

## Week V Report

**Advisor(s):** Gary Tuttle

**Client:** NASA Marshall Space Flight Center

**Members (Roles):** **Isaac Johns**-Team Communicator, **Ryan Bissett**-Team Communicator, **Tom Henry**-Webmaster, **Luke Dahlman**-Team Leader, **Anh Ho**-Key Concept Holder, **Dustin Pierce**-Key Concept Holder, **Antjuan Buffett**

**Project Title:** Remote Deployment Circuit and Mechanism for Lightweight CubeSat Solar Panels

### Weekly Summary

This week we finalized our circuit design of either Programmable Logic Controller (PLC) or an Analog Circuit. Individual contributions will be listed below. On Thursday (10/2) the group submitted our preliminary reports and we finalized those reports into one document Sunday (10/5). Through our researching we gathered questions for John Carr that we were able to ask today (10/6) in our phone conference meeting, Gary Tuttle was present as well. From the information we gathered and discussion that followed we decided that a PLC is a more viable circuit. We plan to move forward with a PLC where we will need to learn/relearn Verilog and review our Digital Logic.

### Meeting Notes

From our weekly meetings:

- It was decided we would like to do a PLC circuit. For a PLC we need to review our digital logic (CprE 281) and to learn/relearn Verilog.
- When it comes to NASA devices, they want to be 99% confident it will work. They would like for the circuit to be tested extensively. The circuit components cannot be simply changed due being in Low Earth Orbit (LEO). Reliability is a major if not most important factor in this design.
- We would like the final circuit design to be completed by November 14 and know what materials are needed by that time. We would like the parts to be ordered by November 20<sup>th</sup>.
- We discussed the PLC sending out one signal for all processes or three separate signals for deployment, retraction, and fail-safe/stop. There seems to be agreement for sending three separate signals. For this to happen we will be needing feedback.
- For the feedback we talked about sensors relaying information about things like boom extension, retraction, and failure to deploy/retract. We haven't specifically found any sensors, but we're keeping this in mind. As of right now the circuit itself is more important.

- Again we talked about how to stop the deployment and retraction of the boom. One idea that was brought up was a bump stop switch. Gary Tuttle mentioned using stepper motors with a limit switch.
- When building the circuit we may use commercial grade components as proof of concept to reduce cost, however, if possible we may build to military spec.
- Finally the talked about the function and goal of this whole project. From our understanding the CubeSat will be used to (i) gather information from solar and temperature sensors, (ii) record data, and (iii) send data for analysis. CubeSats are often used for research missions.

### **10/2/2014 & 10/5/2014      Group Meeting to Decide Course of Action**

**Duration:** 1hr      **Members Present:** Isaac Johns, Ryan Bissett, Tom Henry, Luke Dahlman, Anh Ho, Dustin Pierce

We turned in our documents of PLC vs. Analog and stated which circuit is better with respect to the area we researched. Preliminary documents were due 10/2 and finalization as 10/5.

### **10/6/2014      Group Meeting to Discuss Ideas**

**Duration:** 1hr      **Members Present:** Ryan Bissett, Tom Henry, Luke Dahlman, Anh Ho, Dustin Pierce

#### **Purpose and Goals**

- The purpose of this meeting was to get John Carr up to speed with where we're at currently.
- We sent him a document outlining the pros and cons of PLC vs. Analog. We didn't necessarily discuss the document, but more so talked about moving forward with the PLC.
- We discussed the next steps in this project and staying on task with our project plan. Thus far we are on track.
- We're working on getting the information for the weight to power ratio so that we may design the circuit based on those specifications.

#### **Achievements**

When starting this project our group faced a simple question that has a very complex answer, what type of circuit should be used for space applications. By examining different parameters of Programmable Logic Controllers (PLC) against more traditional analog type circuits we were able to determine pros and cons for each type as outlined in this report. To do this our group determined cost, reliability, fabrication, device implementation and testing, circuit simplicity, and size were the main areas that would determine what type of circuit would perform in a Low Earth Orbit (LEO) environment.

Analog circuits are subject to a higher rate of failure. Use of a PLC with solid state technology will reduce failure when compared to an analog circuit. A PLC exceeds our design objectives, allowing us to add additional sensors for feedback. The relay design would need to be designed on an individual basis to meet our operational constraints, whereas the PLC would already have all we need in a compact package. As illustrated above, we feel the complexity of a PLC circuit will be outweighed by its added flexibility and durability. After analyzing the differences between analog based and PLC circuits, our group has decided to move forward with a PLC design.

### **Pending Issues**

- There weren't any new or immediate issues this week.

### **Plans for Next Week**

- Luke: Contact Professor Tuttle and John Carr
- Isaac and Ryan: Weekly Group Report
- Anh & Dustin: Keep group on Task
- Tom and Antjuan: Manage Google Docs and Weebly site
- In addition, everyone will move forward with designing the PLC, boom, and researching where needed. We will be needing to divide tasks.

### **Individual Contributions This Week**

- Luke: Organized meetings, attending meetings, and finished research on design simplicity of PLC vs. Analog.
- Isaac: Wrote weekly report, attended meetings, and finished research on cost of PLC vs. Analog.
- Ryan: Edited weekly report, attended meetings, and finished research on testing of PLC vs. Analog.
- Tom: Updated online media, attended meetings, and finished research on reliability of PLC vs. Analog.
- Dustin: Attended meetings, kept group on task, and finished research on size of PLC vs. Analog.
- Anh: Attended meetings, kept group on task, and finished research on fabrication of PLC vs. Analog.
- Antjuan: Attended first meeting, pitched ideas, and finished research on implementation of PLC vs. Analog.

## Total Contributions for this Project

### 3 – 1 hour meetings

- Luke: 9hrs
- Isaac: 9hrs
- Ryan: 9hrs
- Tom: 9hrs
- Dustin: 9hrs
- Anh: 9hrs
- Antjuan: 9hrs

### Contributions below

## Cost (Isaac Johns) and Reliability (Tom Henry)

When examining the reliability of a PLC compared to that of an analog circuit, there are a number of sources stating that the use of a PLC is an increasingly common practice. The PLC will see reduced channel conduction over time due to ionization and radiation that the satellite will be exposed to. However, PLCs can be ordered to tolerate up to 300 Krad(Si). A PLC can be reproduced quite easily, due to the fact that a PLC can be purchased and programmed. During programming, the PLC can be loaded with multiple redundant circuits in the event the original fails. In addition, solid state components in a PLC will provide protection against vibration during launch.

With analog components, we can obtain a greater radiation tolerance, dependent on the components selected. An analog circuit can achieve higher performance, but will suffer greatly from “noise” over time due to radiation exposure. When constructing circuits for use in space, analog components are derated much more than microcircuits. According to a lesson from NASA , resistors and capacitors must be derated to 60% of their rating (power for resistors, voltage for capacitors), whereas microcircuits only need to be derated to 75% of their rated power. This is due to the stress ratio at the temperatures encountered in orbit. As opposed to a PLC, analog circuits will have a greater risk of failing due to the vibration that the satellite is subjected to during launch.

| PLC  | Analog                                     |
|--|--|
| Lower Cost of Production   | Greater Radiation Tolerance                |
| Reproducibility  | Higher Performance                         |
| Reduced Channel Conduction over time due to radiation (ionizing) | Increased noise over time due to radiation |
| up to 300K rad(Si) Total Hardness                                |  |
| Redundancy of Programming  |  |

## Implementation (Antjuan Buffett)

Digital filters are a costly alternative to analog filters but are more accurate and consistent. These circuits introduce latency since they use a discrete-time processing and sampling process.

Digital filters:

- Use complex integrated circuits.
- Are far more accurate than analog filters.
- Are programmable, which makes them easy to build and test.
- Do not suffer from as many manufacturing variations or aging.

Analog circuits:

- Are made of mechanical parts.
- Do not require constant power.

| DIGITAL FILTERS   | ANALOG FILTERS  |
|---|---|
| High Accuracy   | Less Accuracy - Component Tolerances                                      |
| Linear Phase (FIR Filters)  | Non-Linear Phase  |
| No Drift Due to Component Variations  | Drift Due to Component Variations   |
| Flexible, Adaptive Filtering Possible   | Adaptive Filters Difficult  |
| Easy to Simulate and Design   | Difficult to Simulate and Design  |
| Computation Must be Completed in Sampling Period - Limits Real Time Operation | Analog Filters Required at High Frequencies and for Anti-Aliasing Filters |
| Requires High Performance ADC, DAC & DSP                                      | No ADC, DAC, or DSP Required  |

[http://www.planetanalog.com/author.asp?section\\_id=3065&doc\\_id=560512](http://www.planetanalog.com/author.asp?section_id=3065&doc_id=560512)

## Fabrication (Anh Ho)

Relays contain mechanical parts, which typically take up more space than its digital equivalent. These circuits need to be designed on an individual basis to meet differing operational constraints. PLCs were first developed to replace relays and relay control systems. PLCs can be hardened for severe conditions and are able to withstand extreme conditions. Controllers are very compact due to the use of integrated circuits instead of analog components.

## Testing (Ryan Bissett)

Testing of digital and analog parts is similar, in that they are both subjected to a test environment similar to what they will experience in LEO. In LEO typical radiation dose rates are between 100 and 1,000 rad/year. Circuit components fall into three categories:

1. Commercial
  - a. Not made for high-rad environments
  - b. Not tested for rad hardness
  - c. Can withstand 2-10 krads typically
  - d. SEU Error Rate:  $10E-5$  errors/bit-day
2. Rad Tolerant
  - a. Rad-hard to a certain point
  - b. Not specifically tested for rad hardness
  - c. Can withstand 20 to 50 krads
  - d. SEU Error Rate:  $10E-7$  to  $10E-8$  errors/bit-day
3. Rad Hard
  - a. Designed to operate in high rad environments
  - b. Wafers are radiation tested
  - c. Can withstand over 1Mrad in certain components
  - d. SEU Error Rate:  $10E-10$  to  $10E-12$  errors/bit-day

Most of the testing is done to check that parts won't fail once in orbit for extended periods. During testing, they are run through many iterations of:

- Heating/Cooling Cycles
  - This concerns both digital and analog components as thermal expansion and contraction can break contacts between parts
  - Extreme heat and cold can affect certain transistor based devices
- Day/Night Cycles
  - In addition to temperature changes, when the circuit is exposed to the sun it is bombarded with radiation throughout most of the spectrum from radio to x-rays.
    - UV rays can damage insulators and other non-treated parts
    - High energy rays can flip bits in digital systems
- Small Impacts

- Most impacts are catastrophic due to the high speeds involved, but having a smaller circuit (PLC) means there is a smaller target for debris to hit.
- Vibration
  - During launch, parts will be subjected to multiple G's, and need to be able to withstand them long enough to get into orbit
    - Analog circuits with discrete components have to worry about the increased weight of larger components- the heavier they are the worse they fare.
    - Both need to be able to remain immobile through high Gs during launch, as well as retain connection in microgravity.

## **Design Simplicity (Luke Dahlman)**

The use of PLCs is a prime example of the application of maintainability design objectives. PLCs are designed with ease of maintenance and troubleshooting as a major function. When virtually all components are solid state, maintenance is reduced to the replacement of modular, plug-in type components. Fault detection circuits and diagnostic indicators, incorporated into each major component, can tell whether the component is working properly. With the programming tool, any programmed logic can be viewed to see if inputs or outputs are on or off. PLCs provide control capabilities not possible with analog circuits.

Typical PLC architecture is modular and flexible, allowing hardware and software elements to expand as the application requirements change. If an application outgrows the limitations of the PLC, the unit can easily be replaced by a unit with greater memory and input/output capacity. PLC attributes make installation easy and cost effective. Their small size allows a PLC to be located conveniently, often in less than half the space required by an equivalent relay control panel.

## **Size (Dustin Pierce)**

An Ace 11 PLC has 12 I/O points and is only 2.5" x 2.5" x 0.5", but will function and operate similar to a large PLC used in manufacturing processes. Therefore size and weight can be minimized while maintaining functionality. A PLC this size could open and close the boom, monitor sensors or run time for extending the boom, and allow termination of operation.

A relay based circuit can range vastly in size, making it dependent on the number of connections required. To achieve the same functionality of the PLC circuit, a multitude of analog components would be required for each portion of the operation.