energy capture



Block Diagram



- Primary energy source converting sunlight to DC power
- 50W with operating voltage $\sim 18.6V$ and current $\sim 2.7A$
- Supplies energy to
 - MPPT for battery charging
 - electronics and servos for panel positioning
- Power output measured by power monitoring system
- Mounted on tracking structure for dynamic positioning
- Wiring must allow full motion without stress or damage
- Must provide 18 to 23V under operating conditions



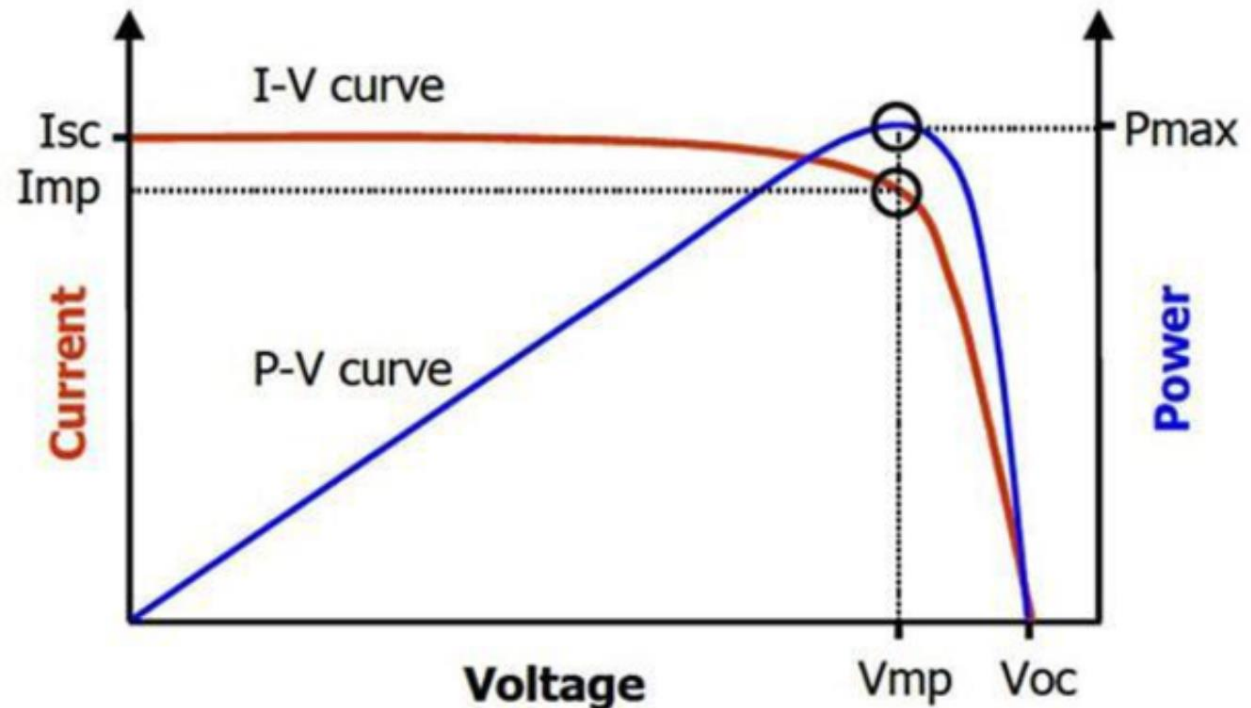
- $P_{max} = V_{mp} \times I_{mp}$
- Solar panels have a single operating point where power is maximized (MPP)
- Defined by voltage (V_{mp}) and current (I_{mp})
- Varies with sunlight and temperature

The MPPT...

- Continuously adjusts panel voltage to stay at V_{mp}
- Ensures maximum power extraction in real time
- Improves efficiency by ~20 to 30 percent

Role in our System

- Input: 18V to 23V from solar panel
- Output: regulated charging to 12V battery bus
- Enables stable downstream rails:
 - 6.0V for servos
 - 3.3V for MCU and sensors



- Stores energy from solar panel
- Powers the positioning system
- 12V 9Ah Sealed Lead Acid (SLA) Battery

Chosen Because...

- Simple charging profile
- Robust and reliable
- Safer than lithium batteries
- Low cost

Battery Must...

- handle charging from solar input safely
- support system load during low or no sunlight



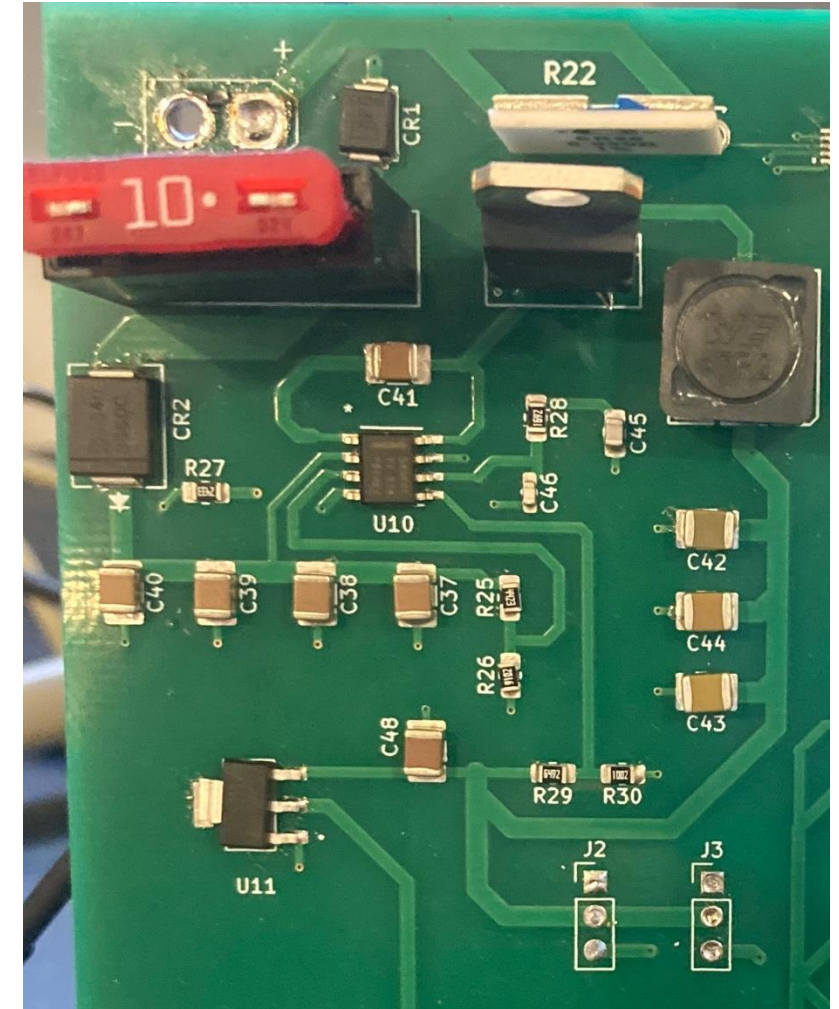
- Converts 12V input to levels required by the system
- Provide efficient power regulation for high-current loads
- Generates:
 - 6V rail for two servos
 - 3.3V rail for MCU and sensors

12V to 6V Buck Converter

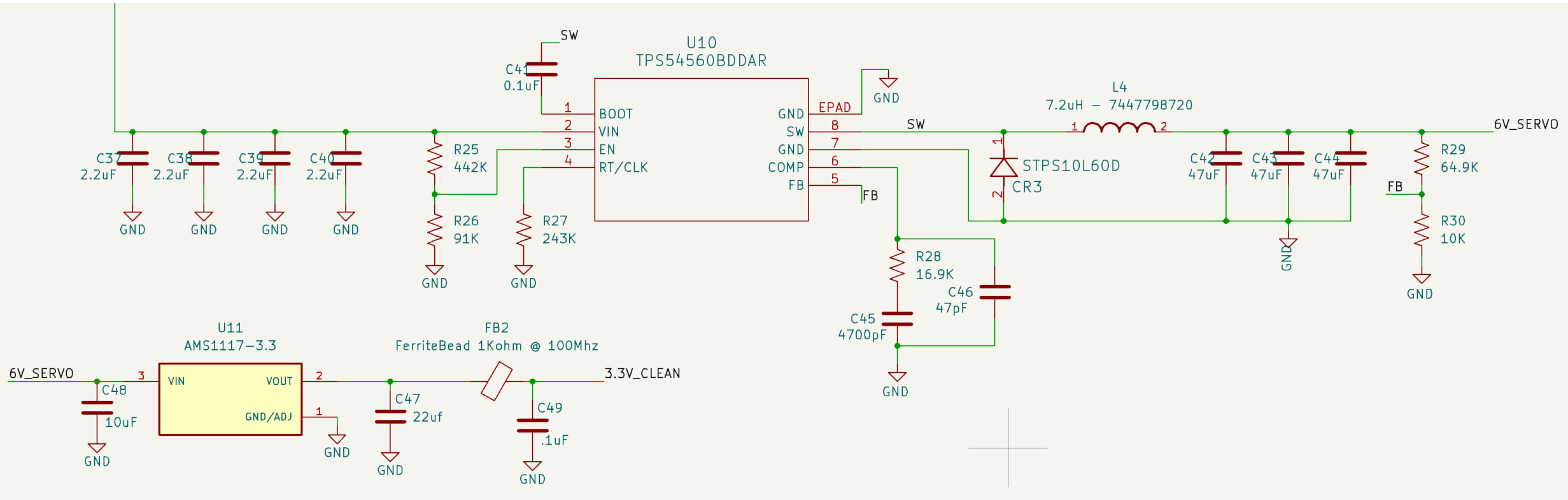
- Steps down input voltage to regulated 6V output
- Uses switching regulator for high efficiency
- Supports high current demand from servos (5A)

6V to 3.3V Linear Dropout Regulator

- Steps down 6 V to stable 3.3 V output
- Powers MCU, sensors, and low-power electronics
- Provides low-noise, clean voltage for sensitive components
- Simple design with no switching components



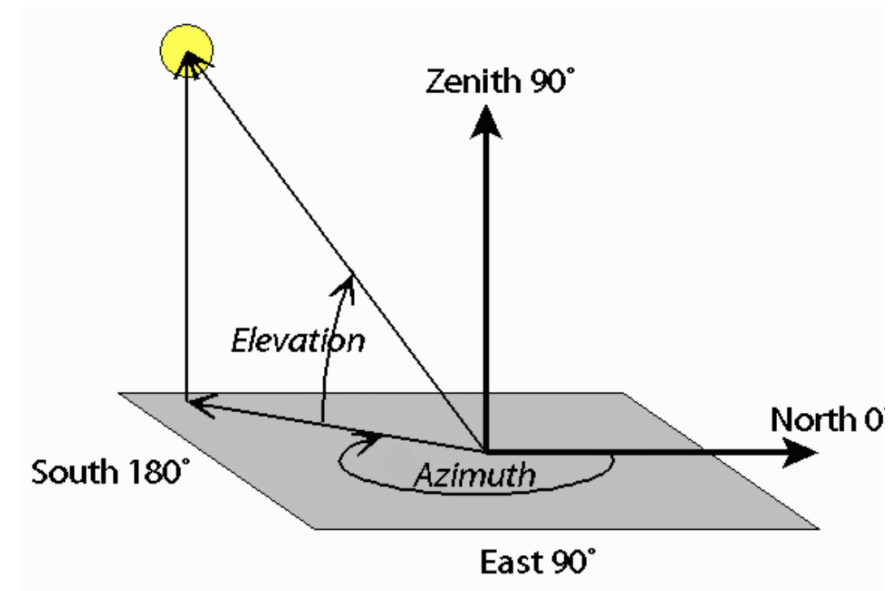
DC-DC Converters Schematic



- ESP32-WROOM Series microcontroller (MCU)
- Uses 12-bit ADC to read light intensity from 8 light sensors
 - 4 sensors for azimuth
 - 4 sensors for elevation
- Commands servos (PWM) to align with maximum sunlight
- Reads data from power monitoring system (I2C)
- Sends data to web dashboard (WIFI)
- Debugging/Flashing (USB)

MCU Must...

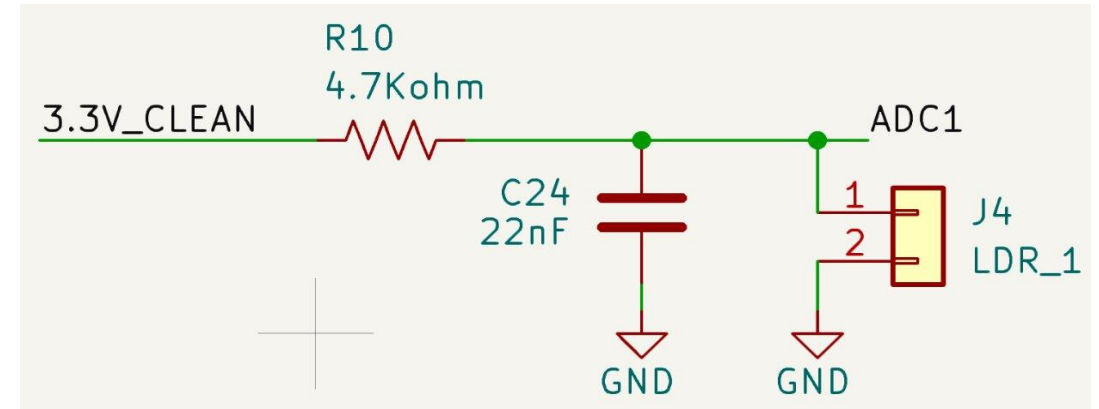
- Operate reliably on 3.3 V without resets
- Sample 8 sensors at 12-bit resolution
- Generate stable PWM signals for servo control
- Support I2C, USB, and WIFI communication



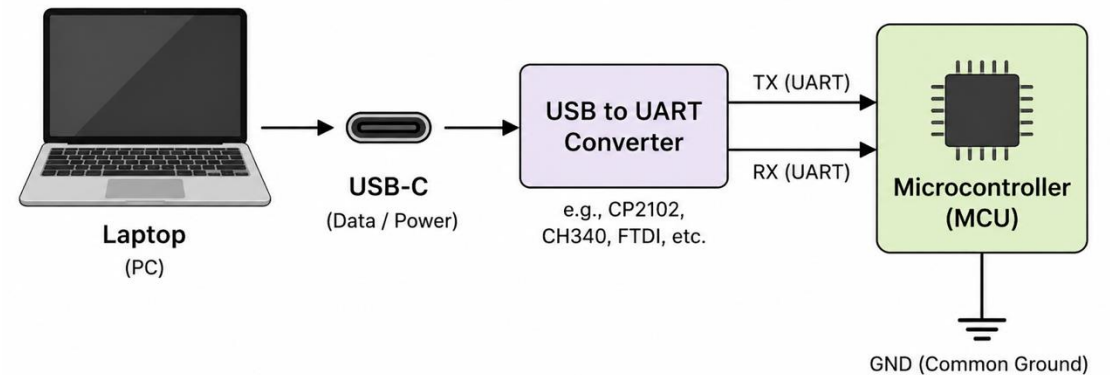
- PDV-P8103 photocell (LDR)
- Sensitive especially in 400-700 nm range, good for panel
- High resistance in dark, low in light
- Voltage divider: probe at midpoint
- Capacitor denoises

Sensors Must...

- Output signals within 0-3.3V range
- Provide detectable difference when under uneven light
- Use filtering to prevent erroneous input
- Be mounted rigidly to system

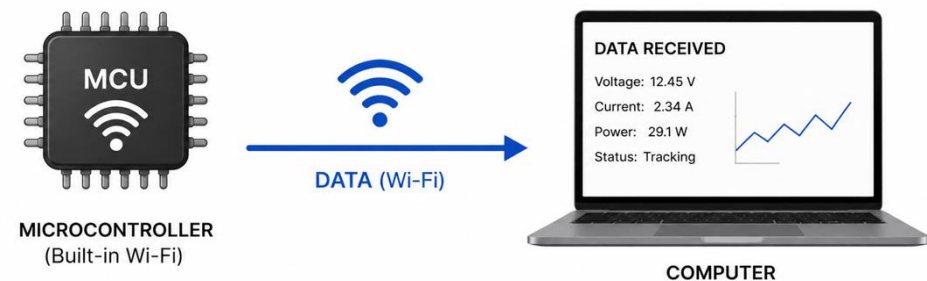


- USB to UART: Laptop to MCU
- Enables flashing program onto MCU
- Enables debugging through prints
- WIFI enables communication w/o physical proximity
- Enables data collection and monitoring
- Solar panel energy harvest + battery SoC



Communication system must...

- Provide UART at 3.3 V logic levels
- Support stable serial communication at 115200 bps
- Share common ground with MCU
- Avoid back powering between USB and system



- Actuation system: move the solar panel
- DS5160 servos
- Cheap, lightweight
- Provide ~60 kgcm torque at 6V
Sufficient for panel + extras
- Speed irrelevant
- Two servos used: one for elevation, one for azimuth

Actuation system must...

- Operate under load at 6V
- Accept signaling at 50Hz 1.0-2.0 ms
- Prevent EMI noise from affecting MCU



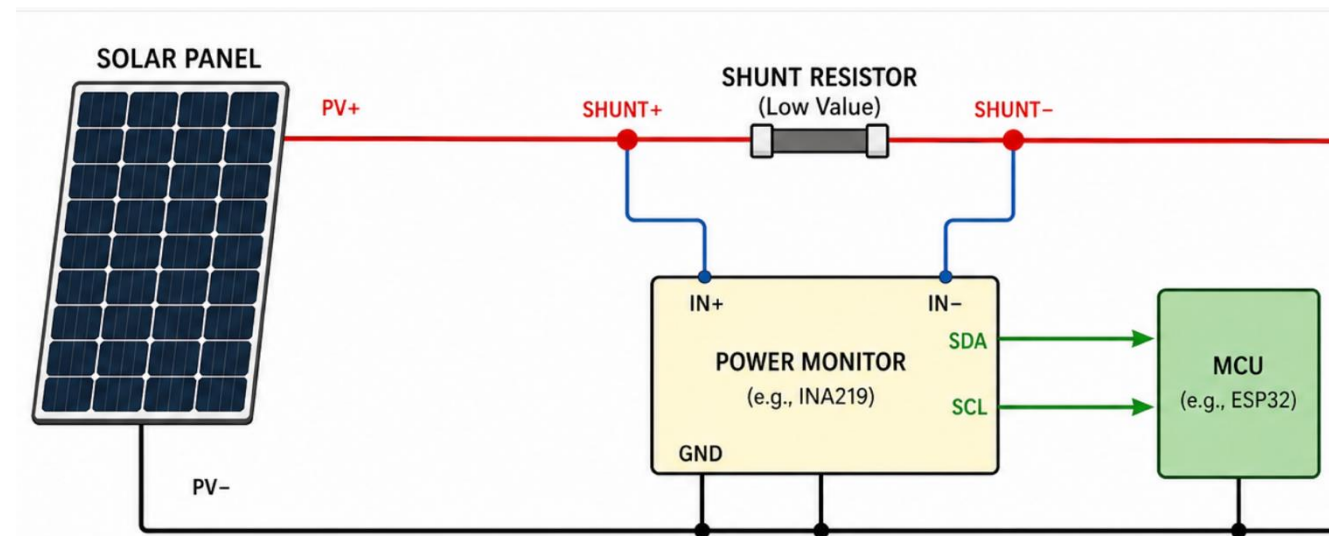
- Tracks voltage, current, and power output
- Shunt resistor to sense current
- Sends data to microcontroller via I2C

How it Works

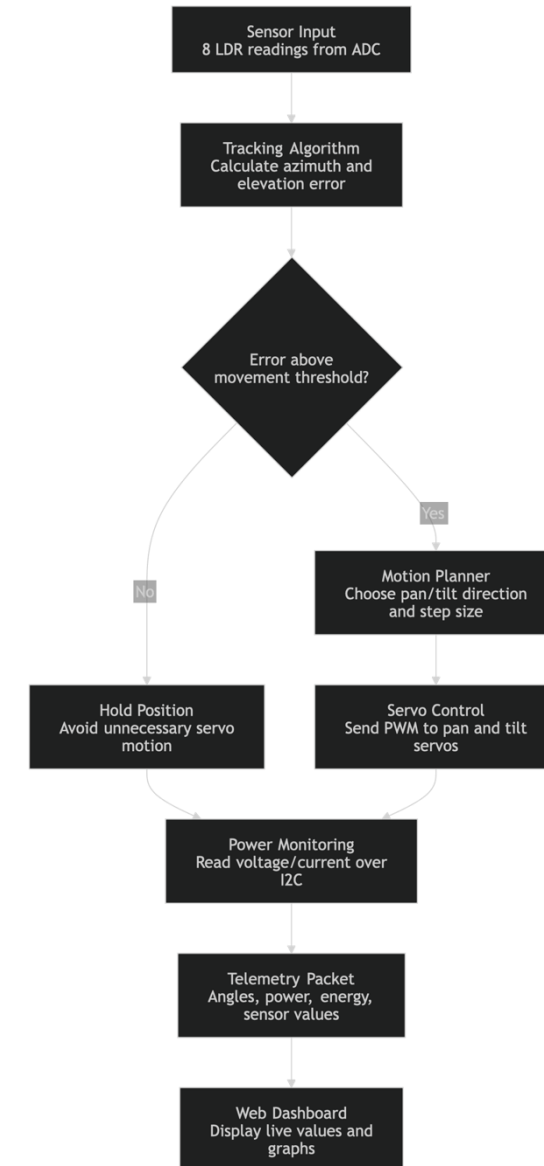
- Shunt resistor (.02 Ohm) in series with power line
- Power monitor measures:
 - Shunt voltage - calculate current
 - Bus voltage - measures panel voltage
- Microcontroller receives data and computes power

Power Monitor Must...

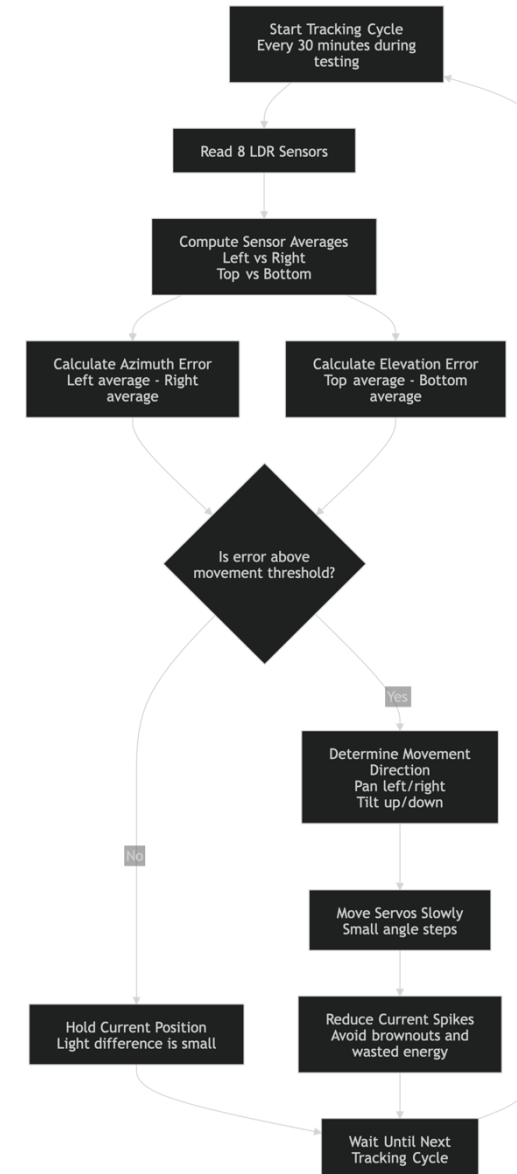
- Must measure current up to 8A peak
- Must send data over I2C reliably



- ESP32 reads 8 LDR sensor values using ADC
- Computes horizontal and vertical light imbalance
- Decides whether azimuth/elevation adjustment is needed
- Sends PWM commands to pan and tilt servos
- Collects voltage/current data over I2C
- Sends telemetry to web dashboard over Wi-Fi



- Average left/right sensors to determine azimuth error
- Average top/bottom sensors to determine elevation error
- Move only if error exceeds threshold
- Step motors slowly to reduce current spikes
- Reposition every 30 minutes during testing
- Hold position when light difference is small



SolarTrack: Web Dashboard

Live monitoring for self-positioning solar panel system.

Last updated: 4/27/2026, 10:09:54 PM

TRACKING MODE

AUTO

LDR-based solar tracking

PANEL ORIENTATION

Azimuth

163°

Elevation

50°

LDR READINGS

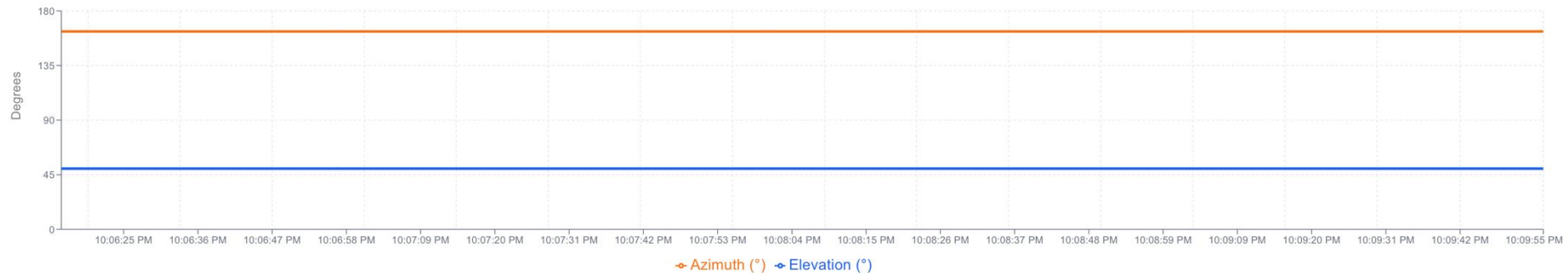
Panel LDRs

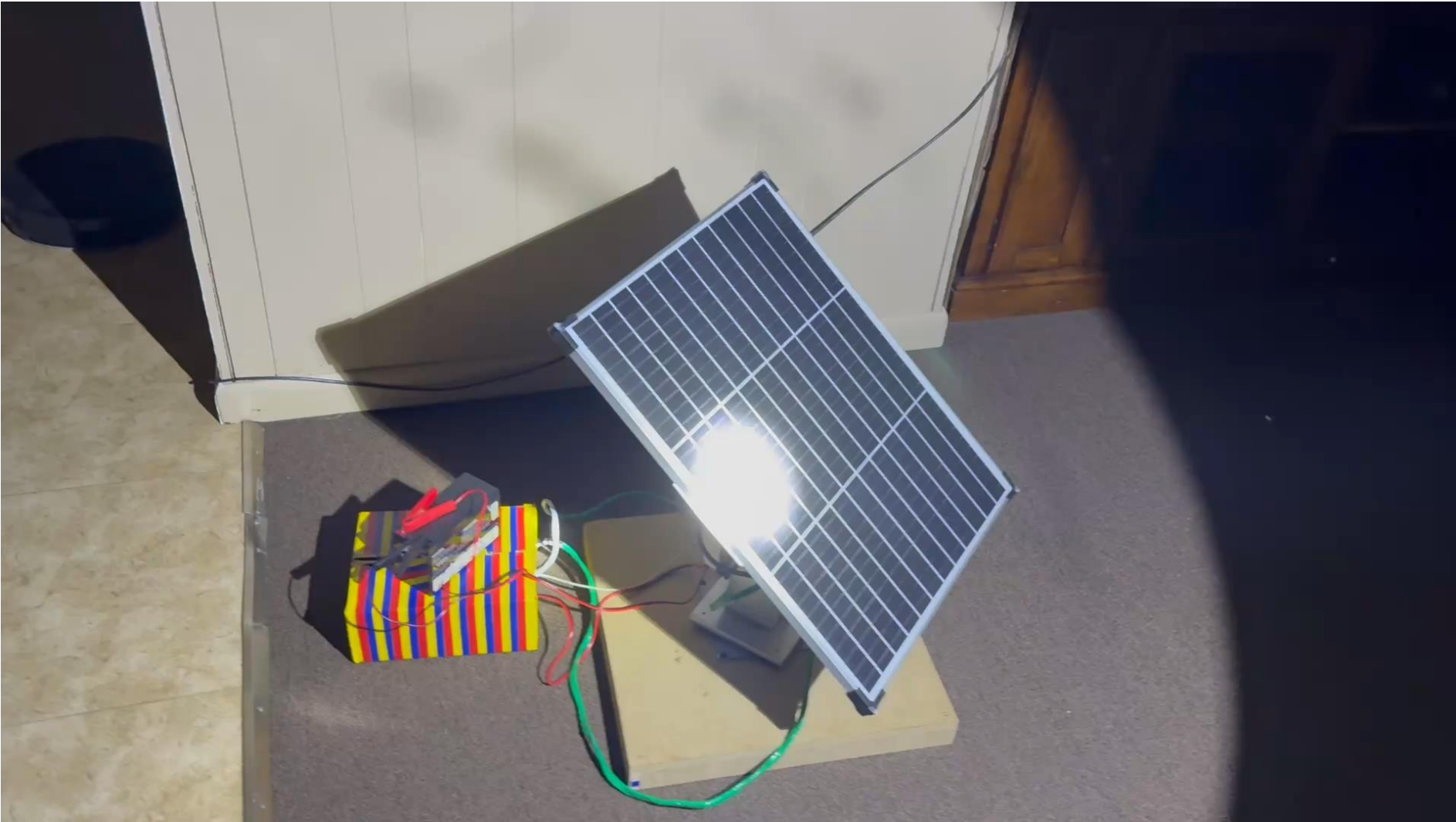
Top Left	148	Top Right	157
Bottom Left	362	Bottom Right	294

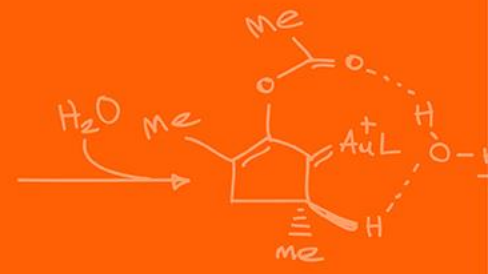
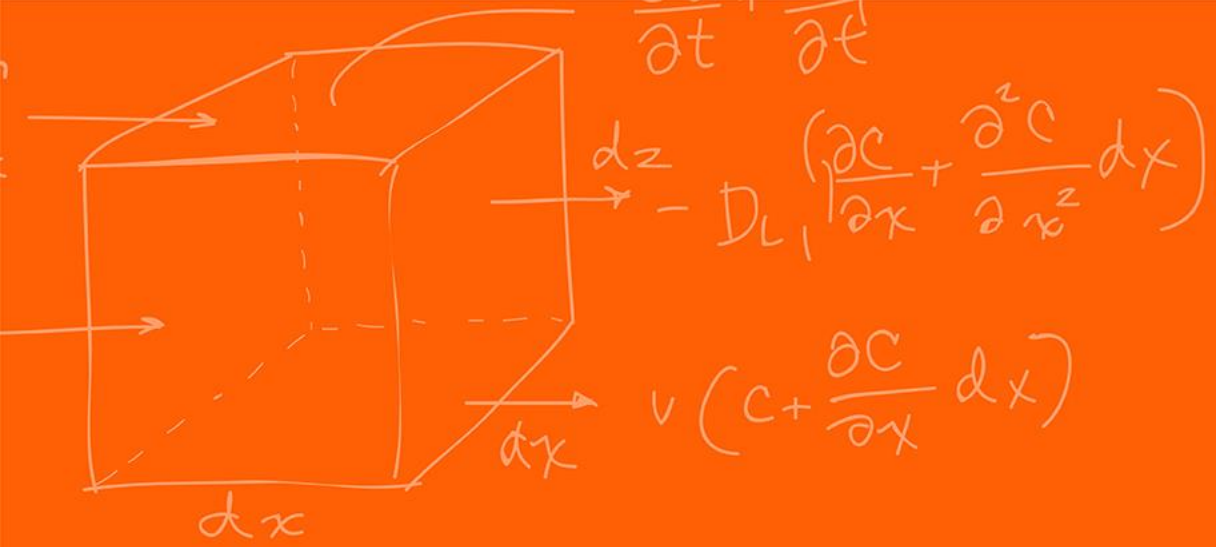
Base LDRs

Top Left	137	Top Right	258
Bottom Left	0	Bottom Right	0

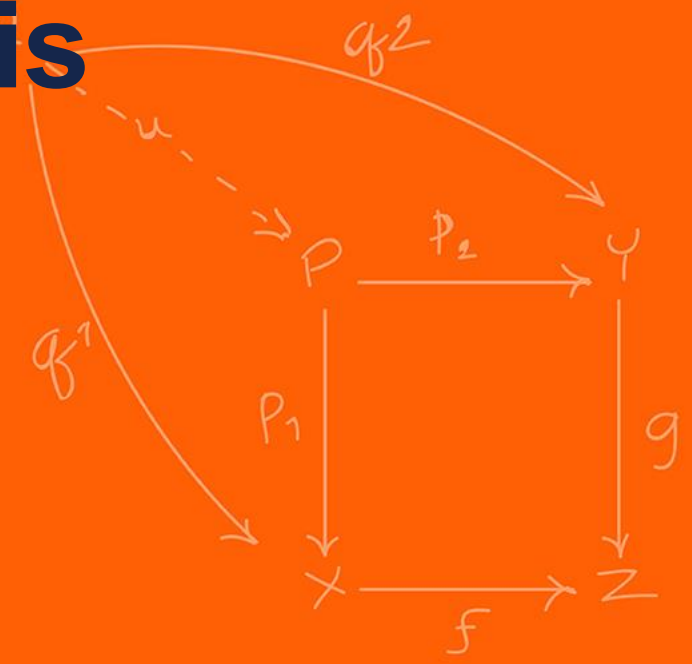
ORIENTATION THROUGHOUT THE DAY







Testing and Analysis



- Selected two clear-sky test days with very similar sunlight conditions to keep the comparison as fair as possible
- Used the same 50W monocrystalline solar panel and a 12V battery starting at ~60% state of charge
- Began each test at 9:00 AM and continued through 3:00 PM
- Recorded system behavior at 10-minute intervals over the full 6-hour test window.

Comparison Metrics

- Compared the static and self-positioning setups using:
 - harvested energy over time
 - net energy gain from tracking
 - tracker energy overhead

Static Test

- At 9:00 AM, manually oriented the panel so it was directly facing the sun
- Left the panel in that position for the remainder of the test
- Recorded:
 - panel power output after MPPT
 - cumulative harvested energy

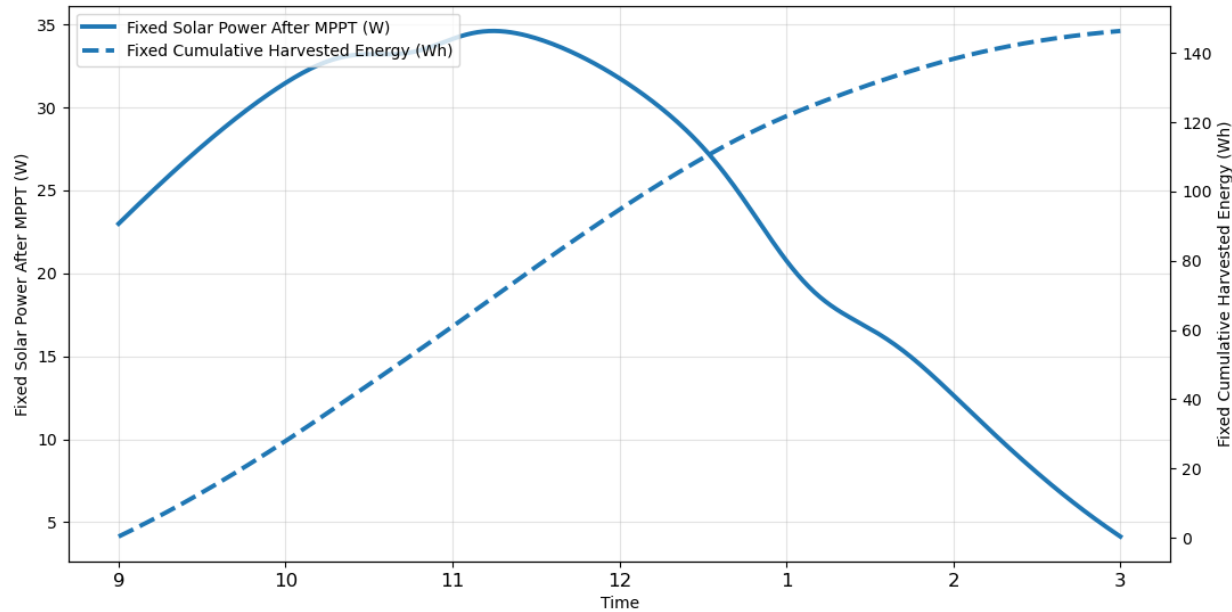
Self-Positioning Test

- Mounted the same 50 W panel on the self-positioning mechanism.
- At 9:00 AM, oriented the panel to face the sun and started the tracking system.
- Programmed the system to reposition the panel every 30 minutes to maintain better alignment with the sun.
- Recorded:
 - gross solar power captured
 - tracking system power use
 - net harvested energy after repositioning losses

Static vs Self-Positioning Power Profiles

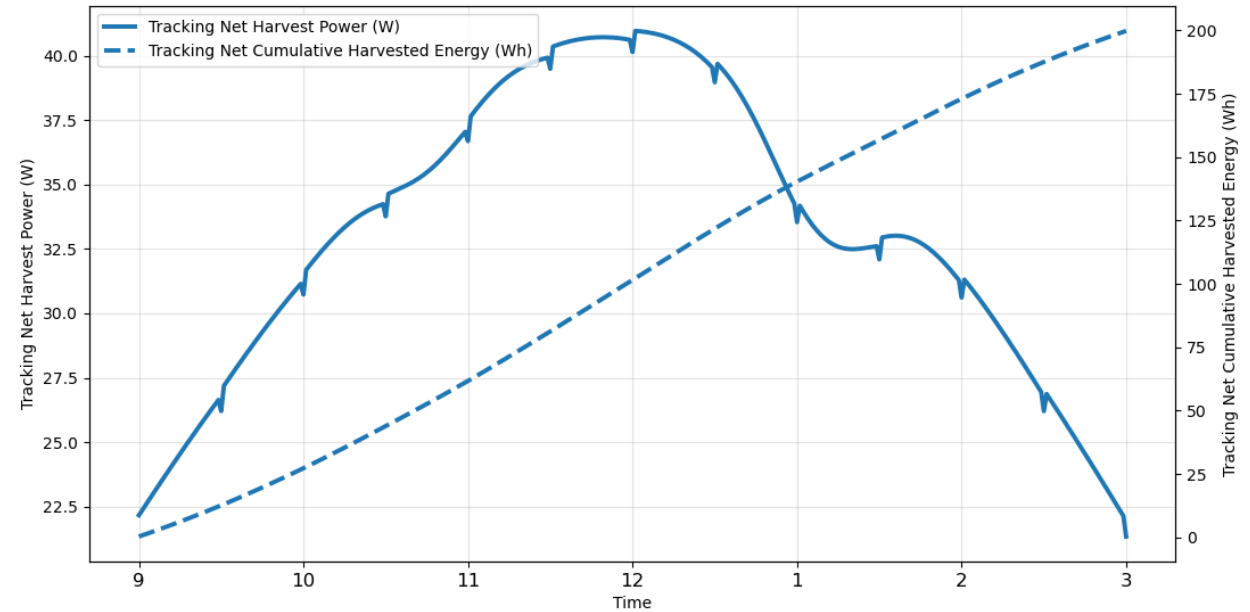


Fixed Solar Panel: Outdoor Test

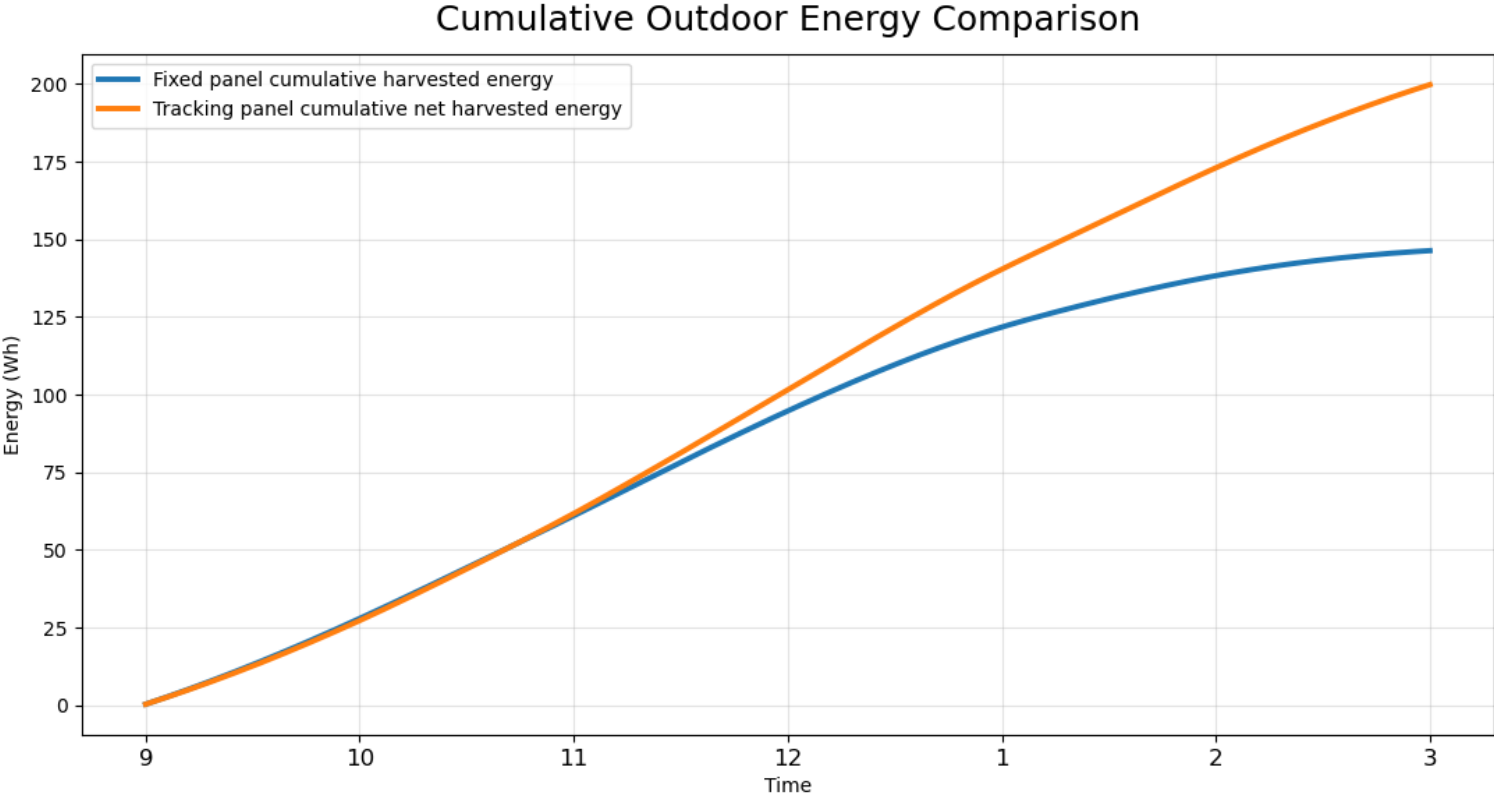


- Started at ~23W
- Peaked at ~34W
- Dropped to ~4W

Tracking Panel Net Captured Energy After Repositioning Losses



- Started at ~22 W
- Peaked at ~40W
- Maintained ~22W
- Small dips in tracking curve every 30min



Fixed 146.35 Wh
Tracking 199.48 Wh

Successes

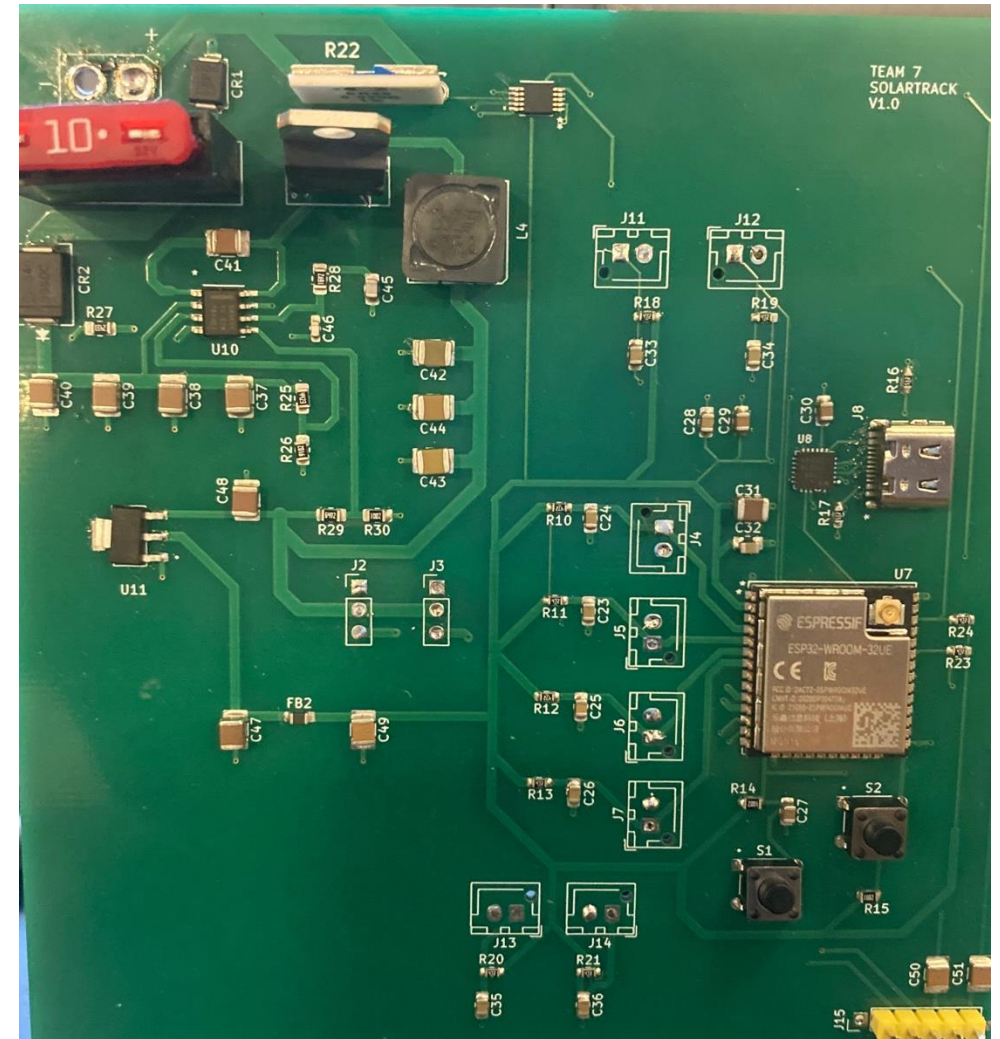
- Clear improvements in performance
- Peak power: +17.6%
- Net harvest: +36.3%
- System clearly viable

Challenges

- Soldering PCB
- Slight inconsistency between days
- Only tested one movement frequency
- More rigorous testing in future

Future Testing

- If multiple solar panels available
- Set to various movement frequencies
- Test simultaneously
- On clear day, cloudy day...
- Short vs long day as well (winter vs summer)



Thank You!

Questions?