Low-cost Fine Sun Sensor - PIC 1- Eletrocap

Problem

Attitude determination (spacecraft orientation in 3D space) is essential for the correct operation of any satellite. This includes keeping solar panels pointed toward a reliable energy source, aligning antennas for communication, and aiming instruments for observation or measurement. Without a consistent external reference, a spacecraft can drift, lose power, fail to communicate, or collect unusable data. This issue becomes even more critical during long missions, autonomous operations, or when reorienting after maneuvers or disturbances. Accurately and continuously knowing the spacecraft's orientation relative to a stable point in space is therefore essential for mission success.
A possible solution to this problem is a Sun Sensor. However, current products on the market are either quite expensive, requiring complex manufacturing processes (therefore being out of reach for small organizations and educational projects) or really inacurate and almost useless. We wish to change that with a simple, more acessible solution while still achieving decently accurate results.

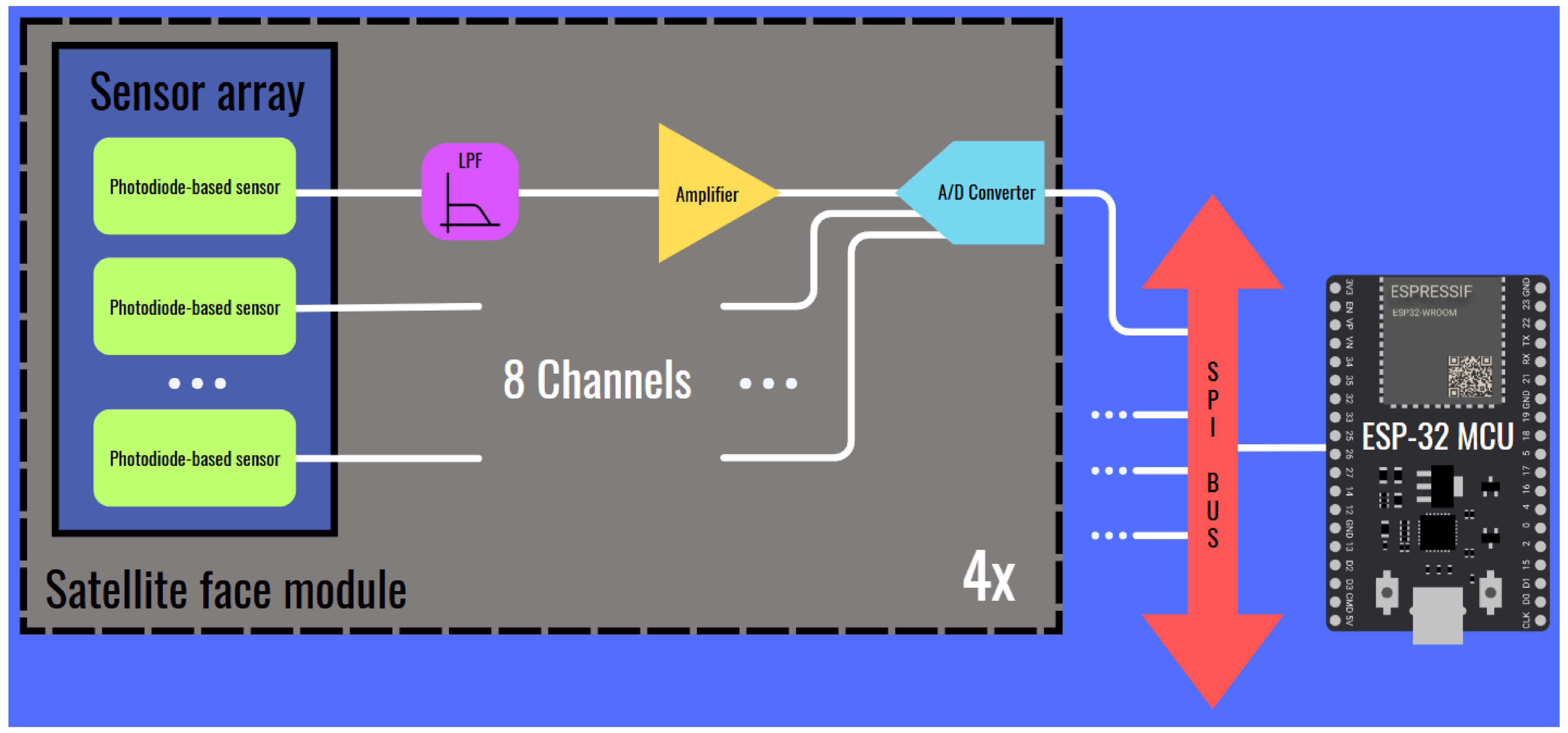
Requirements

Before beginning to design our Sun Sensor, we studied the needs of the market and established requirements based on those needs. We found the following to be adequate:

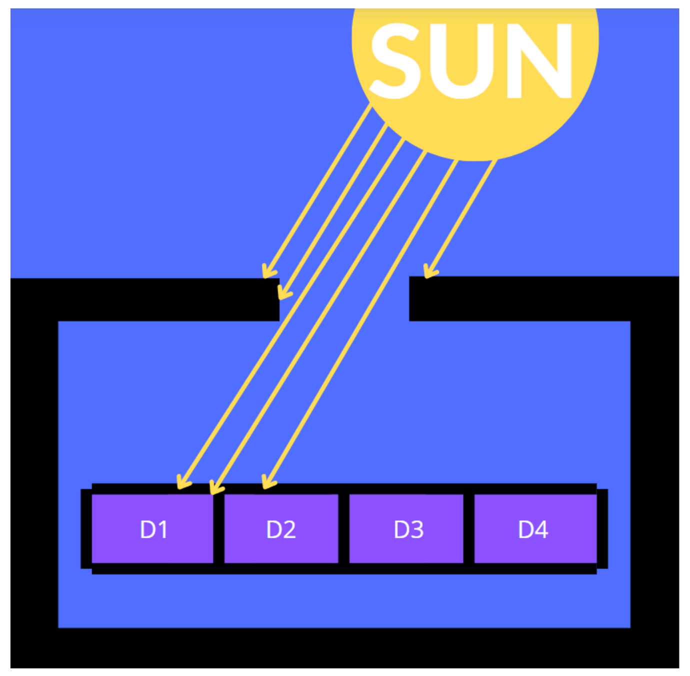
- Accuracy → ±1 °
- Power consumption → 5 W
- Cost → ≤ 100 €
- FOV -> 90 °
- Mass -> ≤ 1.5 kg

Solution

We came up with a photodiode array based solution:



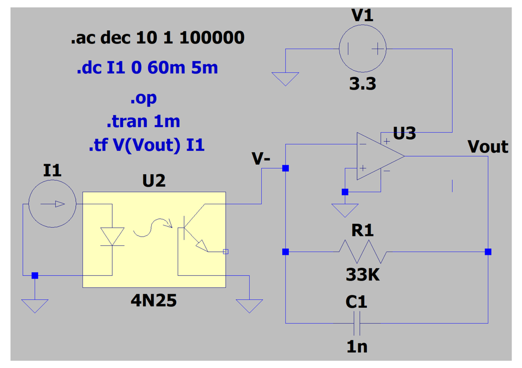
We use two slits which guide the light emited by the sun and make it shine on specific places of the array based on the incidence angle, like this (we have 8 photdiodes in total, four for each axis, one of these slits per axis):



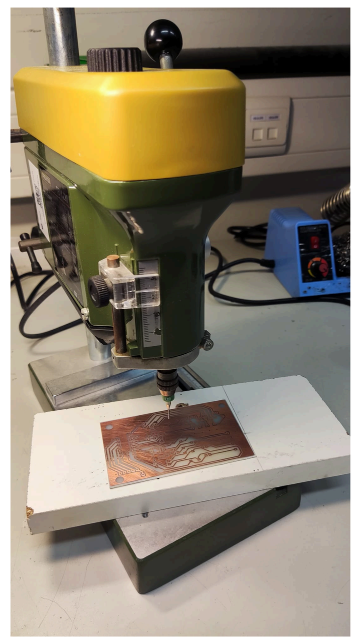
After conditioning and acquiring all photodiodes signals, the data is processed digitaly by an ESP-32 microcontroller which combines the information from all of the sensors on the satellite's faces and determines a "Sun Vector" which points to the deducted position of the Sun. This can later be communicated by the controller to the OnBoard Computer (OBC) which will use the information for attitude determination purposes.

Development and integration

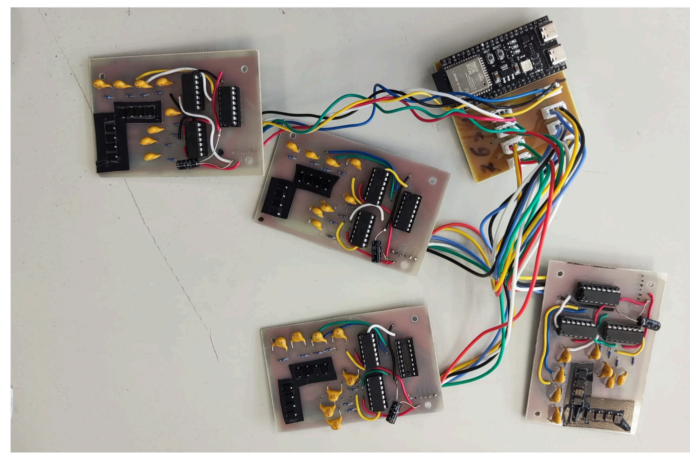
We started by designing the sensor circuit and simulated it in LTSpice to check sizing:



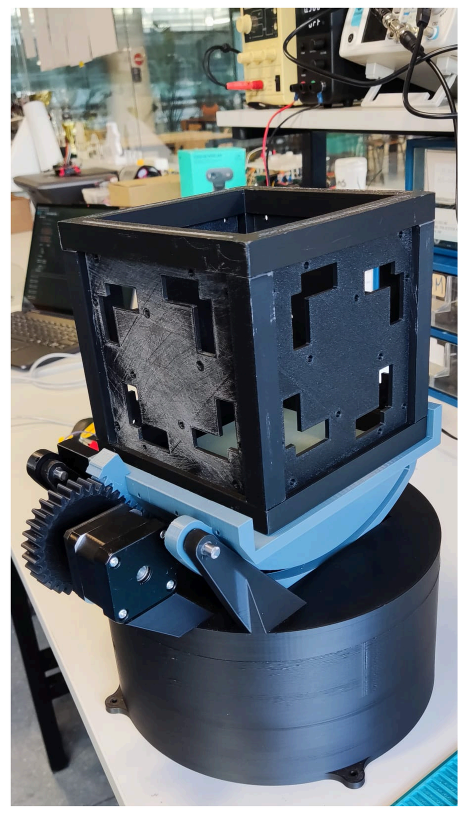
We got the components and tested the circuit. After that we designed and produced PCBs. You can see a video of that on our blog.



After making a couple of these PCBs we had our complete system:



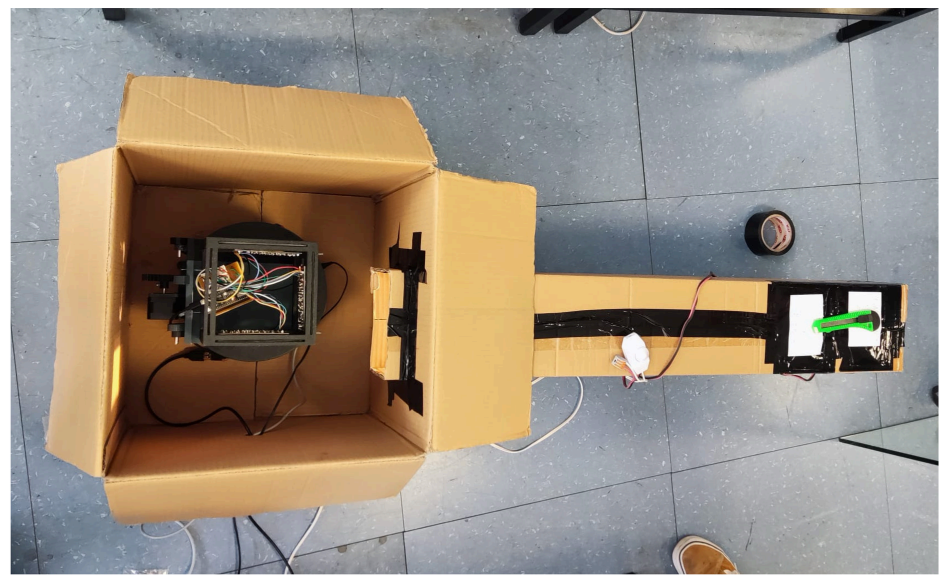
To test our project we had to build what we call a "Deep Space Simulator" which consists on a box with a light source simulating the Sun and a electromechanical system that allows us to orient the satellite inside the box and test multiple positions to check results.



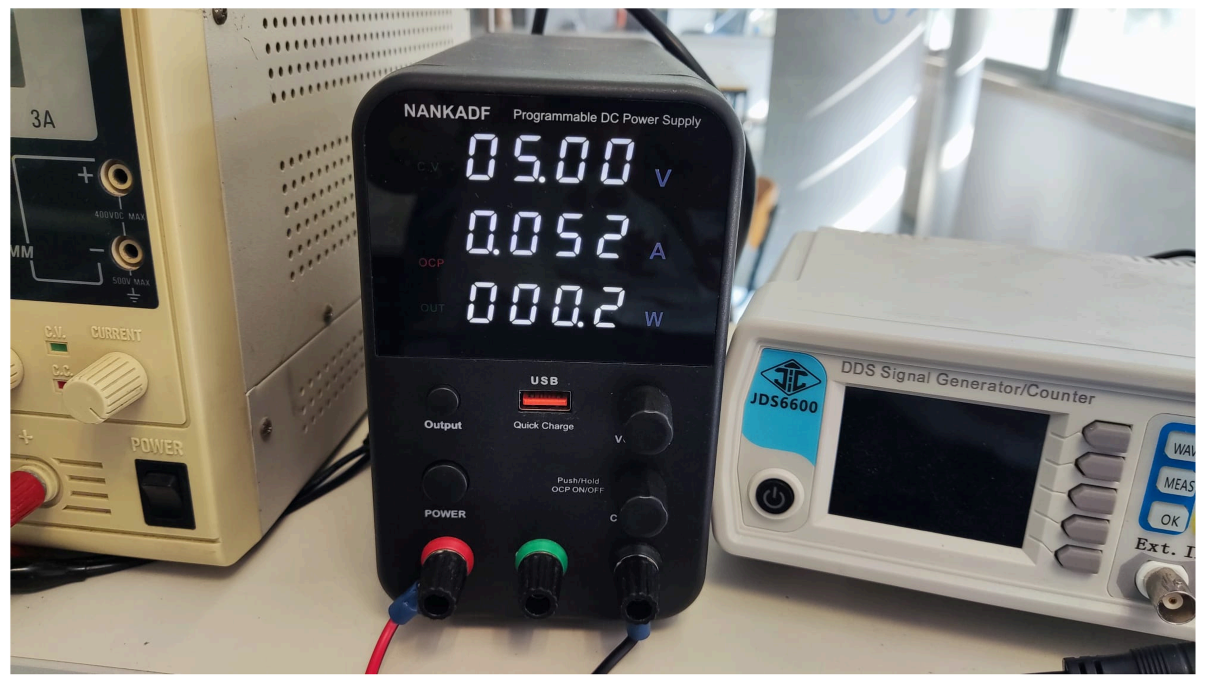
You can see all these parts here at our table. Ask any questions you wish! We will have all the pleasure in showing our prototype to you.

Results

With the Deep space simulator we designed previously, we carried out several tests. Mainly to determine the sensor's real accuracy and validate the design.



After iterating several angles and determining the accuracy and error of the sensor, we also tested its power draw and concluded it is much more efficient than expected. (about 200mW as can be seen on the image)



Final Conclusion

In conclusion the tests were very successful and we obtained positive results, with further testing and validation we believe the sensor can be improved, but it's a good first step into designing a fine low-cost sun sensor. Although not all the requirements were reached within the first testing phase, the results were very promising, with an accuracy of 5º and FOV of 75º. The power draw was the best result, having only a consumption of 200 mW, being much more effiecient than the 5 W we estabilished as a target.

Visit our website!

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