ENSC 305W/440W Grading Rubric for Design Specification

Criteria	Details	Marks
Introduction/Background	Introduces basic purpose of the project.	**/05%**
Content	Document explains the design specifications with proper justification for the design approach chosen. Includes descriptions of the physics (or chemistry, biology, geology, meteorology, etc.) underlying the choices.	**/20%**
Technical Correctness	Ideas presented represent valid design specifications that will be met. Specifications are presented using tables, graphs, and figures where possible (rather than over-reliance upon text). Equations and graphs are used to back up/illustrate the science.	**/20%**
Process Details	Specification distinguishes between design details for present project version and later stages of project (i.e., proof-of-concept, prototype, and production versions). Numbering of design specs matches up with numbering for functional specs.	**/15%**
Test Plan	Provides a functional test plan for the present project version. (Note that project success will be measured against this test plan.)	**/10%**
Conclusion/References	Summarizes functionality. Includes references for information from other sources.	**/05%**
Presentation/Organization	Document looks like a professional specification. Ideas follow in a logical manner.	**/05%**
Format Issues	Includes letter of transmittal, title page, abstract, table of contents, list of figures and tables, glossary, and references. Pages are numbered, figures and tables are introduced, headings are numbered, etc. References and citations are properly formatted.	**/10%**
Correctness/Style	Correct spelling, grammar, and punctuation. Style is clear concise, and coherent. Uses passive voice judiciously.	**/10%**
Comments		

SIGNATUS INC.

School of Engineering Science
Simon Fraser University
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November 17th, 2013

Professor Lakshman One
School of Engineering Science
Simon Fraser University
Burnaby, BC V5A 1S6

RE: ENSC 440 Design Specification for a Wireless Leak Detector and Inhibitor System

Dear Professor Lakshman One,

The attached document demonstrates the design specification for Signatus Inc's Wireless Leak Detector and Inhibitor System. The Wireless Leak Detector and Inhibitor System is a device that detects a water leak inside the property and notifies the owner in order to avoid causing the water damage. In addition, this system could shut off the main water supply inside the property if it was chosen by the user. The purpose of this document is to describe the low level details of the system that will be applied in order to achieve the functional requirements. It provides guidelines on building, testing, and verifying that the final goal of the product design was achieved.

Signatus Inc. consists of four motivated and talented senior engineering students: Petar Arnaut, Olivier Thomas J, Chris Fontaine, and Barry Zou. If you have any questions or concerns about our design specification, please contact me by phone at (604) 328-4996 or by email at paa9@sfu.ca.

Sincerely,

Petar Arnaut

Petar Arnaut
Chief Executive Officer
Signatus Inc.

Enclosure: Design Specification for a Wireless Leak Detector and Inhibitor

Design Specification

Wireless Leak Detector and Inhibitor

SIGNATUS INC.

Petar Arnaut
Chief Executive Officer

Olivier Thomas
Chief Operating Officer

Chris Fontaine
Chief Technical Officer

Barry Zou
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Contact Person: Petar Arnaut
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Submitted to: Lakshman One (ENSC 440)
Mike Sjoerdsma (ENSC 305)

Issue date: November 17th, 2013

Executive Summary

Most houses and buildings experience some kind of unpredictable damage such as a water leak. Damage due to a water leak can be severe if it is not noticed on time. Besides having to pay a lot of money for a property repair, since the many insurance policies will not cover water damage, owners might also have to leave their property until the renovation is completed.

The Wireless Water Leak Detector and Inhibitor offers a solution for preventing excessive water damage to a property. It consists of a water detector, inhibitor, and user management software. Once a water leak is noticed by a detector, a signal is sent to the inhibitor that will shut off the main water supply of the property, thus preventing any further water leakage. In addition, the signal is transmitted to the user management software that notifies the user about the water leak location, battery status of separate devices and possible options of the inhibitor operations. Therefore, shutting down the main water supply depends on the settings in the user management software. User can choose if the main water supply should be turned off, or leave it in automatic settings. Logically, the user will want the main water supply to be turned off in case of being outside the properly for a long time.

Signatus Inc. has talented and motivated members who specialize in computer, systems and electronics engineering. Their skills will drive the project design to a completion.

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Glossary

ISR - Interrupt service routine

PC - Personal Computer

GUI - Graphical User Interface

USB - Universal Serial Bus

RX/TX - Receive / Transmit

1 Introduction

The Wireless Leak Detector and Inhibitor System is a device that prevents homes and business properties from water leak damage. The mechanism has a few ways of operating when the water leak is detected. The first option lets user be notified about the leak location without shutting down the electronic valve that is positioned on the pipe around the leak. An alternative is to have the electronic valve turned off automatically when a water leak is detected so that no water can continue to flow to the leak location. In addition, both options notify the user through the user management software that demonstrates the position of the leak, battery status, and the options available in case of a leak: electronic valve turned on, electronic valve turned off, and automatic settings.

1.1 Scope

The following document represents the design specifications that match with the functional requirements of the Wireless Leak Detector and Inhibitor. It provides full details of the project design implementation.

1.2 Stakeholders and Audiences

This design document is supposed to be used by the members of Signatus Inc. It will be used as a guideline for the future test plans to make sure that the device provides the correct behavior.

2 System Overview

The Wireless Leak Detector and Inhibitor System are comprised of a detector unit, inhibitor unit and software management unit. Figure 1 below demonstrates the software and hardware components of the Water Leak Detector and Inhibitor. The upcoming sections will detail each component separately.

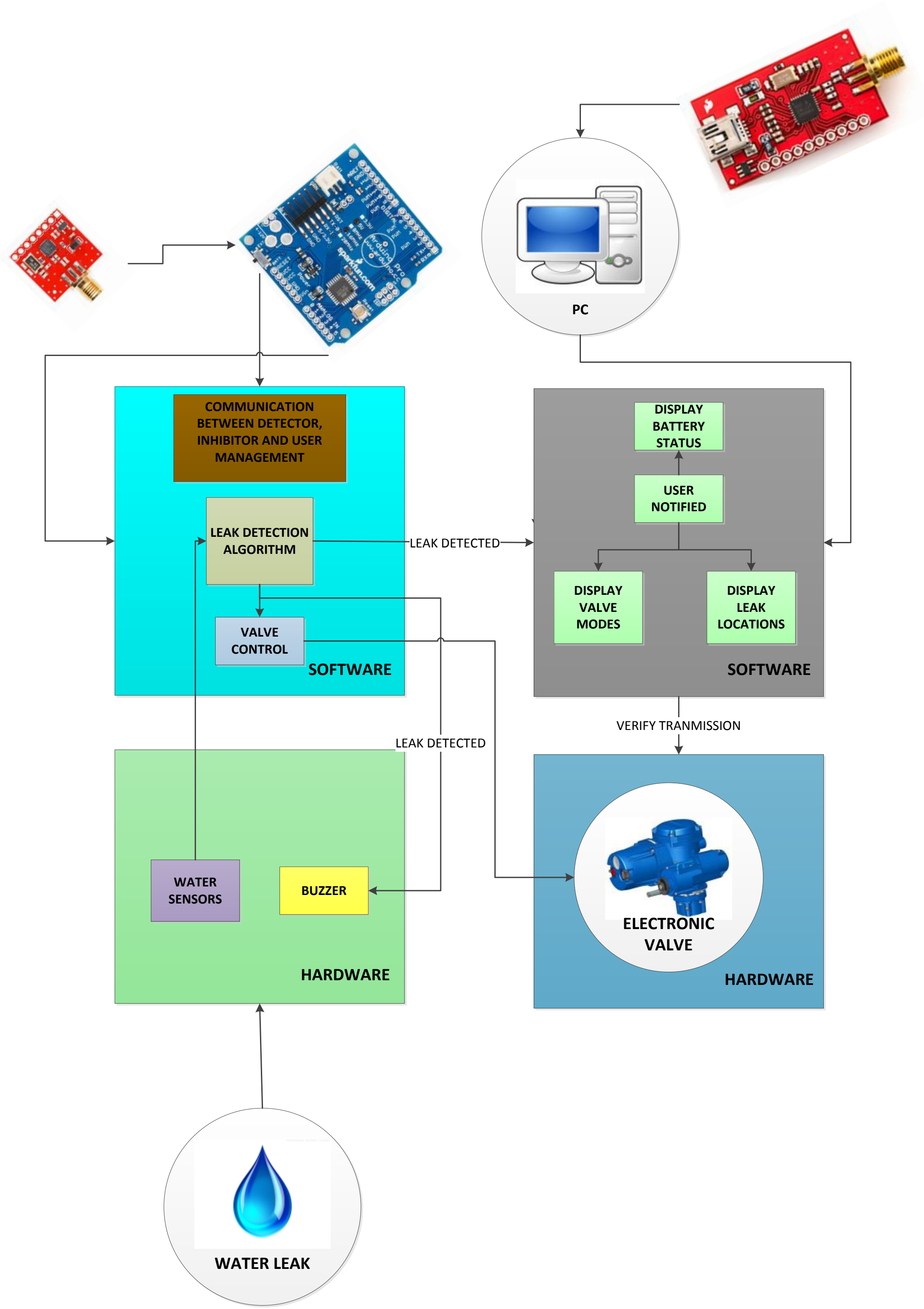

Figure 1: System Overview

3 Hardware

3.1 Arduino Pro MCU

The Arduino Pro is a microcontroller board based on the Atmel ATmega328 as shown in figure 2. The board operates on 5V with a clock speed of 16 MHz It has 14 digital input/output pins, 6 analog inputs, a battery power jack, a power switch, a reset button, and holes for mounting a power jack, an ICSP header, and pin headers. A six pin header can be connected to an FTDI cable for communication to the board. The Arduino Pro is intended for semi-permanent installation in objects or exhibitions. The board comes without pre-mounted headers, allowing the use of various types of connectors or direct soldering of wires. [1] The Arduino Pro is a suitable choice for our proof of concept, due to its expandability and size.

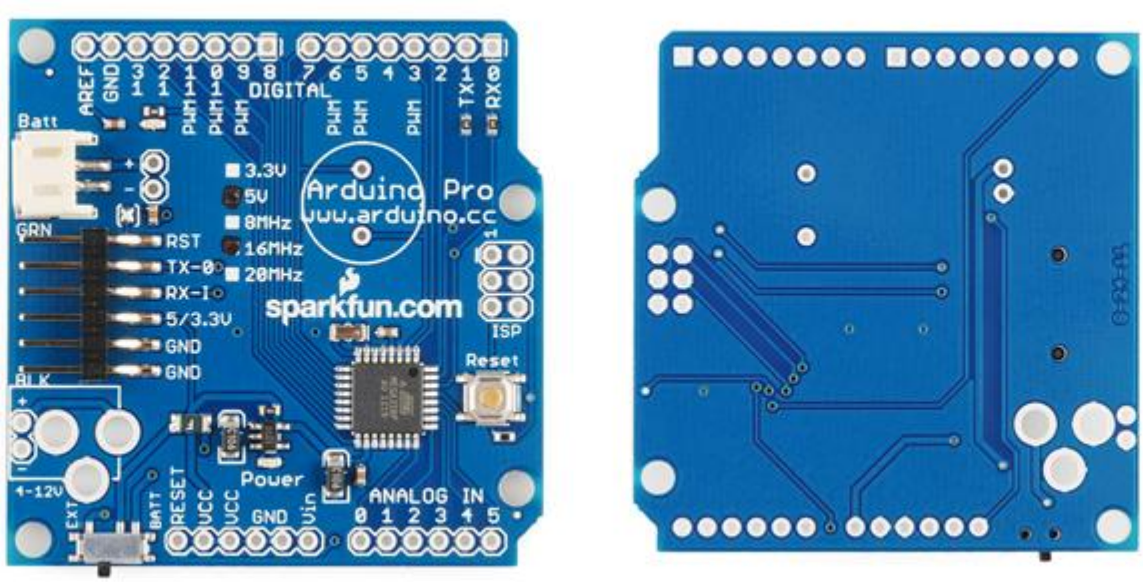

Figure 2: Arduino Pro 5V ATmega328

Table 1: Arduino Pro Specification

Arduino Pro Specification	
Microcontroller	Atmel ATmega328
Operating Voltage	5V
Input Voltage	5-12V
Digital I/O Pins	14 digital I/O pins, some pins have specialized functions: - (2 Pins) Serial Communication - (2 Pins) External Interrupts - (6 Pins) PWM - (4 Pins) SPI - (1 Pin) LED - (2 Pins) I^2C
Analog Input Pins	6
DC Current per I/O Pin	40mA
Flash Memory	32KB
SRAM	2KB
EEPROM	1KB
Clock Speed	16MHz

The primary beneficial features of the Arduino Pro are its miniature form factor which will allow us to fit it within our enclosed mat, SPI communication for transceiver interfacing, external interrupts for power saving, and digital/analog pins for various sensor/controller interfacing. The board's primary use will be to control connection pairing, detect water leaks and battery level, control valve operations, package data, and transmit/receive data using the attached transceiver module. The system will be built using common software which will include both the detector and inhibitor functions, and during startup would select the correct functions based on I/O pin configuration.

3.1.1 SPI Communication

The SPI pins (10 - 13) are used to communicate between the Arduino and nRF24L01+ transceiver. Using these pins, connection pairing, and packets transmission/reception are possible.

3.1.2 I/O Pins

The input/output pins (4 - 9) are used for water sensor input, valve control output, and detector/inhibitor selections.

3.1.3 Battery Monitor

The analog-to-digital pin is used for battery level monitoring using a voltage divider circuit as shown in figure 3 below:

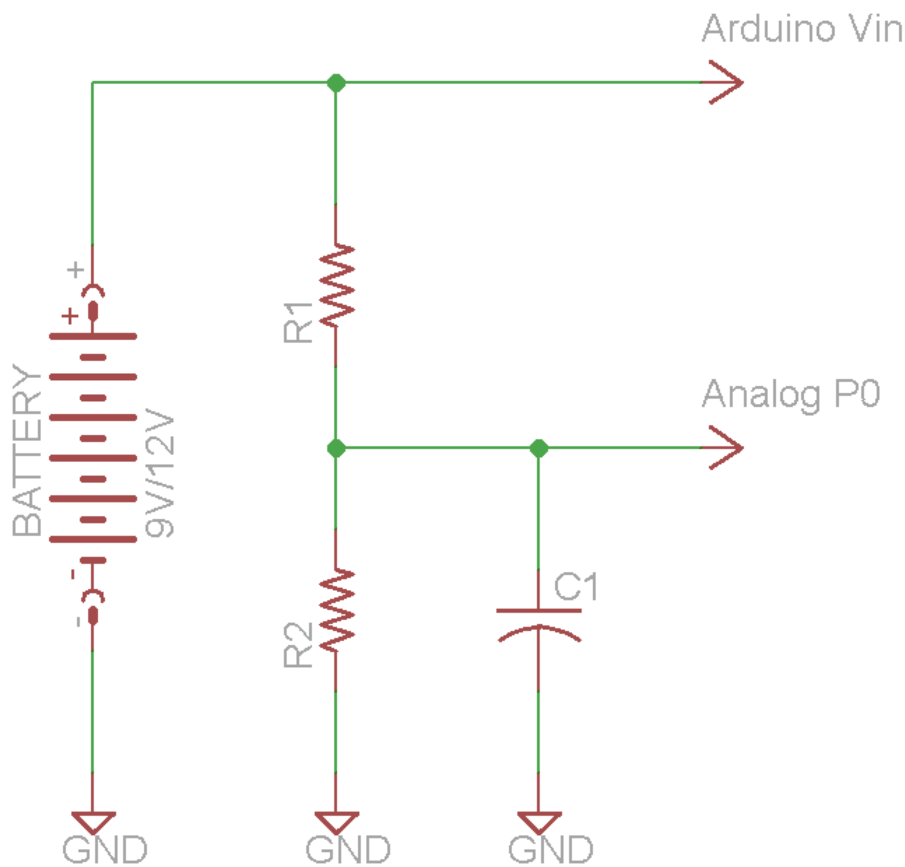

Figure 3: Battery Monitor Circuit Schematic

Using the following equations we can calculate the resistor values for both the 9V (Detector) and 12V (Inhibitor) batteries:

$$Vout = \frac{(BatteryVoltage \times R2)}{(R1 + R2)}$$

$$R1 = \frac{(BatteryVoltage \times R2)}{Vout} - R2$$

$$R2 = \frac{R1}{\left({BatteryVoltage}/{Vout} \right) - 1}$$

$Vout$ should be chosen to accommodate the internal Ref voltage of 1.1V on board the Arduino Pro. In our case, we have chosen 1.05V to ensure the voltage is not above the Ref voltage nor too low, to prevent inaccurate measurements. [2]

Choosing $R1$as $100k\Omega$ will result in an approximate R2 value of:

$$9V: \ \ R2 = 13k\Omega$$

$$12V: \ \ R2 = 9.1k\Omega$$

ADC impedance matching must be handled in our design using the $C1$ capacitor to ensure proper accuracy due to the Arduino's ADC $10k\Omega$ input resistance. Choosing a $C1$value of $100nF$will ensure accuracy in our voltage measurements. [2]

3.2 nRF24L01+ Transceiver

The Nordic nRF24L01+ is a highly integrated, ultra-low power (ULP) 2Mbps RF transceiver for the 2.4GHz ISM (Industrial, Scientific and Medical) band. With peak RX/TX currents lower than 14mA, a sub µA power down mode, advanced power management, the nRF24L01+ provides a true ULP solution enabling months to years of battery life from coin cell or AA/AAA batteries. The Enhanced ShockBurst™ hardware protocol accelerator offloads time critical protocol functions from the application microcontroller enabling the implementation of advanced and robust wireless connectivity with low cost 3rd-party microcontrollers. [3] The nRF24L01+ is a suitable choice due to its ultra-low power, high data rate, hardware accelerator, and ease of use with our Arduino Pro microcontroller.

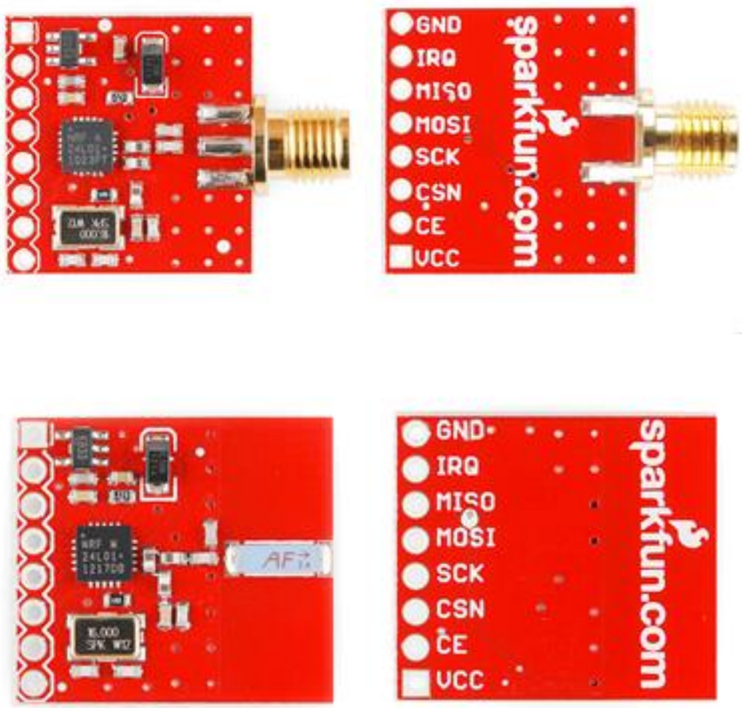

Figure 4: nRF24L01+ Transceiver Module (Top: RP-SMA) (Bottom: Chip Antenna)

Table 2: nRF24L01+ Transceiver Module Specification [4]

nRF24L01+ Transceiver Specification	
Operating Voltage	3.3V
Input Voltage	3.3-7V
Radio	2.4GHz GFSK (License-Free ISM Band)
Data Rate	250kbps - 2Mbps
Range	100m
Data Pipes	6
Channels	125
Antenna	RP-SMA/Chip
Dimension	0.7x0.8" (RP-SMA) 0.8x0.9" (Chip)

3.2.1 Antenna

The antenna will depend on which device the transceiver will be attached to. In the case of the detector, the chip antenna is appropriate due to its size and range. As for the inhibitor an RP-SMA antenna will be used due to its long range and possible inhibitor location (long distance).

Figure 5: RP-SMA Antenna

3.2.2 Power

The transceiver will be powered using the Arduino Pro's on-board 5V regulated voltage, provided by the VCC pin.

3.3 nRF24LU1+ Transceiver

The nRF24L01 is a highly integrated, ultra-low power (ULP) 2Mbps RF transceiver IC for the 2.4GHz ISM (Industrial, Scientific and Medical) band. With peak RX/TX currents lower than 14mA, a sub µA power down mode, advanced power management, and a 1.9 to 3.6V supply range, the nRF24L01 provides a true ULP solution enabling months to years of battery lifetime when running on coin cells or AA/AAA batteries. The Enhanced ShockBurst™ hardware protocol accelerator additionally offloads time critical protocol functions from the application microcontroller enabling the implementation of advanced and robust wireless connectivity with low cost 3rd-party microcontrollers [5]. After the nRF24LO1+ transceiver was chosen as the hardware of choice for communication. The nRF24LU1+ was chosen as it is a popular choice together with the nRF24LO1+ for wireless communication solutions due to combined ultra-low power, high data rate, hardware accelerator, and ease of use.

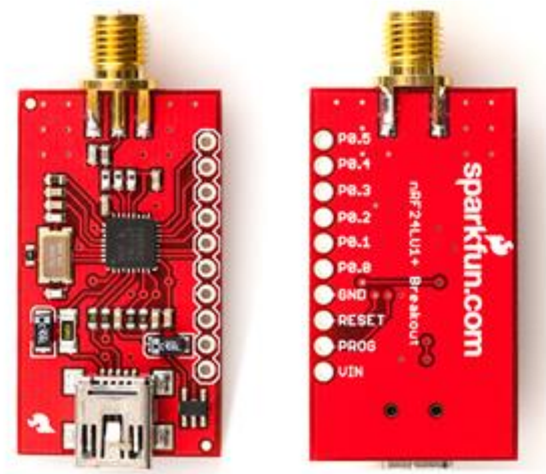

Figure 6: nRF24LU1+ Transceiver Module

Table 3: nRF24LU1+ Transceiver Module Specification [6]

nRF24LU1+ Transceiver Specification	
Input voltage	4-5.25V
Radio	2.4GHz GFSK (License-Free ISM Band)
Data Rate	250kbps - 2Mbps
Range	100m
Data Pipes	6
Channels	125
Antenna	RP-SMA/Chip
Dimension	1.8x0.8" (with RP-SMA)

3.3.1 Serial Port Communication/Universal Serial Bus Communication

The communication between the embedded software on the nRF24LU1+ and the PC GUI will be done through the FTDI to USB connection [7]. The Libusb open source library will be used to access the nRF24LU1+. Libusb is an open source C library available on multiple operating systems that has many functions giving easy access to a variety of USB devices. The method of communication will be as follows. First the GUI application will try to find and claim the nRF24LU1+ transceiver USB device. After successful attachment, asynchronous signal request will be set up and sent from the GUI application. When the nRF24LU1+ is correctly setup in asynchronous state, the GUI application will send an asynchronous data request and wait for that request to be filled by the nRF24LU1+. The specific size of the data packet of the communication protocol is still subject to change. After a request for data is filled by the nRF24LU1+, the GUI will send another request. The data is then processed by the GUI application and the correct device information is updated. This process repeats while the USB device handle is good and the user does not cancel by exiting the application. The communication protocol will use a similar packet and method. When the Inhibitor settings are changed by the user through the GUI application, data will be sent to the nRF24LU1+ which will send the appropriate signal to the Inhibitor.

Figure 7 below shows the communication workflow diagram:

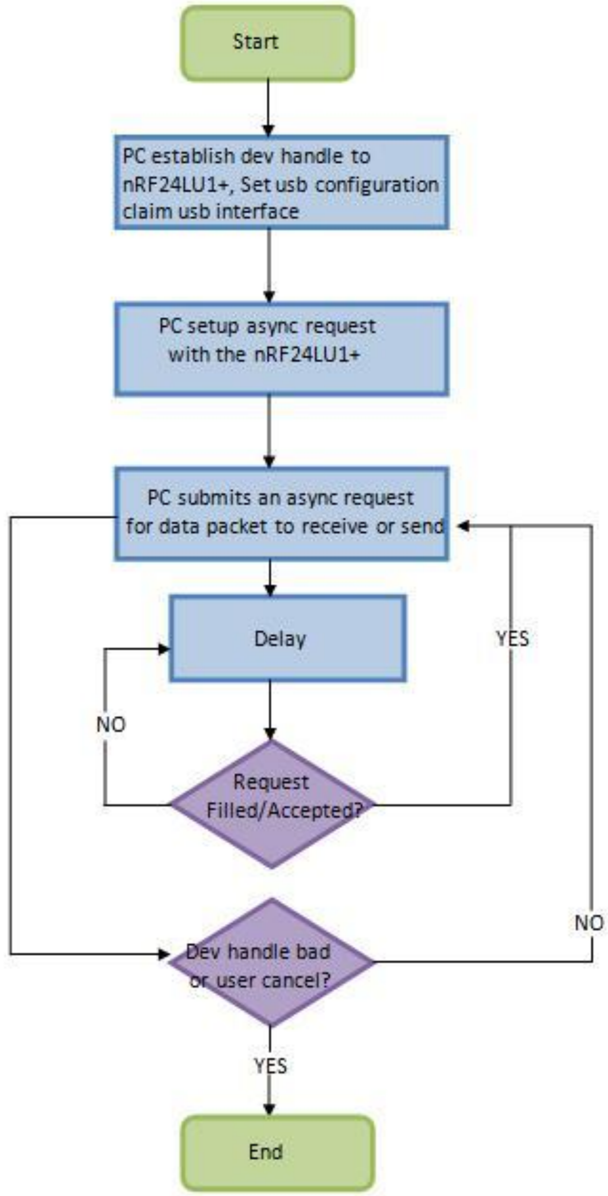

Figure 7: USB Communication Workflow Diagram

3.3.2 Antenna

For the nRF24LU1+ an RP-SMA antenna will be connected due to long range communication. This will extend the range and be able to support data transfer between the devices.

3.3.3 Power

The transceiver will be using the power from a personal computer using a USB connection.

3.4 Detector

3.4.1 Water Sensors

The following figure shows the water detector circuit:

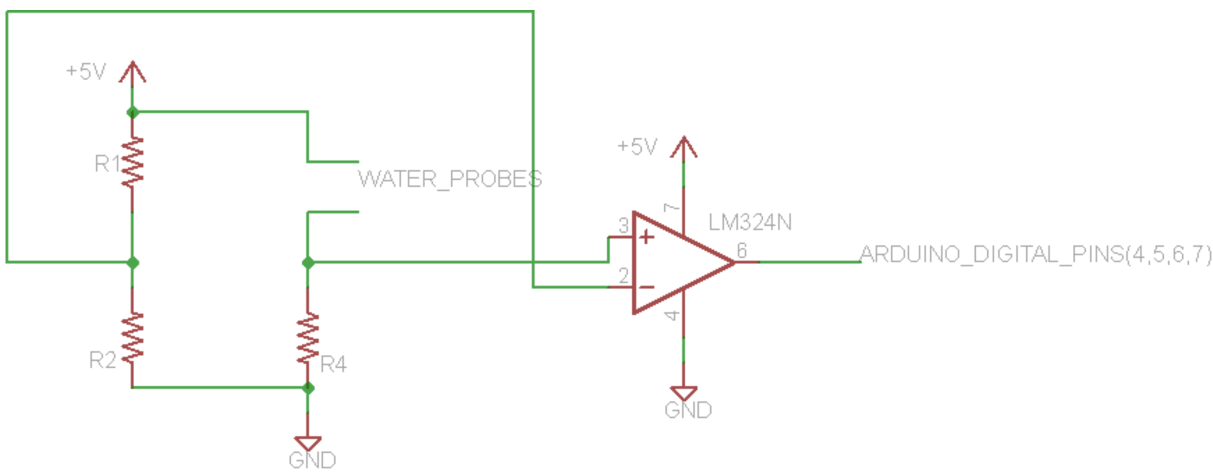

Figure 8: Water Sensor Circuit Schematic

Four circuits shown above will be used on four different sides of a rubber mat in order to detect a leak. On two longer sides of a rubber mat, one water sensor circuit will be used to detect a leak on two parts of each side. Therefore, the entire rubber mat will have six water sensor probes around it. The resistances values will be as follows:

$$R_1 = R_2 = 1\ M\Omega$$

$$R_4 = 15\ M\Omega$$

The value of water resistance varies, but it is between 700 $k\Omega$ and 1.1 $M\Omega$. The water resistance depends on the water resistivity, cross-sectional area of electrodes that are used, and a distance between the electrodes. [8]. The formula is shown below:

$$R = \frac{l}{A} * \rho$$

$\boldsymbol{R}$ is the water resistance between the electrodes;

$\boldsymbol{l}$ is the distance between the electrodes;

$\boldsymbol{A}$ is the cross-sectional area of each electrode (both electrodes have the same area);

$\boldsymbol{\rho}$ is the water resistivity.

Water resistivity of tap water is between 1 and 5 kΩ*cm. The distance between the electrodes is calculated using the following formula:

$$A = \pi * R^2$$

Where R is the radius of a cross-sectional area of each electrode. The electrodes have a radius of 0.15 mm.

Therefore, the area is calculated using the previous formula:

$$A = \pi * (0.15)^2 = 0.07065\ mm$$

The distance l is equal to $1.5\ cm$. Therefore, using the formula for the water resistance with the stated values of l, A, and ρ, we can obtain the water resistance between $700\ k\Omega$ and $1.1\ M\Omega$.

R_4 has a high resistance since the water resistance varies and the output of a non-inverting input of the op amp should be higher than the output for the non-inverting input when the leak is detected. Therefore, when that is true, the comparator will output a Vcc voltage to the Arduino digital pin. If a non-inverting input voltage is higher than the inverting one (this will only be true if there is no water leak resistance since the inverting input will be equal to zero), the output to Arduino digital pin will be equal to zero.

Since four water detector circuits are used, there needs to be a combination of a minimum three water leaks in order to shut down the main valve. The comparator LM324N is used since it has four op amps and we will need four water detector circuits (datasheet and an image of this amplifier is shown below [9]).

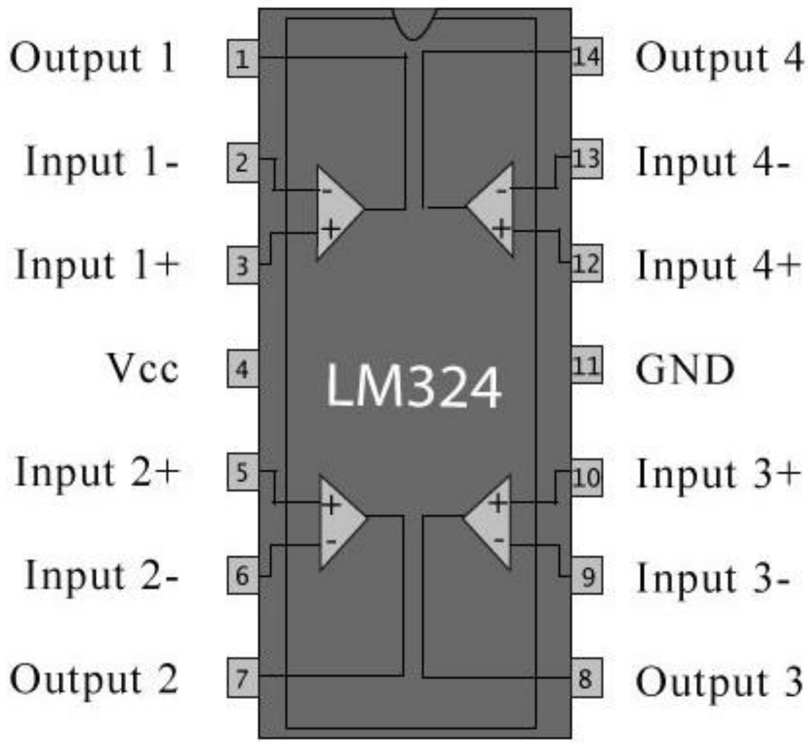

Figure 9: LM324 Op-Amp Schematic

A detector part will be placed in between three layers of a rubber mat. The middle mat is the thickest among all of them since it has a detector circuit in it. In one section there will be an Arduino board, transceiver, and four sensor circuits from figure 8. The second section will have a battery of 9 V. The water probes will be spread from the middle to the bottom layer, and towards the edges of the bottom rubber mat. A button for a buzzer will be placed though a bottom layer so it can be accessed by a customer. Also the battery section will be available to a customer since it needs to be replaced after it discharges. A piece of wood will be located on the top part of a middle rubber mat in order to prevent circuit from breaking after a heavy weight (i.e. person stepping on a rubber mat) is placed on it. Another piece of wood will be positioned under the PCB of water leak detector circuit, Arduino MCU and transceivers.

3.4.2 Buzzer circuit

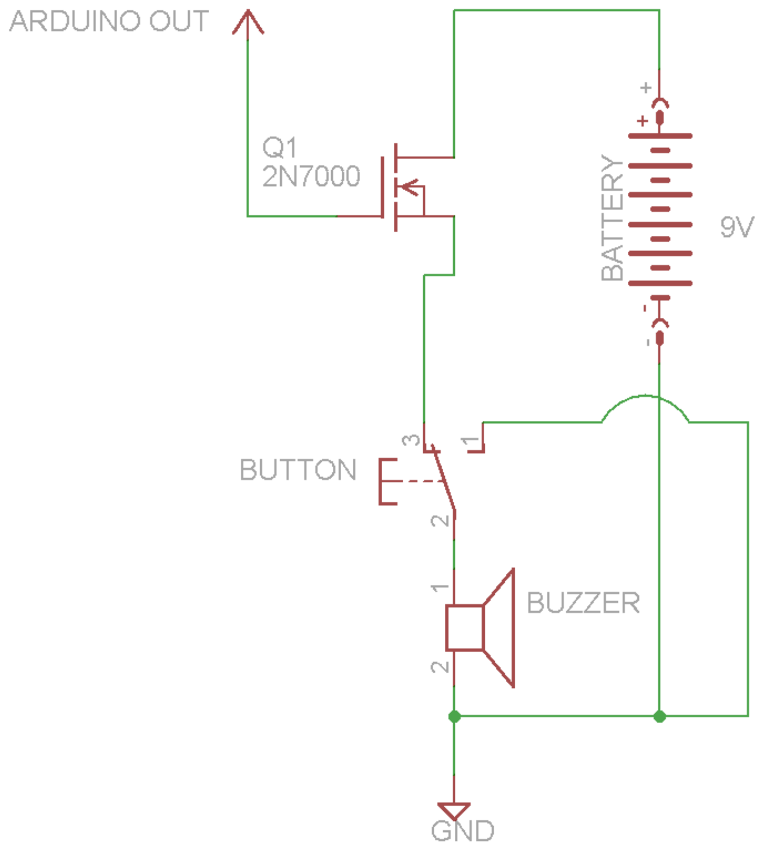

Figure 10: Buzzer Circuit Schematic

Buzzer will turn on if there is a water leak detected. Arduino outputs a digital '1' (Vcc voltage) or a digital '0' (zero voltage). Since Arduino output is connected to the gate of an NMOS, the NMOS will act as a switch in the circuit above. If the voltage at the gate on an NMOS is Vcc, then the NMOS will act like a closed switch and the buzzer will turn on using the 9 V battery. In case the voltage at the gate of the NMOS is a zero, the NMOS will act like an open switch, and therefore the buzzer will not turn on. The voltage at the gate of the NMOS controls the circuit. If Vgs is much greater than the threshold voltage Vth, the NMOS will act like a closed switch and it will be in a saturation region. If Vgs is smaller than the threshold voltage Vth, the NMOS will act like an open switch and it will be turned off [10].

3.4.3 Power

The detector will be powered using a 9V battery which will be regulated using the on-board linear voltage regulator the Arduino Pro to a stable 5V. The water sensors will use the regulated 5V to allow more accurate readings without erroneous noise. Future implementations will include a more power efficient regulator.

Figure 11: 9V Battery

3.4.4 Rubber Mat Enclosure

The detector will be placed in between three layers of a rubber mat as can be seen in figure 12 below. The middle mat is the thickest among all of them since contains the detector circuit and battery. In one section there will be an Arduino board, transceiver, and a four sensor circuits. The second section in the top right will hold the 9V battery. The water probes will spread from the middle layer to the bottom layer, and towards the edges of the bottom rubber mat. A button for a buzzer will be placed between the bottom and middle layer and is accessible by a customer without letting any external contact to the middle layer. The battery section will also be accessible to end-users since it needs to be replaced after it discharges. A strong material will be place above the part main circuit located in the middle to prevent breakage from heavy weight (i.e. person stepping on a rubber mat). Another strong material will be placed under the circuit to mount the water leak detector circuit, Arduino MCU and transceivers.

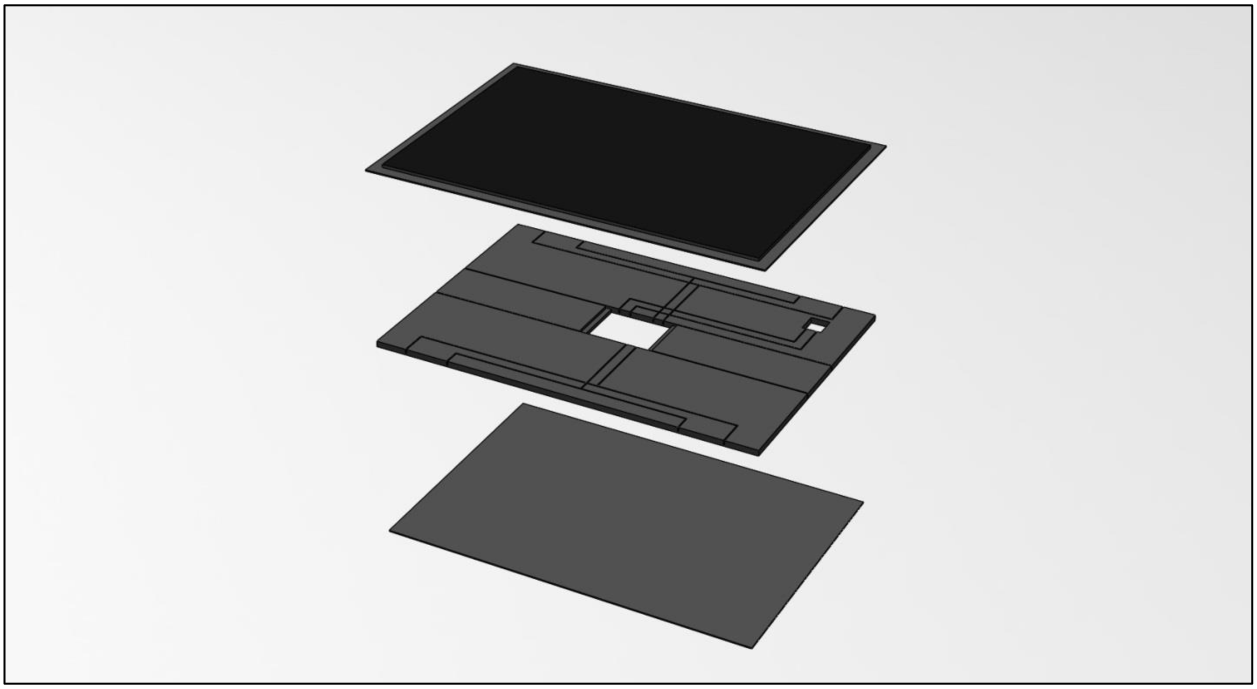

Figure 12: Overview of Mat Assembly (Top Layer: Simple Thin Mat) (Middle Layer: Custom Rubber Designed Mat) (Bottom Layer: Simple Thin Mat)

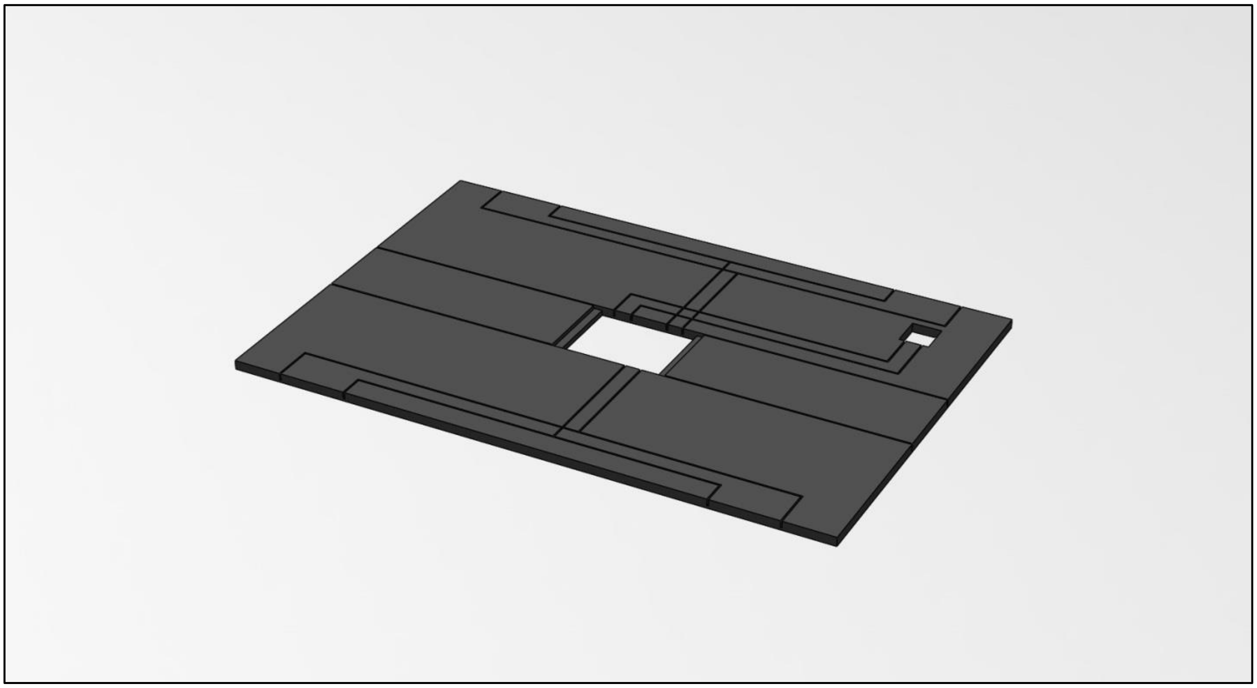

Figure 13: Close-Up View of Middle Layer

3.5 Inhibitor

3.5.1 Electronic Valve

The electronic valve will be provided in multiple sizes, depending on the needs of the user. Typical valve sizes to be offered will be ¼”, ½”, ¾”, 1” and 1½”. The user will purchase the device with the correct valve size to match the existing water main of the property. For the purposes of the prototype device, a ¾” electronic valve will be used. This valve will contain a solenoid actuator powered with a 12V DC supply. The valve is nominally open and remains open so long as there is water pressure above 3 PSI, which is well below the normal water pressure of a household connection. When a 12V supply is sent to the valve, the valve closes, thus shutting off the water. For specialty applications consisting of water pressures below 3 PSI, an alternate electronic valve may be specified for an additional cost that will remain open without water pressure [11].

Figure 14: Electronic Valve 12V DC

3.5.2 Power

The inhibitor will be powered using a 12V battery which will be regulated on-board the Arduino Pro to a stable 5V. The electronic valve will use the unregulated 12V battery for power. Future prospects should include external power from the property, which would allow for more powerful valves and battery free operations.

Figure 15: 12V Battery

3.5.3 Installation and Enclosure

The electronic valve itself will not need to have its own enclosure. The valve will have to be installed within the main water supply. This will be achieved by installing the electronic valve either in place of an existing non-electronic valve for fully electronic control, or downstream of an existing mechanical valve. By installing the electronic valve downstream of an existing mechanical valve, the installation process becomes relatively simple. The existing mechanical valve will be turned off so that the water has stopped flowing through the pipe. The pipe will have a section cut out from it, according to the size of the water valve purchased. The electronic valve will then be inserted into the cutout section; the pipe thread into the input/output of the valve and two brass pipe fasteners will be fastened around the connections to ensure no water leakage.

A plastic enclosure box as seen below will be utilized to prevent water damage to the battery and/or the microcontroller that is controlling the electronic valve. The enclosure is IP66 certified, which will protect it from water and dust.

Figure 16: IP66 Rate Enclosure

Table 4: Inhibitor Enclosure Specification [12]

Inhibitor Enclosure Specification	
Size / Dimension	3.543" L x 3.543" W (89.99mm x 89.99mm)
Height	2.362" (59.99mm)
Area (L x W)	12.6" (81cm)
Design	Cover Included
Material	Plastic, ABS
Color	Gray
Thickness	0.118" (3.00mm)
Ratings	IP66, NEMA 4,4X,12,13
Material Flammability Rating	UL94 HB

IP66 Cable glands will be used to prevent water and dust from entering the enclosure through the external wiring, and antenna. Figure 17 below shows a possible cable gland that may be used in our design.

Figure 17: IP66 Rated Cable Gland

3.6 Manager

3.6.1 Enclosure

A plastic enclosure box will be used to enclose the nRF24LU1+ attached to the PC. This is used to prevent accidental touching and possibly damage the nRF24LU1+ transceiver by the user. The dimensions of the box is picked such that a hole will be drilled on the side of the box to allow the RP-SMA antenna connector be able to stick out through the hole thus allowing the antenna to be connected. On the opposite side a small rectangle will be drilled to allow the opening of the FTDI connector to the PC. The box is from Hammond Manufacturing 1551 Series, and has dimensions of 1.575" L x 1.575" W (40.00mm x 40.00mm) which is just enough for the nRF24Lu1+ to fit excluding the RP-SMA antenna connector. The specifications of the enclosure can be seen on table 5 below.

Figure 18: Manager Enclosure

Table 5: Manager Enclosure Specification [13]

Manager Enclosure Specification	
Size / Dimension	1.575" L x 1.575" W (40.00mm x 40.00mm)
Height	0.787" (19.99mm)
Area (L x W)	2.48" (16.0cm)
Design	Hand Held, Cover Included
Material	Plastic, ABS
Color	Black
Thickness	0.079" (2.01mm)
Ratings	IP54

4 Software

4.1 Software System Overview

When the detector and inhibitor units are activated the software should automatically begin pairing the detectors to the appropriate inhibitor. The manager will also try and pair with detectors and the inhibitor; if this cannot be done the system will continue without the manager as it is not a critical part of the system. The inputs of the water sensor circuit will trigger the MCU on the detector to process a leak using a leak detection algorithm, a packet as seen in the table below with status information and addressing are sent to the inhibitor and manager for actions to be taken. The inhibitor's MCU will receive the packet and process it in order to determine the necessary actions. The manager will overlook the packet transmission and monitor the valve status, to insure that the packet was received and processed accordingly. If an error was found, the manager would relay the packet from the detector to the inhibitor to provide reliable operations. Battery level is sent to the manager software every 24H using a timer.

Each sub-system will use the following packet shown in table 6 to determine information on each device.

Table 6: Data Packet Format

Unique ID	Reserved	Type ID	Conn Status	Data	
				Leak	Battery
8 Bits	4 Bits	2 Bits	2 Bits	1 Bit	7 Bits
23	15	11	9	7	6 0

The packet above is subject to change, due to design complication and functionality.

4.2 Detector

Figure 19 below shows the Detector software flowchart:

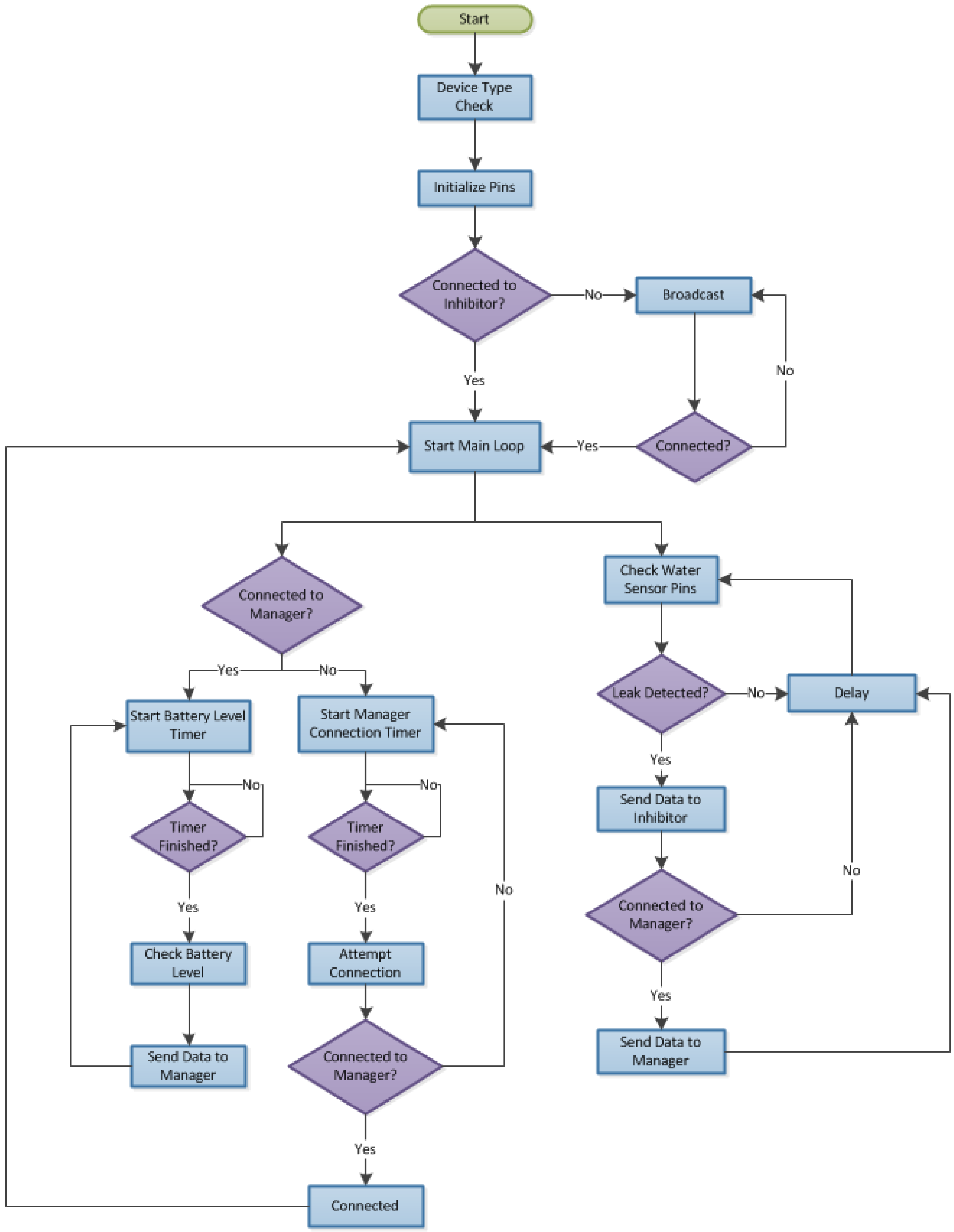

Figure 19: Detector Software Operation Flowchart

4.2.1 Pairing

On startup the detector will broadcast its address and device type for inhibitor pairing. The system will not begin monitoring water leaks until the pairing is complete. Once paired, connection settings are stored within the MCU's EEPROM to insure reconnection in case of power loss. Connection settings for detectors can be managed using the management software.

4.2.2 Water Sensor Algorithm

When the software is the "Check Water Sensor Pin" stage as can be seen in figure 19, the Arduino will determine whether a leak is detected by evaluating the pin inputs. Since we have chosen the digital pins as our input, a combination of 1's and 0's will be used to determine a leak. To ensure that a false-positive won't be detected the algorithm must have at least 3 out of its 4 sensors detect a leak. For example a bit field where each bit represents a water sensor pin, the pin is set high when a leak has been detected on the individual line. When the bits are bundled into bit fields a leak is considered detected when the following bit fields are seen in software, anything else is not:

Bit field 1: 1110
Bit field 2: 0111
Bit field 3: 1011
Bit field 4: 1101
Bit field 5: 1111

4.3 Inhibitor

Figure 20 below shows the Inhibitor software flowchart:

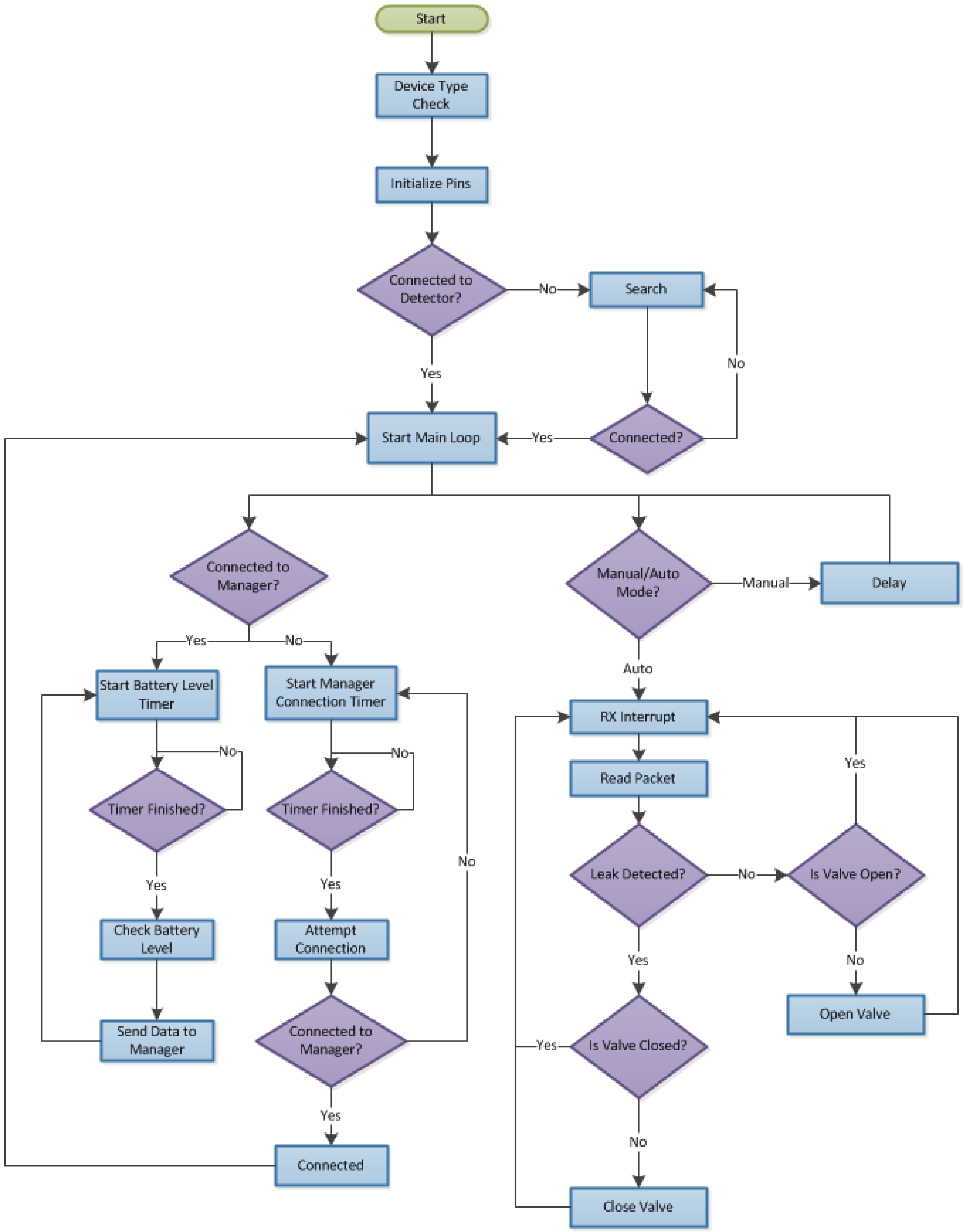

Figure 20: Inhibitor Software Operation Flowchart

4.3.1 Pairing

On startup the inhibitor will search for available detectors in its vicinity. The system will not begin automatic valve operations until a minimum of one detector is paired. Once paired, connection settings are stored within the MCU's EEPROM to insure reconnection in case of power loss. Connection settings for multiple detectors can be managed using the management software. If the management software is not used, a reset switch is used to erase existing connection settings.

4.3.2 Electronic Valve Control

When no leak is detected, the microcontroller will output 0V to the base of the NMOS transistor and therefore the transistor switch will remain off, providing no power connection to the electronic valve. Without power, the electronic valve remains open assuming that there is water pressure within the pipe.

When a leak is detected, the microcontroller will output 5V to the base of the NMOS transistor, thus turning the transistor switch ON and supplying a direct power connection from the 12V DC battery to the electronic valve. When 12V is supplied to the electronic valve, the valve will close, thus shutting off the water source.

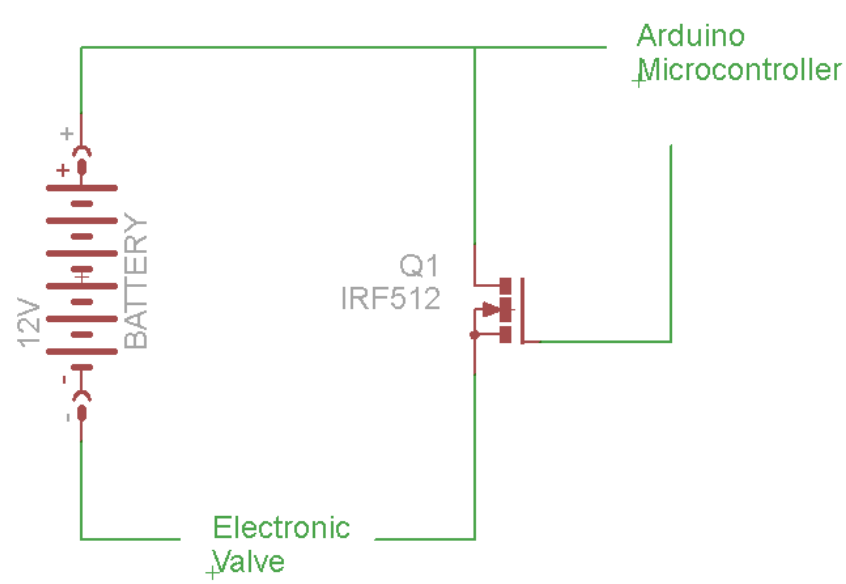

Figure 21: Electronic Valve Arduino Control Circuit

4.4 Manager

4.4.1 Connection Controller

The nRF24LU1+ transceiver is programmed on startup to enable RF wireless communication by setting its associated ports and attempt to pair together with Inhibitor and Detectors. The USB communication ports and settings are set to be able to communicate with the manager GUI application. The transceiver is programmed to transmit any data packets it receives through wireless to the GUI application through USB communication. The manager does not need to take into account of what's in the data packet, since the communication protocol packets are programmed to be the same size whether it is from the Inhibitor or Detector. The manager GUI application will take care of the data parsing.

Figure 22 below shows the manager software flowchart:

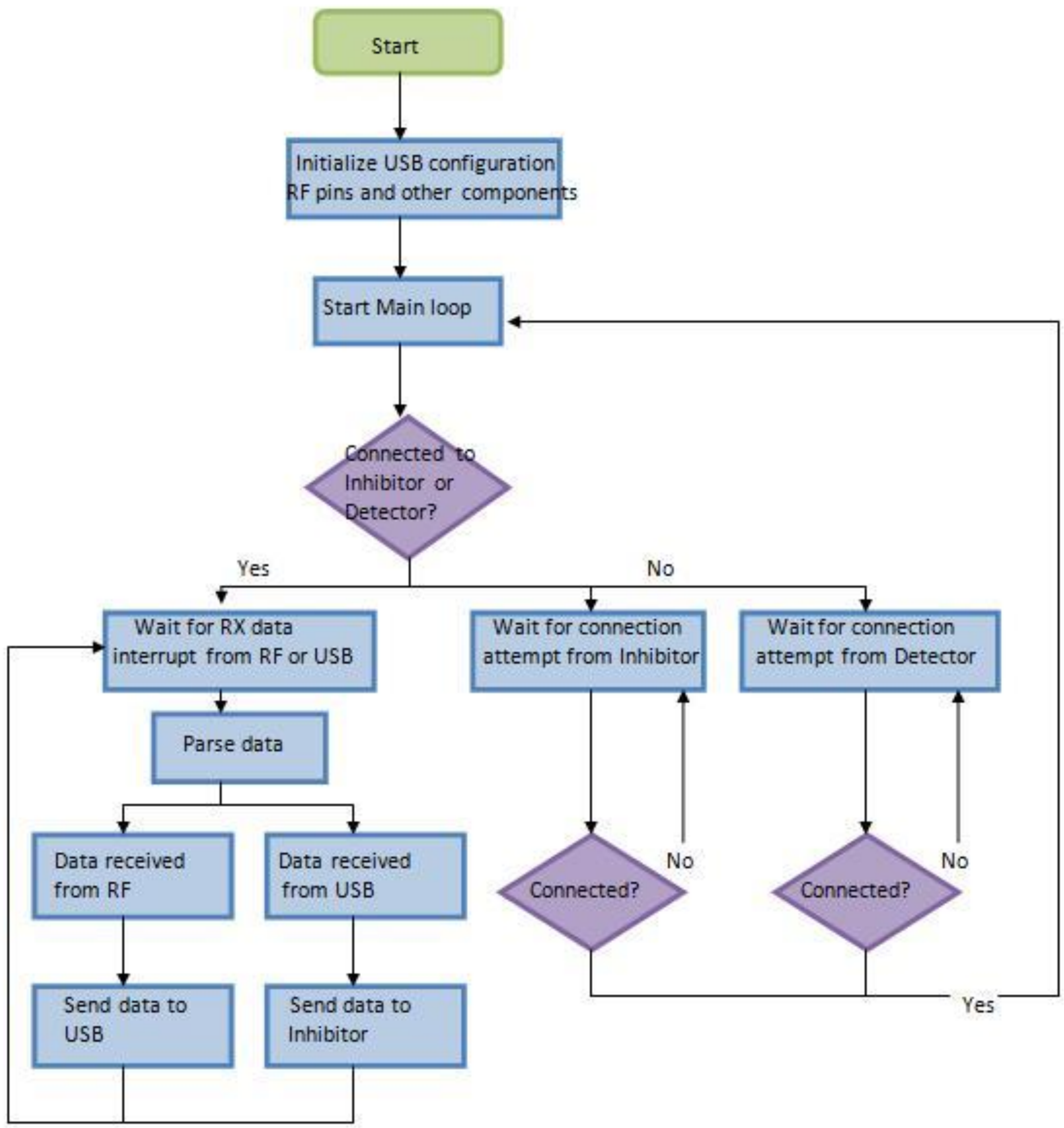

Figure 22: Manager Connection Control Flowchart

4.4.2 Software Graphical User Interface (GUI)

To satisfy functional requirements of the user interface for the Wireless Leak Detector and Inhibitor System, the Qt framework along with Qt Creator 5.1.1 will be used to implement the interface. Qt framework is a GUI development framework that uses the C++ programming language and is able to support multiple different operating systems. However for the system prototype only Windows XP, Vista, and 7 support will be considered. Mac iOS, Linux, and other operating system will be supported for future production model of the system. Figure 23 below shows the current implementation of the GUI, the final implementation may have minor graphical and aesthetic enhancements compared to this version. The GUI's design is simple and concise by choice. Too much information can hinder the very purpose of the interface, which is to deliver key information without requiring significant time from the user.

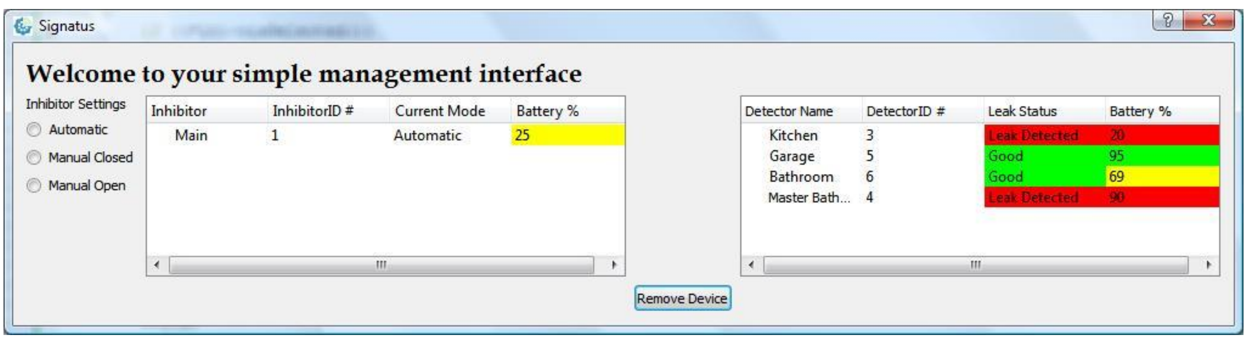

Figure 23: The Graphical User Management Interface

When the interface is executed by the user for the very first time, the interface shown in Figure 23 above will have no inhibitors or detectors mapped and displayed. On detection of data received from wireless and serial communication the interface will be populated. Windows below in Figure 24 are displayed when new device are detected, these windows shall prompt the user to enter a name label for the device. When the name label has been determined valid and confirmed through the ok button, a new device along with its current status information will be populated on the main interface. The user is able to edit the name labels afterwards at any time as they wish and not any of the other information columns. This name modification offers additional ease of use factors if a certain detector is physically moved from the kitchen to the master bathroom as an example.

Figure 24: Prompt Labels from User on New Device Detection

The main interface menu has inhibitor operation mode options shown on the left. The current mode is displayed, it is suggested for the typical user to leave the operation mode on automatic. In automatic operation mode the inhibitor will open or close depending on leak detection. However manual open and close options are available to the user. Choosing them will send a signal to the microcontroller unit at the inhibitor and appropriate actions will be taken. The devices information labels will have various color highlights depending on their status. The battery column will be green from 100 to 80% power, yellow from 80-20%, and red at less than 20% power. Detector specific leak status column will be green when the status is good, and the will be highlighted red if a leak has been detected. The identification number column is used to distinguish individual devices and will be unique to the device. The remove device button allows the user to remove a selected device from the interface. This can be used in cases where a certain detector is deactivated. A confirmation window is used to prevent accidental removals.

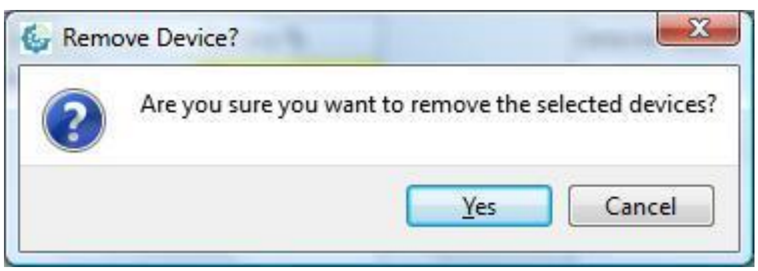

Figure 25: Confirmation Window for Removing a Device from the GUI

Upon proper leak detection a new modal window shown in Figure 26 will pop up, warning of the leak's location along with a timestamp of when the leak happened. A modal window means that the window cannot be hidden into the background; it will be the only application that allows input from the user. This is a design choice that may seem intrusive, but it is key feature to notify the user for a timely response to any possible leaks.

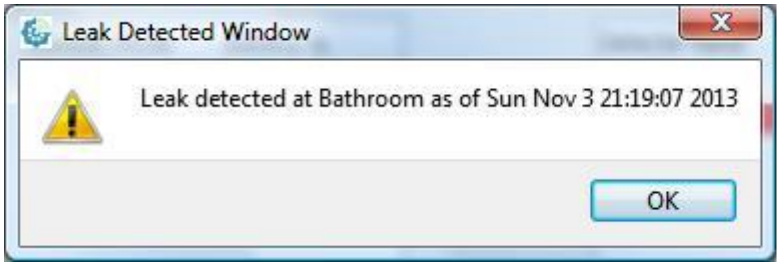

Figure 26: Warning Window when a Leak has been Detected

Figure 27 below is the window shown when the battery of either detector or inhibitor is detected to be less than 20%.

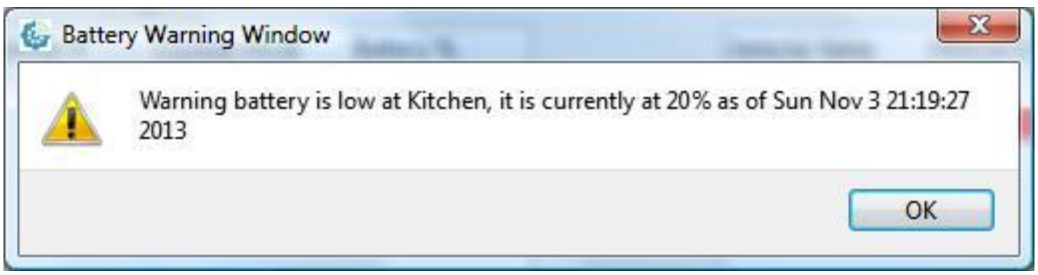

Figure 27: Warning Window when the Battery is Low

The GUI application also provides the ability to save current devices. This feature is automatic and does not require user input. It is provided in case of the user accidental exit of the GUI application. On GUI application startup previously mapped devices will be existing with their names and device IDs; this prevents the hassle of re labelling previously mapped devices as if they are new devices. However the device's battery and leak status will not be mapped. Since such data definitely will have changed since the last time the GUI application was opened. The tables will be populated upon new data received.

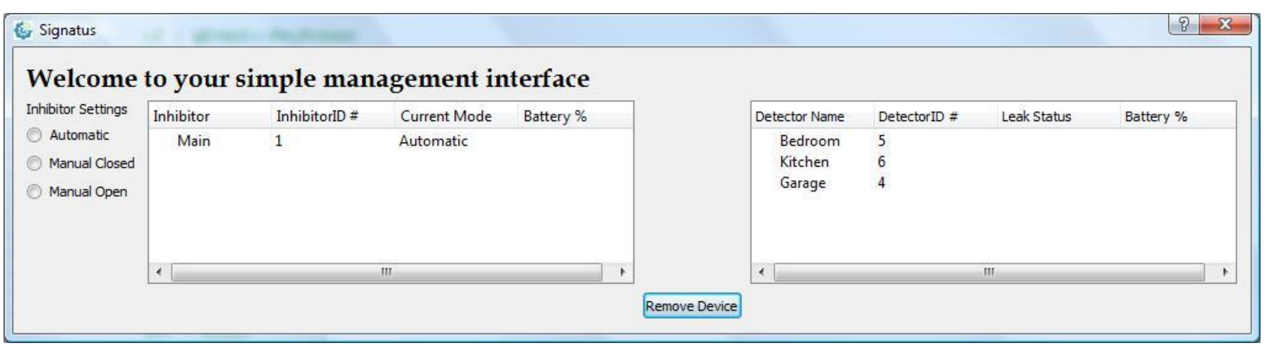

Figure 28: GUI Window on Startup with Previously Existing Devices Mapped

Below in Figure 29 is the flowchart for the user interface described above.

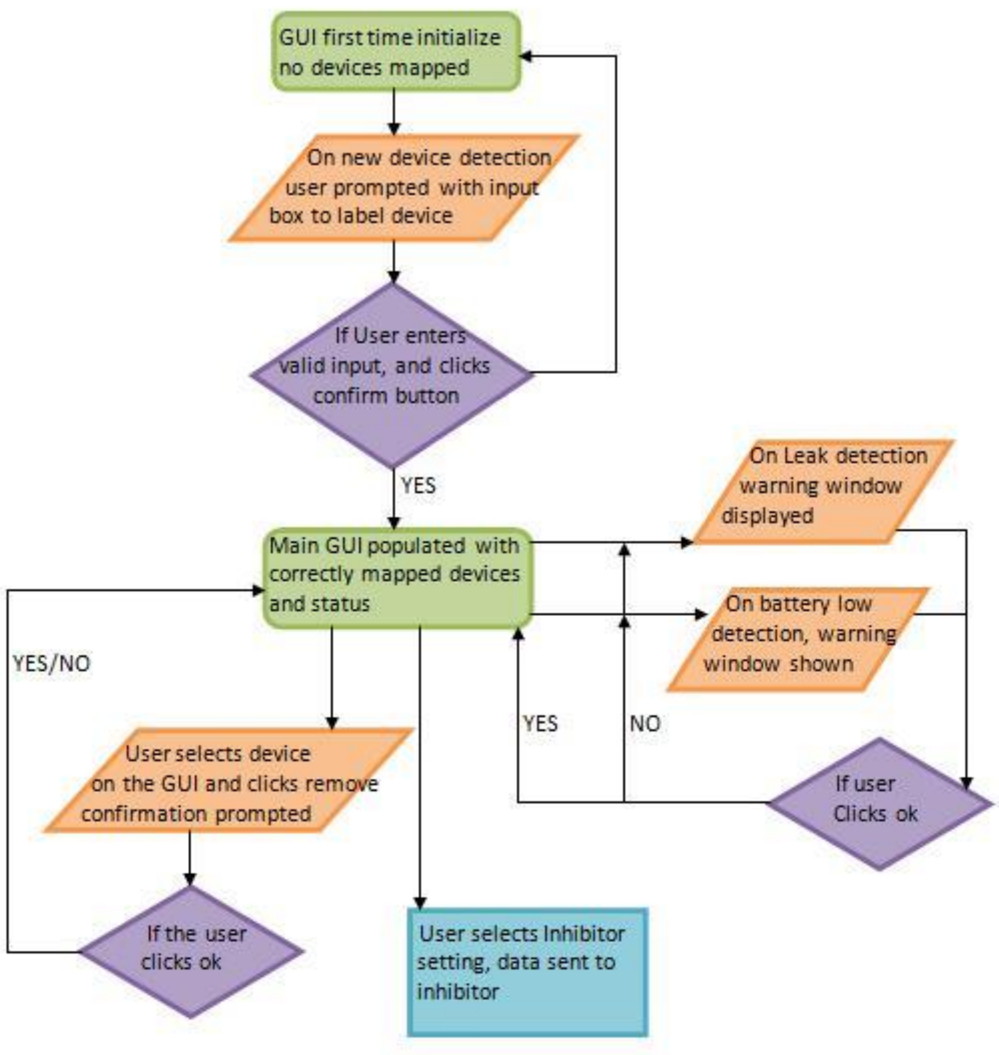

Figure 29: Flowchart for the User Management Software

5 Test Plan

During the testing phase of the prototype, we propose the following tests be done on each stage of the project:

1. The circuit for detecting water leaks shall be constructed and tested by placing water onto the water sensor. When water is placed on the sensor probe, the output of the comparator should read high. When no water is placed on the sensor, the output shall read low.

2. The microcontroller shall be connected to four water detection leak circuits. Each input should be verified by the microcontroller with or without water placed across the sensors.

3. A 12V DC voltage shall be provided to the electronic valve and the valve should close.

4. With water running through the valve and no voltage provided to the valve inputs, the water should run smoothly.

5. The electronic valve circuitry shall be constructed. When an input voltage is provided to the switch, the electronic valve shall close

6. The microcontrollers shall have a test packet sent between each device, to ensure that they can properly communicate with each other.

7. A signal shall be sent from the detector unit microcontroller to the inhibitor microcontroller, providing the inhibitor with a signal to shut off the valve. The valve should shut off.

8. When water is placed upon the detector, the same signal should be sent to turn off the valve.

In order to test the prototype device's functionality, we propose the following steps be taken during the demonstration.

1. Setup the above mentioned user software on a personal computer.
2. Provide a water source for use with the inhibitor device.
3. Connect the water source to a pipe with the inhibitor device pre-installed on the pipe.
4. Place a detector mat within a container to hold excess water.
5. Demonstrate that when one edge of the mat has water placed upon it, the valve still functions as open, demonstrating that a false positive has been detected.
6. Place water along the majority of the mat, causing a positive leak signal to be sent to the valve, turning off the water.
7. Use the graphical user interface to customize the settings of the device to cause a notification to the user in case of a leak instead of shutting off the water.
8. Demonstrate the functionality of the user management software.

6 Conclusion

The document above outlines the design specification of Signatus's Wireless Leak Detector and Inhibitor System. Design choices are made to fit the functional requirements of the system in the most effective and efficient methods when possible. This document describes the thought process and purpose behind each decision for both hardware and software of the system. In addition to the proposed design decisions, test plan information including various test methods are described in detail as well. The test plan will be followed to ensure all the functions of the system meets the original expectation outlined in the functional specification document. The proof of concept prototype is currently in development and Signatus is expecting to have a working model in early December, 2013.

7 References

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