NASA Solar Panel Design

MAY15-12

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11/10/2014

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Problem Statement

Our goal with this project is to be able to deploy a certain area of flexible solar panels in a system that is compact and lightweight. The system consists of three major components; the control circuit, boom and substrate/solar cell. The boom and solar array needs to be flexible enough to be stored inside a 1U (10 x 10 x 10cm) cube along with all other control mechanisms. Our target area for the deployed solar array needs to be between four and nine square feet. The solar cells may not have a bend radius less than 2.5cm. Sensors should be used to accurately relay the position/status of system components. The system must be designed in manner such that the solar cells can be deployed and retracted repeatedly after launch.

Deliverables

First Semester

- Research Low Earth Orbit space
  - Temperature Range
  - Deterioration due to Radiation Levels
  - Altitude Range
  - Vacuum Conditions/Pressure
- Circuit Design
  - Analog vs. Digital Design
    - Reliability/Cost
    - Materials
    - Size constraints
    - Fabrication/Implementation
    - Testing
    - Design Simplicity
  - Machine to Machine Interface
    - Controls
    - Drivers
    - Motors
    - Sensors
  - Human Machine Interface Component
    - Command Interpretation
    - System Feedback
  - Communication in a vacuum
- Boom Design
  - Analyze varying design concepts
    - Scissor Jack
    - Umbrella
    - Tape Measure
    - Silk Fan

        - Telescoping Antenna
        - Origami
    - Torque Requirements
    - Friction
    - Weight
    - Structural Rigidity
    - Mass Production
    - Proof of Concept
- Material Specification
    - Prototype vs. Production Materials
    - Space Worthiness
    - Weight
    - Durability
    - Friction Coefficients
    - Structural Rigidity
    - Finalize Bill of Materials
    - Lead Time
    - Order parts for Prototype
- Keep track of ways to improve

Second Semester

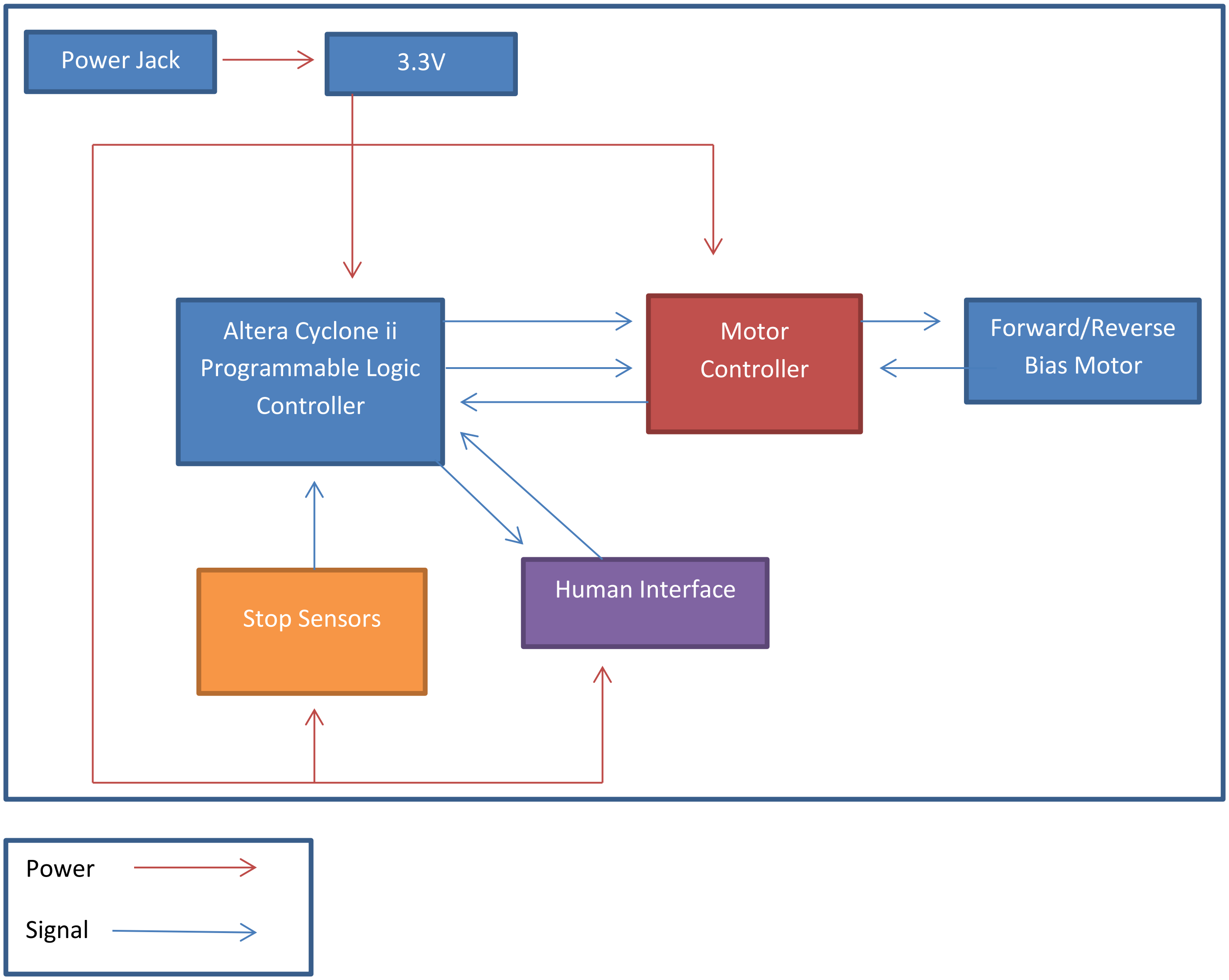
- Complete Circuit Fabrication/Programmed
- Conduct circuit testing
- Make necessary changes
- Have circuit shipped to NASA for testing
- Write Final Report

Specifications

Design Constraints

- Stored within 1U (10 x 10 x10cm)
- Deployed Solar Array area (4 to 9 square feet)
- Weight to area ratio

Hardware Specification

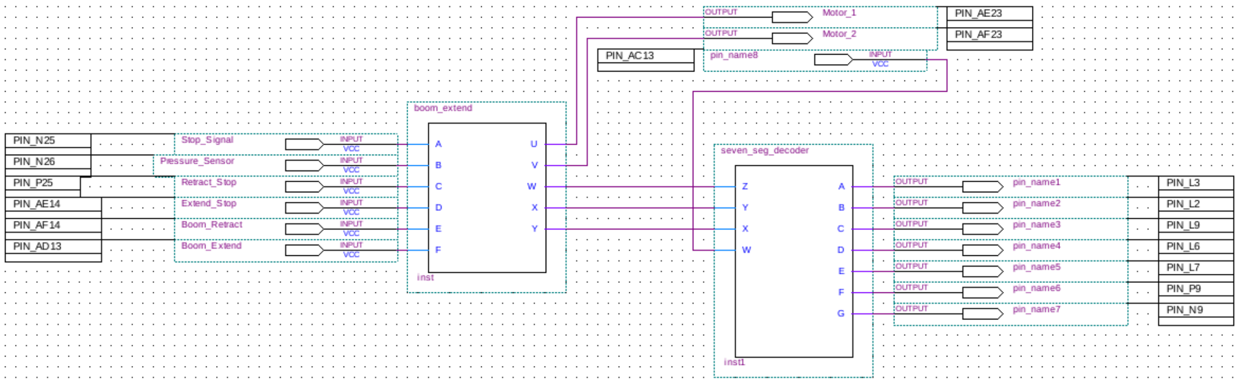


Programmable Logic Controller

For our design we are using an Altera Cyclone II Programmable Logic Controller. This PLC can simulate a wide array of logic systems but uses solid state components instead of relying on several physical logic gates. Overall all this will increase the reliability of the system and allows minor changes to several systems to occur without changing the building process. In our system the PLC will:

- Conduct all of the logic processes
- Accept inputs from sensors to determine the state of the system
- Send/Receive information to the end user to make further decisions
- Send start/stop signal to the motor controller

This acts as the main controller for the entire system. All inputs and outputs are run through our PLC for processing before being sent to another part of the system. This ensures that the entire system is acting in unison and nothing is being over looked. The PLC has been programed to the specifications as outlined below.




```
module boom_extend (A,B,C,D,E,F,U,V,W,X,Y);
input A,B,C,D,E,F;
output U,V,W,X,Y;
        assign U = (~A&~B&~D&~E&F);
        assign V = (~A&~B&~C&E&~F);
        assign W = (B);
        assign X = (~A&((~B&(F&((~C&~E)|(D&E))|(C&(~D|~F))))|(B&(C|D|(E&~F)))));
        assign Y = ~A&((~B&((C&(E|F))|(E&~F)|(~C&D&F)))|(B&(C|D|(~E&F))));
endmodule
```

```
module seven_seg_decoder (A,B,C,D,E,F,G,Z,Y,X,W);
input Z,Y,X,W;
output A,B,C,D,E,F,G;
        assign A=((~Z&~Y&~X&W)|(~Z&Y&~X&~W)|(Z&~Y&X&W)|(Z&Y&~X&W));
        assign B=((~Z&Y&~X&W)|(~Z&Y&X&~W)|(Z&~Y&X&W)|(Z&Y&~X&~W)|(Z&Y&X&~W)|(Z&Y&X&W));
        assign C=((~Z&~Y&X&~W)|(Z&Y&~X&~W)|(Z&Y&X&~W)|(Z&Y&X&W));
        assign D=((~Z&~Y&~X&W)|(~Z&Y&~X&~W)|(~Z&Y&X&W)|(Z&~Y&X&~W)|(Z&Y&X&W)|(Z&~Y&X&~W));
        assign E=((~Z&~Y&~X&W)|(~Z&~Y&X&W)|(~Z&Y&~X&~W)|(~Z&Y&~X&W)|(~Z&Y&X&W)|(Z&~Y&~X&W));
        assign F=((~Z&~Y&~X&W)|(~Z&~Y&X&~W)|(~Z&~Y&X&W)|(~Z&Y&X&W)|(Z&Y&~X&W));
        assign G=((~Z&~Y&~X&~W)|(~Z&~Y&~X&W)|(~Z&Y&X&W)|(Z&Y&~X&~W));
endmodule
```

Motor Controller

The motor controller has been added to the system to allow the motor the appropriate voltage needed to power the boom while still being able to accept 3.3V signals from the PLC. This also allows a secondary system to interpret the torque sensor from the motor before that information is sent to the PLC. The motor controller is programed to send a single once the torque goes outside set bounds. The torque sensor is built into the motor controller which adds an additional layer of protection. The activation of this sensor will automatically send a stop signal to the motor and sends a warning signal that over torque to the end user through the human interface.

Forward/Reverse Bias Motor

For our system we are using a forward and reverse bias electric motor capable of at least 30 inch-pounds of torque. This will give sufficient power to extend and reverse the boom in the near-zero gravity environment. We have also included a buffer zone of 50% torque to ensure the motor will have sufficient torque. The motor chosen must also lock in place when power is not applied. This will decrease the power consumption of the system and ensure the boom stays in the extended or retracted position.

Human Interface

The human interface portion of our system consists of five 7-segment LCD displays and five 2-position switches. Three of the 7-segment displays will relay the torque values in inch-pounds back to the end user while the other two displays relay position information. The position information values will correspond to a set table of values where each value corresponds to different situations as shown below. All of these components are powered off of the 3.3V power supply.

Displayed Value	Meaning
01	Clear, ready for command
02	Boom is retracting normally
03	Boom is extending normally
04	Boom stop has been activated-manual stop set
05	Torque stop has been activated-movement ceased
06	Torque stop has been activated during retraction-movement ceased
07	Torque stop has been activated during extension-movement ceased
08	Torque stop & boom stop both activated
09	Boom Extension OverRide has been activated-boom extending
10	Boom Retraction OverRide has been activated-boom retracting
11	Receiving Signal to both Extend and Retract-boom movement ceased
12	Multiple Contracting Signals-Movement ceased

Stop Sensors

At each end of the screw that moves the boom there are contact sensors. When the boom reaches these sensors a signal is sent to the PLC that stops the motors and sends this information back to the end user through the human interface. These normally open contacts close then activated sending a 3.3V signal.

Node Name	Direction	Location	I/O Bank	Fitter Location	I/O Status	Current Strength
Boom Extend	Input	PIN_AD13	8	PIN_AD13	3.3 V	24mA
Boom Retract	Input	PIN_AF14	7	PIN_AF14	3.3 V	24Ma
Motor Forward	Output	PIN_AE23	7	PIN_AE23	3.3 V	24mA
Motor Reverse	Output	PIN_AF23	7	PIN_AF23	3.3 V	24mA
Pressure Sensor	Input	PIN_N26	5	PIN_N26	3.3 V	24mA
Stop Signal	Input	PIN_N25	5	PIN_N25	3.3 V	24mA
Retract Stop	Input	PIN_P25	6	PIN_P25	3.3 V	24mA
Extend Stop	Input	PIN_AE14	7	PIN_AE14	3.3 V	24mA

LCD_1	Output	PIN_L3	2	PIN_L3	3.3 V	24mA
LCD_2	Output	PIN_L2	2	PIN_L2	3.3 V	24mA
LCD_3	Output	PIN_L9	2	PIN_L9	3.3 V	24mA
LCD_4	Output	PIN_L6	2	PIN_L6	3.3 V	24mA
LCD_5	Output	PIN_L7	2	PIN_L7	3.3 V	24mA
LCD_6	Output	PIN_P9	2	PIN_P9	3.3 V	24mA
LCD_7	Output	PIN_N9	2	PIN_N9	3.3 V	24mA

Software Specification

We will be using a PLC to operate all controls in the design. The PLC will be programmed with Altera Quartus II software, using code written in Verilog. A signal will be received from the operator, then interpreted by the PLC, which will execute the command while monitoring for problems.

Basic Operations:

PLC

- The system must be able to receive a deployment signal from the operator.
- The system must be able to interpret the received extension signal.
- The system must be able to execute the deployment command.
- The system must be able to receive an error for excessive boom tension, indicating a problem with deployment.
- The system must be able to automatically stop deployment at full extension.
- The system must be able to return a signal that the boom successfully extended.
- The system must be able to receive a retraction signal from the operator.
- The system must be able to interpret the received retraction signal.
- The system must be able to execute the retraction command.
- The system must be able to receive an error for excessive boom tension, indicating a problem with retraction.
- The system must be able to automatically stop retraction at full retraction.
- The system must be able to return a signal that the boom successfully retracted.
- The system must be able to receive a stop signal to interrupt deployment or retraction during any step of command execution.

Note: The communication between the base station (operator) and the satellite will be taken care of by NASA.

We will be using a motor controller to determine the torque which the motor is exerting on the shaft during operation. By using our knowledge from classes, we know that the harder a motor is working, the electric potential across the input terminals will decrease and the current draw will increase. By monitoring these values in comparison to predetermined threshold values, we can monitor for torque and locked rotor conditions.

Motor Control Circuit

- The system should be able to measure current draw.
- The system should be able to measure electric potential.
- The system should be able to decide which threshold range the values fall into.
- The system should be able to determine what needs to be done within that threshold range.
- The system should be able to return a decision to the PLC.
- The system should be able to constantly iterate these checks and evaluations during boom operation.

Based on the requirements for this motor control circuit, we will most likely need to use a microcontroller to carry out these operations.

Schedule

Due Date	Tasks	Team Assignment
Oct-5-14	**Wired filters or PLC**	
	Design Simplicity	Luke/Dustin
	Size(mass)	Luke/Dustin
	Cost	Tom/Isaac
	Reliability	Tom/Isaac
	Fabrication	Antjuan/Ryan/Anh
	Implementation	Antjuan/Ryan/Anh
	Testing	Antjuan/Ryan/Anh
Oct-31-14	**Circuit Outline/Improvements**	Team
Dec-1-14	**Final Circuit Completion**	Team
	Material Selections	Anh
	Bill of Materials (BOM)	Team
Dec-8-14	**Material Ordering**	Team
Jan-25-15	**Draft Design and BOM send to NASA**	Team
Jan-30-15	**Circuit Assembled**	Team
Feb-6-15	**On surface Testing**	Team
Feb-20-15	**Testing Completion**	Team
	Ship Circuit to NASA	Team
	Boom Design	Team