Design Review

IROTS

Illinois River Otter GPS Tracking System

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Contents

INTRODUCTION

The Illinois River otter tracking system is enticing on many different fronts. We will be working on a project that will massively improve the tools researchers have to perform studies that involve animal tracking. The Illinois River otters are amazing creatures, extremely active, curious and playful. Working on a device that will improve our understanding of such enjoyable animals is in itself enough motivation. The project is also attractive for the challenges we will face on the road to creating a viable product. We will have to accommodate stringent size restrictions, power availability, and product life and data accuracy requirements.

Objectives

The goal of the project is to create a device to track the Illinois River otter movement patterns. The device will need to be sub-cutaneous so as to minimize risk of injury to the otter, while ensuring the device is secured to the otter. This device will periodically acquire and store its GPS (global positioning system) coordinate. When the otter is within the download range of the base station, the implant will automatically relay the information to the base station. The base station will have a USB interface for ease of data retrieval by the researchers.

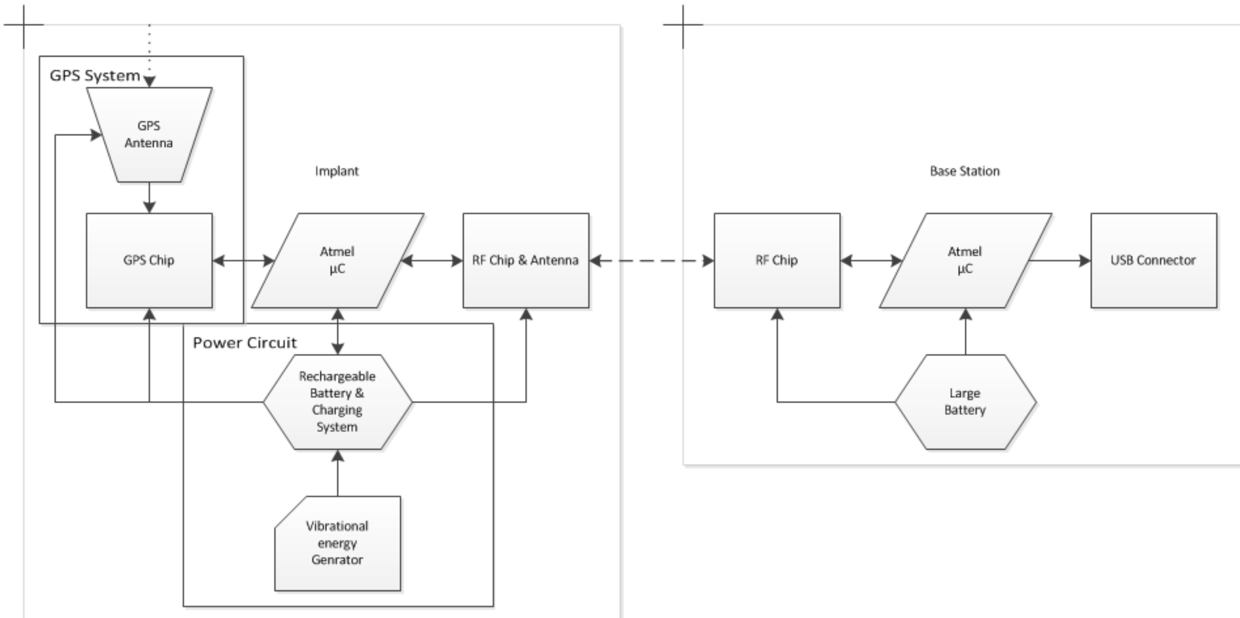
Benefits

- Alternative tracking system(for animals where collars or vests are impractical)
- Ease of use for researcher
    - No need to re-capture otter for data download
    - Data easily downloaded from base station in text format
    - Easily readable data present/full indicator (turned on only if USB activity present so as to not scare otters away)
- Reduced risk to the animals
- High mapping definition with data point every five hours
- Base station uses easily replaceable and/or rechargeable battery packs

Features

- Micro-power and small size
- Base station operational for 1-2 weeks before battery change
- Stores latitude, longitude, altitude, and time stamp information
- Implantable within the animal
- Automatic data transfer to base station
- Antenna is non-directional

BLOCK DIAGRAM



Note: µC ⇒ Microcontroller; Note: RF ⇒ Radio Frequency

Block Description

IMPLANT

GPS System: This system acquires the GPS location data from the satellites. This data includes the time stamp, Longitude, and Latitude. The altitude is acquired if possible, but not necessarily.

Implant µC: This is the processing center of the implants. It controls power consumption and data storage. It receives the data from the GPS system and stores it. It receives battery level information from the Rechargeable Battery & Charging System and uses this information, along with its internal clock, to control the RF chip and GPS system.

Rechargeable Battery & Charging System: This block contains the energy harvesting block which rectifies the energy being generated by the Vibrating Energy Generator (VEG). It also contains the rechargeable battery being charged by that system. It sends information about the battery power level to the µC. It also powers all components of the implant.

RF Chip & Antenna: This relays the stored data from the µC to the base station. It receives its power from the battery in the Rechargeable Battery & Charging System.

Vibrational Energy Generator (VEG): This device converts vibrational energy to electrical energy. It relays the converted energy to the Rechargeable Battery & Charging System

BASE STATION

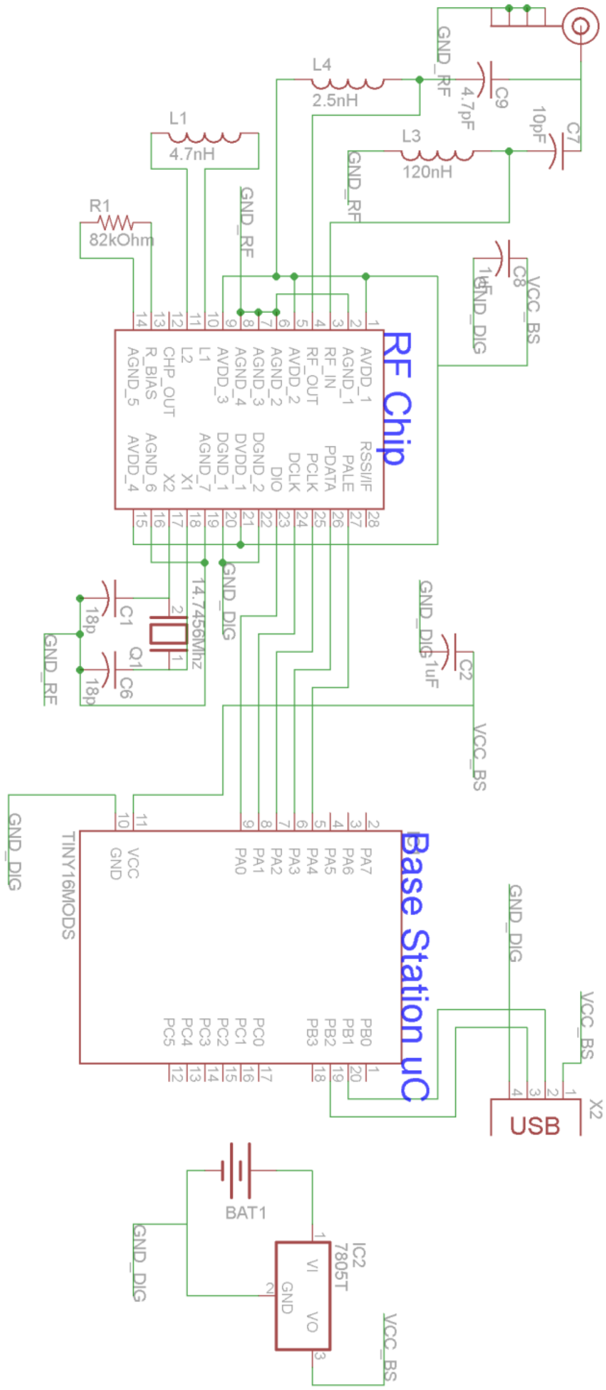
Large Battery: This battery will supply power to the other components of the base station. It will be rechargeable and easily changeable.

RF Chip: This receives the relayed data from the implant and sends it to the µC on the base station. It receives its power from the battery in the large battery.

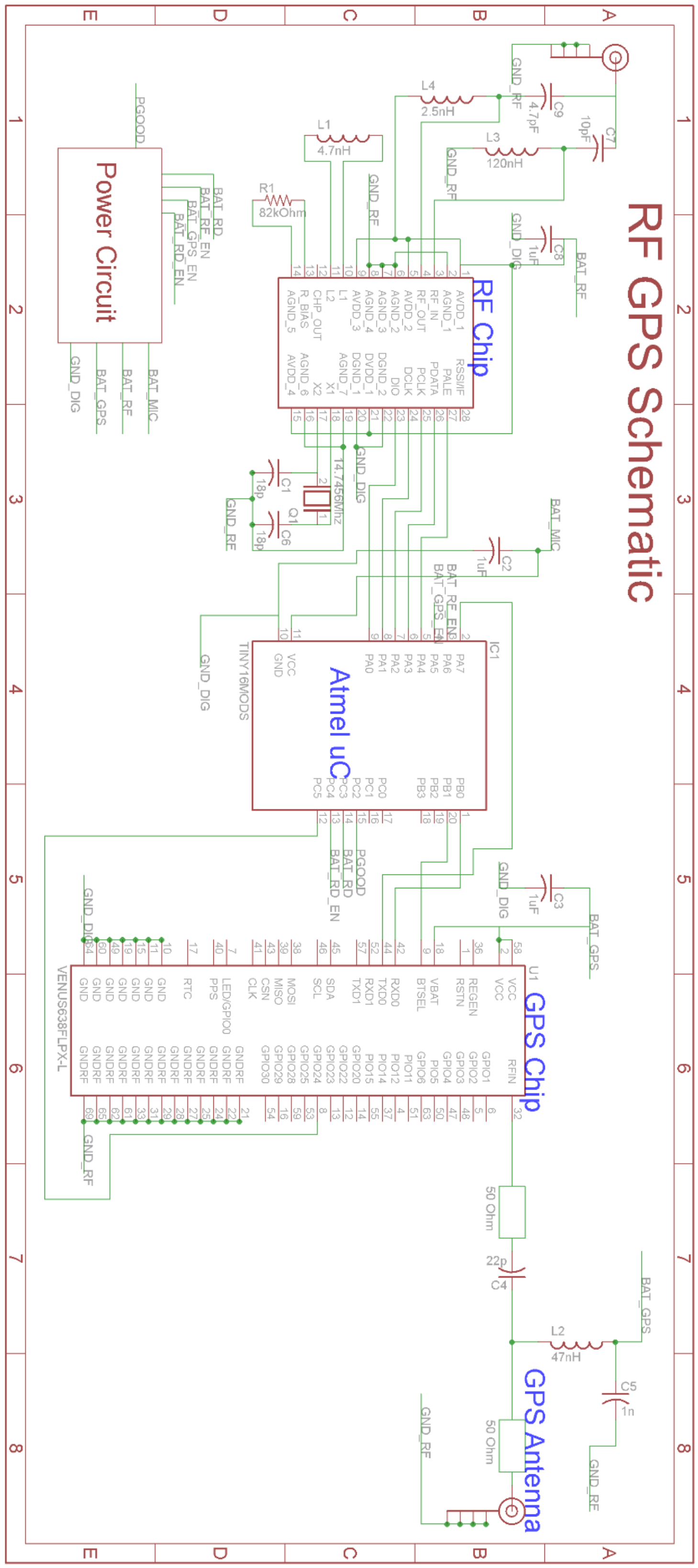
Base Station µC: This is the processing center of the base station. It controls power consumption and data storage. It receives the data from the RF chip and stores it. It receives power from the large battery.

USB Connector: This is used to transfer the stored data to the USB stick when data is being retrieved by the researcher. It gets its power from the large battery, and its data from the µC.

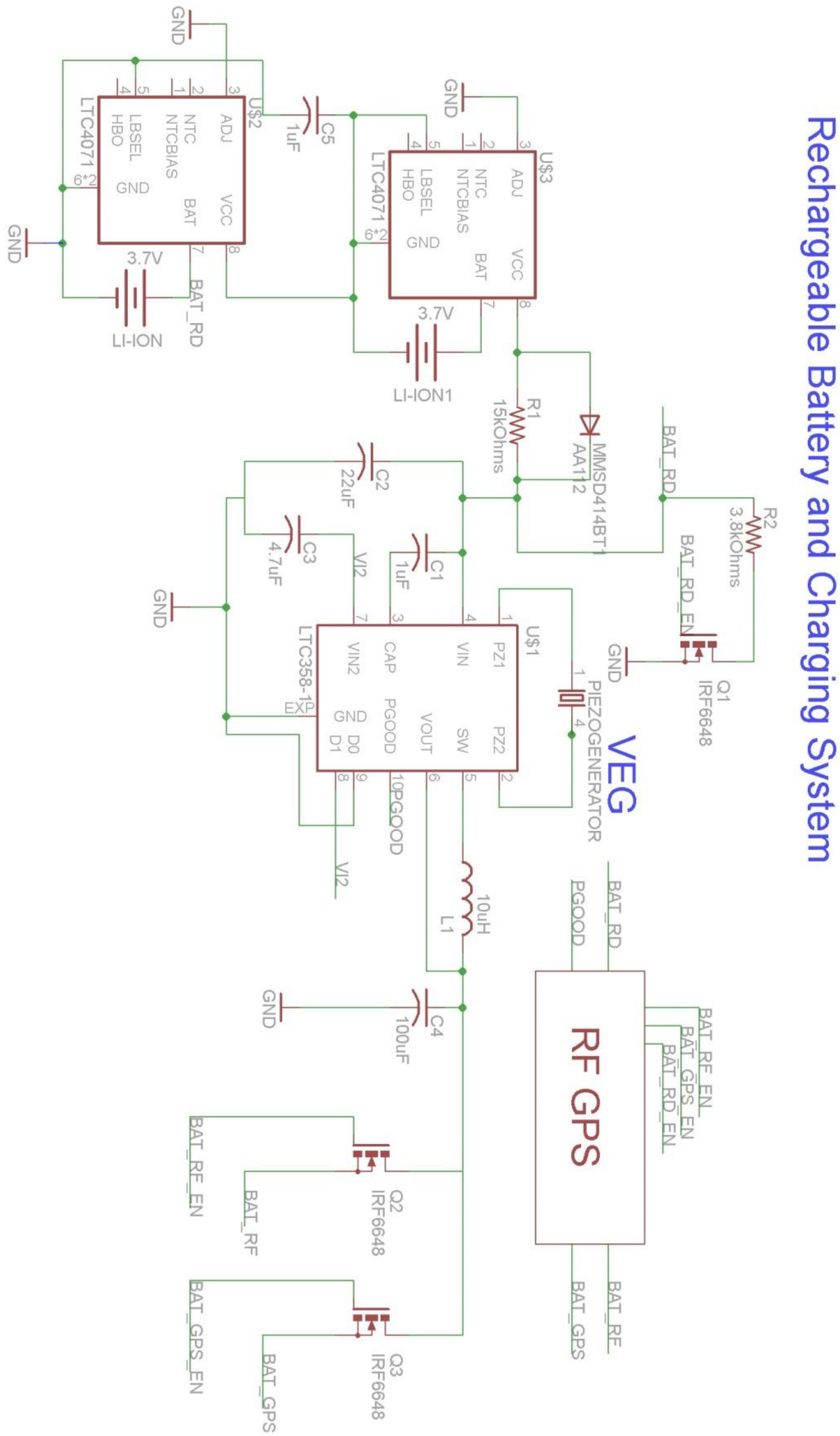
SCHEMATICS



Base Station Schematic



Implant Schematic



Power System Schematic

We have used Schematic-4 (next page) as a reference for this design.

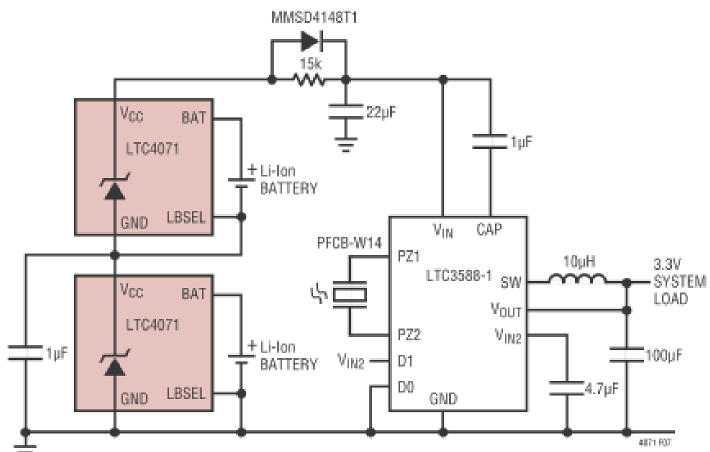


Figure 7. Piezoelectric Energy Harvester with Battery Backup

Schematic 4[3-4]

Schematic Description

IMPLANT

GPS System: [1] This system consists of the GPS antenna and the GPS chip. The Antenna signal goes through a small filter network [1] and goes into the RF_{in} and RF_{out} of the GPS chip. The other two pins on the antenna are connected to ground. The GPS chip has communication pins RXD0 and TXD0 that are connected to the TX and RX pins of the microcontroller respectively. Power has to be supplied to the GPS chip to the VCC and VBAT pins which is done using the signal called GPS_BAT so that the microcontroller can completely shut off the GPS chip to conserve power.

Implant µC: [2] Other than the connections mentioned above the microcontroller is connected to the RF chip and the Rechargeable Battery and Charging System. The RF chip connections are discussed in the RF chip and Antenna section of the Schematic description. The signals BAT_RF_EN, BAT_GPS_EN are signals that enable power to the RF and GPS chips and antennas respectively. BAT_MIC is connected to VCC of the implant microcontroller and is the supply voltage out of the rechargeable Battery and Charging system. The BAT_RD_EN signal enables the BAT_RD signal to have a voltage that is a fraction of the battery voltage so that the µC can read the battery voltage and estimate the amount of power left.

Rechargeable Battery & Charging System: [3-4] Most of this schematic is based off Schematic 4[3-4]. The additions are the signals out. A resistor divider is activated when the BAT_RD_EN signal is low. BAT_GPS and BAT_RF are connected to the output voltage when BAT_GPS_EN and BAT_RF_EN are low. The capacitors at Vin, Vcap and Vin2 are to store energy temporarily while charging the batteries. Both LTC4071 are charge controllers to control charging and discharging of the Lithium Ion batteries. C4 and L1 are to help maintain voltage and current at Vout.

RF Chip & Antenna: [5] The antenna filter network for the RF antenna is based off the design from the datasheet [5]. The external oscillator is to maintain the internal clocks so as to encode and decode RF signals. At the RF bias pin a high-precision resistor is connected for the band gap of the internal system. The inductor L1 is the high-precision inductor for the internal tank circuit. The connections PALE, PDATA and PCLK are communication pins to set up the operating modes of the chip. They are connected to the microcontroller GPIO pins as the TI-CC1000 does not follow any standard communication protocol. Similarly the DCLK and DIO are the communication pins for data transfer and are connected to GPIO pins of the µC.

Vibrational Energy Generator (VEG): [6] This is a piezoelectric crystal and produces a small AC voltage-current across its terminals when some pressure is applied to it.

BASE STATION

Large Battery: This will have two terminals. The positive terminal will go into the 7805 to be regulated and the negative terminal will be considered as ground for the internal circuit.

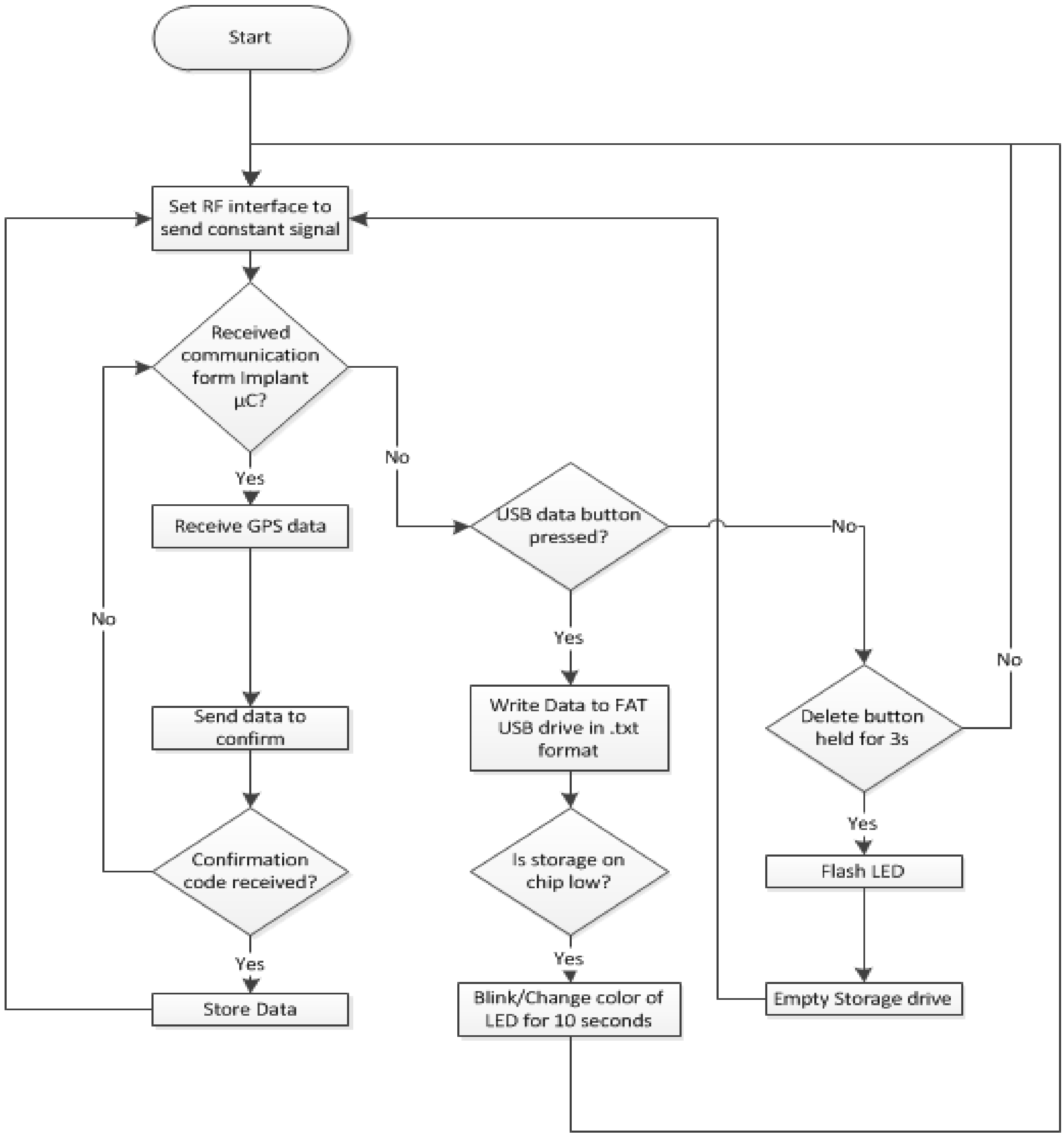
RF Chip: This will be hooked up almost exactly the same as in the implant.

Base Station µC: The connections to the RF chip are exactly the same. VCC is connected to the output of the line regulator 7805. The USB connector is connected to the µC via GPIO pins so as to implement the FAT32/16 library to write files onto the USB device connected.

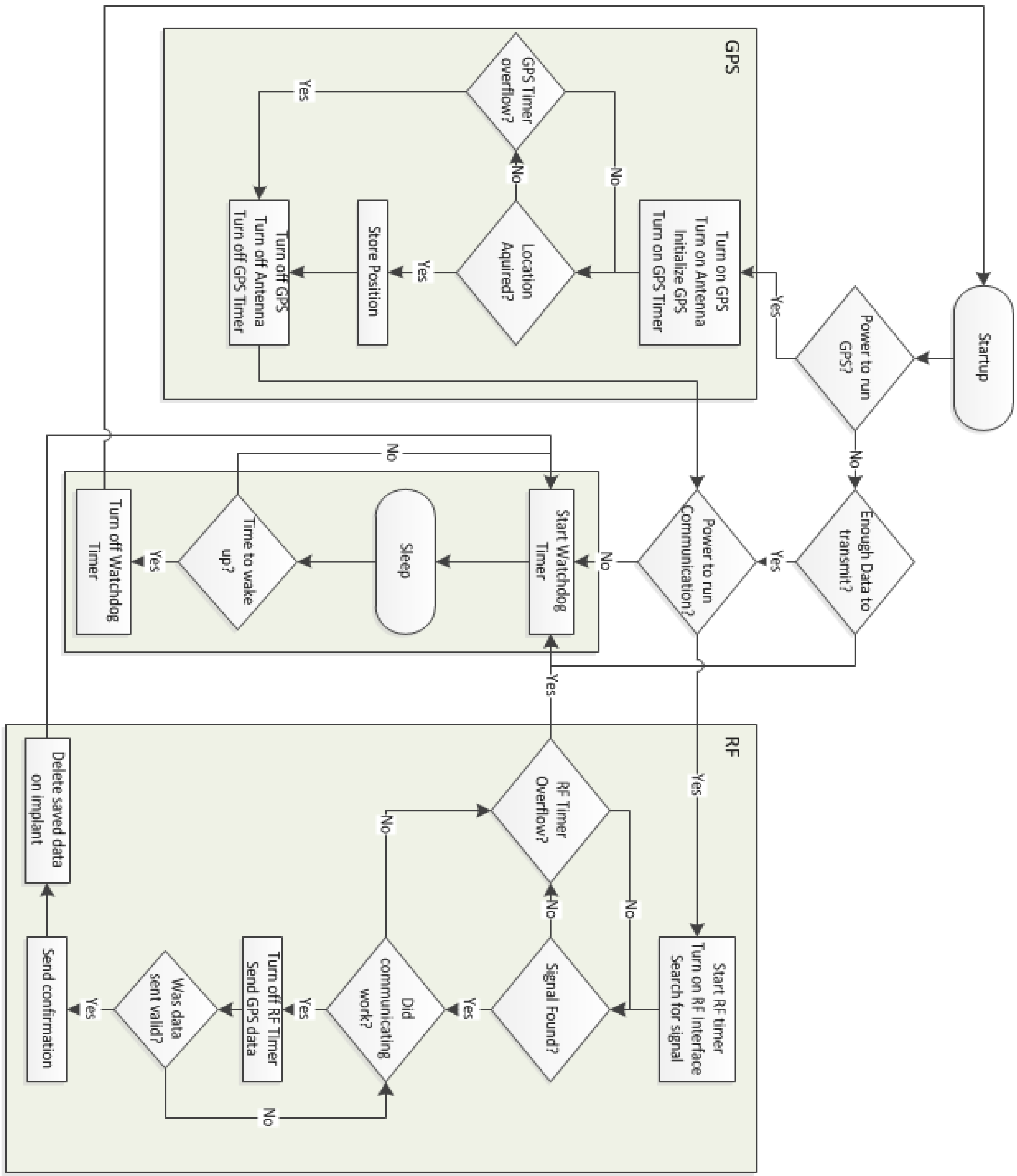
USB Connector: This is a female USB connector to enable easy connection of a portable USB stick to the solder pads of the Base Station µC

CODE BLOCK DIAGRAM

The code block diagrams are shown below. All of the code will be written in C and commented thoroughly. The compiler will be avr-gcc (from win-avr). We will be using an in-system-programmer (ISP) called USB-ASP.



Code Flowchart 1 – Base Station



Code Flowchart 2 – Implant

REQUIREMENTS AND TESTING

Requirements	Reasoning	Testing
I. GPS System 1. Valid location (Two or Three dimensional location and time stamp) acquisition within 10 minutes of power up	1. The GPS system needs to acquire a valid signal within 10 minutes of power up so the GPSTimer does not overflow. . Chip needs to retrieve the Longitude, Latitude, time stamp and (optionally) Altitude for every properly stored GPS coordinate in designated time.	1. Power the GPS system by connecting 3.3V to pins 58 & 2 of the GPS chip and to the Vcc pin of the GPS antenna. Connect ground to pins 10 & 11 of the GPS chip and pins 1 & 3 of the antenna. Connect RX of a tested and ready µC to pin 44 and connect the antenna pin 2 to the GPS chip pin 32. Within 10 minutes of these connections, the µC should receive a $GPGGA (in ASCII) through the RX terminal followed by the location co-ordinates. Use the datasheet [2] to check if location is within 100m of actual location.
	1. a) Make sure the measurement environment has a signal by checking for GPS activity on a thoroughly tested device.	1. a) Look for a GPS signal using a smartphone with AGPS (Assisted Global Positioning System, i.e. turn off sensor abiding and WIFI) turned off.
	1 b) The GPS chip needs a signal of at least -148 dBm to acquire a location fix.	1. b) Use a signal analyzer to measure the amplitude of the antenna output at the RF out pin of the antenna. 1. c) Check amplitude from another antenna (rerun Test I.1.a with another antenna)
2. Non directional	2. The antenna needs to be non-directional so as to receive the GPS satellite signal regardless of the orientation of the otter.	2. Check time to make GPS acquisitions in different antenna orientations using a stop watch. (Cold start every time, i.e. restart the GPS power before every test)
	2.b) Varying current will result in	2.a) Check output amplitude from the antenna (Test I.1.a) using different orientations

	varying acquisition times.	2. b) Ensure the power to GPS chip is not varying by using a current meter to measure the current into the chip at the VCC pins.
3. Low power consumption	3. To save power and ensure long product life, we need to make sure the GPS system does not consume excessive power.	3. Use current meter to measure current from the battery during GPS acquisition when antenna is used in active mode. Power consumed (measured current * 3.3V) should be less than 165mW. (Use connections as in **I**.2.b)
	3. a) Ensure that the power saver mode on the GPS chip works	3. a) Use current meter to measure the current from the battery in normal mode and in power saver mode. Power saver mode consumption should be less than 75% of normal mode consumption.
	3. b) To check if the problem is in the software.	3. b) Hardwire power saver mode by connecting pin 8 of GPS chip to Vcc and rerun Test **I**.3.a.
4. Send data in Skytraq Binary format via UART (Instead of NMEA)	4. In order to minimize the data being transmitted without reducing data quality we will be transmitting and storing data in binary format.	4. Use tested LCD-µC pair with same connections as in Test **I**.1 to receiving location data.
	4.a) Querying the software version is the simplest command that utilizes the TX and RX	4. a) Check the communication of GPS chip by querying the software version. Details of test given in GPS chip datasheet[5]
		4.a.i) Check GPS chip power using a volt meter across its terminals
	4.b) To make sure there is no error in SkyTraq Binary conversion	4.b) Read data in NMEA using the µC
5. Greater than 100m accuracy	5. 100 m accuracy is reasonable for tracking animal movement patterns over long periods.	5. Use a USB serial convertor and connect the TX and RX terminals of the GPS chip to the RX and TX terminals of the serial convertor. Power the GPS chip and connect the grounds of the convertor and the GPS chip. Receive the co-ordinates using any standard serial reading program. Check received co-ordinate in Google
	5.a) Check that power saver mode is not the problem	

	5.b) Check that antenna orientation is not the problem	Maps and compare with confirmed GPS location. 5. a) Rerun Test **I**.3 when not in power saver mode. 5. b) Rerun Test **II**.4 with a different antenna orientation.
II. Implant µC 1.Store 48 GPS data points (16 in 256 bytes in EEPROM) (32 in 512 bytes in SRAM)	1. µC should be able to store locations corresponding to ~10 days of activity. Each GPS location will include latitude (4 bytes), longitude (4 bytes), time stamp (Has to be reduced from 6 bytes to 4 bytes), and altitude (4 bytes). Also verify non-volatility of the EEPROM 1.a) Check if the problem is in storage algorithm 1.b)Check if GPS system is sending data to storage.	1. Using a GPS chip we will generate several GPS locations and store them on the chip (connections as in Test **I**.1) Using the LCD screen we will be able to see the multiple GPS locations. Also turn off power in between write and read operations. Use tested µC-LCD pair. 1. a) Hard code data using test program and check values. 1. a.i)Check the storage code program for bugs. 1.b) Check GPS communication by rerunning Test **I**.1
2. UART interface should work at 4800 BAUD	2. The GPS chip communicates with the microcontroller at a minimum of 4800 baud using one of the UART interfaces.	2. Using a standard USB to serial convertor we will communicate with a computer to check that the UART works at 4800 BAUD. Connecting TX, RX and GND of the µC to the RX, TX and GND of the serial convertor respectively. 2.a) Check that the µC is powered using a voltmeter across its VCC and GND terminals.
3. Consumes 25% of run time power during sleep mode	3. The micro controller spends most of its time in sleep mode. This would help utilize as little power as necessary.	3. Using a current meter to measure current (into the VCC pin) test and make sure power in sleep mode is less than 25% of the power in active mode.
III. RF Chip 1. Communicate at a minimum	1. The otters are known to get within at least a 10 meter radius of a known location. Use two tested µCs	1. Connect the two RF chips to two different µC's as described in the schematic, and send a test signal from

distance of 10 meters	to simulate the base station and implant, test the communication between two RF chips 10 meters apart. 1. a) Make sure the RF chip has power 1. b) Confirm that the RF chips are outputting data 1. c) Test RF Transmitter 1. d) Test RF Receiver	the transmitter to the receiver. Received data should be identical to the sent data. 1.a) Check power to the RF chips using a voltage meter connected to its VCC and GND pins 1. b) Connect the RF_OUT pin out to a signal analyzer. Output should be same as test data. 1. c) Using a signal analyzer 10m away with a wire antenna, analyze the transmitted signal. 1. d) Connect the output pins of the test receiver RF chip to a data analyzer when transmitter is within range and transmitting a test signal. Output simulation should be same as test data being sent from the tested transmitter **If problems persist, debug µC-RF software interface. (including compiler optimization)**
2. Lower power consumption in receive mode	2. 10 mA is a reasonable low power receive for sub 1Ghz RF.	2. Use current meter to measure the current used by RF chip when in Receive mode. Measured value should be less than 10 mA.
3. Low power consumption in in transmit mode	3. This balances power consumption with communication distance and reliability without creating unreasonable expectations for a cheaper RF chip	3. Use current meter to measure the current used by RF chip when in Transmit mode. Measured value should be less than 17mA 3.a) Change Power output configuration till spec is met.
IV. Rechargeable Battery & Charging System 1. There should have a minimum of 60	1. 60 mAh estimated maximum daily power usage by the implant. The total power stored will be supplemented by the VEG.	1. Using a resistor and voltmeter hooked up to the positive and negative terminals of the battery, we will run

mAh at 3.0-3.6V 2. Able to provide a current of 60 mA for ten minutes. 3. Able to charge the batteries with short instantaneous bursts of power.	 2. Battery must be able to supply 60 mA of current continuously during active mode, which has a timer of ten minutes. 3. Power generated by the piezoelectric crystals are in short instantaneous burst, thus the charging system must rectify and buffer these currents to properly charge the batteries.	down the battery to test the energy rating of the battery. 2. Using a resistor, voltmeter and current meter (similar to Test IV.1 except the current meter measure the battery current) to consume 60mA. The battery should be able to provide the required current for at least 10 minutes. 3. Using a voltmeter and a function generator, we will measure the battery voltage while charging the battery up using short bursts of energy similar to those created by the charging system and verify that the battery charges as expected.
V. Vibrational Energy generator (VEG) 1. Generate minimum of 60 mAh per day 2. Have dimensions of no more than 50mm x 4mm x 4mm	1. The GPS unit will be need 60mAh a day to have enough energy to function. 2. To keep to the size constraints of the overall implant, the VEG must not be larger than the listed dimensions.	1. Using a half-wave rectifier and a capacitor set up we will measure the energy that one vibration would create. Using this value we will estimate the amount of energy the system will generate inside the otter. 2. We will use a ruler to measure the lengths of the largest sides of the VEG.
VI. Base Station Microcontroller 1. Minimum 3 kB non-volatile data storage. 2. Including RF chip and Antenna should be consuming less than 30 mA	1. The storage is for at least 4 month intervals of GPS data from 4 otters (3 kB) 2. We need the base station to run without needing to recharge for at least a week.	1. Rerun Test **II**.1 to with the base station and turn off the power to the µC in between the data write and data read. 2. Use a current meter test the current consumption.
VII. USB	1. For ease of transfer of data.	1. Use the USB interface to write a

connector and interface 1. Connect, power and write files to USB as required	1.a) To check if there errors in the USB format of the data being transferred.	sample GPS text file to a USB stick and check it on the computer. 1.a) Read the data directly from the µC to insure the data has actually been written
VIII. Large Battery 1. Greater than 5 V output power for 2 weeks	1. Assuming data is retrieved once every 1-2 weeks, the battery must maintain power to the RF chip for this time frame.	1. Test the battery capacity by running it down using a large resistor while measuring the voltage and current using a voltmeter and current meter. Similar to set up in Test **IV**.2

Size/Weight Requirements

The weight will be less than 1.5lb
The size will be: 15mm-20mm wide 20mm-25mm thick 95mm-100mm long

Casing Requirements

Casing must completely isolate the device from the otter and last at least 9 years.

Full System Test

In order to test the functionality of the completed device, we will need to put it through conditions similar to what it will be facing while implanted in the otter. The signal quality is the main area that will be impacted by the field environment. The otter's skin and hair will attenuate the signal. To see how this impacts device functionality the implant will be wrapped in slightly wet fur. Otters spend a large portion of their time on the forest floor. It is possible to test this environmental factor directly by traveling to a forest and running the device underneath the canopy. The device will then be placed within 10 meters of a base station. Data will be offloaded onto a USB drive and taken to a generic laptop. The test files data will then be put into Google maps. The resulting maps will be compared to the actual locations the device was taken to complete the full system test.

Tolerance Analysis

The implants successful tracking and recording of the GPS locations are heavily dependent on the Microcontrollers both at the base station and on the implant. Since we are using microcontrollers that are ‘Pico-power’ the energy required to keep the chip running is very minimal. The microcontrollers should be functional even at voltages as low as 2.0 +/- 0.2 V and only require currents as low as 1 +/- .1 µA when in sleep mode. To test that the microcontroller can function at 2.0 +/- 0.2 V a 1.8 V signal from a power supply will be given to the Vcc pin on the microcontroller. We will then do a software version test on the GPS chip and read this onto an LCD screen. To test the sleep mode we will write test code that saves data into the ram and then goes onto sleep mode. Once in sleep mode, we will use a multi meter to test the current being drawn by the chip. Once the chip wakes up the program will output the ram to the LCD screen. These numbers will be tested against the numbers from the same test code without the sleep mode included. Passing both these tests gives the implant the ability to store data over a lengthy period of time when in power saver mode (not acquiring new GPS locations). At <3V we have used up ~75% of the power on the battery. If the battery drops below 3V then we will switch to power saver mode where the priority will be to get the data to the base-station.

CALCULATIONS

These calculations were used to make an approximate on the power generation requirements. These are all done on a day basis.

<u>GPS & Antenna power usage</u>

Assuming a worst case 10 minute, 5 times a day GPS search would give us
50 minutes of GPS searching a day will give us. Assuming a voltage supply of 3.3V
Time in hours * (GPS current + Antenna current)
(50/60) *(50mA + 5mA) = 45.8mAh
@ 3.3V => 45.8*3.3 = 151.14mAhV = 151.14*60*60mJ = 544.1J

<u>Micro Controller Power Usage</u>

Assuming the micro controller sleeps for the rest of the time.
Active time: 50/60*(0.4mA) = 0.33mAh
Sleep time: 1µA*24= 24µAh
Total = 0.354mAh
@3.3v => 0.354*3.3 = 1.1682mAhV = 1.1682*60*60mJ = 4.205J

<u>RF Power Usage</u>

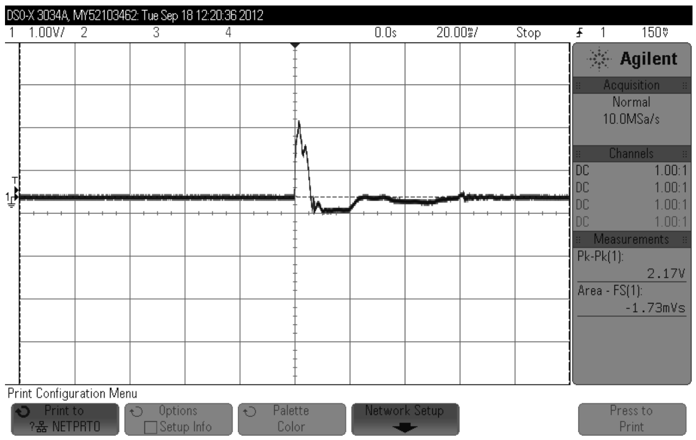
Assuming we run for 10 seconds 5 times a day gives us
Time in hours * Receiver Current usage
(10/60/60) *10mA = 0.027mAh
@3.3V =>0.027*3.3 = 0.09166mAhV = 0.09166*60*60mJ = 0.33J

<u>Total Power Usage</u> is ~= 545J

SIMULATIONS

Power Generation Simulations

The first test was using the Multicomp piezo element (MCFT-9.9T-7.0A1-93). We used an oscilloscope to measure the voltage created when we 'gently tapped' the crystal and then measured the same voltage when we added a 1MΩ resistor in parallel to measure current driving capacity.



Voltage output by single piezoelectric crystal with 1M ohm resistor in parallel

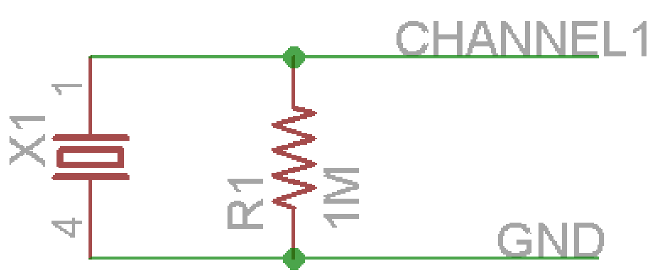
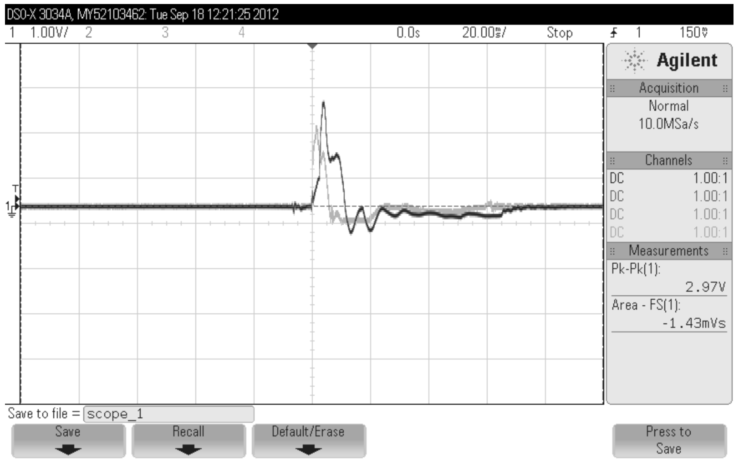


Figure 1



Voltage output with a 1MΩ resistor in parallel superimposed on voltage output without resistor.

Figure 2

The second test was making our 'device' and testing it. The 'device' (figure 2) is a cube made out of piezo elements. Inside the box was an insulated metal ball. We connected all the elements in the box in parallel with one capacitor. We also had diodes in series with each individual element to prevent back flow of current. In theory with every movement the ball would bounce around inside the box and generate small amounts of power that would be transferred onto the capacitor. We did some initial testing and our results are shown below. Each 'motion' was emulated by a light tap to the box. During our tests/assembling process 2 of the 12 piezo element connections came off and so these tests are with only 4 of the 6 crystals connected in the circuit.

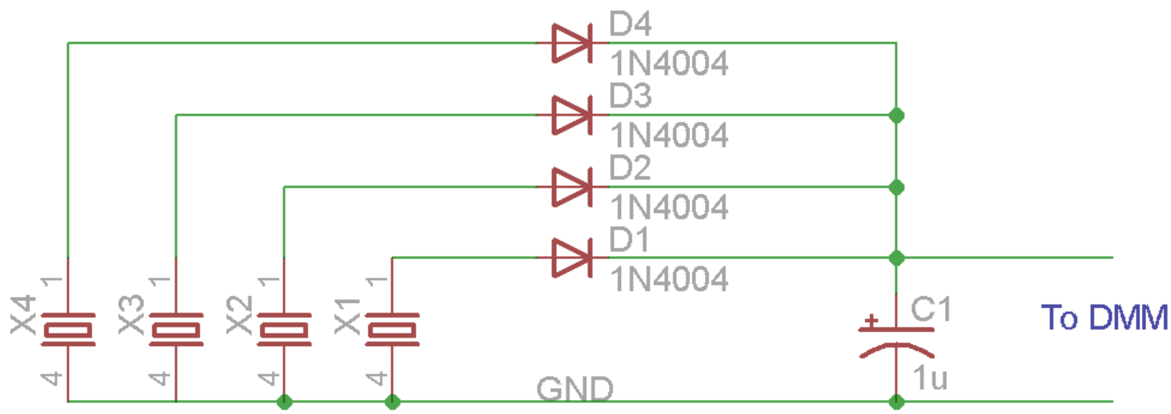


Figure 3

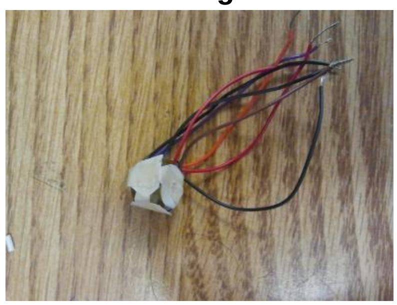


Image of the test device

Power Generation Test Results

Initial Voltage (V)	Voltage after hit (V)	Energy from hit (J)
4	4.11	4.46E-07
0.1	0.134	3.98E-09
0.09	0.23	2.24E-08
0.26	0.378	3.76E-08
0.35	0.549	8.95E-08
0.52	0.924	2.92E-07
0.92	0.97	4.73E-08
0.0109	0.29	4.20E-08
0.072	0.182	1.40E-08
0.15	0.18	4.95E-09
0.17	0.2	5.55E-09
0.185	0.52	1.18E-07
0.035	0.048	5.40E-10
0.042	0.075	1.93E-09
0.065	0.084	1.42E-09
0.075	0.085	8.00E-10
0.132	0.154	3.15E-09
0.149	0.179	4.92E-09
0.174	0.204	5.67E-09

The average power generated from a hit is $6.03*10^{-8}$J. This implies that if we need ~550J of energy a day, the piezoelectric crystal will need to vibrate $9.04*10^{9}$ times.
Note: These tests were with piezoelectric elements and not with the crystal designed for energy harvesting that we are planning on using.

GPS Test Results

Using the test breakout board we were able to test a sample of the GPS chip which we will use. The antenna used was a patch antenna and was not under open sky. We started by testing communications with the chip. Using an LCD screen we were able to display the ASCII (NMEA) and the Hex (Skytraq Binary™) output. Since the NMEA output has a higher space requirement we decided to use the binary output as conversion would just add time/power requirements. Here are some readings we were able to obtain from the GPS chip.

Name of Value	Format	Scale	Hex Value read	Scaled value
Latitude*	SINT32	10^{-7} degrees	0x17e8d479 0x17e8d470	40.1134713°N 40.1134704°N
Longitude*	SINT32	10^{-7} degrees	0xcb6a26e4 0xcb6a20ee	88.2235676°W 88.2237202°W
Week number	UINT16	Counted up from 1/6/1980	0x06ac	1708 ⇨Week of 9/30/2012
Time of week	UINT32	10^{-2} seconds	0x13776b8	2041220.88 seconds ~9am Tuesday GMT

*From two different cold starts.

This is a Google Maps image of the locations acquired (two blue pins) and the actual position(approximately green pin).
The distance between the measurements and the actual location is very small compared to the required accuracy.

COST AND SCHEDULE

Cost Analysis

Parts	**Unit price ($)**	**Quantity (#)**	**Total cost ($)**
Attiny 1634 (Microcontroller)[1]	1.80	2	3.60
Piezoelectric Bending Generator (Samples on the way)[6]	197	1	197
Venus638FLPx-L (GPS chip)[1]	39.95	1	39.95
GeoHelix GPS Antenna[7]	22.95	1	22.95
USB A female connector	0.71	1	0.71
Texas Instruments CC1000[5] RF transceiver	7.17	2	7.17
Linear Technologies LTC3588-1[4] Piezoelectric Energy Harvesting Power Supply	4.96	1	4.96
Linear Technologies LTC4071[3] Shunt Li-ion battery charger	3.79	2	7.58
Polymer Lithium Ion Battery - 110mAh	6.95	1	6.95
Panasonic LC-R064R5P Battery (To be bought)	14.90	1	14.90
USB storage disk 256MB	3.00	1	3.00
PCB main board (Design to be completed and sent)	36.46	1	36.46
TOTAL:			347.23

People	Hourly Rate	Hours per Week	Total
Bilal Gabula	$20*2.5	24	14400
Osayanmo Osarenkhoe	$20*2.5	24	14400
Gerard McCann	$20*2.5	24	14400

Project Total: $43545.23

SCHEDULE

Week	Task	Assignment
9/16	~~Proposal Design, schedule, choose GPS chip~~	Bilal
	~~Proposal Requirements/verification, Begin testing piezoelectric viability~~	Osa
	~~Proposal introduction, PCB design requirements~~	Gerard
9/23	~~GPS chip testing code layout~~	Bilal
	~~Power system management requirements~~	Osa
	~~GPS antenna type, design review sign up~~	Gerard
9/30	~~Design Review(DR) simulation data, detailed schedule~~	Bilal
	~~DR power, ethical section, cost~~	Osa
	~~DR electrical design, test PCB sent to fab~~	Gerard
10/7	Begin implementing base station USB interface code	Bilal
	Finalize power system design begin implementation	Osa
	Research resin casing for implant begin final PCB design	Gerard
10/14	RF interface with micro controller	Bilal
	Solder components to test board	Osa
	Finish main PCB design/order	Gerard
10/21	Testing RF communication, IPS (Individual progress) reports	Bilal
	Construct begin testing the base station, IPS reports	Osa
	Finalize protective resin for implantation in otter, IPS reports	Gerard
10/28	Mock up demo implant prep	Bilal
	Mock up demo base station prep	Osa
	Mock up presentation preparation	Gerard

11/4	Project overview/validation	Bilal
	Solder final board	Osa
	Order resin for encasing	Gerard
11/11	Field testing GPS on final board	Bilal
	Field test RF offloading on final board	Osa
	Field test battery life on final board	Gerard
11/18	Thanksgiving break	
11/25	Mock Final demo	Bilal
	Final demo preparation/sign up	Osa
	Encase board for implantation,	Gerard
12/2	Final paper Intro/Design	Bilal
	Final paper, Verification costs	Osa
	Final paper conclusion	Gerard
12/9	Turn in final paper	Bilal
	Presentation organizer	Osa
	Checkout organizer	Gerard

ETHICAL CONSIDERATIONS

We plan to follow all aspects of the IEEE code of ethics when designing and implementing this project. Since we are implanting the device into an animal there are extra issues that arise. We have to make sure the device does not bother or injure the otter. The area of greatest concern is the degradation of materials inside the otter. We should make the product so that it can last indefinitely inside the otter and are looking into casings that do not degrade in a subcutaneous environment. The battery of the device is a lithium polymer battery. We will have to ensure that this is charged properly so that it does not heat up or explode.

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