

UTAH STATE UNIVERSITY

---

**Passive Tracking Device  
– Senior Project –  
Final Report**

---

DALLIN MARSHALL

COMPUTER ENGINEERING

December 6, 2015

# Contents

<b>1</b>	<b>Executive Summary</b>	<b>1</b>
<b>2</b>	<b>Introduction</b>	<b>1</b>
2.0.1	Introduction . . . . .	1
2.0.2	Problem . . . . .	1
<b>3</b>	<b>Methods</b>	<b>1</b>
3.1	Microcontroller . . . . .	2
3.2	Cell Module . . . . .	2
3.3	GPS Module . . . . .	3
3.4	Power Regulator . . . . .	3
<b>4</b>	<b>Results</b>	<b>3</b>
4.1	Item Definitions . . . . .	3
4.1.1	Interface Description/Functional Block Diagram . . . . .	4
4.2	Characteristics . . . . .	4
4.2.1	Performance Characteristics . . . . .	4
4.2.1.1	Physical Characteristics . . . . .	4
4.2.1.1.1	Form Factor . . . . .	4
4.2.1.2	Electrical Characteristics . . . . .	4
4.2.1.2.1	Power Constraints . . . . .	4
4.2.1.2.2	Prototype Connections . . . . .	4
4.2.2	Environmental Characteristics . . . . .	5
4.2.2.1	Natural Characteristics . . . . .	5
4.2.2.1.1	Temperature Rating . . . . .	5
4.2.2.2	Induced Environment Characteristics . . . . .	5
4.2.2.2.1	Shock Test . . . . .	5
4.2.2.2.2	Vibration Test . . . . .	5
4.2.2.2.3	Dust Test . . . . .	5
4.3	Electromagnetic Interference . . . . .	6
<b>5</b>	<b>Discussion</b>	<b>6</b>
5.1	Characteristics . . . . .	6
5.1.1	Performance Characteristics . . . . .	6
5.1.1.1	Physical Characteristics . . . . .	6
5.1.1.1.1	Form Factor . . . . .	6
5.1.1.2	Electrical Characteristics . . . . .	6
5.1.1.2.1	Power Constraints . . . . .	6
5.1.1.2.2	Prototype Connections . . . . .	7
5.1.2	Environmental Characteristics . . . . .	7
5.1.2.1	Natural Characteristics . . . . .	7
5.1.2.1.1	Temperature Rating . . . . .	7
5.1.2.2	Induced Environment Characteristics . . . . .	7
5.1.2.2.1	Shock Test . . . . .	7

5.1.2.2.2	Vibration Test . . . . .	8
5.1.2.2.3	Dust Test . . . . .	8
5.2	Electromagnetic Interference . . . . .	8
<b>6</b>	<b>Conclusion</b>	<b>8</b>

## List of Figures

# 1 Executive Summary

## 2 Introduction

There are many businesses that use ATVs (All Terrain Vehicles) to accomplish their work. These businesses range from construction companies to civil engineering firms, to the National Forest Service. Many times the larger the company the harder it is to manage the fleet of vehicles. The task of keeping track of these vehicles is further compounded by human error as well as geographical isolation and dispersion of resources. These businesses need a device that facilitates the management of their fleet.

### 2.0.1 Introduction

There are many tracking solutions available for public and enterprise use but they generally all have the same problem. They are active tracking solutions. This means that the vehicle being tracked can only be tracked in real-time. The client of one of these active solutions could use the monitoring software to see on a map the location and movements of the vehicles in their fleet. While there are applications where active monitoring is necessary there are some major drawbacks to such a system. Three of the largest drawbacks are:

1. Active systems require large amounts of power and physical space
2. Active systems are quite costly
3. There are applications that don't require real-time updates of vehicle location

This means that the tracking bug itself is responsible for periodically transmitting its location to the client. From the client's side, the client can only see the last known location of the vehicle. The PTD is a passive tracking solution that is targeted to counter these drawbacks of active solutions by functioning in low-power environments that do not require real-time updates and at a reasonable cost. By targeting markets that don't require active solutions the tracking bug can be made cheaper, smaller, more power efficient, and provide a cheaper solution overall for the customer.<sup>1</sup>

### 2.0.2 Problem

The PTD is targeted at making this task considerably easier. The PTD, once installed in an ATV, uses the internal battery of the ATV to periodically transmit its location to the managing individual. This will help monitor vehicle usage as well as recover vehicles in the event of theft.

## 3 Methods

In this section I will expound upon each of the sub-systems and explain in greater detail their function and components. The Passive Tracking Device consists of four subsystems:

- **Microcontroller** - I chose the Tiva-C TM4C123G for prototyping this project because it has plenty of serial UART communication modules as well as an internal 3.3 V generator that

---

<sup>1</sup>See the Problem and Objectives sections of this document for information regarding this topic.

can be used to power the Copernicas 2 GPS Module. It also operates in a fairly low power range.

- **Cell Module** - I chose the Adafruit FONA 1946 Cell Module. The FONA Cell Module was chosen because of its ease of prototyping and compatibility with all 2G and 3G GSM Cell Networks. It is also controlled via a UART communication module to send text messages. This Cell Module also happened to be at the most attractive price point when compared to other Cell Modules. This Module makes use of the SIM 800L cell component which was previously looked at as a viable option for this project because of its commonality in standard cellular devices. <sup>2</sup>
- **GPS Module** - I chose the Trimble Copernicas 2 GPS Module. The Copernicas 2 GPS Module requires a 3.3 V voltage source for power and uses a serial UART communication module operating at 4800 BOD to communicate its location to other systems. <sup>3</sup>
- **Power Regulator** - I chose to purchase the DROK Adjustable Switching Voltage Regulator for the purpose of prototyping this project. This DROK Regulator makes use of the Texas Instruments LM2596 Switching Regulator which I had previously chosen as my target regulator. This prefabricated module made the task of prototyping manageable. I also chose this power regulator because of its adjustable functions that would later allow me to use it on other projects and because it can source a maximum of 3 amps. <sup>4</sup>

### 3.1 Microcontroller

The Tiva-C microcontroller operates at 16 MHz by default. I chose to use this default setting of 16 MHz because a higher clock frequency was not necessary and if I had increased it then it would have required more power. I chose to activate three of the available eight UART communication modules for the PTD. I needed one UART module for each of the following: receive GPS location from GPS Module, send formatted GPS location as a message to the Cell Module for SMS transmission, and one to allow the client easy cell number destination configuration for text messages. I chose to use interrupts instead of pulling a status bit for each of the UART modules to make code more understandable and maintainable. [Possibly put wiring diagram here somewhere](#)

### 3.2 Cell Module

The Adafruit FONE 1946 Cell Module has a BOD detecting UART module that detects the transmission speed from the communicating system and replies at the same speed. Because of this convenient feature I used 4800 BOD to communicate with the Cell Module because the GPS Module requires 4800 BOD. This allowed me to simplify my configuration for all UART modules by using the same speed configuration for all modules. This module uses the common AT command set to control cellular functions.

---

<sup>2</sup>Included in this subsystem of the project it should be noted that a small lithium ion battery for transmission power stability, an SMA ducbill cell antenna, and a uFL to SMA adapter are required to complete this subsystem.

<sup>3</sup>Note that this subsystem requires a GPS antenna that uses the common SMA connector. This is in addition to the Cell Module antenna because the two antennas operate on very different bands of communication.

<sup>4</sup>The PTD does not come close to 3 AMPS but I wanted this feature for future prototyping

### 3.3 GPS Module

The Trimble Copernicas 2 GPS Module works well because of it's easy "plug and play" set up. Upon receiving power this module initializes and after a few seconds begins to transmit locational data every second at a rate of 4800 BOD. The microcontroller is responsible for parsing this string and translating it into a more human readable GPS location to be sent via SMS to the client.

### 3.4 Power Regulator

I selected the LM2596 Texas Instruments Switching Regulator because of it's low-idle power loss as well as it's voltage range and current operating output. When looking to buy the individual LM2596 components the spec sheet made it clear that external capacitors, inductors, diodes, resistors, and potentiometers needed to be purchased separately in their desired configuration in order to correctly control the output voltage of the Switching Regulator. To avoid this headache during the prototyping phase I opted to buy the DROK Switching Regulator which comes preassembled with the desired components. Both the microcontroller and the Cell Module require a 5V source to operate. The LM2596 regulator provides this necessary voltage regulation from a typical ATV battery which normally are 12V 11Ah batteries. From the beginning switching regulators were preferred over linear regulators due to the improved power characteristics from a switching power regulator. The constant power dissipation of a linear regulator makes them undesirable for low power operation.<sup>5</sup>

## 4 Results

This section outlines the requirements and results of the tests for those requirements.

### 4.1 Item Definitions

The PTD consists of 4 main subsystems, namely:

- Cell Network Interface
- Global Positioning System
- Controller Circuit
- Power Converter/Regulator

The PTD system will be a passive system, meaning that the PTD will power down to a very low power state while not in use. At an appointed trigger it will power up and transmit it's location to the PTDs owner via a cell network. There is no plan for the owner of the PTD to be able to activate the device externally. The PTD shall operate in this power-up, transmit location, power-down sequence.

The PTD designed follows the block diagram in Figure: **number** shows that all sub-system functions have been used to complete with the clients expectations.

---

<sup>5</sup>This is a part of the PTD that would need to be custom manufactured on a large scale manufacturable PCB

#### 4.1.1 Interface Description/Functional Block Diagram

The PTD used a micro-controller to act as a intermediary logic location for the signals between the GPS and Cell Module. All UART communication used in the project is configured to run at 4800 BOD. Put block diagram here

### 4.2 Characteristics

The following section provides a technical summary of the PTD's characteristics.

#### 4.2.1 Performance Characteristics

To comply with the specification document the PTD must complete tests or justify adequately that the device will complete the tests at a later stage of development.

##### 4.2.1.1 Physical Characteristics

The PTD shall meet the following physical requirements:

###### 4.2.1.1.1 Form Factor

The PTD shall conform to the following form factor: 16cm by 8cm by 5cm This is a test to see what is happening with the hanging indent

**Test** - The PTD shall be placed in a small box of dimension stated in requirements.

**Result** - Talk about results

##### 4.2.1.2 Electrical Characteristics

The PTD shall meet the following electrical requirements:

###### 4.2.1.2.1 Power Constraints

The PTD shall operate using the power provided by a standard ATV battery, specifically, 12V 11Ah battery.

**Test** - The PTD shall function with only the power provided by an ATV battery. The PTD shall also be tested while the ATV's engine is actively running and under normal operation. requirements.

**Result** - Talk about results

###### 4.2.1.2.2 Prototype Connections

For the purposes of proof of concept the PTD may make use of a breadboard to connect the components.

**Test** - The PTD shall have connections that function, The design of these connections is not specified in the *Specifications Document*. requirements.

**Result** - Talk about results

## 4.2.2 Environmental Characteristics

### 4.2.2.1 Natural Characteristics

The PTD shall meet the following natural environmental characteristics. The PTD shall meet the requirements of this specification during and after exposure to any combination of any of the following natural environments. The PTD may be packaged to precluded exposure to any environments that would control the design.

#### 4.2.2.1.1 Temperature Rating

The PTD shall function between 0° C and 40° C.

**Test** - The PTD shall be tested for full functionality at both ends of the temperature spectrum. requirements.

**Result** - [Talk about results](#)

### 4.2.2.2 Induced Environment Characteristics

The PTD shall meet the following induced environmental characteristics. The PTD shall meet the requirements of this specification during and after exposure to any combination of any of the following induced environments. The PTD may be packaged to precluded exposure to any environments that would control the design.

#### 4.2.2.2.1 Shock Test

The PTD shall withstand mechanical shocks of 3 ft drop test 5 times onto concrete.

**Test** - The PTD shall function after the drop tests. requirements.

**Result** - [Talk about results](#)

#### 4.2.2.2.2 Vibration Test

The PTD shall withstand vibrations of 1 oscillations per second with an amplitude of 1.5cm for 1 hour.

**Test** - The PTD shall function after the vibration test is performed. re-quirements.

**Result** - [Talk about results](#)

#### 4.2.2.2.3 Dust Test

The PTD shall function in a dusty environment, specifically, the shock and vibration tests shall be repeated after 15 grams of fine sand is applied to the device.

**Test** - The PTD shall function after the dust test is performed. re-quirements.

**Result** - [Talk about results](#)



### 4.3 Electromagnetic Interference

The PTD shall conform to the standards found in the *Applicable Documents* section of this document. The EMI shall be measured and shall meet the requirements found in the *Applicable Documents* section of this document. Tell them what the applicable documents are or add section

## 5 Discussion

This section is designed to discuss the *Results* section of this document. The methods of testing and possible design modifications resulting from testing will also be covered here.

### 5.1 Characteristics

The following section provides a technical summary of the PTD's characteristics pertaining to the *Results* section.

#### 5.1.1 Performance Characteristics

To comply with the specification document the PTD must complete tests or justify adequately that the device will complete the tests at a later stage of development.

##### 5.1.1.1 Physical Characteristics

The PTD shall meet the following physical requirements:

###### 5.1.1.1.1 Form Factor

The PTD shall conform to the following form factor: 16cm by 8cm by 5cm.

This is the single section from the *Specification Document* that was not achieved during the testing phase of this project. After talking to the client it was decided that the reason for the specified dimensions was to allow for a prototyped solution. When this project moves to the next phase of development where custom PCBs will be manufactured with all of the components on the same board the form factor will be well within the needed size constraints for this project. It was therefore decided not to judge this project as a failure as a result of failing to meet the form factor requirements.

###### 5.1.1.2 Electrical Characteristics

The PTD shall meet the following electrical requirements:

###### 5.1.1.2.1 Power Constraints

The PTD shall operate using the power provided by a standard ATV battery, specifically, 12V 11Ah battery.

The PTD was designed with these power constraints in mind and it is able to operate given an ATV battery. It should be noted that the PTD expects that the ATV battery is in good working condition. Ordinarily when testing the PTD the Battery functioned perfectly. This was back in September. As temperatures in Logan began to drop the upon ignition of my motorcycle the PTD

began to reset itself. This was caused by the momentary drop in the power provided to the PTD from the battery. This is not a flaw in the PTD but an example of the importance of using a ATV battery in good working condition. My Motorcycle battery is about 5 years old and should soon be replaced.

#### **5.1.1.2.2 Prototype Connections**

For the purposes of proof of concept the PTD may make use of a breadboard to connect the components.

Originally the PTD was prototyped using a bread board but for reasons that will be discussed in the *Drop Test* section the design of the prototype was altered to use perf-board to better secure connections between components. This completes and exceeds the specifications.

### **5.1.2 Environmental Characteristics**

#### **5.1.2.1 Natural Characteristics**

The PTD shall meet the following natural environmental characteristics. The PTD shall meet the requirements of this specification during and after exposure to any combination of any of the following natural environments. The PTD may be packaged to precluded exposure to any environments that would control the design.

##### **5.1.2.1.1 Temperature Rating**

The PTD shall function between 0° C and 40° C.

These tests were done at very different times of the development. The hot test of 40° C was done in late September and the cold test of 0° C was done in December. To complete with the hot test I created a chamber out of a cardboard box. I used my wife's hair dryer as the heat source, and here instant read cooking thermometer to verify the temperature. I then ran the GPS antenna out the window and verified that at 40° C, which is 104° F, the tracking bug functioned. The cold test was a little less involved. I waited until a cold winter night and took the PTD out to my patio and left it for 3 hours. The PTD functioned fine during and after each of these tests.

#### **5.1.2.2 Induced Environment Characteristics**

The PTD shall meet the following induced environmental characteristics. The PTD shall meet the requirements of this specification during and after exposure to any combination of any of the following induced environments. The PTD may be packaged to precluded exposure to any environments that would control the design.

##### **5.1.2.2.1 Shock Test**

The PTD shall withstand mechanical shocks of 3 ft drop test 5 times onto concrete.

This test was pretty straight forward. My plan was to drop the PTD on my kitchen floor which is concrete as see what happen. I was a little hesitant because at the point of this testing the PTD was still developed using a bread board. Upon dropping the PTD the components and wires practically exploded out of the bread board. They still functioned after the reconnection of all the

components but because of this experiment and to make the PTD more compact and clean looking I used perf-board to create a new more permanent structure for the PTD. The rest of the drop tests were completed after the change of structure and were more successful.

#### 5.1.2.2.2 Vibration Test

The PTD shall withstand vibrations of 1 oscillations per second with an amplitude of 1.5cm for 1 hour.

This test was the worst test for me to complete because it took my active attention for a solid hour. Luckily I used this time to catch up on one of my favorite tv shows during the time that I was shaking the PTD. The PTD functioned fine after this test. This test was done after the perf-board modifications.<sup>6</sup>

#### 5.1.2.2.3 Dust Test

The PTD shall function in a dusty environment, specifically, the shock and vibration tests shall be repeated after 15 grams of fine sand is applied to the device.

Like most American households I didn't have a food scale available so I used a little math to estimate the volume of dirt necessary to represent 15 grams. I know that 4 grams of sugar is about one teaspoon of sugar. Using this rough estimate I used my wife's measuring spoons<sup>7</sup> to gather 4 teaspoons of dirt which I placed in a box with the PTD. I then closed up the box and repeated the shock and vibrations tests. I then used an air compressor to clean off the PTD before verifying that the PTD worked and function was not degraded by the stress.

## 5.2 Electromagnetic Interference

The PTD shall conform to the standards found in the *Applicable Documents* section of this document. **Tell them what the applicable documents are or add section** The PTD was created with components that all comply with the electromagnetic interference standards described in the *Applicable Documents* section and because the normal function of the components was not changed the completed project also conforms to with these standards without needing to be tested.

## 6 Conclusion

---

<sup>6</sup>It is actually a lot harder than expected to shake something for an hour straight.

<sup>7</sup>I don't think my wife enjoys it when my experiments infringe on her cooking utensils.