FPGA Based Single Chip Controller For a Dual-Axis Sun Tracking System

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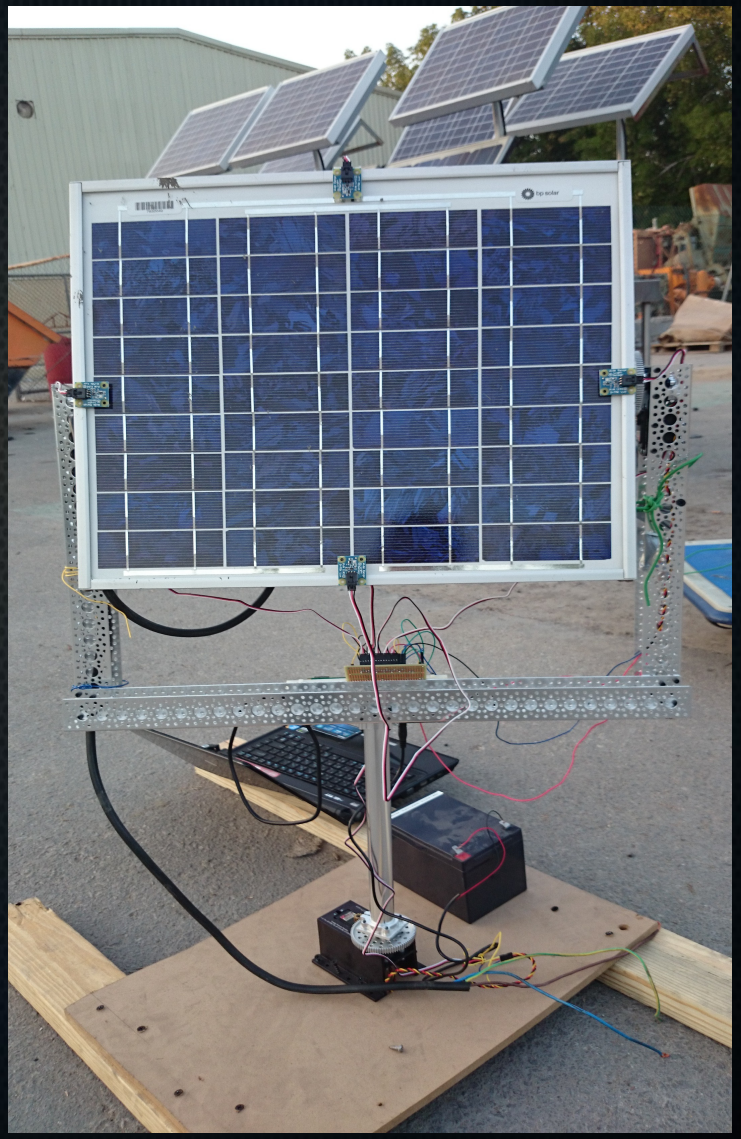
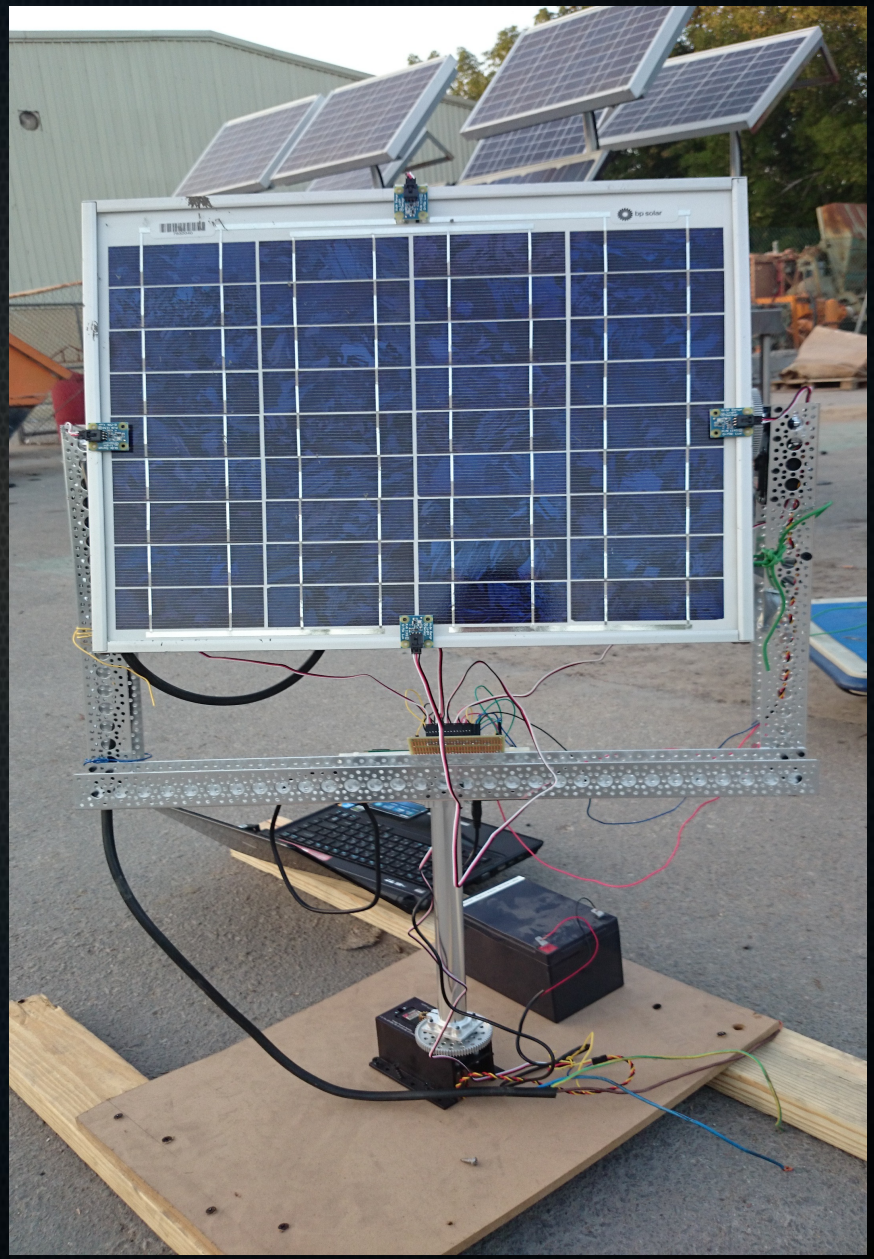


Outline

- Introduction
- Selecting Parts
- Architecture
- Components design and implementation
- Testing and analysis
- Development tools
- Conclusion

Introduction

- Potential of solar energy.
- Harvesting solar energy.
- Sun trackers.



Sun Trackers Types

- Based on axis:
  - Single axis.
  - Dual axis.
- Based on tracking method:
  - Open loop.
  - Closed loop.
  - Hybrid.

Design Approach

- Dual-axis
- FPGA based
- Tracking the sun using
  - Time
  - Light sensors
- Moving the solar panel using two closed-loop servo motors
- Motors control signal generated by the FPGA chip.

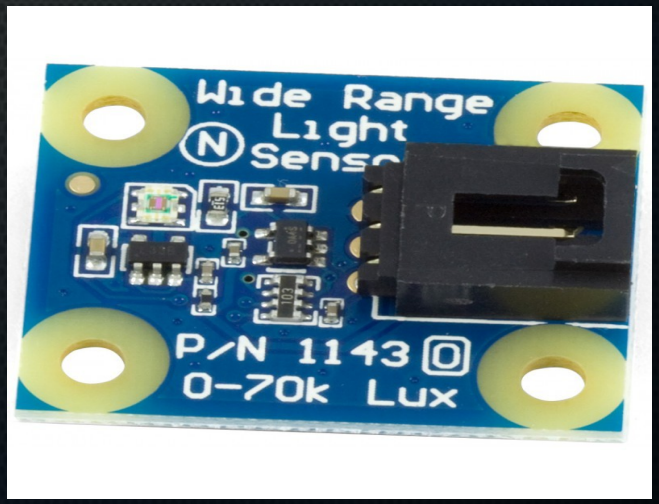
Selecting Parts

- FPGA chip:

Altera MAX10

- Light sensors: Phidgets 1143
- Motors:

Two servo motors



MAX10

- Relevant Specs:
- 12 bit ADC
- ADC measurement range: 0 – 2.5 V
- 32KB User Flash memory

- Why chosen?
- One chip
- Light sensors interfacing
- Storing records

Phidgets 1143

- Relevant Specs:
- Range:

0 – 70K lux

- Output signal range:

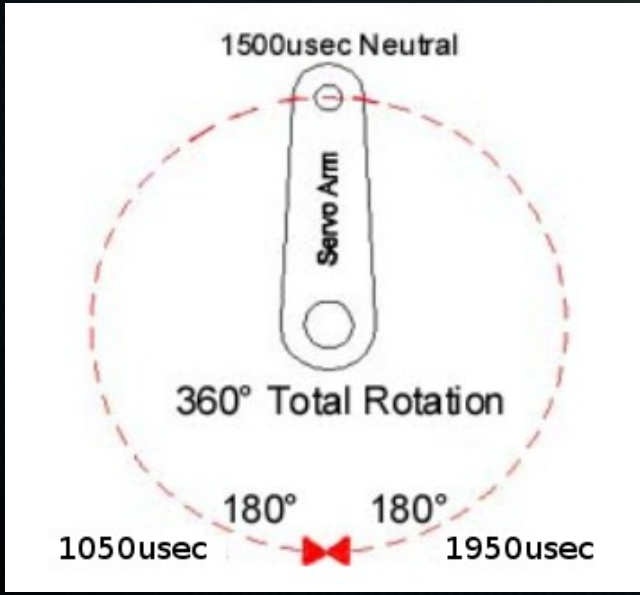
0 – 2.5 V

- Why chosen?
- Direct sunlight, around 75k lux
- Full Resolution

Illuminance	Example
0.002 lux	Moonless clear night sky
0.2 lux	Design minimum for emergency lighting (AS2293).
0.27 - 1 lux	Full moon on a clear night
3.4 lux	Dark limit of civil twilight under a clear sky
50 lux	Family living room
80 lux	Hallway/toilet
100 lux	Very dark overcast day
300 - 500 lux	Sunrise or sunset on a clear day. Well-lit office area.
1,000 lux	Overcast day; typical TV studio lighting
10,000 - 25,000 lux	Full daylight (not direct sun)
32,000 - 130,000 lux	Direct sunlight

Servo Motors

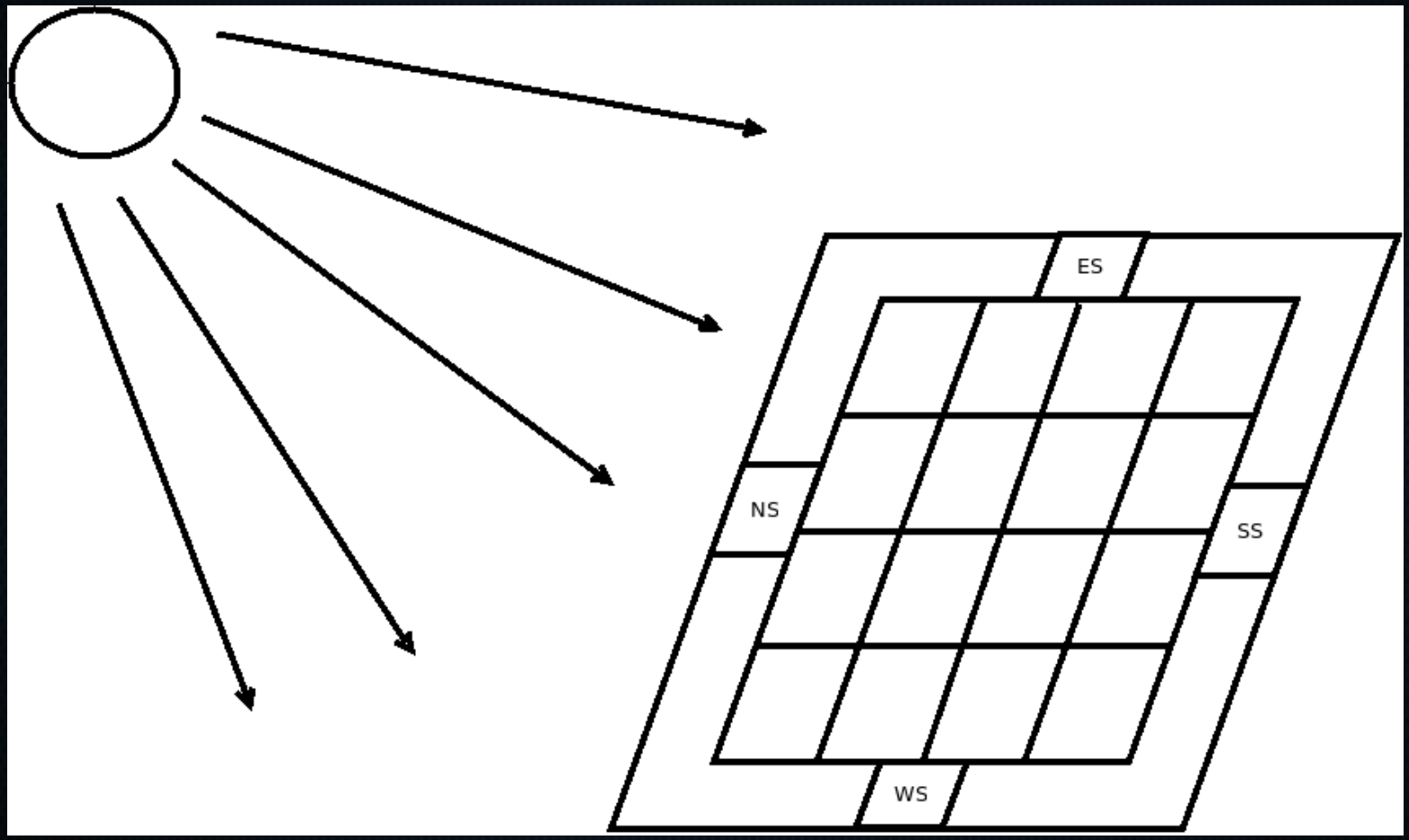
- Power consumption
- Closed loop



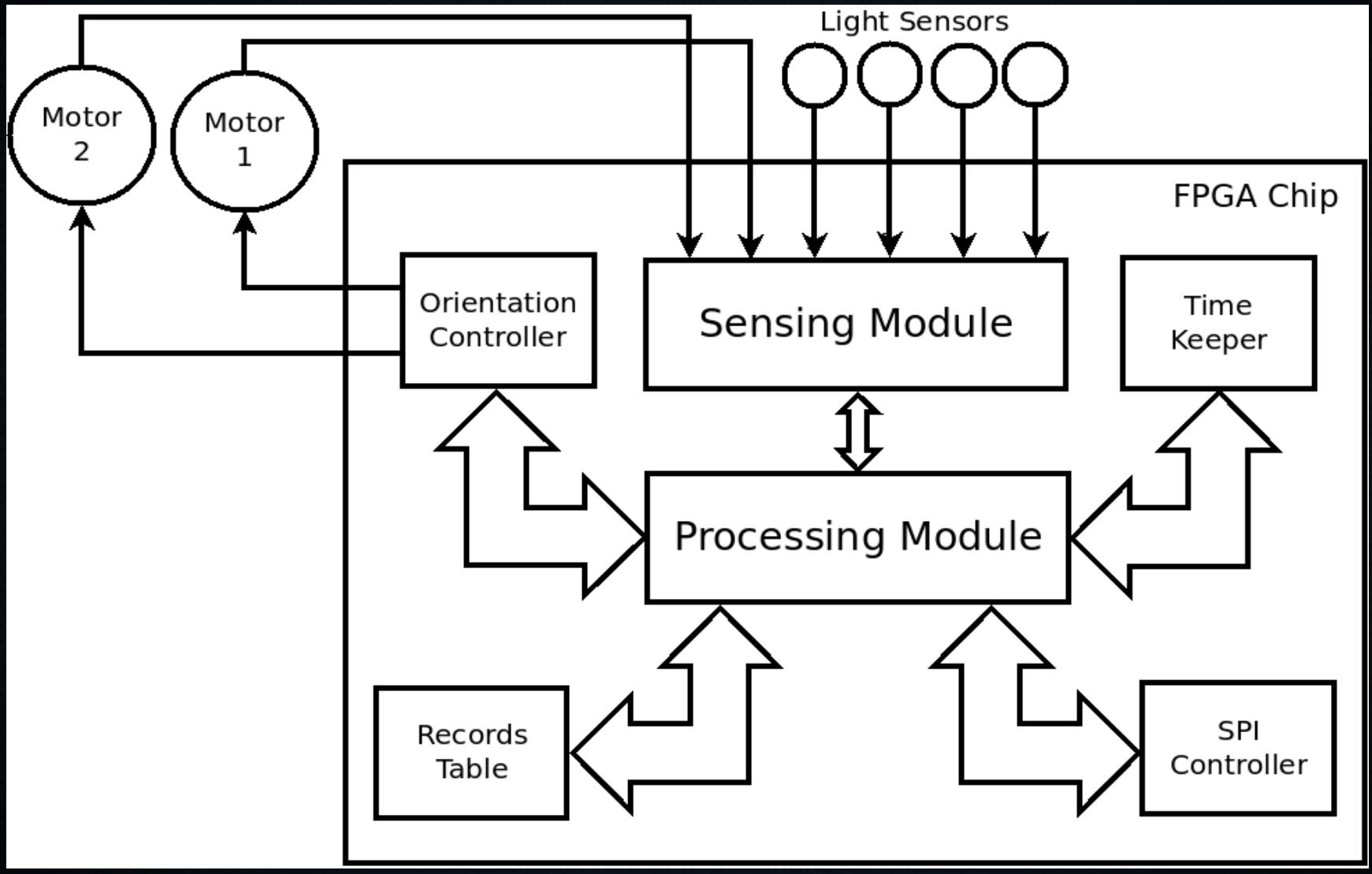
- Why chosen?
- Power consumption
- Accuracy
- Simplicity

Mechanical Architecture

Detecting and Computing the Position of the Sun



Design Architecture



Component Design and Implementation

- Time keeper.
- Orientation controller.
- Records table.
- SPI controller.
- Processing unit.

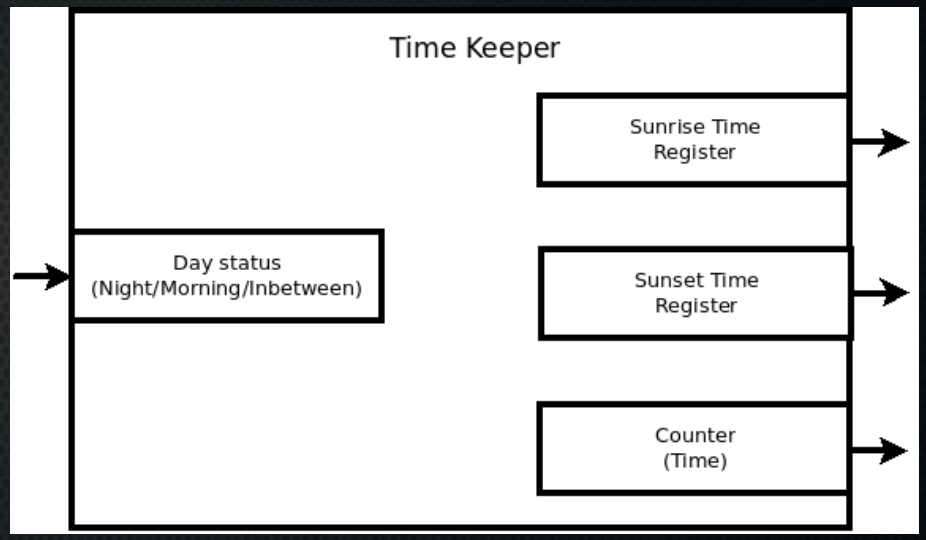
Time Keeper

Objective:

Keep track of the time.

How it works

How it is implemented



Sensing Module

Objective:

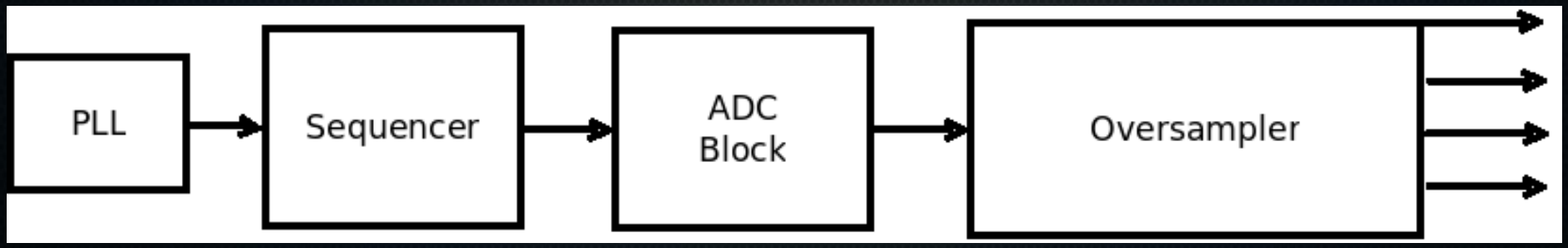
Provide the reading from the sensors to the processing unit.

How it works:

A sequencer controlling the ADC block to fill a register for each sensors.

How it is implemented:

ADC block and sequencer generated using Qsys



Orientation Controller

Objective:

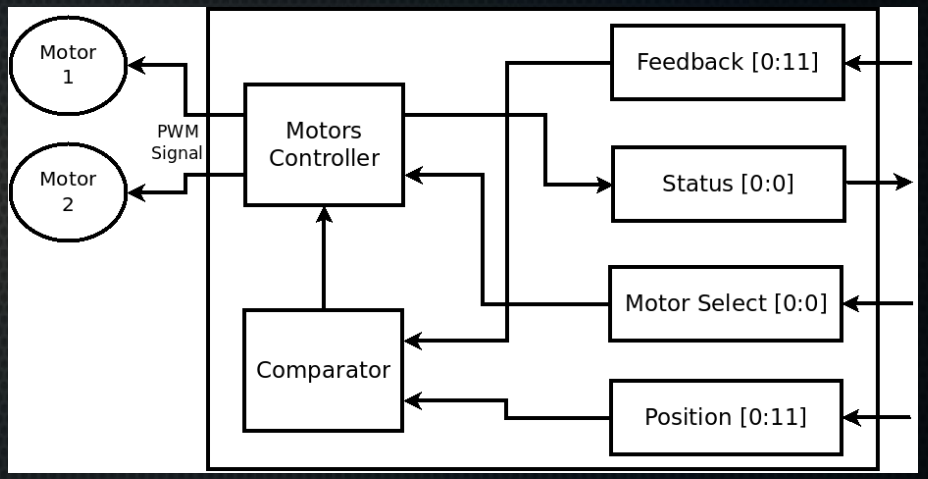
Control the position of the motors.

How it works:

Generates position signal based on position value from the processing unit.

How it is implemented:

Two PWM generators.



Records Table

Objective:

Stores data collected from the environment.

How it works:

Each record has an address.

How it is implemented:

On the flash memory

Hour	Minute	Position X	Position Y	LE	LW	LN	LS
1	00	106	154	2.0	2.0	2.0	2.0
1	15	110	160	2.2	2.2	2.2	2.2
1	30	115	160	2.5	2.5	2.5	2.5
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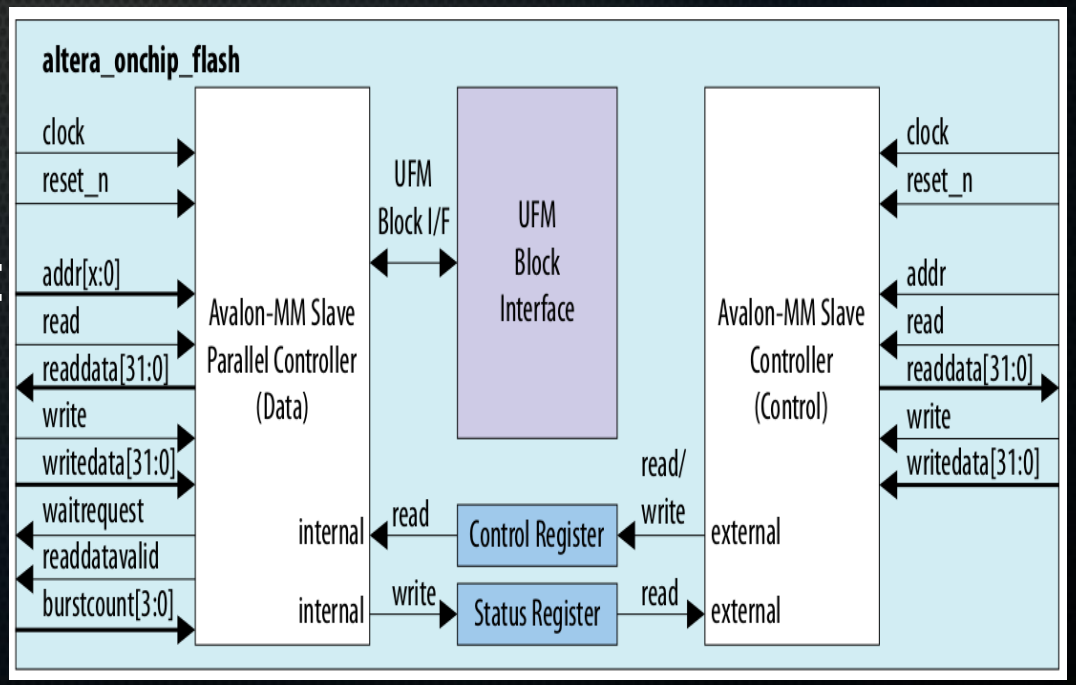


SPI Controller

- Objective:
- Communicates with external systems and provides or writes registers in the registers bank.
- How it works:
- How it is implemented:

Processing Unit

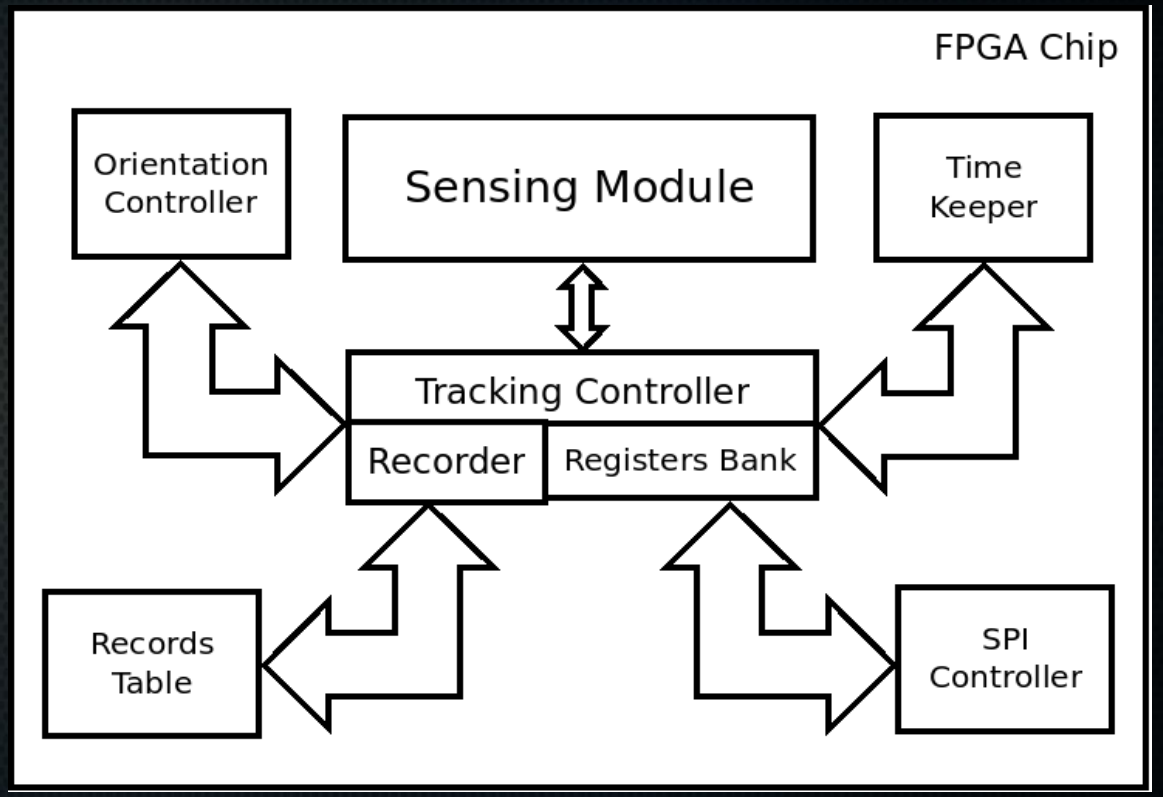
Objective:

Management and computations.

How it works:

How it is implemented:

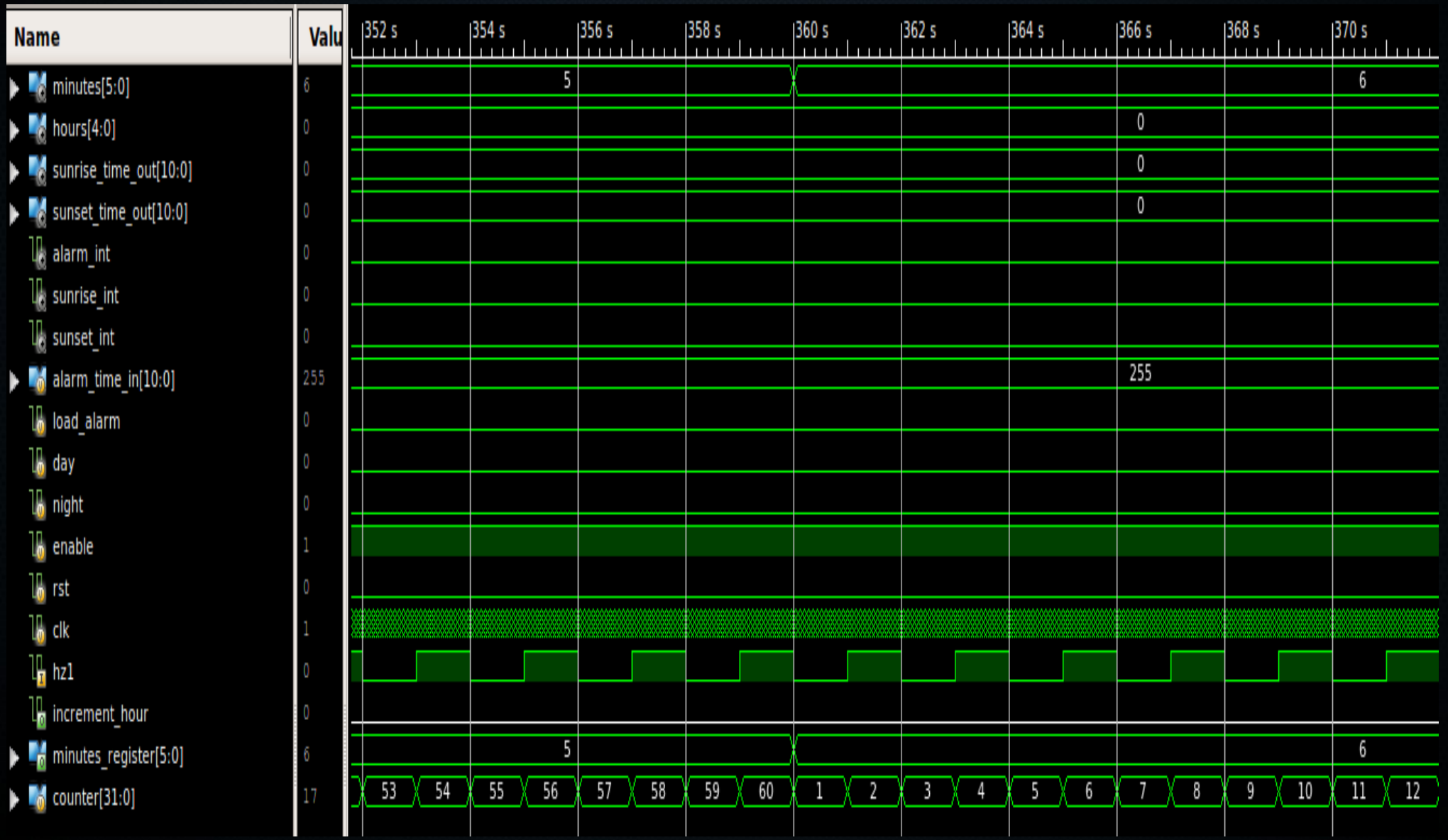
Behavioral description of the tracking algorithm.



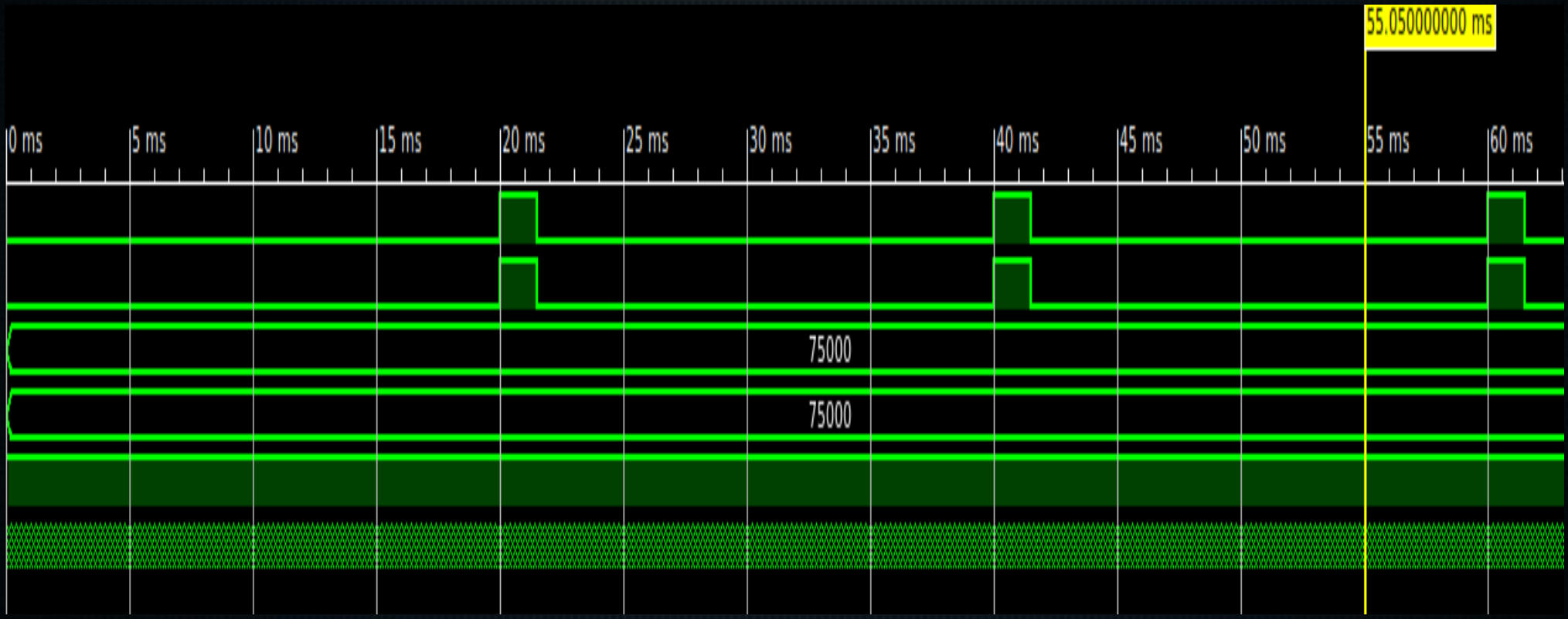
Tracking Algorithm

- Detecting and computing the position of the sun.
- Machine learning
- Adjusting records

Testing and Analysis, Timekeeper



Testing and Analysis, Orientation Controller



Development Tools

- Development Software: Quartus 2 (Altera)
- Development Board: Bemicro MAX10
- Simulation Software: iSimulator (Xilinx)

Videos

https://www.dropbox.com/s/zpxymc70a5ccuzw/MOV_0160.mp4?dl=0

https://www.dropbox.com/s/dk37ijd4j7j09yh/MOV_0124.mp4?dl=0

https://www.dropbox.com/s/5io0ha47fnvwmbq/MOV_0156.mp4?dl=0

Difficulties

- Very new IC to the market.
- Rare tutorials.
- Limited documentation.

Conclusion