February 6th, 2012
Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Re: ENSC 440 Functional Specifications for a Wireless Waterflow Monitoring System

Dear Dr. Rawicz

The attached document clearly outlines all the necessary information regarding the functional specification of a wireless waterflow monitoring system. The functional specifications will describe all the appropriate components that will go towards the design and modeling of the system at hand.

In the given document there are several aspects of the final product discussed among which are the following: General system requirements, encompassing the overall requirements in terms of system functionality; Performance requirements, including details about the system features and how they integrate to achieve the goal of detecting water leakage; Reliability and durability of the product, usability and ease of usage in various conditions and safety requirements ensuring product safety.

In putting together this document, our team has focused on separate analysis of each component's functionality in the design of the final product. Also, to ensure that the system works properly we have paid a great deal of attention to the microcontroller performance requirements. For this reason, our microcontroller of choice is Arduino Uno as mentioned in the document.

It is noteworthy that our team at GreenSense Systems is dedicated to adhering to standards and requirements outlined in this document. However, as we move toward the design stage there may be some minor changes made to ensure a better working system and a successful demonstration at the end.

Sincerely,

Timbo Yuen

Product Manager

GreenSense Systems

GreenSense Systems

Functional Specification for

Wireless Ultrasonic Waterflow Monitoring System

Project Team:

Timbo Yuen
Eric Lo
Ehsan Arman
Ye Lin
Babak Razzaghi

Contact Person:

Ehsan Arman
eaa14@sfu.ca

Submitted to:

Dr. Andrew Rawicz – ENSC 440
Steve Whitmore – ENSC 305
School of Engineering Science
Simon Fraser University
Issued date: January 2012

Executive Summary

Water leakage is a problem to water supply systems and in some situations it is even more problematic when trying to investigate the location of the leakage. To reduce these losses in industrial water systems, the Wireless Ultrasonic Waterflow Monitoring System is an accurate system to detect water flow and flags an alarm if there is a water leakage. It will also provide the vital water flow information available to a computer device over Wi-Fi. This data will then be interpreted by convenient and human readable GUI application.

The development of the Wireless Ultrasonic Waterflow Monitoring System requires specifications that describes the components and the overall system functionalities by GreenSense Systems. The attached document contains the functional specifications required for product development. It is important the overall system maintains consistent values when developing the product in both its software and hardware stages. Upon completion for the product prototype, the following stages must apply functional specifications:

- Hardware (RF Electromechanical) - PIC Microcontroller, Transceiver
- Hardware (Electrical) - PIC Microcontroller, Ultrasonic Flow Sensor, Transceiver, Circuit Elements
- Software (Program) - PIC Microcontroller, Transceiver, Ultrasonic Flow Sensor
- Software (GUI Application) - PIC Microcontroller, Transceiver, Computer Device

During the product development stages, GreenSense Systems' development team will refer to the functional specifications when integrating both hardware and software of each system components. The Wireless Ultrasonic Waterflow Monitoring System's functional specifications will conform to all North American national and regional standards and guidelines, which will be received by approval from the American National Standards Institute (ANSI), the Canadian Standards Association (CSA), the International Organization for Standardization (ISO), and the Canadian General Standards Board (CGSB), and the Federal Communications Commission (FCC).

Table of Contents

Table of Figures

Glossary

ADC Analog-to-Digital Converter

DAC Digital-to-Analog Converter

DIP Dual In-Line Package

EEPROM Electrically Erasable Programmable Read-Only Memory

FCC Federal Communication Commission

I2C Inter-Integrated Circuit

MCU Micro-Controller Unit

PCB Printed Circuit Board

SRAM Static Random Access Memory

SPI Serial Peripheral Interface

TWI Two Wire Interface

USART Universal Asynchronous Receiver/Transmitter

1. Introduction

The Wireless Ultrasonic Waterflow Monitoring System will accurately measure the amount of water flowing through an industrial water pipe and sends data to a PC via wireless transmission. By using transit time flow metering, the water flow within a pipe can be calculated by using the time the ultrasonic beam is transmitted and the time it arrives at the ultrasonic transducers. With the two measurements of the downstream and upstream transit times of the transducers, the Wireless Ultrasonic Waterflow Monitoring System intelligently calculates the water flow within the pipe. The requirements for the Wireless Ultrasonic Waterflow Monitoring System are described in this functional specification.

1.1 Scope

This document describes the functional requirements that must be met by a functioning Wireless Ultrasonic Waterflow Monitoring System. This set of requirements are intended to fully describes the proof-of-concept device and partially describes the production device, but as the prototype is being developed, there may be revisions. The requirements defined for the Wireless Ultrasonic Waterflow Monitoring System will be used in the design, but with possible revisions during the prototype development.

1.2 Intended Audience

The functional specification is primarily intended for use by all members of GreenSense Solutions and for Enginuity Consulting LTD. The product manager shall refer to the functional requirements as a guideline for overall design goals and a guide when developing and implementing the prototype. Also, it will provide those who are interested in our product as a source of information and as a brief introductory glance at our Wireless Ultrasonic Waterflow Monitoring System.

1.3 Classification

For our requirements, the following are conventions for classification purposes:

[Rn-p] - a functional requirement

n - the functional requirement number

p - the priority of the functional requirement, which is one of the three:

A - requirement applies to the proof-of-concept system only.

B - requirement applies to both proof-of-concept and final production system.

C - requirement applies to the final production system only.

2. System Requirements

The requirements for the "Wireless Ultrasonic Waterflow Monitoring System" are presented in this section.

2.1 System Overview

The GreenSense Wireless Ultrasonic Waterflow Monitoring System measures the rate of flow in a pipe based on the ultrasonic Transit-time measring theory. A typical transit-time flow meter operates based on the time difference that ultrasonic waves take to travel between transducers. The flow measuring is made by releasing the ultrasound waves in the same and opposite direction of the flow and obtaining the time difference between two directions. The signals will be processed by Arduino microcontroller. After analysing, the data will be transmitted to receiver and then will be displayed on the users` computers. The output may be presented either by figures or by graphs. The data can be stored in memory, analysed, and used for further usages such as leakage detection and pipe ruptures.

In case of leakage, the users will be informed appropriately. If ruptures have been detected an alarm system will go off and inform the users of an emergency situation in the system.

In GreenSense system, the sensors will be mounted outside of the pipes without any intrusion into the pipes (clamp on method). In order to work efficiently, the transducers should be situated in specific distance from each other. In addition, the system works accurately when the transducers are installed in sufficient distance (proportional to the pipe diameter) from the obstacles along the pipes such as faucets, elbows, and pumps.

The transceiver unit will transmit and receive over 802.11b Wi-Fi wireless transmission to communicate the water flow data from the Arduino Uno microcontroller to a PC or a computer device.

The figure 1 shows the System Block Diagram.

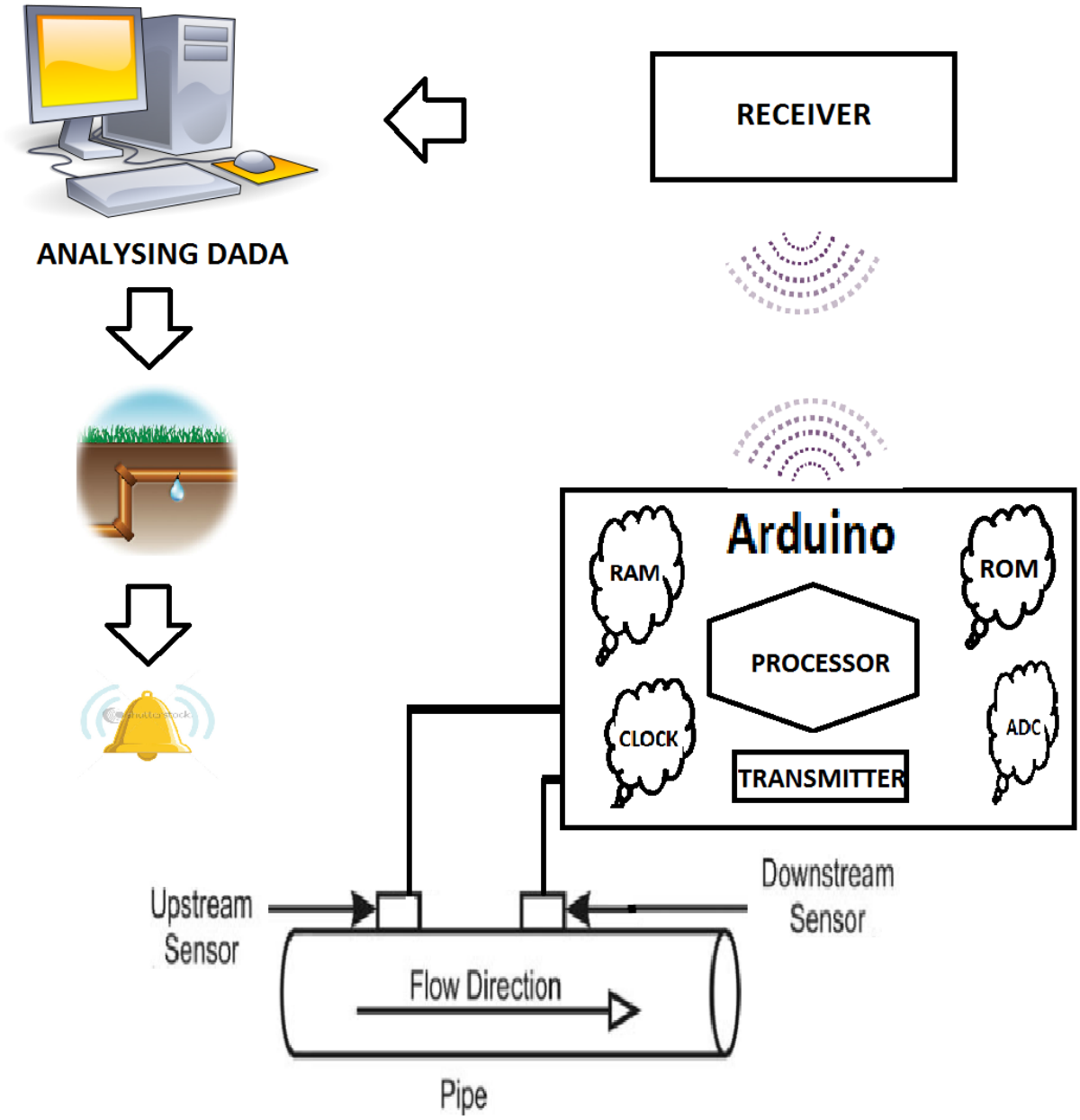
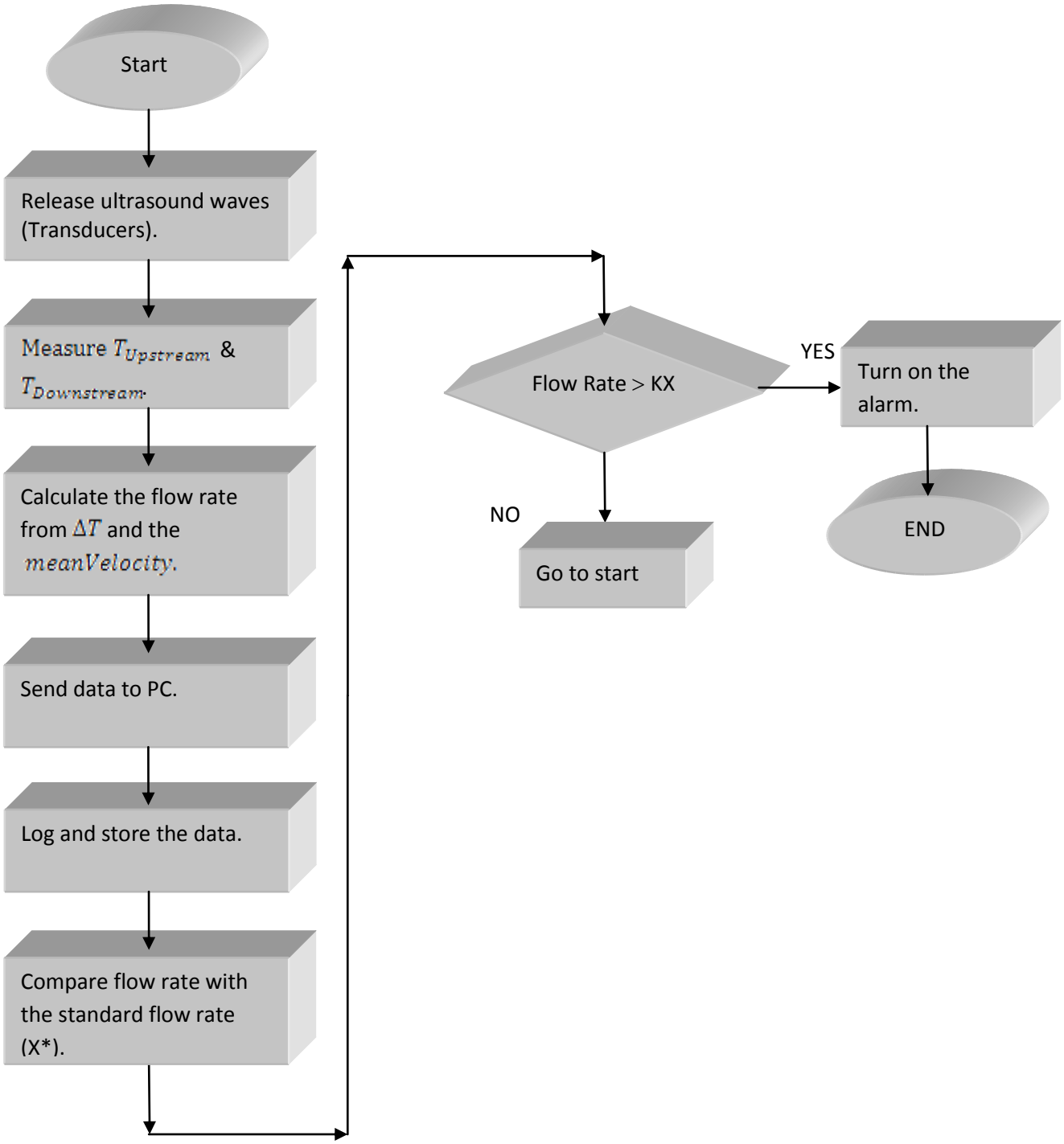


Figure 1 - System Block Diagram [3][4][5].

Figure below displays our system's flow chart.



2.2 General System Requirements

The project general requirements that were assined by ENGINUITY Engineering Consulting are mentioned below:

[R2.21 C] The ultrasonic water flow sensors shall be mounted outside of pipes (fit up to 1")[8].

[R2.22 C] The dada shall be transferred by WIFI from sensors to pc [8].

[R2.23 C] Users shall access to calibrated flow dada in[m^3/s] at a minimum of 5 minute periods[8].

[R2.24 C] The system shall be operated 24 hours a day, and the power supply shall provide electricity to units continuously[8].

[R2.25 C] The data shall be logged for each 5 minute interval during a 24 hour period.

[R2.26 C] The system shall demonstrate the leaks in the pipe[8].

[R2.27 C] The users shall be informed from leakage by alarm[8].

[R2.28 C] The system will meet all appropriate CSA requirements

[R2.29 C] The system shall comply with FCC standards for unintended radiation

[R2.210 C] The price of the finalized system shall be under CAD$1000

[R2.211 C] The system shall utilize WiFi protocols for wireless network communication

[R2.212 C] Our system has to be user interface friendly

[R2.213 C] The system is able to track one pipe at a time.

2.3 Reliability and Durability

[R2.31 C] The system will be serviceable by a trained technician.

[R2.32 C] The system is erosion resistance.

[R2.33 C] The system shall function electronically and mechanically in a satisfactory and predictable, expected manner for a period not less than three years.

[R2.34 C] The system will be resistant to shock and vibrations

2.4 Safety Requirements

[R2.41 C] All electrical and mechanical components of the system will be enclosed and inaccessible by the user.

[R2.42 C] Failure of the hardware will not cause any danger for the user.

[R2.43 C] The system will be electrically safe and well protected from water.

[R2.44 C] The system should not explode or leak any hazardous material.

2.5 Usability Requirements

[R2.51 C] The system will be simple and intuitive to use.

[R2.52 C] The system will be operable by one person.

[R2.53 C] The system should be used for water monitoring but not water controlling.

[R2.54 C] We can connect more than one sensor to the PC to track water usage in different places.

2.6 Performance requirement

[R2.61 C] Water flow Sensor to fit up to 1" pipe (Ultrasonic Sensor preferred)

[R2.62 C] WiFi Wireless Transmitter/Reciever to transmit sensor data from sensor to PC.

[R2.63 C] PC user interface that displays the calibrated flow values in [m3/s] at a minimum of 5 minute periods

[R2.64 C] The system should be operational 24 hours a day (continuous power source to units)

[R2.65 C] The flow data should be logged for each 5 minute interval during a 24 hour period and logged into a .CSV file for later processing.

[R2.66 C] Demonstrate that the system can "detect leaks" – If the current follow surpasses by X standard deviation from previous flow data, an alarm

3. Flow Sensor Requirements (Clamp on type)

An ultrasonic transmitter-receiver pair is used in a typical transit-time flow meter. The flow meter operates by measuring the time for sound to travel between the medium. The velocity and the frequency can be calculated from the time difference[4].

3.1 General Requirements

[R3.11 C] The Ultrasonic transducers (Clamp on type) shall be mounted either in V-method or W-method[4].

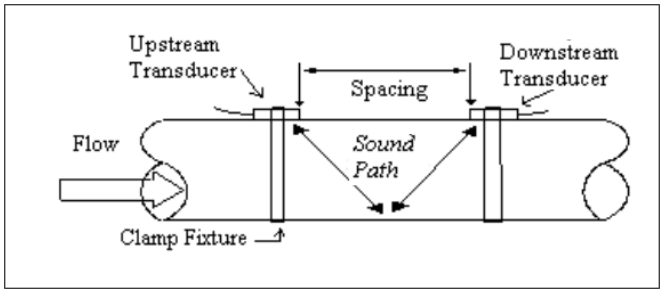


Figure- 2 - method which is suitable to pipe size from 1" up to 12" [4].

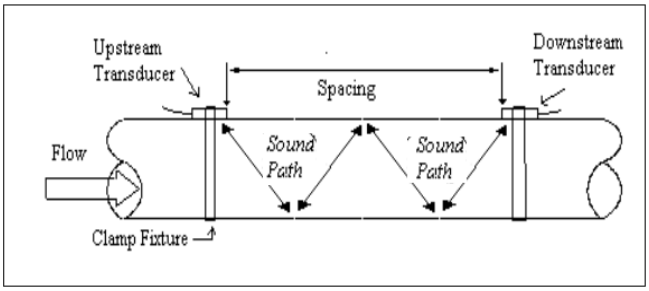


Figure 3 - W-method which is used for pipes less than 1" or 1/2" [4].

[R3.12 C] The two transducers shall be mounted on the same side of the pipe with the specific sapasing to eachother[4].

[R3.13 C] The sound pulse shall cross the pipe flow.

[R3.14 C] The sound shall be transfered continuously between two transducers.

[R3.15 C] The velocity of the liquid in the pipe shall be measured by the difference in the transit time between two transducers[4].

[R3.16 C] The flow rate shall be directly calculated from the velocity of the flow[4].

[R3.17 C] The liquid passing through the pipe shall not exceed a temperature of 110°C, and the temperature of the pipe shall not be more than 80°C [4].

[R3.18 C] The liquid passing through the pipe shall not be lower than a temperature of -20°C, and the temperature of the pipe shall not be lower than -30°C [3].

[R3.19 C] The ultrasonic sensors shall be used for pipes with diameters between 20mm-6000mm[3].

[R3.110 C] The ultrasonic sensors in the upstream shall be mounted at a point with Min. distance of 10D[3].

[R3.111 C] The ultrasonic sensors in the downstream shall be mounted at a point with Min. distance of 5D[3].

[R3.112 C] The ultrasonic sensors in the upstream shall be mounted at a point with Min. distance of 30D from access of a pump [3].

[R3.113 C] The turbidity level of liquid shall be less than 10000 ppm.[3].

[R3.114 C] The ultrasonic sensors shall be used for steel, stainless steel, cast iron, and plastics pipes[3].

3.2 Physical Requirements

[R3.21 C] The flow sensor shall have dimensions shown in below.

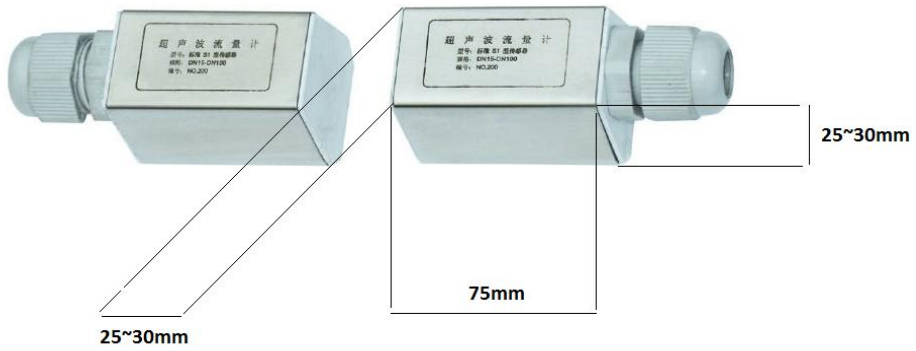


Figure 4 - Dimension of Flow Sensor

Note: The dimension may differ according to the producer.

3.3 Electrical Requirements

[R3.31 C] The ultrasonic transducer shall generate the frequency more than 15khz [3].

[R3.32 C] The ultrasonic transducer shall generate the frequency less than 75khz[3].

[R3.33 C] The flow sensor shall be supplied with DC voltage higher than 5V[3].

[R3.34 C] The flow sensor shall be supplied with DC voltage lower than 36 V[3].

4. Microcontroller Requirements

Microcontroller is the core of the system. The microcontroller is used for connecting the sensor to the PC by USB and process the data sent from the sensor. We chose Arduino Uno which is a popular open-source single-board microcontroller as our processor. Also the microcontroller will be able to switch the mode of the system between run and sleep. The importance characteristic of the microcontroller includes low pin count, small form factor, flexible flash program memory, low power capability, and ease of use.

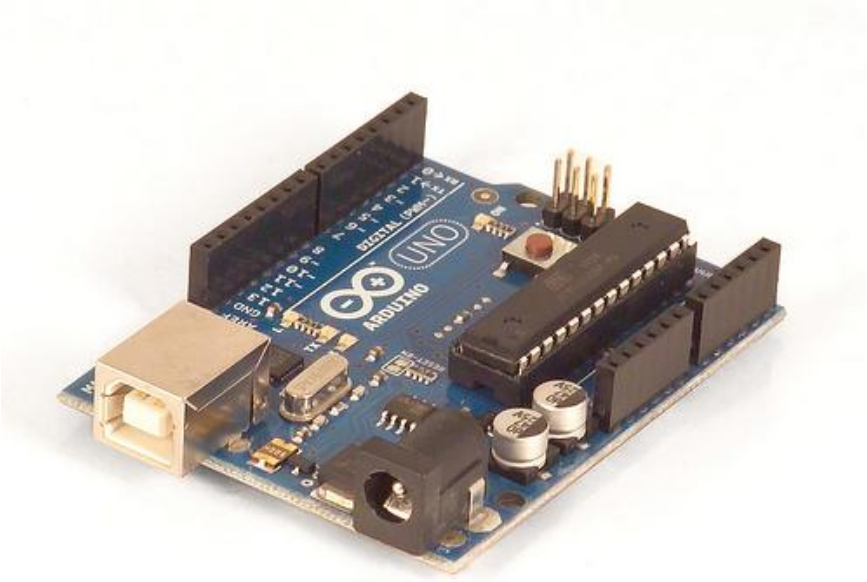


Figure 5 - Arduino Uno MCU

4.1 General Requirement

[R4.11 C] The microcontroller shall support C or JAVA programming

[R4.12 C] The microcontroller is able to do A to D conversion and the resolution of the ADC must be at least eight bits

[R4.13 C] At least 6 analog input pin

[R4.14 C] At least 6 digital input/output pin and with PWM pin

[R4.15 C] The microcontroller is able to connect PC via USB

[R4.16 C] The microcontroller has low power consumption

[R4.17 C] The MCU should be as simple as possible while supporting all required features.

4.2 Physical Requirements

[R4.21 C] The dimension should be within 68.6 mm × 53.3 mm

[R4.22 C] In the prototype, the MCU should be in a dual in-line package (DIP). Therefore, it can easily be mounted on a breadboard

4.3 Electrical Requirements

[R4.31 C] The microcontroller can be powered by USB and external DC power supply.

[R4.32 C] The board can operate on an external supply of 6Vto 20V

[R4.33 C] The operating voltage of the processor is around 5V.

4.4 Reliability Requirement

[R4.41 C] The processor shall have at least 20KB flash memory

[R4.42 C] The processor shall have at least1 KB SRAM

[R4.43 C] The processor shall have at least 512 bytes EEPROM

4.5 Safety Requirement

[R4.51 C] The processor shall operate above -35 degree Celsius to 55 degree Celsius

5. Transceiver Unit Requirements (MRF24WB0MA)

The transceiver unit will transmit and receive over 802.11b Wi-Fi wireless transmission to communicate the water flow data from the Arduino Uno microcontroller to a PC or a computer device.

5.1 General Requirements

[R5.11 C] The transceiver shall be restricted to communicate over a radio frequency range of within 2.412 GHz to 2.484 GHz [2].

[R5.12 C] The transceiver shall transmit data at a bit rate not exceeding 2 Mbps [2].

[R5.13 C] The transceiver shall receive data at a bit rate not exceeding 2 Mbps [2].

[R5.14 C] The transceiver shall not transmit data exceeding 400 m distance away [2].

5.2 Physical Requirements

[R5.21 C] The transceiver shall be operated at a temperature not below 0 °C [2].

[R5.22 C] The transceiver shall be operated at a temperature not exceeding +70 °C [2].

5.3 Electrical Requirements

[R5.31 C] The transceiver's transmitter shall be powered by a DC source not below 2.7V [2].

[R5.32 C] The transceiver's transmitter shall be powered by a DC source not exceeding 3.6V [2].

[R5.33 C] The transceiver shall consume approximately 250 µA when it is in sleep mode [1].

[R5.34 C] The transceiver shall consume approximately 230 mA when consuming maximum power [1].

5.4 Safety Requirements

[R5.41 C] The transceiver device shall not cause harmful interference to radio or television reception [2].

[R5.42 C] The transceiver device shall accept any interference received during its operation [2].

[R5.43 C] The transceiver device shall maintain a separation distance of 20 cm or more to persons during its operation [2].

[R5.44 C] The transceiver's antenna/transmitter shall not be operating in conjunction with any other antenna or transmitter [2].

6. User Document Requirements

User documents will be available on the internet and in hard copy to support our product distribution channels and end customers.

6.1 General Requirements

[R6.11 C] The user document shall include detailed installation instruction.
[R6.12 C] The user document shall include detailed operation instruction.
[R6.13 C] The user document shall include technical specification of components.
[R6.14 C] The user document shall be written in English, Spanish, French, and Mandarin.
[R6.15 C] There shall be a website containing all the documents mentioned above.

7. System Test Plan

To ensure the stability and function of the system, GreenSense team will use several steps to make sure the product is in good shape and works properly. First, the system will be tested under extreme situations such as high water temperature, fast water flow speed. The tester's goal is to make the system fail. If GreenSense team diagnoses any error during the process, GreenSense team will provide a detail report of the error. After GreenSense team ensures the stability of the system, the test will be elaborated to second stage. For second stage, we will use common barrier to try to block the signal of transmitter to see if the connection can stay consisten. The testing plan will be executed near the completion of the product. Below lists the tests that will be performed:

- System Parts Quality Test

- Extreme Situation Test

- Signal Blocking Test

- Overall System Check Test

After GreenSense team finishes the test procedure, the team will report the errors to the customers and correct the errors. The test plan will be executed repeatedly until no errors can be detected.

8. Conclusion

This function specification lists all of the requirements that are needed for our Ultrasonic Waterflow Detecting System. GreenSense team will construct the prototype according to the function specification. Our first goal is to finish all the hardware installation, and then we will optimize the user interface. With this function specification, GreenSense can design a safe and correct product. The prototype will be completed by April, 15th.

9. References

[1] LinkSprite, CuHead WiFi Shield for Arduino, January 30, 2012. [Online]. Available: http://www.linksprite.com/product/showproduct.php?id=73&lang=en. [Accessed: February 4, 2012].

[2] Microchip, MRF24WB0MA/MRF24WB0MB Data Sheet, April 2010. [Online]. Available: http://ww1.microchip.com/downloads/en/DeviceDoc/70632A.pdf. [Accessed: February 4, 2012].

[3] Alibaba.com. *Ultrasonic flow Transducer*. January *2012*. [Online]. Available : http://www.alibaba.com/product-gs/448451869/Ultrasonic_flow_Transducer.html

[4] Shenitech, LLC. *Ultrasonic Flow Measurement Technology:* Transit-time Ultrasonic Flow Meter. January 2012. [Online]. Available: http://www.shenitech.com/flow-meas-ultrasonic-transit-time-flowmeter.htm

[5] Wikipedia, *Desktop computer*, January 2012. [Online]. Available : http://en.wikipedia.org/wiki/Desktop_computer

[6] Shutterstock Images. *Vector Format.* January 2012. [Online]. Available : http://www.shutterstock.com/pic-69762418/stock-vector-vector-chiming-golden-bell-no-gradients.html

[7] Winnipeg 311 city Services. *Water pipe responsibilities for property owners.* February 2011. [Online]. Available : http://winnipeg.ca/waterandwaste/water/pipeResponsibilities.stm

[8] Enginuity Engineering Consulting, *Wireless Water Monitoring System :(Product Requirements)*, January 2012.