Low-Power Custom-Built Sun Sensors For Nanosatellite

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Abstract

ESTCube-1 is a 1-unit CubeSat to be launched in mid-April, 2013. Its primary mission is to measure the Coulomb drag force exerted by a natural plasma stream on a charged tether and thus to perform the basic proof of concept measurement and technology demonstration of electric solar wind sail technology[3]. The attitude determination and control system (ADCS) performs detumbling, pointing and high rate spin control of the satellite[2]. The attitude determination system uses three-axis magnetometers, three-axis gyroscopic sensors and two-axis Sun sensors, one on each side of the satellite. While commercial off-the-shelf components are used for magnetometers and gyroscopic sensors, Sun sensors are custom-built, based on analogue one-dimensional low-power Position Sensitive Detectors (PSD).

Sun Sensor Design

Figure 3 shows Sun sensor hardware layout. Two PSDs are located under a mask with two slits perpendicular to the corresponding PSDs. Light beam travels through a slit and when reaches a PSD, introduces photocurrent. Depending on position and intensity, two outputs are generated which are converted to voltages and measured using analogue to digital converter (ADC). Given spot light positions on PSDs, height of the mask and illuminated side of the satellite, direction of the Sun can be calculated.

Testing

Sun sensors are thoroughly tested for two reasons. First, to define accuracy and, second, to qualify for space environment. The main influential factors are: temperature, vacuum, radiation, response characteristics, noise and geometrical, optical and electrical properties that are not ideal.

Angle test provides calibration data and indicates field of view. Figure 4 shows the test setup.

Temperature test indicates if sensors work in expected temperature range (from -30°C to 40°C) and provides measurement dependency on temperature. Figure 5 shows the test setup. A Sun sensor (1) is in a thermal chamber (2). It is illuminated through a hole by a light source (3) which located outside the chamber. Three temperature sensors (4) are used. All readings are gathered by a LabJack U9 ADC (5) and processed by a computer (6).

Irradiance test indicates how sensor responds to increasing irradiance. The test shows if sensors get saturated by irradiance level expected in space which is 1953 W/m²[3].

Vacuum test indicates if vacuum causes permanent damage to sensors.

UV test indicates if ultraviolet radiation causes permanent damage to sensors.

Results

Angle test. Figure 6 shows measured incident light position dependency on rotation angle.

Temperature test. Figure 7 presents three temperature tests, where Sun sensor was illuminated at three different angles. These results show that the indication of apparent position shifts when temperature is raised.

Conclusions

Custom-built Sun sensors were tested in conditions expected in low Earth orbit. These pre-launch test results indicate that Sun sensors can operate in space environment. Uncertainty is estimated to be 1.55 deg. It could be reduced by creating an analytical model of the sensor which takes the most influential physical quantities into account, e.g. temperature, to interpret measurements.

The choice to develop a sensor instead of using commercially available devices has justified itself because the development process has provided great technical knowledge and valuable educational experience. Performance of Sun sensors fulfills the requirements of ESTCube-1 mission.

References