UNIVERSITY OF ARIZONA
STUDENT SATELLITE PROJECT

Technical Note

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Revision 1.0: Initial Draft

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1. Document Overview

This document shall describe requirements, design, interface, current status, and test plan for the UASat sun sensor. A sun sensor is a device that can determine the location of the sun. Many living things can accomplish this task in nature, but how does one give a spacecraft, such as a solar powered satellite, the ability to autonomously determine the direction of the sun? Many schemes have been successful over the years. One of the most simple and highly accurate methods is to use photovoltaic cells. By arranging these cells in a known geometry and comparing the outputs of identical cells, the direction of the sun can be determined. This information is vital to the generation of the maximum amount of power from the solar arrays.

2. Requirements

2.1 Location of Sun

To generate the maximum amount of energy, a solar array needs to be facing the sun, perpendicular to the incident sunlight, as flux through a surface is greatest when the flow direction is normal to that surface. The satellite must be capable of determining which axes to rotate about in order to maximize the power generated from its solar cells. One way to accomplish this is to directly measure the position of the sun with onboard sensors. Using spherical coordinates, two angles are required in order to locate the sun. This is shown graphically in Figure 2-1.

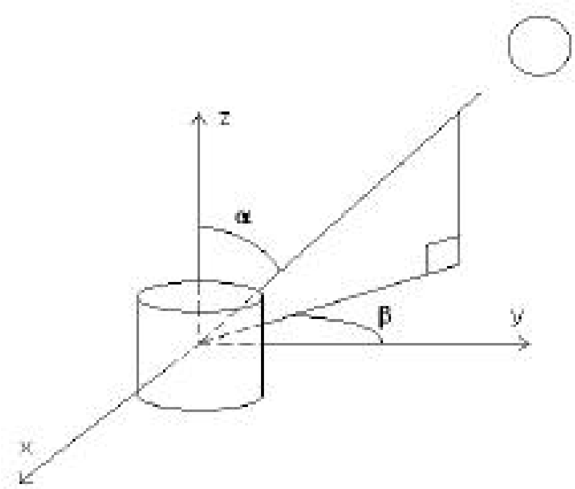

Figure 2-1. Sun can be located by finding two angles.

2.2 Accuracy

The accuracy of the sun sensor shall be of the order of +/- 5%; subject to mission purpose.

2.3 Cost

Cost shall be held as low as possible within the mission budget.

2.4 Power

The sun sensor shall consume <<1 Watt of power while active.

2.5 Size

The sun sensors base dimensions shall be kept within a size constraint of 3 cm by 4 cm.

2.6 Production

The sun sensor shall be built in-house by the GNC team.

2.7 Environmental Requirements

2.7.1 Temperature Cycling

2.7.2 Shock

2.7.3 Random Vibration

2.7.4 Vacuum Testing

2.7.5 Radiation Testing

3. Descriptions/Designs/Discussion

3.1 Principle

As the sun is the largest source of irradiation near the earth, photovoltaic cells shall be used to determine the location of the sun. The cells shall be strategically arranged in a known geometry and the outputs of the identical cells shall be compared. A single photovoltaic cell is not advisable because it would require the satellite to change its position in order to make a comparison. The sun is of significant size and distance that it can be considered a point source to something the size of UASat. This allows the total solar irradiation to be considered constant over the projected area of the satellite normal to the incident sunlight.

3.2 Algorithm

3.2.1 Model

The sun sensor shall be model in XYZ coordinates. A two face sensor prototype and its coordinate system are shown in Figure 3-1.

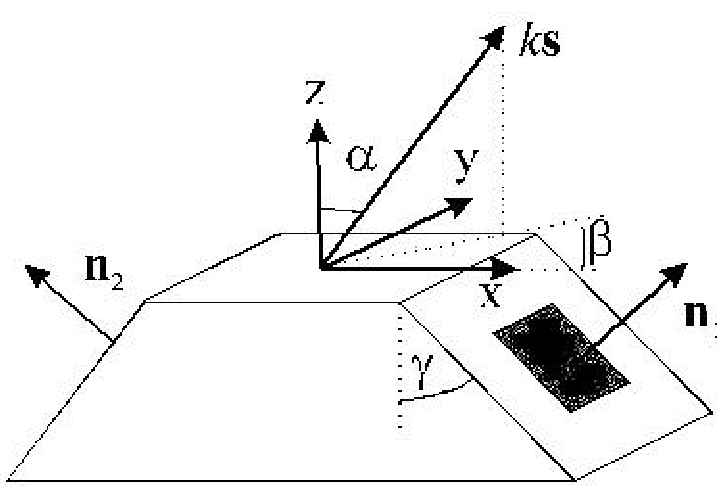

Figure 3-1. Two faced sun sensor coordinate system

3.2.2 Equations for Angles

The derivation for the results below can be found in the appendix.

$$\alpha = \tan^{-1}\left(\frac{(\varphi_1 - \varphi_2)\sin\gamma}{(\varphi_1 + \varphi_2)\cos\gamma\,\cos\beta}\right) \qquad \beta = \tan^{-1}\left(\frac{(\varphi_3 - \varphi_4)\sin\gamma}{(\varphi_3 + \varphi_4)\cos\gamma}\right)$$

Equations 3-1 and 3-2. Relationship between flux, geometry, and direction of sun.

1.3 Hardware

1.3.1 Texas Instruments TSL230B

The TSL230B is a programmable light intensity to frequency converter. It allows for adjustable sensitivity and scalable output. The output is digital and the frequency is linearly proportional to the intensity of the light. A possible wiring configuration for a two TSL230B sensor is shown in Figure 3-2.

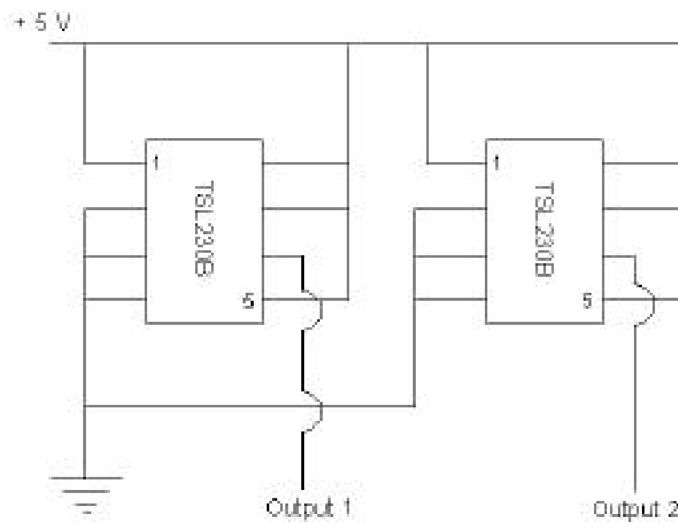

Figure 3-2. TSL230B Wiring Diagram.

1.1.2 Other Hardware Considerations

The output frequencies of the TSL230Bs could be inputted into a microcontroller. The output will be scaled down by a factor of one hundred to increase the resolution of the period measurement. The actual resolution will be directly related to the reference-clock rate of the microcontroller. Scaling the output improves the accuracy of the measurements as the scaled output represents the average of one hundred periods of the principle frequency. Random or high frequency variations are averaged out.

1.4 Software

Mission software has not been developed.

4. Lists

5. Interface Requirements and Specifications

5.1 Placement

The current design requires two sensors in different orientations working together to determine the direction of the sun. One such configuration is shown in Figure 5-1.

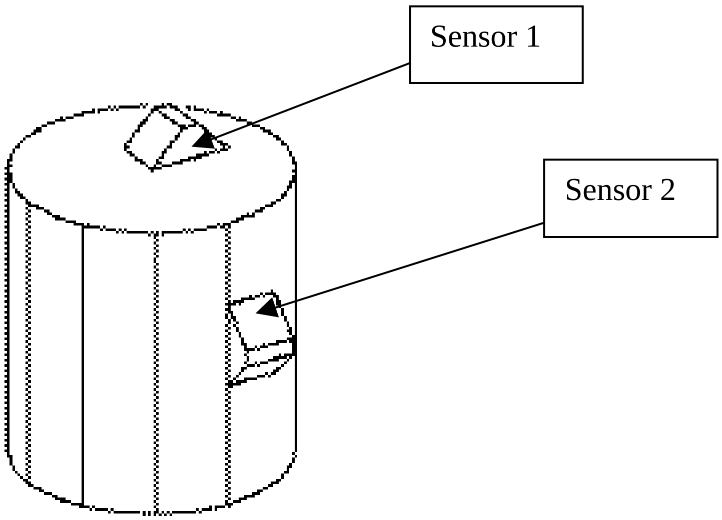

Figure 5-1. Sun Sensor Configuration (not to scale).

5.2 Power

5.3 Onboard Computer

6. Current Status

The sun sensor is currently being tested. Test software has been written and hardware is available. The frequency output of the TSL230B is being measured using a computer data acquisition card. The current schedule is shown in Table 6-1.

	DATE									
Task	8-May	15-May	22-May	29-May	5-Jun	12-Jun	19-Jun	26-Jun	3-Jul	10-Jul
Interface TSL230B with 82C53 and computer program	----------	----------	-----Δ							
Demonstrate sensor capibility			Δ----	------------	-----Δ					
Calibration			Δ----	------------	-----Δ					
Decide on satellite interface method, ie microcontroller				Δ----	------------	------------	-----Δ			
Design mounting apparatus, select satellite location				Δ----	------------	------------	-----Δ			
Write up design	------------	------------	------------	------------	------------	------------	------------	------------	------------	-----Δ
Determine how information will be communicated					Δ----	------------	------------	------------	-----Δ	
Determine how to select most relevant sensor					Δ----	------------	------------	------------	-----Δ	

Table 6-1. Sun Sensor Schedule.

7. Test Plan

7.1 Test Software

Software has been written to measure the frequency output of the sun sensor. The current algorithm is shown below and the entire program can be found in the appendix.

1. Initialize 8253 counter and 8255 I/O gate
2. Take readings of counts from sun sensor
3. Read captured time and counts
4. Calculate the frequencies
   Frequencies are calculated by stopping all counters at once and comparing the count of the known frequency, the 2 MHz clock, to that of the unknown frequencies, the TSL230Bs.
5. Use frequencies to calculate angles
   Using the frequency information the equations from Section 3.2.2 can be used to calculate the angles.

7.2 Test Hardware Configuration

Test hardware consists of a breadboard, the TSL230Bs, computer data acquisition card, and associated wiring. The output of the TSL230B is first conditioned using a capacitor, resistor, and NAND (4093) gate. One of the inputs to the NAND gate is controlled by port C of the 8255. This allows the output of the NAND gate to be turned on and off. The output of the NAND gate is inputted into the clock input of one of the counters on the 82C53. The DAC’s internal 2 MHz clock is inputted into the clock input of counter B0 on the 82C53. The gate input of all the counters is controlled by Port C of the 8255. This configuration is shown in Figure 7.1.

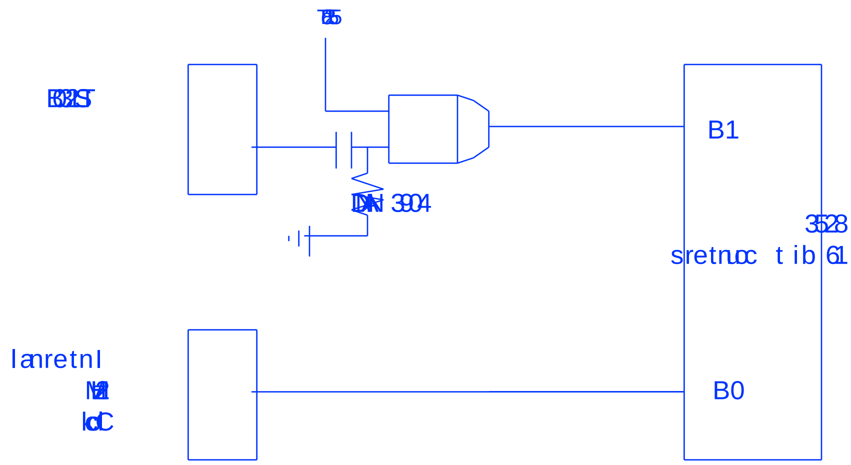

Figure 7-1. Test Hardware Configuration.

8. Concerns and Open Issues

8.1 Testing Problems

The test program that has been written is still in the process of being debugged.

8.2 Possible Three-sided Sensor

The current design calls for two sensors, each with two photodiodes, to determine the location of the sun. This provides four equations, but there are only three unknowns. Consideration is being given to an alternative design consisting of a pyramid shaped sensor using only three photodiodes. Currently the algebraic manipulation of the resulting three equations has proved too cumbersome to provide useful information.

8.3 Determination of Best Sensors

To have the ability to predict the location of the sun at any given attitude, more than one set of sun sensors will be required. The method of determining which sensors to take data from still needs to be developed. It may be possible for more than one set of sensors to be receiving light input at any given time. The strongest source of light UASat encounters will be the sun and therefore the sensors outputting the highest frequencies should be used.

9. References

[1]

10. Appendix