Atmospheric Solar Cell Test

Team Red Paint

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4/16/2016

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Abstract

Our goal is to design and create a small device that will gather information about the amount of power a solar cell can produce as it raises through the atmosphere on a weather balloon. In addition to solar cell power output, our device will also record the temperature as it rises through the atmosphere to find any correlation between temperature and solar cell efficiency. This data will be transmitted from our device to a ground station using AM radio waves.

Introduction

The purpose of this device is to gather data about how solar cells operate in the atmosphere. This information will only become more and more relevant as our need for alternative energy grows and as solar technology becomes more efficient [4]. Major projects planning on utilizing solar cells in the atmosphere are already well into development, such as Google's Project Loon, which aims to bring internet connections to rural areas using internet relaying balloons. Project Loon will be beginning large scale tests in Indonesia this year. Projects like these are why solar energy in the atmosphere is important, which is why we are creating this device to find out more about how solar cells operate in the atmosphere. Temperatures in upper troposphere can range from 60°F to -60°F [5]. We intend to see how the temperature changes experienced while rising through the atmosphere will affect the solar cell's ability to generate power.

Methods, techniques and design

Our device logically starts at the solar cell, which is a small 3-inch by 3.7-inch solar cell encased in a plastic shell (Pic. 4). To determine the power output of the solar cell, the current (Fig. 5) and voltage (Fig. 4) produced from the solar cell are being measured separately by two different circuits, then sent and read separately by the PIC microcontroller. The PIC microcontroller is a small chip that allows us to process data, and send that data out with PWM (Pulse Width Modulation) as a specific radio frequency. Both pieces of data will be transmitted separately, with the total power output being calculated on the ground by multiplying both together. Between the solar cell and the PIC, an op-amp will be used to amplify the voltage to get it into an acceptable range for the PIC.

At the same time, current will be running through a small thermistor circuit (Fig. 3). The thermistor (Pic. 5) will resist current varying on the temperature, giving a voltage that will vary depending on the temperature. For this, tests on the ground will need to be done to find the correlation between the voltage drop and the actual temperature so the data coming from the balloon can be interpreted as a temperature.

The PIC will read both of the solar panel outputs and the thermistor output as analog data (a voltage), and then convert the data into a 10-bit digital number that will then be used to modify the frequency of the PWM being outputted by the PIC.

The CricketSAT is a 433Mhz transmitter that transmits the data to the ground station using the PWM sent out from the PIC. The PIC will alternate sending thermistor data and one of the two solar cell data to the CricketSAT. Each transmission has a marker to identify whether the transmission holds solar cell data or thermistor data, in case a transmission is lost and the alternating pattern is broken.

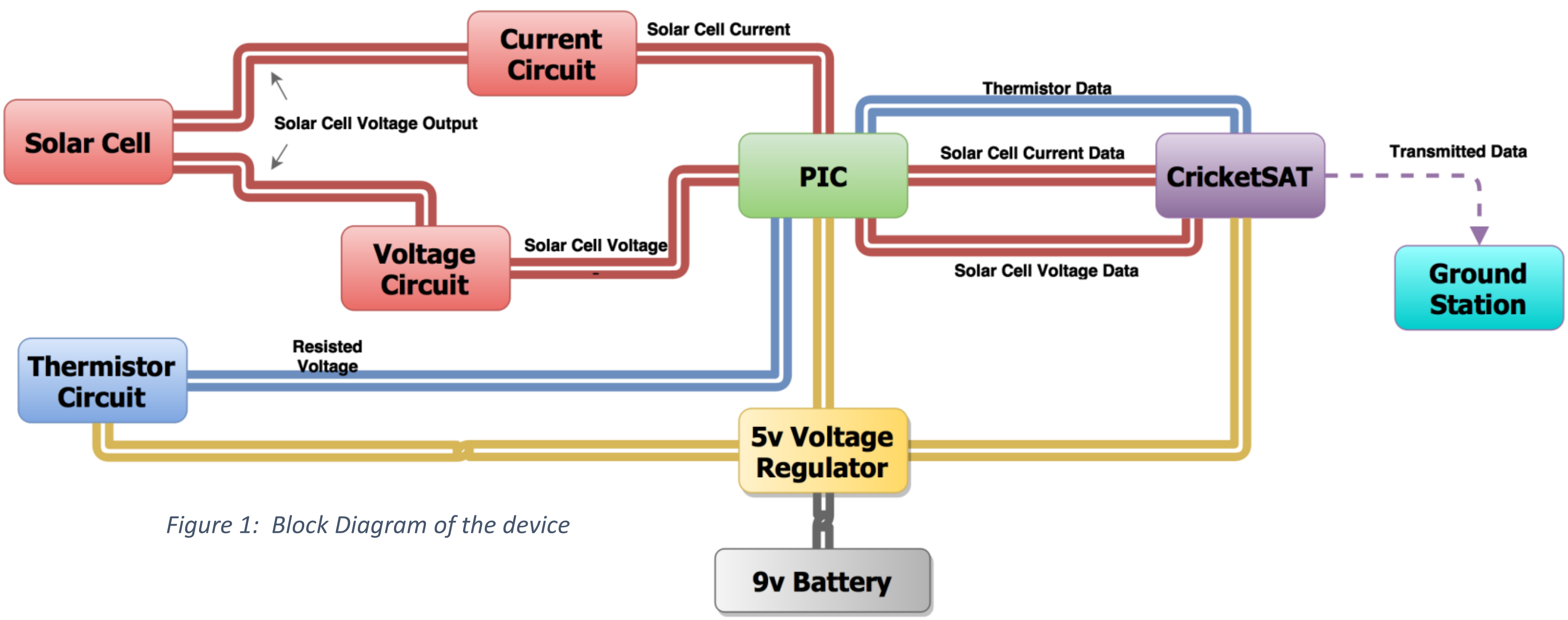


Figure 1: Block Diagram of the device

Testing and Design Verification

Much of the testing that was planned was not able to be carried out due to setbacks, mainly difficulties programming the PIC microcontroller, but some testing was done. We ran tests on prototyped breadboard circuits to ensure that our sensors and circuit designs worked as intended, as well as testing our sensors to find what voltage ranges they will output on our circuits. More testing was done to map frequencies transmitted from our device to voltages outputted from our sensors (Fig. 2).

Prior to the tethered flight, a large amount of testing went into the transmissions coming from the CricketSAT, mainly ensuring that it was in fact transmitting at around the frequencies we were expecting, and that the PIC was successfully switching between analog channels to read from and transmit from all of our sensors.

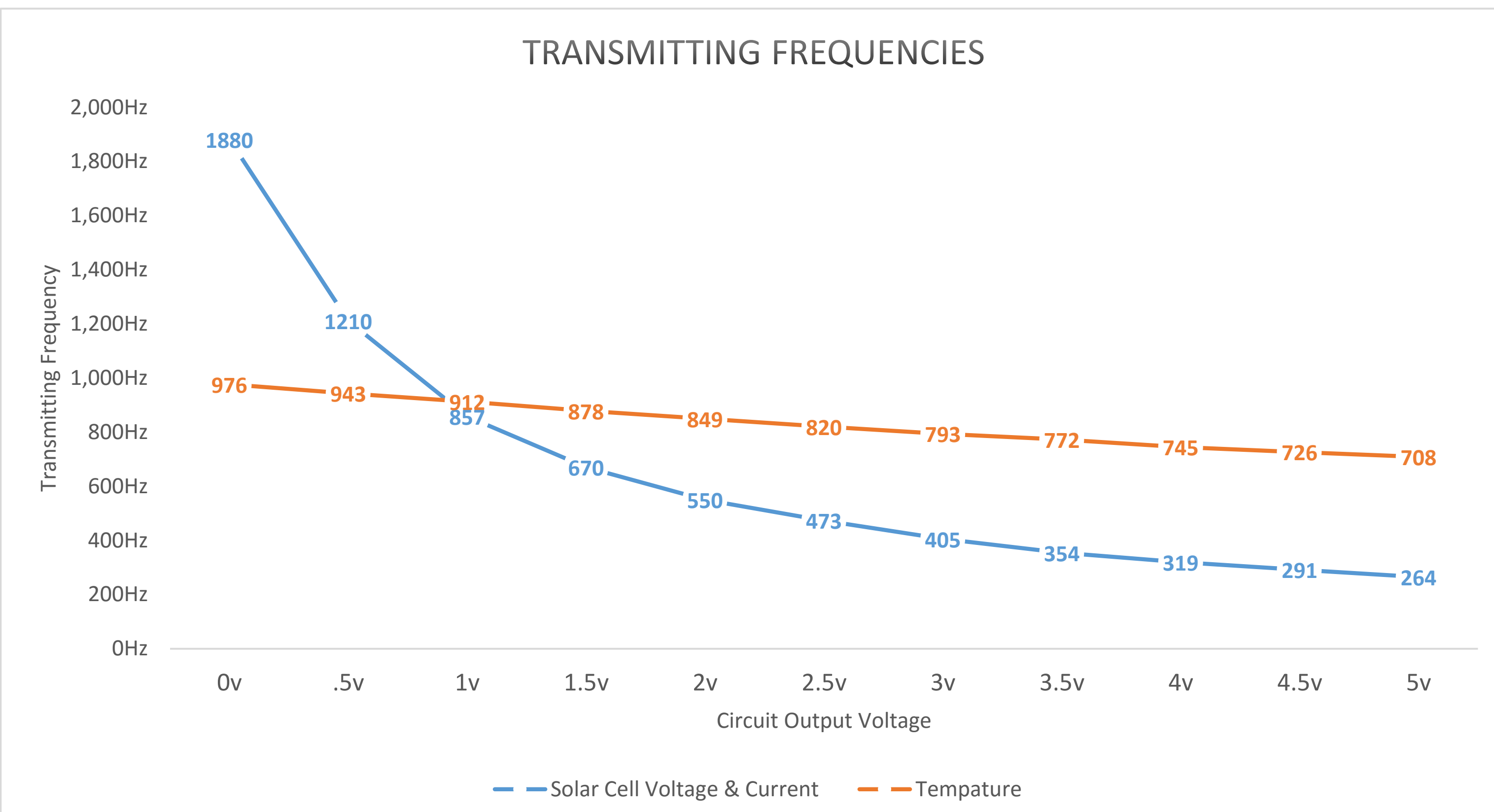


Figure 2: Transmitting frequencies of sensors based on output voltage

Discussion

Our design was overall not very complicated and went through very few iterations before we landed on a design for our project that was simple and worked the way we needed it to. The voltage test circuit is our simplest design and needed no amplification to work as intended, because our solar cell can only output 2v at maximum (Fig. 4). The PIC was never in danger of taking in too high of a voltage, so we put on a few capacitors to help stabilize the output and fed the voltage directly into the PIC to be read. Our Temperature sensor was also a simple design (Fig 3). We created a voltage divider using our 1k thermistor and a 1k resistor to lower the output of our 9v source so it is safe to be read by the PIC and as the temperature changes, the voltage will also change as the ratio of resistances in our divider changes as well. Lastly, our current testing circuit was the most complicated circuit to understand and implement and our iterations on design boiled it down to a version more suited for our uses (Fig 5). Essentially, to measure the current we measure the voltage drop across a resistor and feed it into the PIC, then using ohm's law we calculate the current output by our Solar Cell. We took this opportunity to amplify the voltage so that it is easier to read at lower values for our PIC, we had originally created the circuit with a gain of three in mind, but quickly realized it would not work as at max output from the Solar Cell 6v would be put into the PIC so we reduced the gain in order to not risk damaging our PIC. We did run into a few hiccups during our project. An error in the design of our PCB switched out the OP-AMP we intended to use with an OP-AMP with a completely different pin-out which meant we could not use the OP-AMP we wanted to, luckily the second OP-AMP fit right into the PCB and immediately began working as intended.

There were many problems encountered during programming the PIC, mainly setting the correct registers for PWM and ADC. This ended up eating away a lot of our time, but we were able to get it into working order before the flight. Another large challenge we faced with the PIC was getting the PIC to output a good range of frequencies based on our voltage output from our sensors. This was also fixed before the tethered flight, however the PIC voltage and current sensors transmitted at the exact same frequency range, which caused them to be hard to tell apart when we reviewed our data. This was going to be solved by placing markers in our transmissions, but the markers did not show up consistently in our data, and did not provide us with any useful information.

Conclusions and Future Work

The results from the tethered launch of our atmospheric solar cell power measurement circuit were not perfect. We did verify that we were able to successfully record and transmit the voltage and current outputs from our solar cell, however because of errors in transmitting and receiving our marker frequencies, it is difficult to tell what sensor transmitted each piece of data. This is further complicated by the fact that the current and voltage sensors transmitted in the exact same frequency range.

Despite our ambiguous data, the tethered flight confirmed that we were able to successfully record data from three different sensors, encode that data, and alternate transmitting one of the sensors over radio using the CricketSAT.

In the future, more work will need to be done to make the transmitted data less ambiguous. Adjustments to markers, or adjustments to the transmitting frequency of each sensor can be made to distinguish the data being transmitted from each sensor.

Acknowledgments

Team Red Paint would like to thank Jeremy Thomas for organizing the project and helping us through the whole process of completing this project. We would also like to thank Christopher Theriault for ordering our parts and being an addition resource to help us on our projects. We also thank Jimmy for the readily available and relevant support he provided to our team.

Author Contributions

Ryan Price: Initial presentation, PIC programming, MatLab data decoding, PCB design, final paper.

Justin Romero: Initial presentation, schematic design/testing, PCB population, Payload Creation, final paper.

References

[1] Google.com, "Loon for All – Project Loon – Google", 2016. [Online]. Available: https://www.google.com/loon/. [Accessed: 29- Jan- 2016].

[2]B. Malik, "solar panel parameters measurement system", *Microcontrollers Lab*, 2014. [Online]. Available: http://microcontrollerslab.com/solar-panel-parameters-measurement/. [Accessed: 29- Jan- 2016].

[3] "Photovoltaic Effect." *AccessScience* (n.d.): n. pag. *Teachengineering*. Teachengineering. Web.

[4] Shahan, Zachery. "Solar Panel Efficiency Has Come A Long Way (Infographic)." *CleanTechnica*. CleanTechnica, 06 Feb. 2014. Web. 16 Apr. 2016.

[5] "NWS JetStream - Layers of the Atmosphere." *NWS JetStream - Layers of the Atmosphere*. NOAA, n.d. Web. 16 Apr. 2016.

Appendix

Schedule

Week	Justin	Ryan
1	Research project	
2	Proposal	
3	Present / Written proposal	
4	Research parts	Finish proposal
5	Circuit Prototyping	
6	Circuit Prototyping	PCB Design
7	Circuit Prototyping	PCB Design
8	PCB Rev-0	
9	PCB Rev-1	
10	PCB Population	PIC PWM
11	PCB Population	PIC PWM/ADC
12	Box & PCB Testing PIC Transmission Testing	PIC ADC PIC Transmission Testing
13	Tethered Balloon Flight	
14	Final Report & Presentation Prep.	
15	Final presentation	

Table 1: Weekly schedule

This is how we divided tasks throughout the project. We would often work on separate parts of the project in parallel.

Parts

Part	Store	Store#	Part#	Quantity	Price
1k Ω Thermistor	Vetco	VUPN6551		1	$1.20
2V 200mA Encapsulated Solar Cell	Vetco	VE-SOL4		2	$12.40
TX434 Transmitter	Digikey	WRL-10534		1	$4.00
PIC 12F1572 microcontroller	Digikey	PIC12F1572-I/SN-ND	PIC12F1572-I/SN	1	$1.00
5v Voltage regulator	Vetco	NTE977		2	$2.00
100uf (25v) capacitor	Sparkfun	COM-00096		2	$0.70
10k resistor	Vetco	RES-10K-OHM-2W		3	$3.00
22k resistor	Vetco	NTE-HW322		2	$0.70
2k2 resistor	Vetco	RES-2.2K-OHM-2W		2	$2.00
1.5 Ω shunt resistor	Vetco	NTE-10W1D5		1	$0.35
2200pf capacitor	Vetco	VUPN7512		1	
LM258 Op-Amp	Mouser	595-LM258P	LM258P	1	$0.40

Table 2: Parts list

Figures

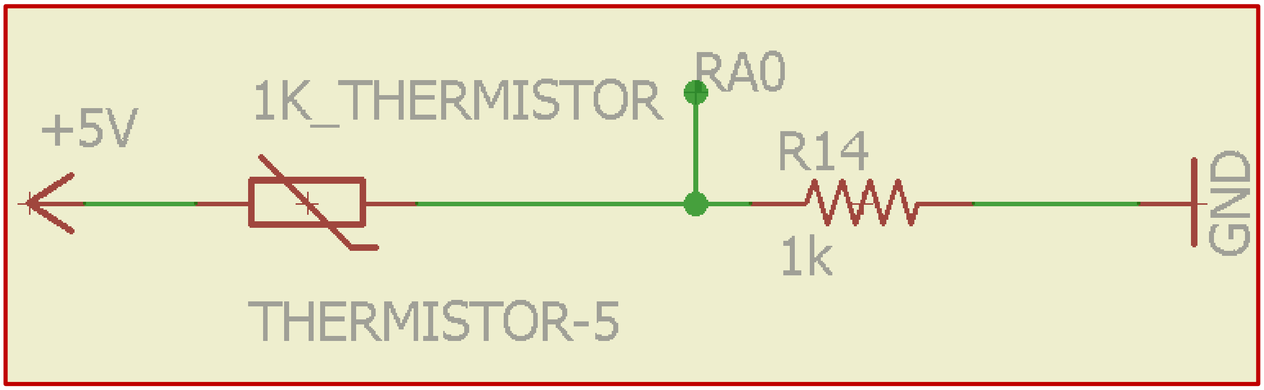


Figure 3: Thermistor circuit schematic that is a voltage divider we use to calculate the resistance of the thermistor.

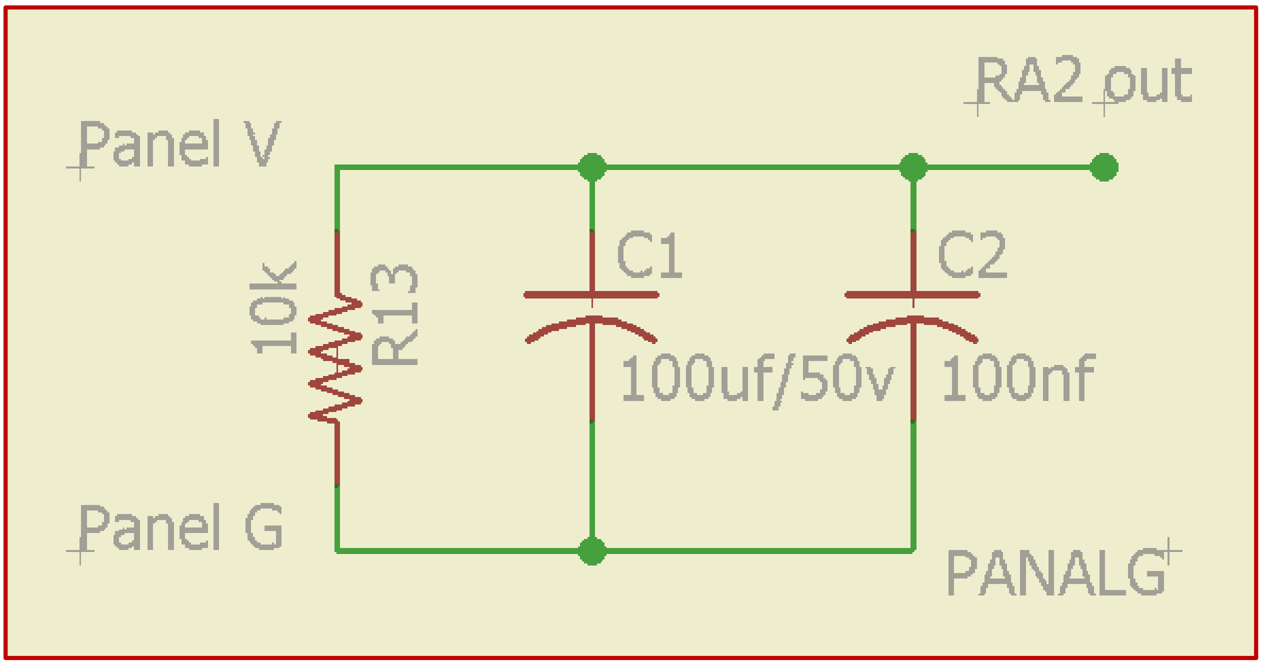


Figure 4: Voltage measuring circuit schematic. Adapted from a circuit created by Bilal Malik[2]

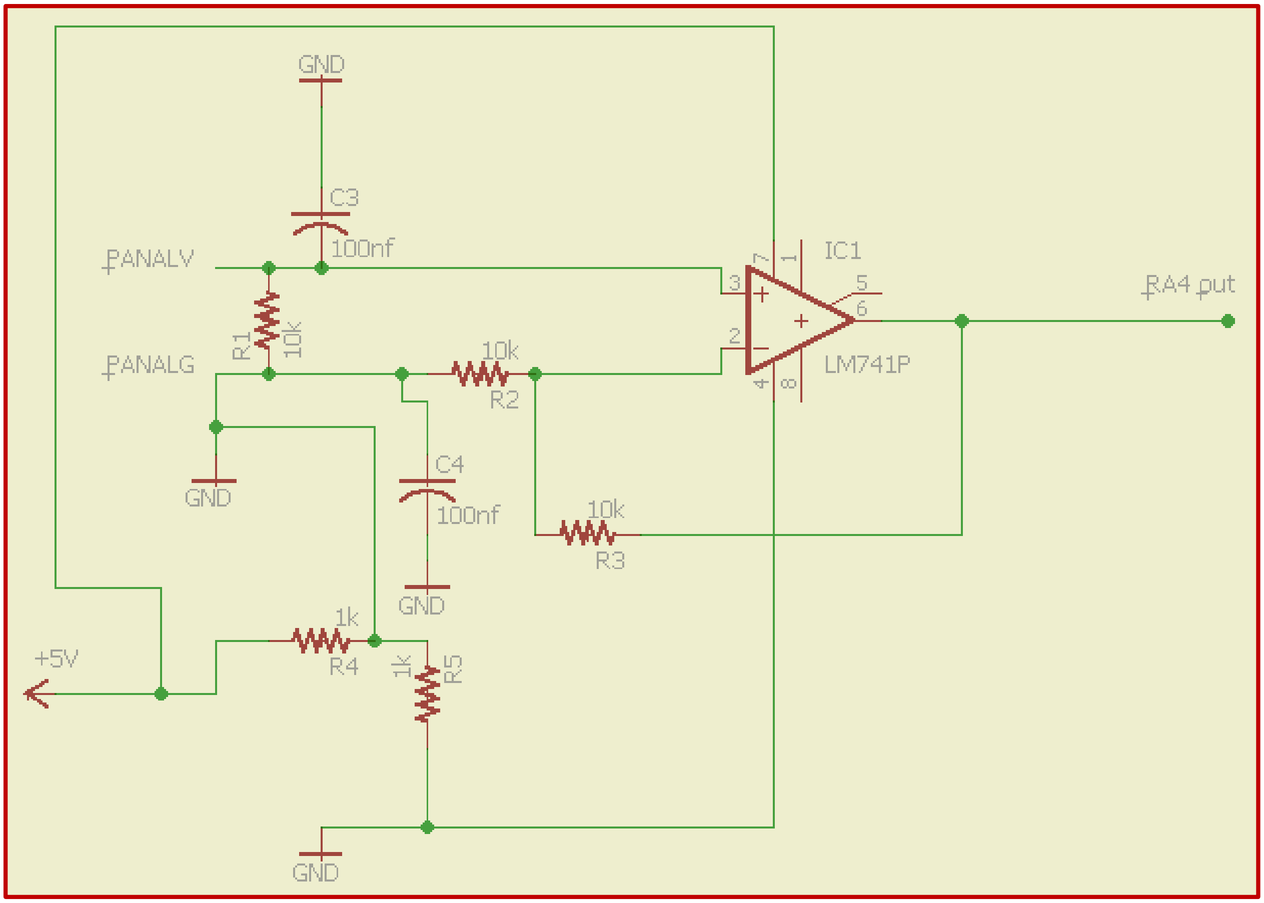


Figure 5: Current measuring circuit schematic. Adapted from a circuit created by Bilal Malik[2]

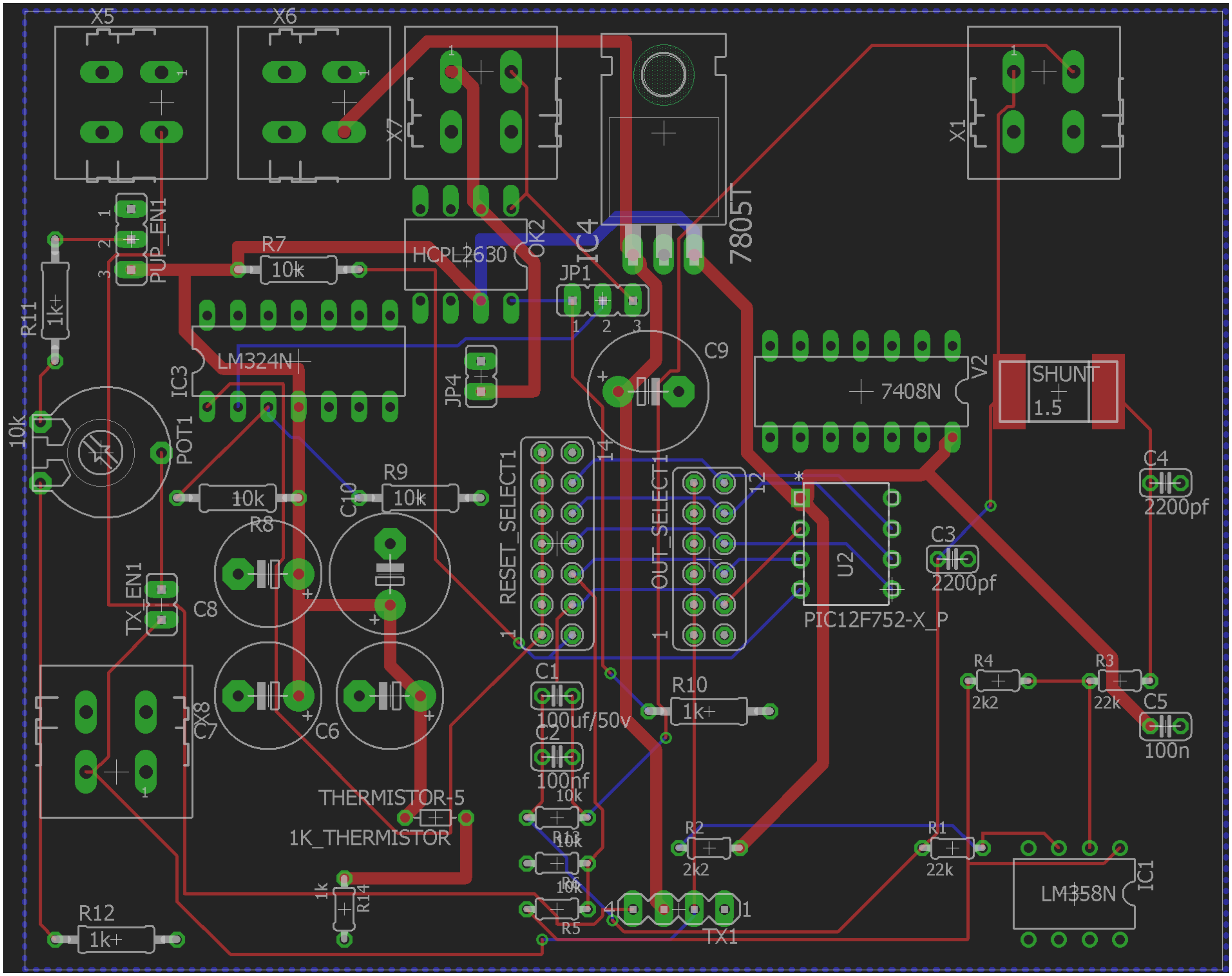
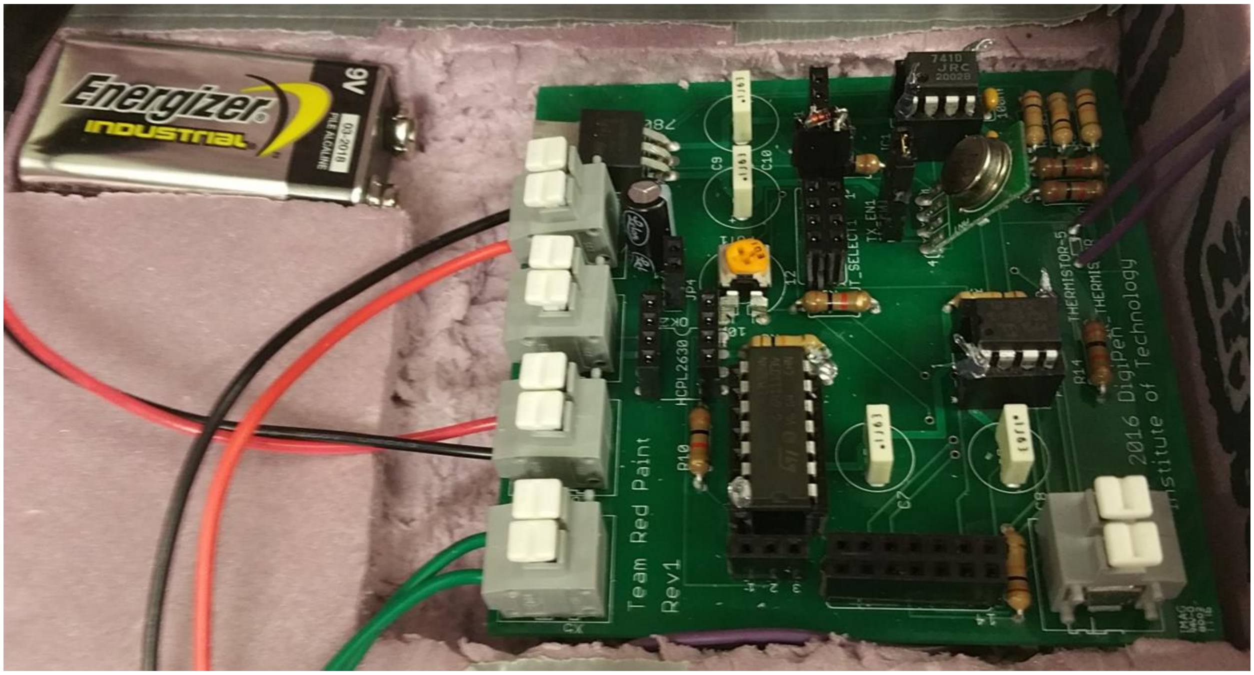
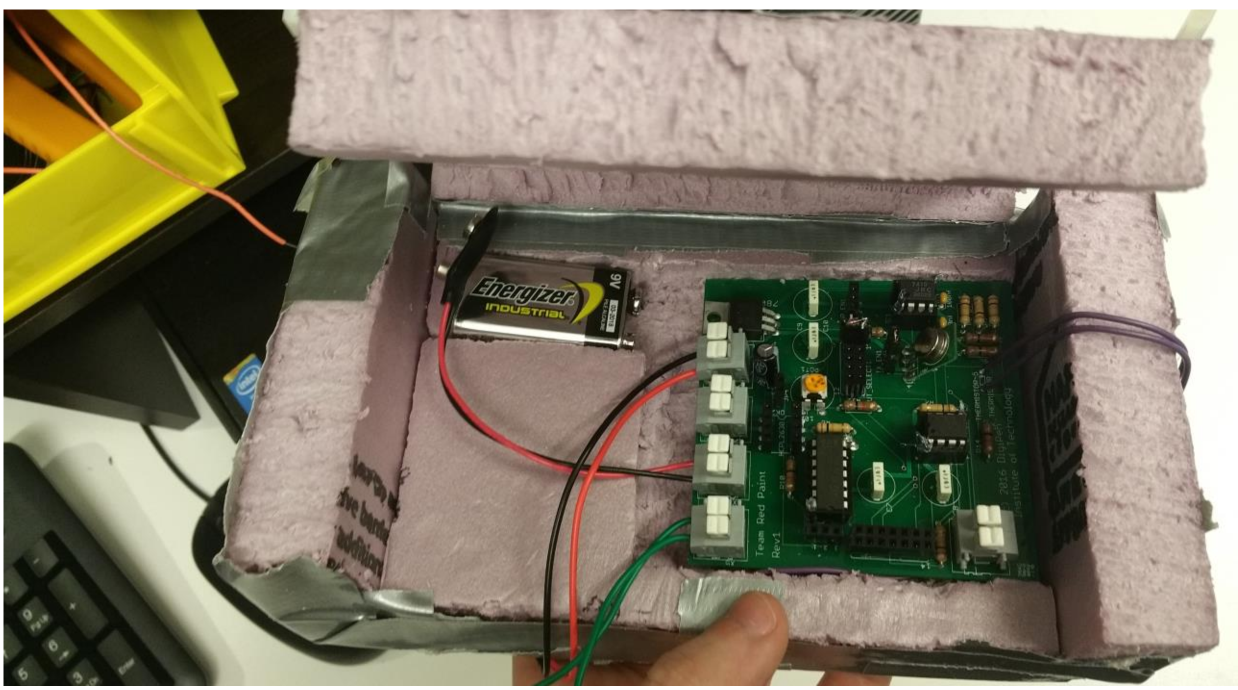


Figure 6: Final PCB design

Pictures

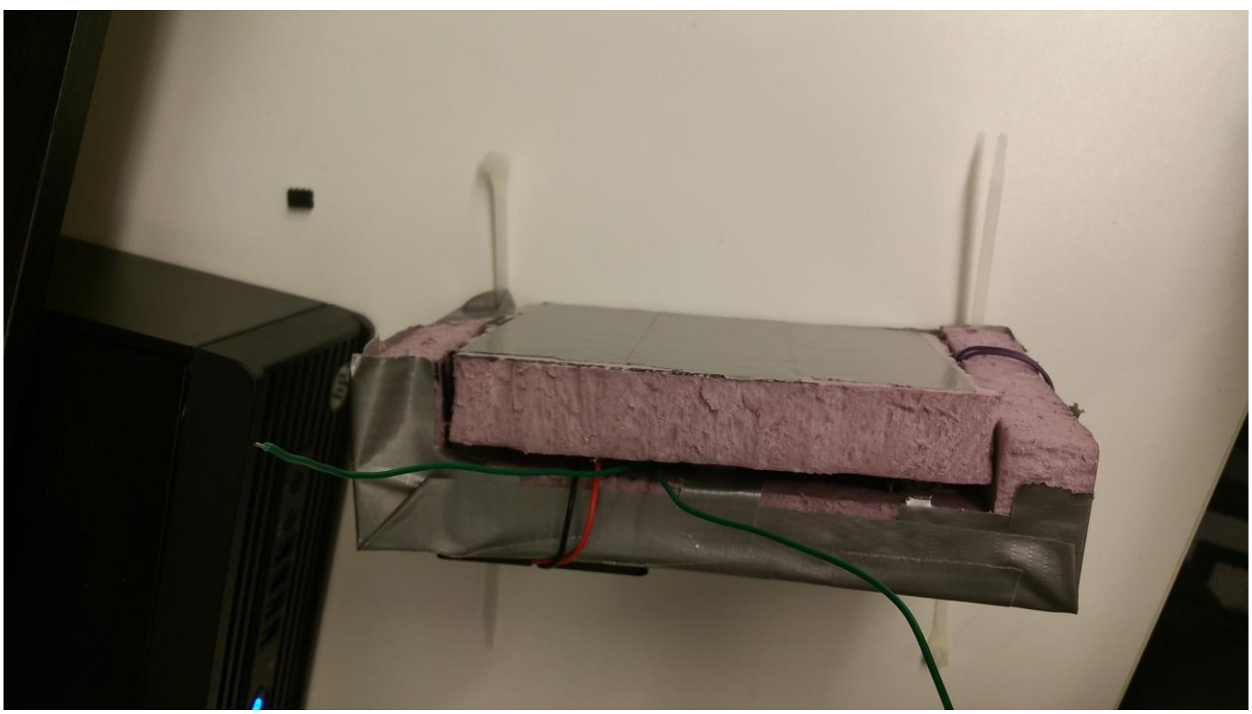


Picture 1: Close up of PCB

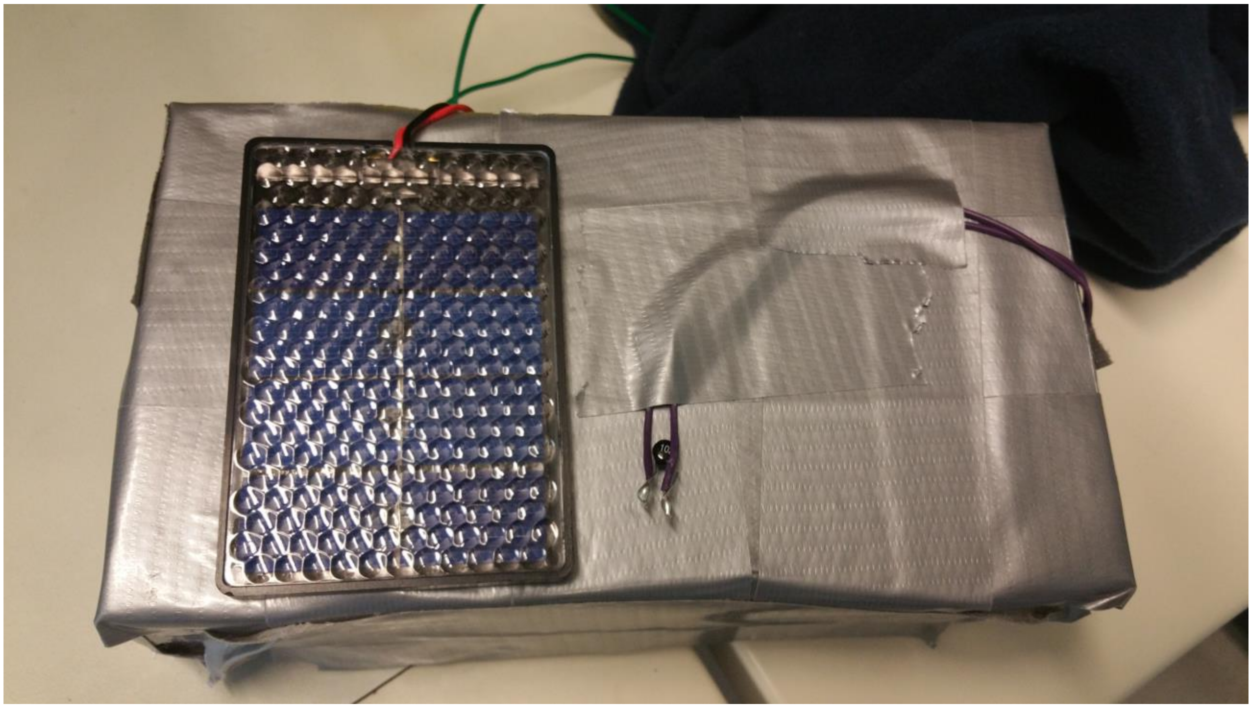


Picture 2: Complete Payload

Picture 3: Payload on Tethered flight



Picture 4: Closed payload



Picture 4: Solar Cell (left) and Thermistor (right) on reverse side of payload