RC BOAT POWER AND SIGNAL LEVEL INDICATOR

Design Review
ECE 445

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TA :- Yamuna Phal

1. Objective

RC Toys are a multimillion dollar industry, with buyers from across the planet. One of the main problems faced by enthusiasts is the short battery life of the vehicle. Most batteries last only

10-15 minutes and the battery degrades over time. Another frequent complaint is the low signal range, which often leads to vehicles straying out of range and getting stuck, lost or otherwise damaged. We decided to work specifically on a RC boat because these issues are most prevalent when the toy is in the water as it makes retrieving the toy the hardest as compared to a RC car or a RC bike.

We propose to solve this problem by providing an indication of low levels of signal strength and power, and therefore giving the user a chance to save his boat from harm. We would further propose to implement a tracking mechanism to keep tab on the boat in case it is misplaced (within the range) during operation. The battery level would be detected in hardware (using a simple comparator) and the location would be obtained using a GPS chip the data would then be transmitted via wireless communication to be displayed to the user.

Our device would be located physically on the RC Boat, and would be active during the boat's operation. It would transmit location and battery data to a receiver module at the user end. This receiver module acts basically as an amplifier, which receives data from the boat and then sends it to the smartphone. An app on the cell phone would have an interface to display signal range, battery level and location. Furthermore, if time permits us to extend our project, we would like to get the boat to steer back to the user in case of low signal or power levels, with the use of magnetometer direction readings and GPS coordinates.

2. Background

Most of us love to play with different types of RC toys, be it a car, boat or even a plane. RC toys are super fun to play with and can fit into anyone's budget. They can cost from anything around $20 - $2000 depending upon the functionality and the complexity. But many users have experienced and complained about major flaws in it's functionality which make them annoying to play with ,

1.) Firstly, The battery life of these toys is around 10-15 minutes after one full charge (which takes 8-10 hours for the first charge and then 4-6 hours for every subsequent charge), which is very insufficient considering how long it takes to charge them in the first place. On top of that one can imagine how annoying it must be to lose a toy or even damage a toy because it ran out of power.

2.) Secondly, for a RC toy costing around $20, the control range is around 115 feet which is not a lot for anyone playing with it and therefore they have to always keep in mind a boundary of sorts and stay inside that or risk losing their toy forever.

Keeping the above two issues in mind and also looking at how big the RC toy industry is throughout the globe, we decided to provide a simple and efficient solution to the problem. We took up the challenge to provide some sort of indication to the user whenever the battery level or the signal level runs below a defined threshold value and time permitting we would like to implement a mechanism to bring the boat back to the user if it strays out of range.

3. Requirements

Our set of requirements are stated as follows:

1. Notify the user when the boat is about go out of the specified range.
2. Our mobile unit should be capable of indicating low battery levels.
3. Our mobile unit should be capable of measuring the approximate location and direction of the vehicle.

4. Block Diagram

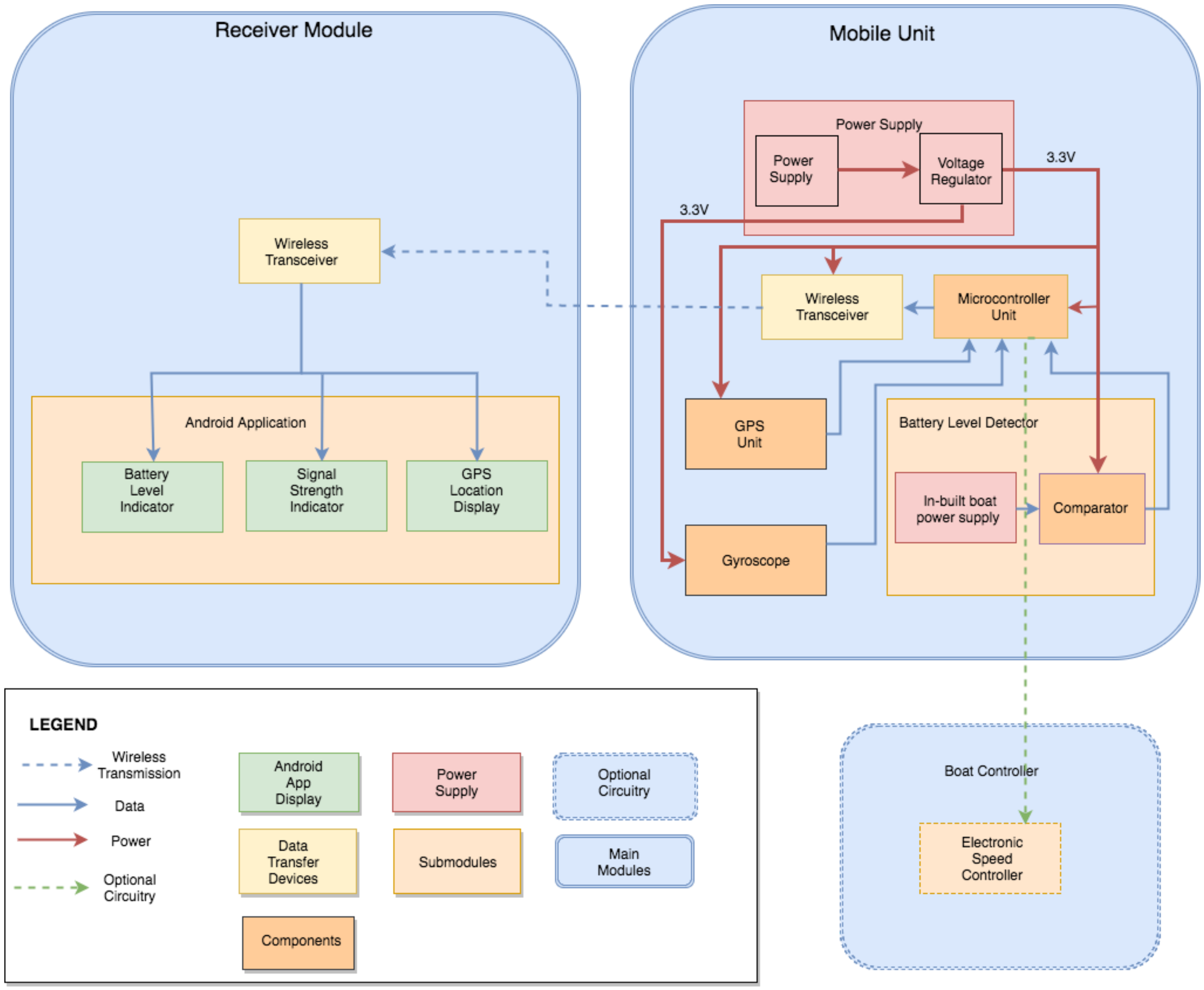

Figure 1. Block Diagram

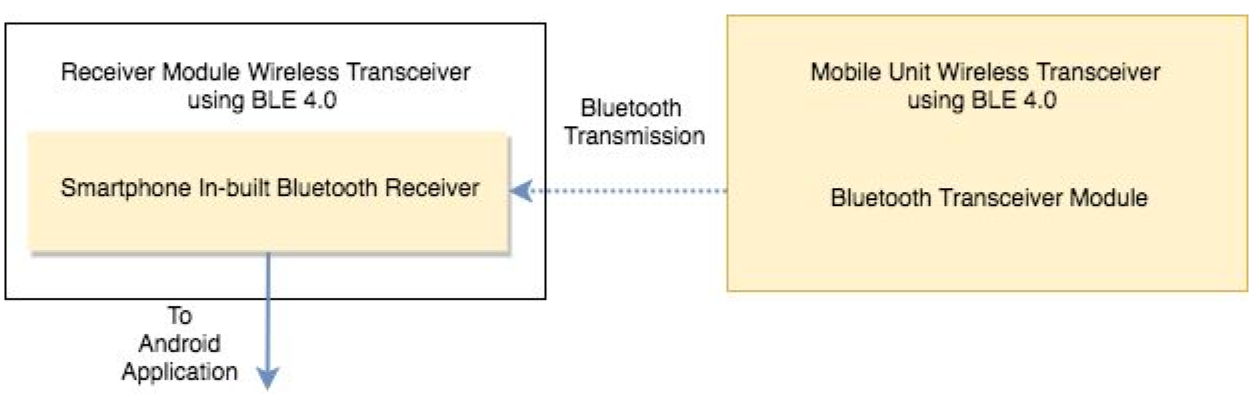

Figure 2. Bluetooth Transceiver Block

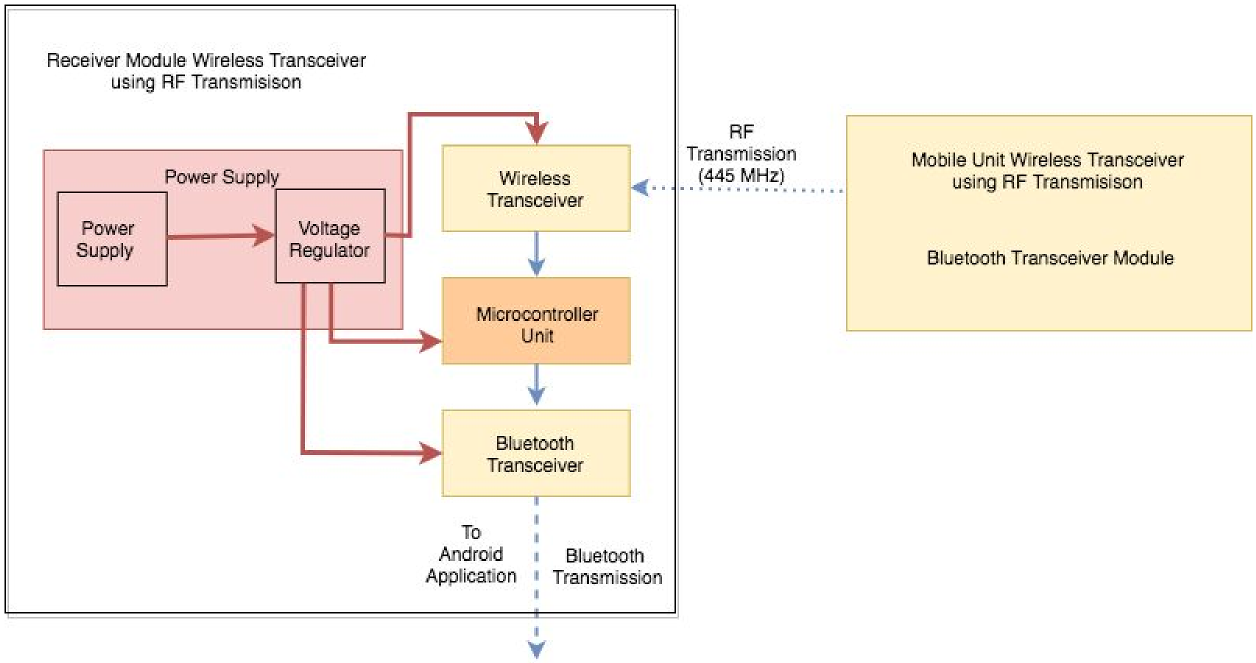

Figure 3. 445 MHz Transceiver Block

5. Description

Our project will consist of two main units, namely the mobile unit, and a receiver module which includes a data transceiver and a mobile app which is used to display the data to the user.

We have two separate designs for prototypes, each of these involve a different method for wirelessly transmitting data.

The first design uses Bluetooth Low Energy 4.0 [1] as the main communication protocol. The band of communication is approximately 2.4 GHz (Figure 2).

The second design uses Wireless Transmission at a radio frequency of 445 MHz(Figure 3).

Regardless of the type of communication, the wireless transceiver on the boat is responsible for transmitting the following information :-

a. Battery level
b. GPS location
c. Direction of the boat

While the wireless receiver on the control unit will be responsible for sending the data to the mobile application.

The gyroscope on the boat senses the direction that it is facing, using measurements of the magnetic field of the earth, as well as the angular momentum of the device . It gives us a rotation about each of the 3 axes : x, y and z.

The GPS unit will be in constant communication with Geostationary satellites. Each satellite transmits a unique time signal along with orbital information that allows us to decode our latitude and longitude. If we receive signals from 4 or more satellites , we can accurately decipher our location and altitude, which will be transmitted back to the cell phone unit.

Finally, the optional circuitry indicated by the dotted green line is for bringing the boat back into range in case of emergency. This works by measuring the location and direction of the boat, and calculating a new path that would take it back into range of the user. We plan to implement this as an extension the the project, if time permits.

The app interface provides the user easy and simple access to the information sent from the boat. The following image shows our basic app layout,

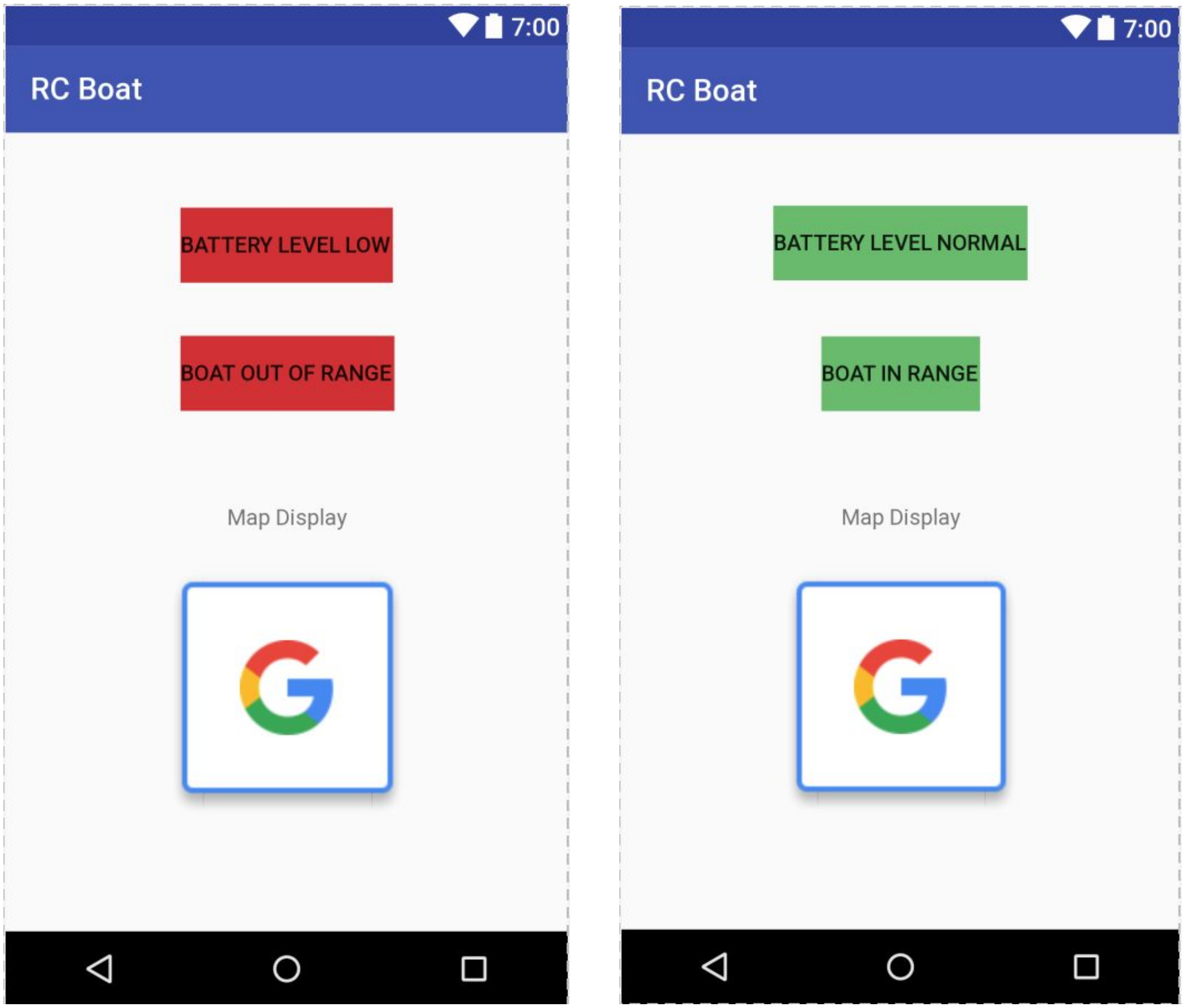

Figure 4. App UI

6. Functional Overview

In the functional overview, we have described the overall operation of the devices in detail. Additionally, for the wireless transceivers, we have included detailed descriptions for each of our separate designs, including separate schematics.

6.1 Wireless Transceiver

Design 1 (Bluetooth Communication)

Block Diagram

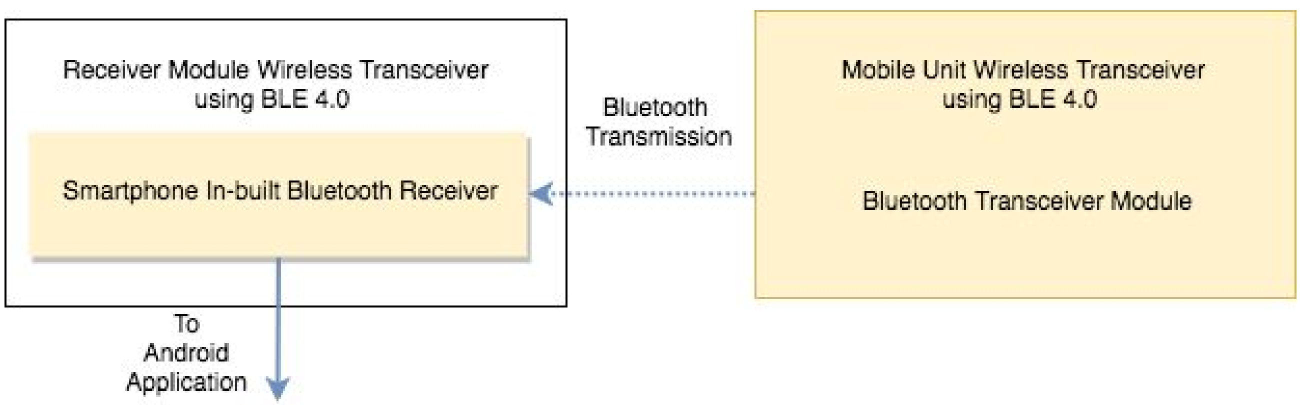

Figure 5. Bluetooth Transceiver Block

Schematic

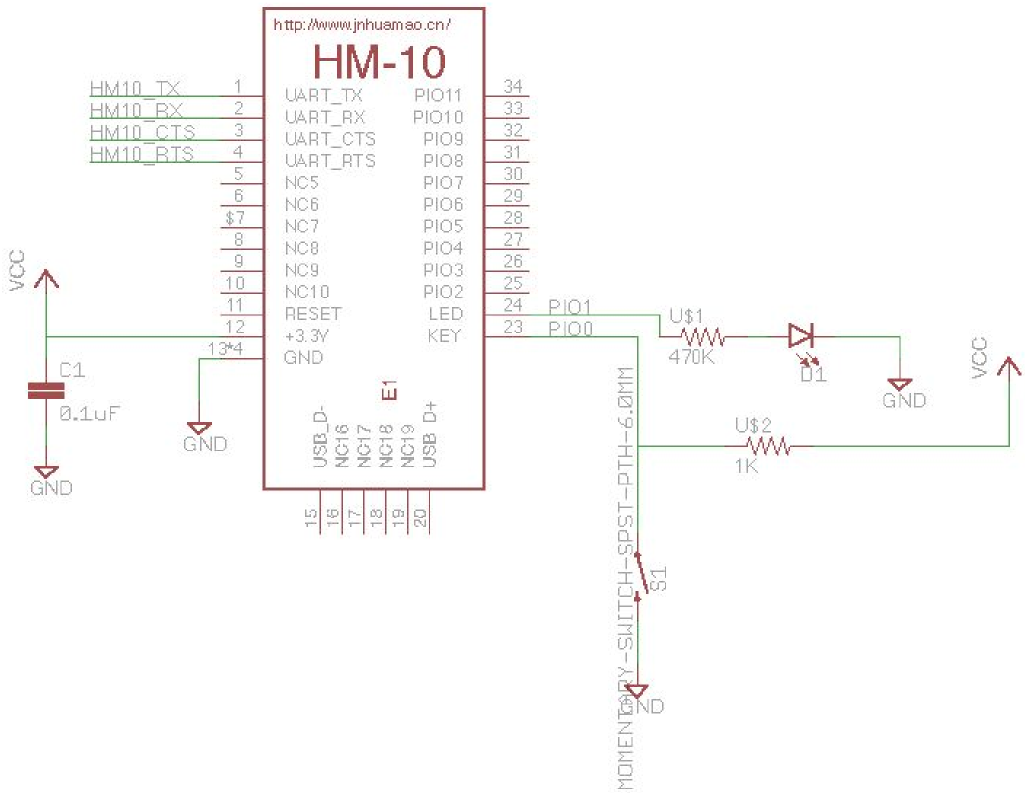

Figure 6. Bluetooth Transceiver Schematic[13]

Description

In this design, We will be utilizing Bluetooth for our wireless communication. On the mobile unit, we will have the HM-10 Bluetooth Module which will receive data from the GPS, Comparator and Gyroscope units regarding location, battery level and direction, and transmit this data to our Android Cellular Device. The protocol we will be using is Bluetooth Low Energy (BLE) 4.0. This is an updated bluetooth standard that emphasizes low power consumption for bluetooth devices.

The HM-10 Bluetooth Module is a BLE 4.0 Compatible device that transmits at a frequency of around 2.4 GHz. It has a transmit power between -6 dBm to 6 dBm and a receive sensitivity around -97 dBm.

A typical cellular phone has an Bluetooth transmit power between -5 dBm and 0 dBm and receive sensitivity around -70 dBm. It transmits at a frequency of 2.4 GHz [2].

Using the link equation [3], and the values given above, we can determine the distance of transmission between phone and module.

$$range\ (in\ miles) = antilog\left(\frac{P_{TX}+G_{TX}-L_M+G_{RX}-P_{RX}-104}{20}\right)$$
$$P_{TX} - Transmitter\ power$$
$$P_{RX} - Receiver\ power$$
$$G_{TX} - Transmitter\ antenna\ gain$$
$$G_{RX} - Receiver\ antenna\ gain$$
$$L_M - Link\ Margin\ (0\ for\ outdoors\ transmission)$$

$$d_1(phone\ to\ module) = antilog\left(\frac{0+97-104}{20}\right)$$

$$d_2(module\ to\ phone) = antilog\left(\frac{5+70-104}{20}\right)$$

with some margins added, we get a range between 30 to 100 m. Our RC Boat has a functional range of around 30 metres, so we require at least that range.

Table 1. Requirements and Verification for HM-10 Bluetooth Module

Requirements	Verification
1. HM10 Bluetooth Module must have a maximum transmit power of +6dBm.	*1. The transmission strength of the device is tested with the help of a vector signal analyzer.*
2. *Android phone must have a transmit strength between -5 dBm and 0 dBm.*	*2. The transmission strength of the device is tested with the help of a vector signal analyzer.*
3. Android phone must be able to communicate with HM-10 Bluetooth module at a range of at least 30 metres.	*3. The prototype circuit containing the HM-10 is placed at a distance of 30 metres in the line of sight of the android device. We will test signal transmission between the two devices.*
4. Low input voltage $V_{in} = 3.3\ V$ with $\pm 5\%$ tolerance.	*4. The device will be hooked up according to the schematic shown above.* *5. Some dummy data will be used to simulate the data transfer conditions.* *6. The 3.3 V DC power supply will be given to Vcc and then the operation of the module will be monitored.* *7. If we receive the data at the receiver, then the requirement has been satisfied.*

Design 2 (Radio Frequency Transceiver)

Block Diagram

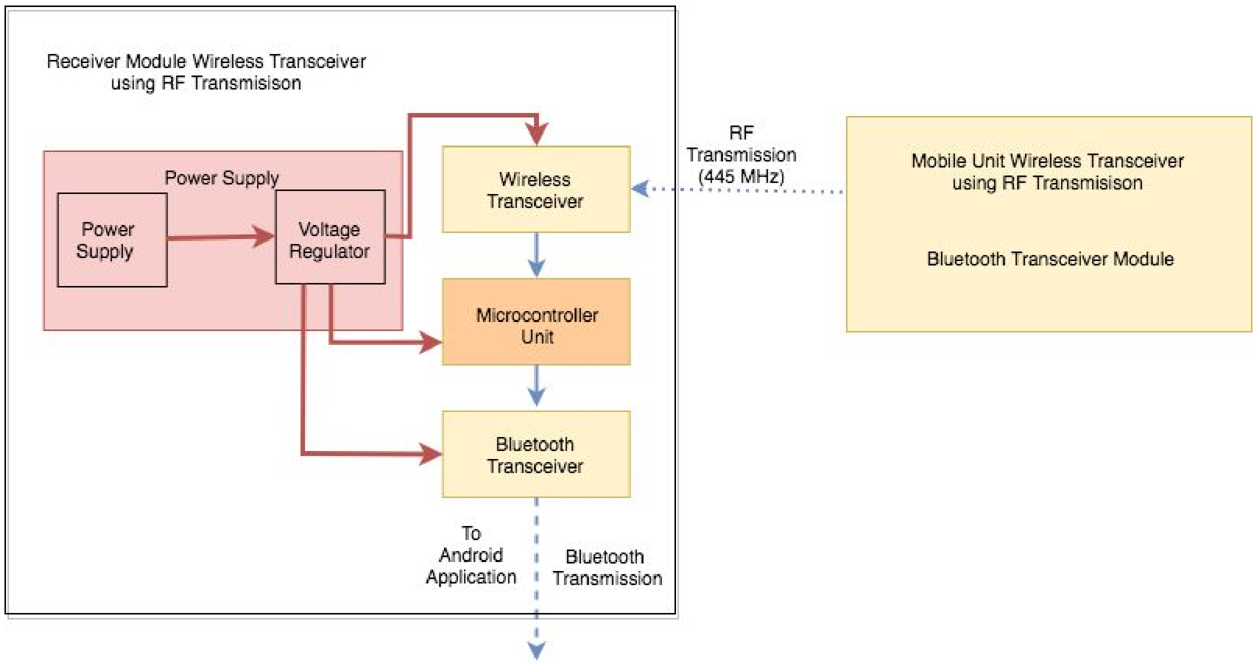

Figure 7. 445 MHz Transceiver Schematic

Schematic

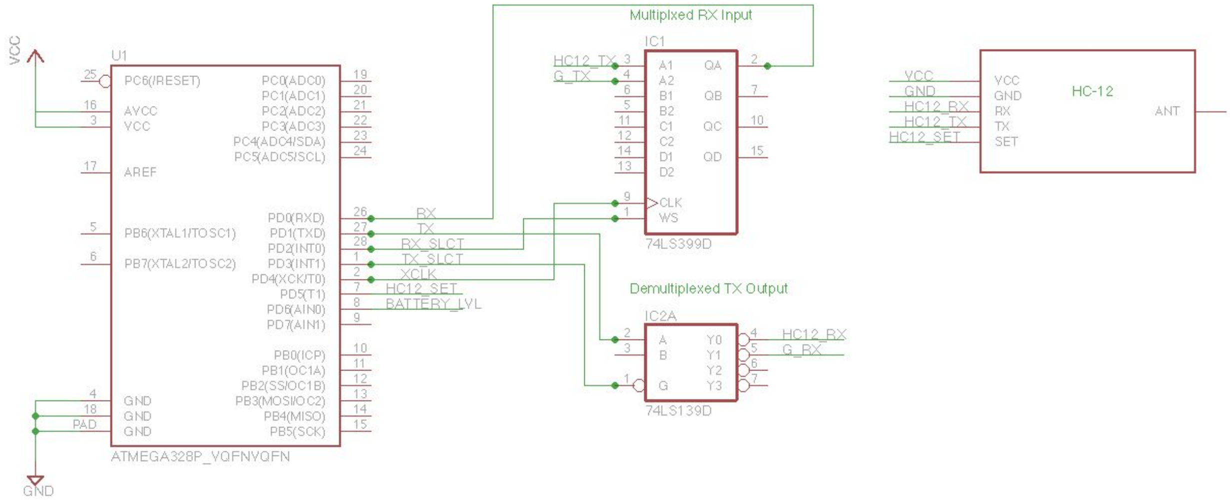

Figure 8. Mobile Unit interface of MCU with HC-12

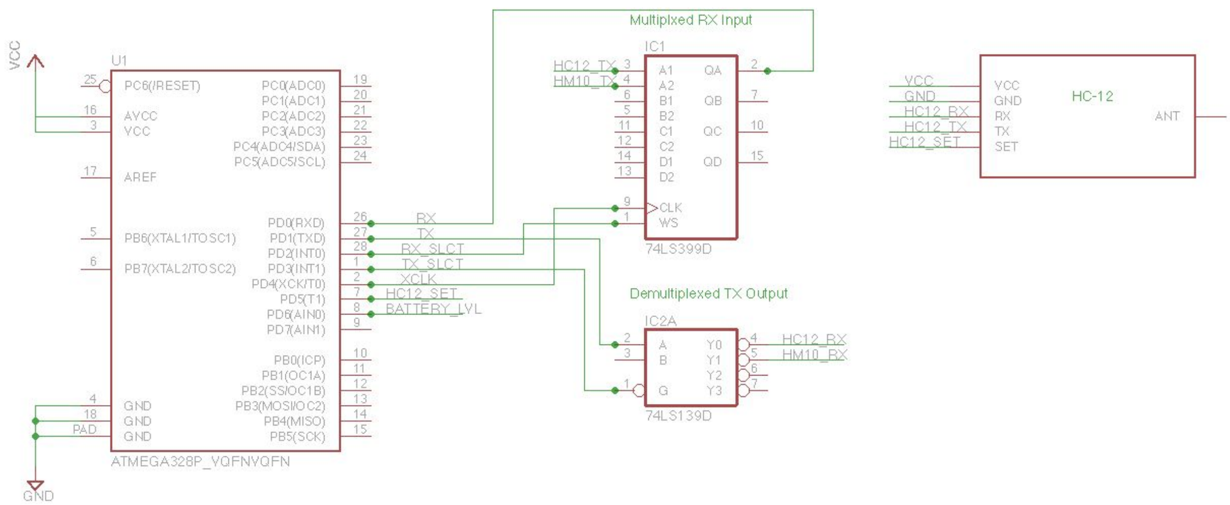

Figure 9 Ground Unit interface of MCU with HC-12

Description

In this design, we will use the HC-12 module as a transmission medium between the mobile unit and a separate ground based control unit. We are using an Atmega328 microcontroller to handle data transfer from our peripherals and then send it to the HC-12 for transmission to the ground based control unit. This ground based control unit will then transmit the signal a second time to the Android cell phone, using the HM-10(explained above) Bluetooth Module.

The HC-12 is a half-duplex wireless serial communication USART module with 100 channels in the 433.4-473.0 MHz range that is capable of transmitting up to 1 km. The HC-12 is a half-duplex 20 dBm (100 mW) transmitter paired with a receiver that has -117 dBm [4]. We chose this module because of 2 main reasons,

1. The frequency bandwidth has over a 100 channels which would reduce the interference of our desired signal with any other noise signals in the area.

2. The transmitter power is around 20 dBm which ensures that the signal range would be around 1km which is much larger than our desired range of 30m.

Table 2. Requirements and Verification for HC-12 Module

Requirements	Verification
1. *Must be able to transmit data over a range of at least 30m.*	1. *The transmission range of the device is tested with the help of a vector signal analyzer.* 2. *If we receive a signal stronger than -70dBm at 30m range, we have satisfied this requirement*
2. *Low input voltage* $V_{in} = 3.3\ V$ *with* $\pm 5\%$ *tolerance.*	1. *The device will be hooked up according to the schematic shown above.* 2. *Some dummy data will be used to simulate the data transfer conditions.* 3. *The 3.3 V DC power supply will be given to Vcc and then the operation of the module will be monitored.* 4. *If data is received the requirement is satisfied.*

Once the data is received by the HC-12 on the control unit at the user end, the data is transferred to the HM-10 bluetooth module. The HM-10 then transfers the data to an android application via bluetooth where the user can see it.

The HM-10 Bluetooth Module is a BLE 4.0 Compatible device that transmits at a frequency of around 2.4 GHz. It has a transmit power between -6 dBm to 6 dBm and a receive sensitivity around -97 dBm.

A typical cellular phone has an Bluetooth transmit power between -5 dBm and 0 dBm and receive sensitivity around -70 dBm. It transmits at a frequency of 2.4 GHz.

Using the link equation, and the values given above, we can determine the distance of transmission between phone and module.

$$range\ (in\ miles)\ =\ antilog(\frac{P_{TX}+G_{TX}-L_M+G_{RX}-P_{RX}-104}{20})$$

$$P_{TX} - Transmitter\ power$$

$$P_{RX} - Receiver\ power$$

$$G_{TX} - Transmitter\ antenna\ gain$$

$$G_{RX} -\ Receiver\ antenna\ gain$$

$$L_M -\ Link\ Margin\ (0\ for\ outdoors\ transmission)$$

$$d_1(phone\ to\ module)\ = antilog(\frac{0+97-104}{20})$$

$$d_2(module\ to\ phone)\ =\ antilog(\frac{5+70-104}{20})$$

with some margins added, we get a range between 30 to 100 m. Which is a very large range as the user will keep the control unit next to him.

Table 3. Requirements and Verification for HM-10 Module

Requirements	**Verification**
1. HM10 Bluetooth Module must have a maximum transmit power of +6dBm.	*1. The transmission strength of the device is tested with the help of a vector signal analyzer.*
2. *Android phone must have a transmit strength between -5 dBm and 0 dBm.*	*2. The transmission strength of the device is tested with the help of a vector signal analyzer.*
3. Android phone must be able to communicate with HM-10 Bluetooth module at a range of at least 30 metres.	*3. The prototype circuit containing the HM-10 is placed at a distance of 30 metres in the line of sight of the android device. We will test signal transmission between the two devices.*
4. Low input voltage $V_{in}\ =\ 3.3\ V$ *with* $\pm 5\%$ *tolerance.*	*4. The device will be hooked up according to the schematic shown above.* *5. Some dummy data will be used to simulate the data transfer conditions.* *6. The 3.3 V DC power supply will be given to Vcc and then the operation of the module will*

	be monitored. *7. If we receive the data at the receiver, then the requirement has been satisfied.*

Comparison

Below we have summarised the two types of data transfer mechanisms explained above.

Table 4. Comparison between HM-10 and HC-12

Parameter	HM-10	HC-12
Size	26.9mm x 13mm x 2.2 mm	27.8mm x 14.4mm x 4mm
Communication Protocol	Uses a TI CC2540 BLE chip to communicate over bluetooth.	Uses STM8S003F3 microcontroller and the Si4463 transceiver to communicate at a frequency of 445 MHz.
Data transfer Range	As it is a Class 1 transceiver it can communicate over a distance of 100-150 m.	Can communicate over a range of 1 km.
Power Consumption	As it uses BLE protocol [2] the max current consumption during transmission is 8.5 mA and requires a voltage of 3.3 V.	Max current consumption during transmission is 100 mA and requires a voltage of 3.3 V.
Ease of integration into our design	Would make our design less bulky as we could transmit data directly to the user's mobile phone without having to design a transceiver at the user end.	Would require the design of a transceiver module which would take in data coming at a frequency 445 MHz and then transmit it via bluetooth to the user's mobile phone.

As you can see that both the modules have their pros-cons we have decided to wait and finalize on one of these once we get the hardware and start testing the system with it.

6.2 GPS Unit

Schematic

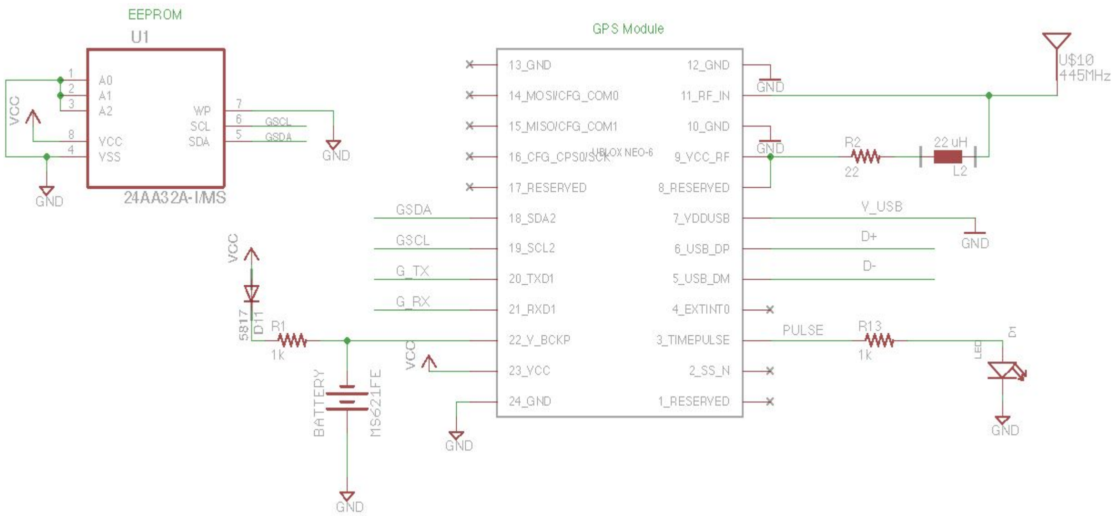

Figure 11. Schematic for GPS Module[11]

Description

For receiving location data, we will be using the NEO-6M GPS Module. The GPS module is responsible for updating the position of the boat periodically on android device. The GPS receives timing data from GPS satellites that orbit the Earth at fixed position.

The NEO-6M module has a receiver sensitivity of -162 dBm to detect GPS signals from space. It can give readings for position that are accurate to about 2.5 m. It can be configured to update position at up to 5Hz [5].

Table 5. Requirements and Verification for GPS Module

Requirements	Verification
1. Must be capable of receiving GPS signals from at least 4 satellites and giving a fix on the location.	*1. The GPS module is tested outdoors with clear line of sight* *2. If we receive a fixed location, this requirement is met.*

2. Low input voltage $V_{in} = 3.3\ V$ with $\pm 5\%$ tolerance.	*2. The module will be tested within the tolerance range, using a power supply.*
3. Must be able to update position at a rate of at least 1 Hz and up to 5 Hz	*3. The GPS module is tested at different update rates.* *4. If it can correctly receive location data, this requirement is met.*

6.3 Battery Life Detector

Schematic

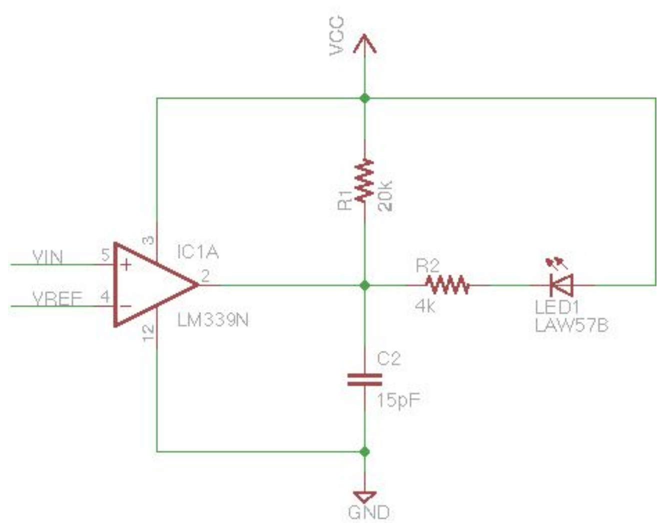

Figure 12. Schematic for Battery Level Indicator

Description

Measures the battery level of the onboard power supply. To implement this, we will use a simple comparator to compare a reference voltage with the voltage level of the boat inbuilt battery. We are planning to use LM339 quad comparator to accomplish this as it is readily available in the senior design lab. We are using the LM339 comparator because it draws a current of only 50nA from the circuit and is also available in the ece shop for our use [6].

To determine the threshold level for the battery, we ran the battery in one one minute intervals and measured the voltage across the terminals at intervals of 1 min. We obtained the following curve,

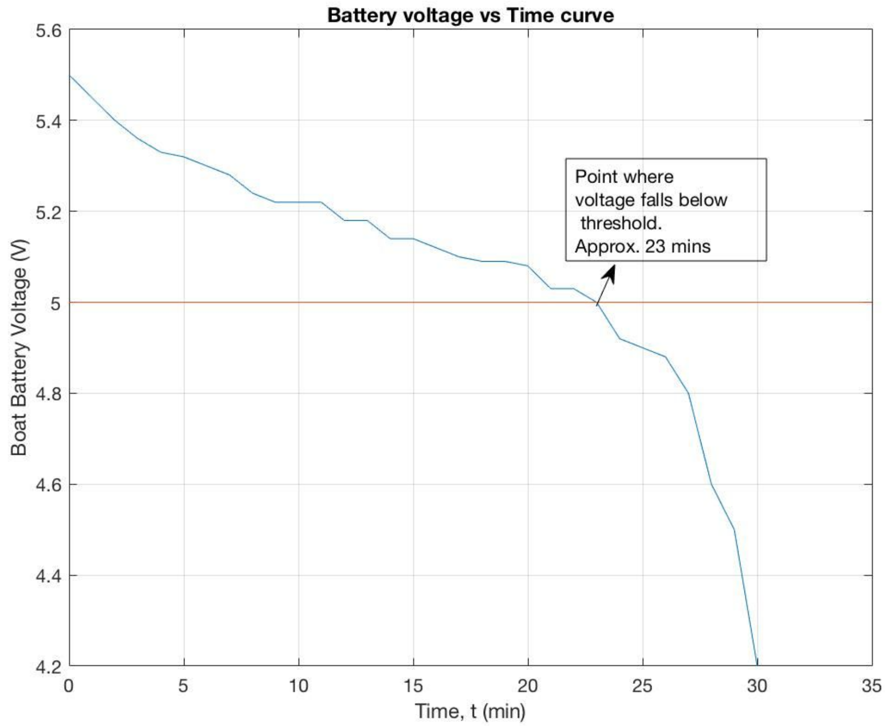

Figure 13. V-t curve for battery potential

We observed that after the 5V mark, we had around 3-4 minutes before the battery started stalling. As a result we chose 5V mark for our threshold, giving the user enough time to bring his boat back and prevent it from being stranded.

Table 6. Requirements and Verification for battery level indicator Module

Requirements	**Verification**
1. Must be able to determine the accurate ($\pm 5\%$) voltage level of the battery accurately when it goes below 5V.	*1. The on-board battery is charged up to its full potential and the voltage is recorded using a DMM.* *2. The batteries are plugged into the boat, and it used for up to 10 minutes after which the battery voltage is again measured using a DMM.*
2. Must provide a low signal when the voltage level falls below the reference voltage and a high signal when the voltage is above the reference voltage .	*1. The schematic shown in below (Figure 3) is set up on a breadboard.*

	2. V_{ref} is set to 5 V using a constant DC power supply. V_{cc} is set to 8 V using the constant DC power supply, with $I_{in} = .1\ mA$. 3. V_{in} is provided from a variable DC power supply. (Set to V_{in} = 6V). 4. As $V_{ref} < V_{in}$, the output of the comparator is high-Z and the LED is turned off. 5. V_{in} is reduced in steps of 0.5V and it was observed that the LED turns on when V_{in} < 5 V, as shown in Table 1.

Table 7. Results for above conducted Test

V_{Ref} (V)	V_{In} (V)	$LED\ State$
5	6	**OFF**
5	5.5	**OFF**
5	5	**OFF**
5	4.9	**ON**
5	4.9	**ON**

6.4 Power Supply

Schematic

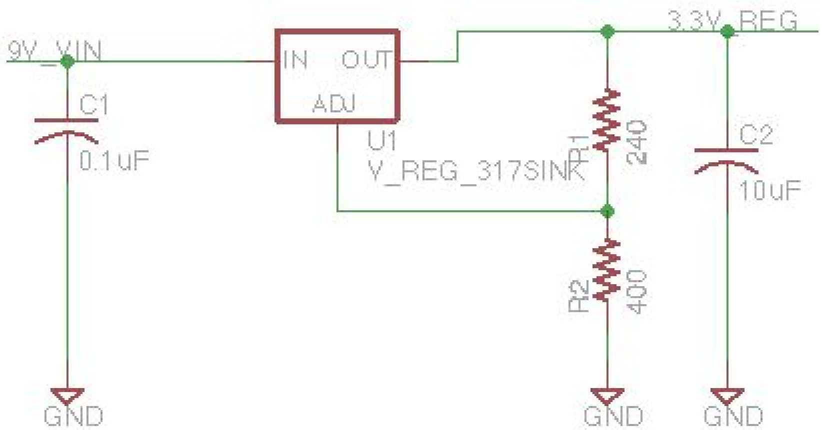

Figure 14.Schematic for voltage regulator

Description

We use a alkaline battery to provide power to the onboard hardware. The power from the batteries is fed into a voltage regulator which gives us regulated DC 3.3 V to power the rest of the circuit. We are using LM317 as a voltage regulator for our circuit.
Voltage regulator supplies the necessary power to individual components on the Mobile Unit. We need the regulator provide 3.3V to the circuitry. The total current consumption can be estimated using following numbers obtained from the datasheets,

Table 8. Total Current consumption calculation

Element	Approx Current Consumption
Comparator	*≃ 50 nA*
Magnetometer	*≃ 10 mA (normal operation)*
GPS Unit	*≃ 10 mA*
Wireless Transceiver (HC-12)	*≃ 16 mA (low power mode),* *≃ 100 mA (data transmission),* *200 mA(required)*
Bluetooth Module (HM-10)	*≃ 1.5 mA (low power mode),* *≃ 8.5 mA (active mode),*

	50 mA (required)

All the above units function on a 3.3 V - 3.5 V supply and adding up their current consumption and keeping in mind rough margins we can estimate the total current consumption during normal operation of the design to be around 50 mA whereas for peak operation during data transmission it is $\simeq$ 250 mA. We are planning to use LM317 IC as our voltage regulator. It has variable fixed voltages of 2.5V, 3.3V and 5V and also has a current capacity of 1.5 A which gives us a lot of wiggle room in case any of our components draw excess current during data transfer (Although we could have used a regulator with a lesser current capacity, due to the fact that LM317 is readily available in the ECE shop we chose to use it).

The following calculations drive the design choice for the LM317 circuit. According to the datasheet[7],

$$V_{OUT} = V_{REF}(1 + \frac{R_2}{R_1})$$

LM317 has an internal V_{REF} of 1.25 V and for our design we need V_{OUT} = 3.3V. Substituting these numbers, we get

$$R_2 = 1.64\, R_1$$

Therefore we choose R_1 = 240 Ω and R_2 $\simeq$ 400 Ω.

Table 9. Requirements and Verification for voltage regulator

Requirements	**Verification**
1. Must be able to provide a stable 3.3 V with a tolerance of $\pm 5\%$.	*1. Circuit shown in the schematic above is set up on a breadboard.* *2. A signal generator is hooked up at the input of the regulator* *3. The signal is a sinusoid with DC value +9V and amplitude 0.5 V* *4. A variable load is hooked up to the output, and voltage is measured across the load.*

	5. *If the Voltage stays within the parameters, this requirement is satisfied.*
2. Must be able to provide at least 100 mA current to the load at all times.	1. *Circuit shown in the schematic above is set up on a breadboard.* 2. *A load of 30 Ω is hooked up at the output of the regulator and the current through the load is checked using a DMM.* 3. *If the current stays above 100 mA, this requirement is satisfied.*

6.5 Gyroscope/Magnetometer/Accelerometer

Schematic

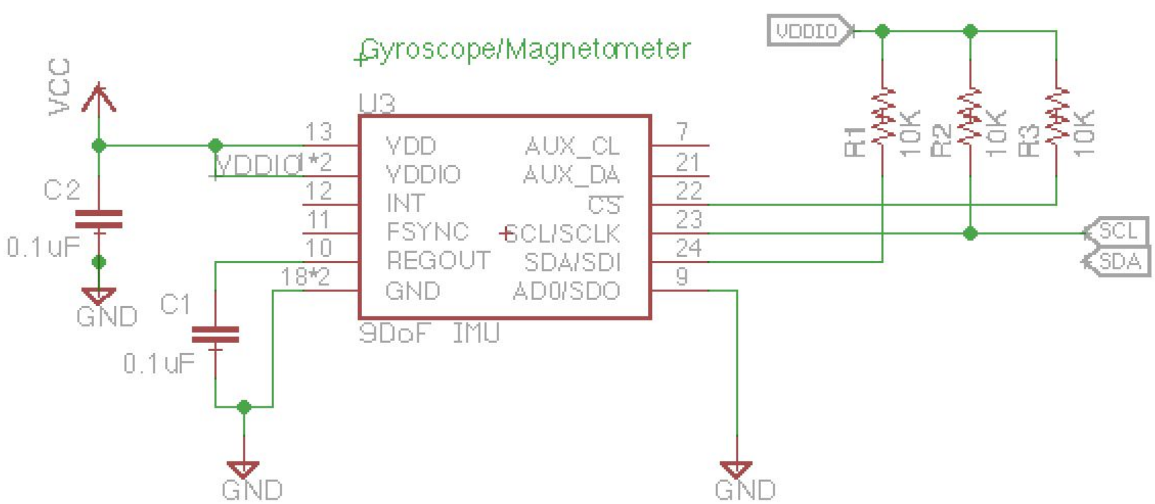

Figure 15. Schematic for Gyroscope Unit[12]

Description

We will be using the MPU-9250, which is a tri-axis magnetometer + gyroscope + accelerometer to keep track of the heading of the boat unit .

The MPU-9250 has a magnetometer that provides a vector measurement in 3 axes accurate to $\pm 0.6\ \mu T$. We can use this information to calculate a heading.

It also has a gyroscope, which measures vector angular velocity to an accuracy of 7.6×10^{-3} °/s . We can use this information to calculate a change of heading.

Finally, there is an accelerometer, which measure acceleration in 3 axes to an accuracy of $6.1 \times 10^{-5}\ g$, where g is acceleration due to the Earth's gravity. We can get another heading from this device [8].

Each component has some form of instability. The magnetometer is sensitive to tiny changes in magnetic field, the gyroscope has a constant drift component and the accelerometer is sensitive to small acceleration. If we combine the magnetometer, gyroscope and accelerometer together into a second order filter, we will get a more accurate measurement of our heading. For our design purposes, we only require a general direction.

Table 10. Requirements and Verification for Gyroscope Module

Requirements	**Verification**
1. *The unit should be capable of providing a heading that is accurate to about* $\pm 10°$ *using magnetometer/gyroscope/accelerometer readings in a second order filter.*	*1. The module is tested outdoors under normal operating conditions.* *2. The readings are fed into our filtering algorithm.* *2. If the heading we receive is within 10° of a compass heading, we consider this requirement fulfilled.*
2. Low input voltage $V_{in} = 3.3\ V$ *with* $\pm 5\%$ *tolerance.*	*2. The module will be tested within the tolerance range, using a power supply.*

6.6 Microcontroller

Schematic

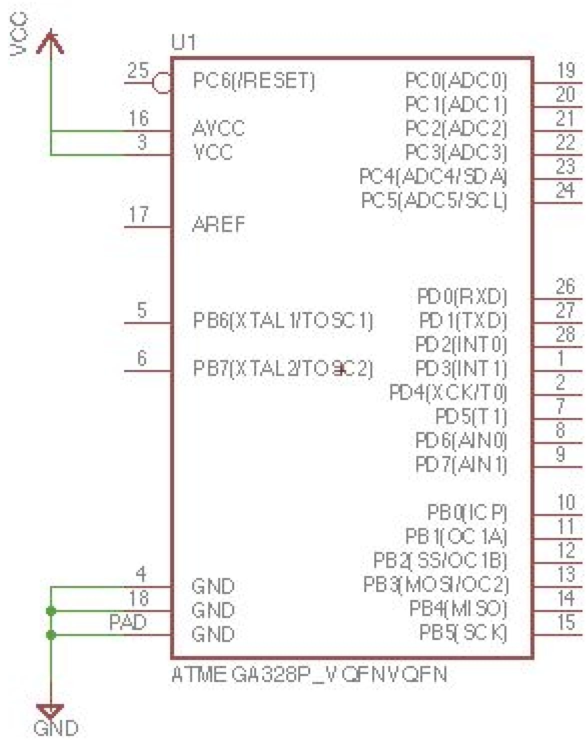

Figure 16. Atmega328

Description

The Atmega328 32KB ISP flash memory with read-while-write capabilities, 1KB EEPROM, 2KB SRAM, 23 general purpose I/O lines, 32 general purpose working registers,serial programmable USART, a byte-oriented 2-wire serial interface, SPI serial port and it operates between 1.8-5.5 volts [9].

We are planning to use the Atmega328 for 2 main reasons,

1. It functions on a voltage of 1.8-5.5 V similar to rest of our hardware components.

2. It supports serial programmable USART, which is the type of communication we chose for our design.

Table 11. Requirements and Verification for MCU

Requirements	Verification
1. *Works on low input voltage $V_{in} = 3.3\ V$ with $\pm 5\%$ tolerance.*	5. *The device will be hooked up according to the schematic shown above.* 6. *Some dummy data will be used to simulate the data transfer conditions.* 7. *The 3.3 V DC power supply will be given to Vcc and then the operation of the MCU will be monitored.* 8. *If we receive the data at the receiver, then the requirement has been satisfied.*
1. *Can transmit/receive data using* serial programmable USART.	3. *We connect two Atmega328 together, program one as a receiver and the other as a transmitter.* 4. *The data is then transmitted through the transmitter to the receiver.* 5. *If the data is received on the receiver then the requirement is satisfied.*

7. Scheduling

The following schedule was designed keeping in mind the time frame of 1 semester (approx. 16 week). As the first two weeks mainly comprise of us forming teams and attending lectures we did not include that in the schedule. Also, the last 2 weeks are mainly there for demos and final presentations, we decided that our product needs to be completed in a 12 week time frame. This is a very reasonable ask as shown below in our schedule,

Table 12. Schedule

<table>
<tr><th>Week 1 & 2</th><th>Week 3</th><th>Week 4 & 5</th><th>Week 6</th><th>Week 7 & 8</th><th>Week 9</th><th>Week 10</th><th>Week 11 & 12</th></tr>
<tr><td colspan="2">Finalize design Requirements (S,S,V)</td><td>Breadboard testing for hardware (V)</td><td>Software design (S,S)</td><td colspan="2">PCB assembly and debugging (V)</td><td colspan="2">Test integrated system (S,S,V)</td></tr>
<tr><td colspan="3">Research about possible wireless communication protocols (S)</td><td colspan="2">Schematic and PCB Design (V)</td><td>Debugging software with PCB (S,S,V)</td><td></td><td></td></tr>
<tr><td></td><td></td><td colspan="2">Look for MCU compatible with our wireless protocol (S)</td><td>Software Debugging (S,S)</td><td colspan="2">Debugging refined system (S,S,V)</td><td></td></tr>
</table>

Rows 2,3,4 run in parallel for each week.
S - Sanchit
S - Sho
V - Vaibhav

8. Costs

We estimated the development costs for our project to be our labor plus the costs for our components. We estimated the labor to be $30/hour, 10 hour/week for three people which lasts for 12 weeks this semester. The labor for team members is calculated to be:

3 x $30/hr x 10 hr/wk x 12 = $10,800

We estimated the labor from TAs, professors and faculty members to be $40/hour with 3 hour/week. The labor for them is calculated to be:

$40/hr x 3 hr/wk x 12 wks = $1440

The costs for our parts are shown below:

Table 13. Cost analysis

Part	Quantity	Part cost	Cost

Gyroscope/Accelerometer/Magnetometer (Amazon; HiLetgo MPU9250)	1	$8.49	$8.49
GPS Module (Amazon; HiLetgo GY-NEO6MV2)	1	$5.49	$5.49
Comparator (LM339N)	1	$1.50	$1.50
Bluetooth Transceiver (Amazon; DSD TECH HM-10)	2	$9.99	$19.98
Microcontroller Unit (Atmega328)	2	$2.07	$4.14
Wireless Transceiver (Amazon; HC-12)	2	$8.99	$17.98
Power supply (Button Cells 3.3V)	3	$3	$9
Voltage Regulator (LM317)	2	$0.83	$1.66
Assorted resistors, capacitors, op-amps	1	$10	$10
RC Boat	1	$31.99	$31.99
Total			$110.23

9. Tolerance Analysis

The limiting factor for data transmission over bluetooth is the limited capability of the class 2 radio on the android device. The max receiver sensitivity of a class 2 radio is around -86 dBm and its max transmission power is around +3 dBm. Whereas for a class 1 radio the receiver sensitivity is -97dBm with max transmission power of +17dBm . Therefore by using a class 1 radio with a class 2 radio we can expand the range of the data transmission of the class 2 radio on the handheld device as the class 1 module on the boat has a better sensitivity which means that it can detect smaller signals transmitted over a long range. According to our calculations,

$$range\ (in\ miles)\ =\ antilog\left(\frac{P_{TX}+G_{TX}-L_M+G_{RX}-P_{RX}-104}{20}\right)$$

$$P_{TX} - Transmitter\ power$$

$$P_{RX} - Receiver\ power$$

$$G_{TX} - Transmitter\ antenna\ gain$$

$$G_{RX} - \ Receiver\ antenna\ gain$$

$$L_M - \ Link\ Margin\ (0\ for\ outdoors\ transmission)$$

$$d_1(phone\ to\ module)\ = antilog(\frac{0+97-104}{20})$$

$$d_2(module\ to\ phone)\ =\ antilog(\frac{5+70-104}{20})$$

We easily get a range of 30 to 100 metres to and from the boat. One of the major assumptions we made is that the link margin is zero for outdoor transmissions and that the antenna would provide us with a certain gain. But if the module we receive is not capable of handling that range or if the max transmission power falls due to uncertainties in design, then that could affect our project greatly. Therefore we have to make sure that our system data transmission stays in the above specified gain limits.

10. Ethics and Safety

There are several cases that can run into potential hazards with our project, according to IEEE Code of Ethics [10]: “to maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitation”. Our built-in battery uses Lithium ion battery which can explode if overcharged or bought to extreme temperatures. We must monitor the power supply, and ensure that the voltage and current are within reasonable limits to avoid any meltdown or explosions according to the course battery safety.
Voltage regulator serves as a heat sink for many connected components that can prevent them from overheating and meltdown. However, if the regulator keeps serving power for a long time, regulator itself will encounter overheating and meltdown. Therefore, we must come up with a method to monitor the temperature of the regulator and keep its thermal stable.

Since our boat is an outside electrical device, we must make our device waterproof to prevent any kind of moisture that can damage to our module leading to short-circuits. We will make our design follow IP66 or higher guidelines that can keep the internals of the boat dry for playing period.

One of main concerns during the project, according to IEEE Code of Ethics, is “to accept responsibility in making decisions consistent with the safety, health, and welfare of the public, and to disclose promptly factors that might endanger the public or the environment”. First, special precautions must be taken for the mobile unit. In case water enters the sealed container, it should not be unsafe for handling, or provide any risk of electrocution.

During the development procedure, technical issues may occur, and need the TA to help us out. We want to make sure that we “seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others”, and give proper credit to any help that is offered not only from TAs, professors but also others.

Finally, all team members should “assist colleagues and co-workers in their professional development and to support them in following this code of ethics”. We will make sure that we respect each other, offer and accept criticism within our team, and support each other when in need.

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