Project Title:
Rocket Tracking and Recovery

Team Name:
Rocket Men

Team Members

<table>
<thead>
<tr>
<th>Name</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bryant Lam</td>
<td><a href="mailto:lam5k@ufl.edu">lam5k@ufl.edu</a></td>
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<td>Terry Ngin</td>
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</tbody>
</table>

Project Abstract

Our project consists of circuitry mounted within a lightning-trigging rocket that will record raw data about the orientation and acceleration of the rocket. When the rocket has completed its flight, a light will blink when it is dark, providing a visual location of the rocket. The orientation and acceleration data will come from a tri-axis sensor in binary form and will be stored initially in RAM, for speed. All of the data will be saved to non-volatile memory so that the information can be recovered potentially after the power supply has run out.
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Project Features

This project is being designed specifically for the needs of the Lightning Research Group at the University of Florida. The goal of the project is to create a module that will reside within a lightning-triggering rocket that will record the rocket's acceleration and orientation, detect light pulses from the tip of the trailing ground wire, and assist in locating the rocket once it has landed by turning on LEDs when it is dark. Features include:

- Recording orientation and acceleration in three dimensions to a microSD card
- Recording interval between and pulse count of precursor pulses to microSD card
- Daylight sensing circuit to turn on rocket-locating LEDs
- Small size
- Ease of use
- Long battery life

Analysis of Competitive Products

The most similar products to our project are electronic payloads that measure altitude or provide flight controls. These devices are mounted within a rocket, just as our electronics are mounted. These payloads, however, typically have only altimeters that provide data on the height that the rocket flies, either with accelerometers, as in our system, or more commonly by measuring the ambient air pressure, which decreases predictably with height.

Our system additionally provides gyroscope data, allowing the user to determine the orientation of the rocket in addition to being able to determine the altitude. Some of these commercial payloads also have flight controllers which can control multistage rockets, which are not necessary in our application. The price of these payloads typically ranges from $50 to $100, much less than our system, but lacking the crucial gyroscope data that is necessary to determine the trajectory of the rocket.
Components

These are the primary components that will be used by the module, along with justifications as to why the component was chosen relative to other devices on the market.

• ADIS16350AMLZ – Tri-Axis Gyroscope/Accelerometer
  
  ◦ The main objective is to record orientation and acceleration, both of which are provided by this device, shown in figure 1, a tri-axis gyroscope/accelerometer. Accelerometers are common and relatively inexpensive; however, gyroscopes prove to be more difficult to find. This device in particular was chosen because of its ability to withstand an impact force up to 2000g. Such a force would likely destroy the module itself, but this component can be salvaged and reused in such an event.
  
  ◦ The main disadvantage of this device is its cost, at approximately $500 USD (2009). The device has been funded by the Lightning Research Group for the design of their module.

• µDRIVE-uSD-G1 – Tiny Embedded “DOS micro-DRIVE” Module
  
  ◦ The component provides a simple interface between the microprocessor and the microSD card, allowing non-volatile storage of information. Many alternative non-volatile memory solutions exist, such as USB flash memory, but a microSD card would be more in line with the space constraints of the design specification. The module being used in our design is shown in figure 2.
• Atmel ATmega32
  ◦ This microprocessor was chosen because of its cheap cost and ease of prototyping. An alternative is Analog Device's Blackfin® microprocessor, which has interface code already written for the gyroscope, but was deemed prohibitively expensive relative to an Atmel microprocessor.

• Photodetector and LEDs
  ◦ A simple light-to-voltage photodiode circuit, shown in figure 3, will be used to detect light pulses and ambient daylight. A low gain will be used for the precursor detection circuit to ensure that only bright flashes are detected while a higher gain will be used for the daylight sensor, to better detect when it is dark. The photodiode used is an N-type silicon PIN diode, a C30807 from PerkinElmer optoelectronics, provided by the Lightning Research Group.
  ◦ The LEDs are Kingbright general purpose low power LEDs. These LEDs were chosen because they have relatively high luminosity and need only 20mA, allowing for longer battery life.

• Battery
  ◦ The power source for the module will be two 2500mAh AA batteries stepped up to 5V. The step-up we are using limits the continuous output current to 200mA, which is within the power draw of our system.
  ◦ Other possibilities were small cell batteries and diodes in series to obtain 5V or using a 9V battery with a 5V linear voltage regulator. Using the small cell batteries would have provided the smallest size for the power source, but the largest capacity for these was only about 1000mAh. The second option, the 9V battery, would have allowed us to run the photodiode at a larger reverse bias and to drive more LEDs, while having a capacity of about 2000mAh. Using the two AA 2500mAh batteries, though, will provide the longest battery life for the module, which was determined to be the most important criteria.

Figure 3: Photodiode Circuit
Technical Concepts

The main requirement of the project is to facilitate a means to record the orientation and acceleration of a lightning-triggering rocket with a sample rate of at least 100 samples per second over a duration of roughly 20 seconds.

1. In order to facilitate recording data at real-time speed, raw orientation and acceleration data will be stored to the RAM as it is received. Therefore, the RAM has to be large enough to store the information.

2. A possible scenario is that the module's power supply will deplete before the rocket can be successfully retrieved, so the information has to be stored in non-volatile memory. Our project will be using a microSD card.

3. In a point during the rocket's trajectory, a parachute will deploy in order to safely guide the rocket back to the ground. One possible scenario is that the parachute will fail to deploy and the rocket containing the module will crash into the ground. To alleviate any impact damage, the cone of the rocket will be outfitted with foam insulation that will hopefully protect the module. If the module is destroyed, the gyroscope can be salvaged as it can withstand up to 2000g of impact force.

4. The module consists of electronic components that must be protected from the triggered lightning. The proposed solution is to enclose the electronics in a Faraday cage.

5. As the rocket begins its descent, it may drift into a surrounding forest or be somehow difficult to locate. Our project uses LEDs to aid in the location of the rocket once it has landed. The LED system has a photodiode circuit that will detect when the ambient light is sufficiently dark to turn on the LED. Another considered solution for locating the rocket was to include a GPS or RF transmitter that would more effectively allow for recovery of the rocket, independent of line-of-sight. However, having the Faraday cage to protect the electronics from lightning prevents us from implementing these transmitters in our design conveniently.

6. The module may spend several hours idle between the time it is loaded and when it is fired. The module, then, must have sufficient battery life to stay active during this idle period and still be able to record the data during flight.
Project Architecture

The components of our project are interfaced together as shown in figure 3.

To maximize battery life, the module will be loaded into the triggering rocket before an approaching storm arrives and idle in the launch tube. The system will read samples from the ADIS16350, looking for a peak in acceleration indicating that launch has occurred.

Once launch has been detected, the microprocessor will read in data from the ADIS16350 at 100 samples per second and store that data in the FRAM through SPI. Precursor data from the photodiode is also recorded and stored in the microprocessor's RAM. The analog comparator counts the number of light pulses and the input capture unit calculates the time between pulses.

Once the memory is filled and no more data can be saved, the microprocessor begins saving the data to non-volatile memory, a microSD card. The µDRIVE-uSD-G1 provides the interface between the microprocessor and the microSD card through the microprocessor's USART system.

Once the data is saved to non-volatile memory, the data collection portion of the routine is complete and the microprocessor begins its rocket recovery routine. The light level from the photodiode circuit is sampled through the microprocessor's ADC. When the light level is low enough, bright LEDs will be turned on to aid in locating the rocket.
Distribution of Labor
A breakdown of each team member's projected labor, by approximate percentage, is shown in table 1.

<table>
<thead>
<tr>
<th></th>
<th>Bryant Lam</th>
<th>Terry Ngin</th>
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<tr>
<td>Preliminary Research</td>
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<td>Gyroscope</td>
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<td>FRAM</td>
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<td>Physical Assembly</td>
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<td>Testing and Debugging</td>
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*Table 1: Distribution of Labor*

Bill of Materials
The prices for the materials used in our project and cost to us are shown in table 2. The major components of the project cost were paid for by the Lightning Research Group.

<table>
<thead>
<tr>
<th>Component</th>
<th>Quantity</th>
<th>Price</th>
<th>Our cost</th>
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<tbody>
<tr>
<td>ADIS16350AMLZ</td>
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<td><strong>Total</strong></td>
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*Table 2: Component Costs*
Project Timeline

Figure 5: Gantt Chart of Timeline