Smart Pet Water Fountain

ECE 445 Design Document

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1 Introduction

We will build a smart pet water fountain for people that have pets at their homes. To help my customers better ensure the health conditions of the small pets and accommodate the water supply when he/she needs to leave home for several days, the smart pet water fountain is designed.

Our product solves my customer's problem by monitoring the water quality while maintaining a sufficient amount of freshwater in the freshwater tank.

1.1 Objective

Today, more people around the world have pets than ever before. According to American Pet Products Association's survey in 2020, 67% of U.S. households own a pet which is about 84.9 million homes. This proportion has increased by 20% in thirty years [1]. The breakdown of the pet types shows that cats and dogs are the most popular animals and contribute about 80% of all pets. Same trend of raising cats and dogs happens all over the world. On average, one in three households own a dog globally and about a quarter of households worldwide own a cat [2]. Both cats and dogs prefer flowing water. [3] A source of fresh clean running water can encourage pets to drink. Drinking a certain amount of water daily plays an important role in long-term health for pets, especially cats. As a result, a pet water fountain is essential to most households having cats or dogs as pets. However, owners cannot ensure the water quality when they are away from home for several days. It is likely that pets finished all remaining water in the pet water fountain, or water was polluted somehow by the pet. These can cause the pet to be unwilling to drink water from the fountain.

Our goal is to design a smart pet water fountain that can monitor the water quality and automatically replace water when polluted (not healthy) or running out. We will use sensors to measure the water quality. Common water quality measurement factors include temperature, pH-value, conductance, turbidity, and hardness [4]. Considering the pollution at home can only affect limited factors, we choose temperature, pH-value, and conductance as the three properties used for calculating water quality in our pet water fountain. These data will be collected, calculated, and conveyed to the user in terms of "Good", "Average" and "Bad". The pet water fountain is also designed to self-filter the water every time water is pumped through the submersible water pump.

1.2 Background

There have been many pet pet water fountain products on the market [5], while most of them have only filtration as an extra function besides providing running water [6]. The size of the pet water fountain limits the capacity of the water source, so that most pet water fountains cannot store enough water for multiple pets to drink in several days.

Our pet water fountain can be connected to an extra water source that provides enough water for long-term usage. The link is adaptable to universal water bottles for convenience. The sufficient water source as well as an automatic replacing and refilling function enable pet owners to leave home for several days without worrying about the water supply for pets.

1.3 High Level Requirements

- Able to drain the polluted water and replace it with fresh water. Specifically, the polluted water will be drained by a motor-controlled valve to the “polluted water temporary storage tank” part. After completing the draining process, fresh water will be pumped from the general water supply. The pump should be able to drain the water in 20 to 30 seconds.
- The fountain must accurately monitor the water quality (water temperature, pH value, conductivity). The sensors will be calibrated to an overall accuracy of 5% for all the sensors.
- Water quality index should be displayed on the screen. The readings from the three sensors related to the water quality (water temperature sensor, conductivity sensor and pH-value sensor) will be taken every minute. And the overall water quality index (good, average, poor) will be updated and displayed in the same timely manner.

2 Design

To ensure the health of small pets while our customers are away from home, water quality is a critical point. The water quality monitor system embedded in the smart pet water fountain is the highlight of this project. Water quality will be determined according to three major factors: temperature, PH-value, and conductivity. The results will then be demonstrated with three levels: poor, average, and good. When the water quality is determined to be poor, then the polluted water will be drained, and freshwater will be pumped into the freshwater tank. This leads to the second highlight of this project: the automatic water replacement mechanism. A universal connector will be designed to make it convenient for the customers to purchase big-bottled freshwater and connect to the pet water fountain easily.

2.1 Block Diagram

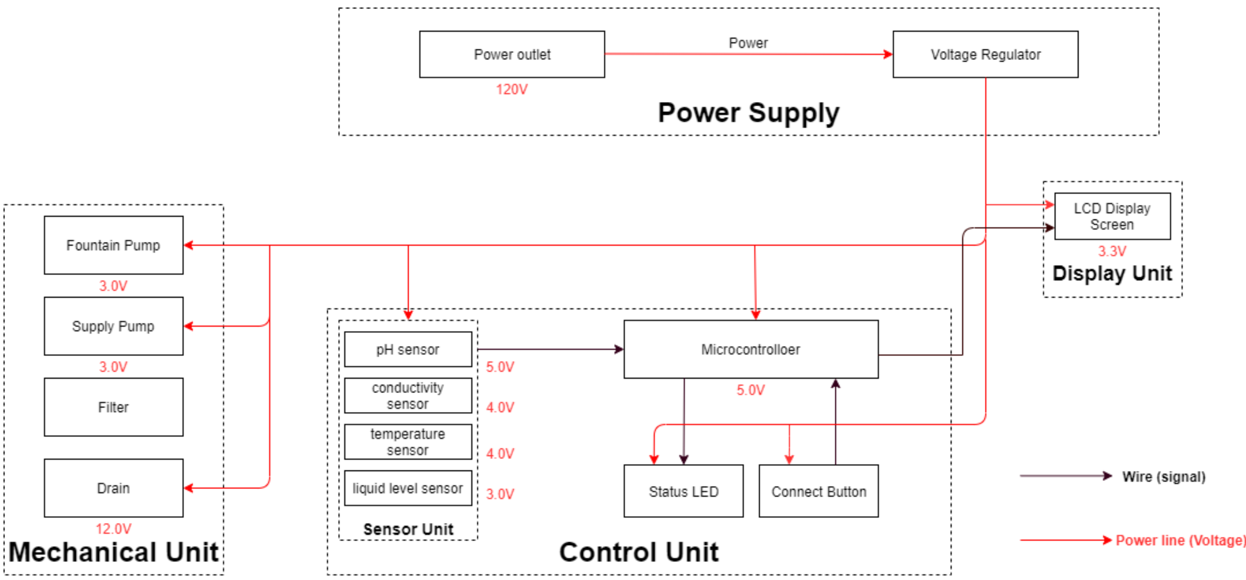

Figure 1 Block Diagram of Smart Water Fountain

2.2 Physical Design

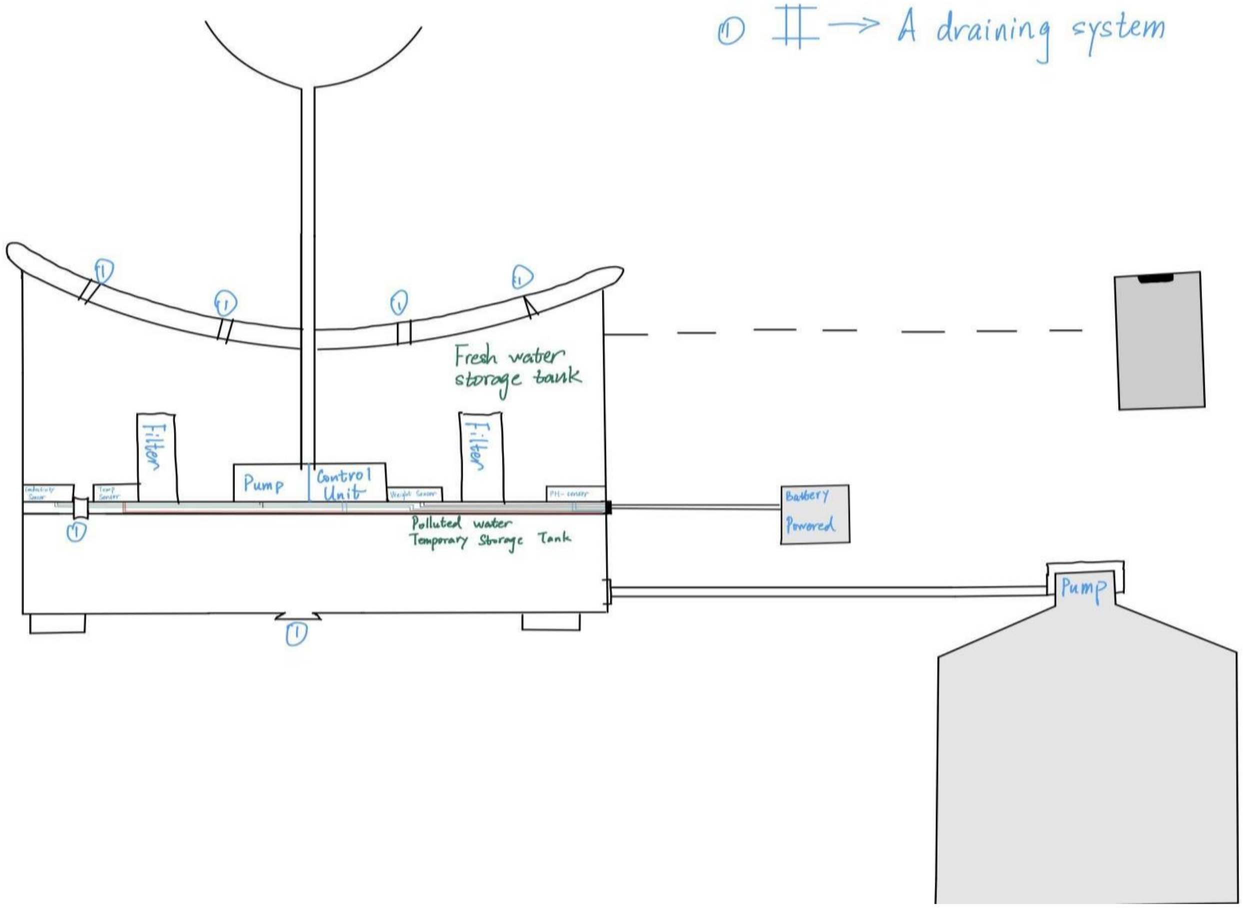

Figure 2 Smart Fountain Physical Diagram

3 Requirements & Verification Tables

3.1 Sensor Unit

This block contains the four sensors. The data acquired from the sensors will be transmitted to the control unit. The control unit will then have some logic designed to send corresponding signals to control other blocks of the water fountain. At the same time, the display screen on the water fountain will display the readings along with the determined water quality level and remaining water quantity.

For the PH-value sensor, temperature sensor and conductivity sensor, values will be retrieved and calculated to determine the overall water quality level. When poor water quality is determined, the water replacement procedures will take place. The weight sensor readings will be used to determine the amount of fresh water left in the water tank.

3.1.1 Temperature Sensor

A water-proof temperature sensor is chosen for the design. The part number from sparkfun is: DS18B20 [7]. This temperature sensor is compatible with a relatively wide range of power supply from 3.0V to 5.5V. The measured temperature ranges from -55 to +125 celsius degrees. Between -10 to + 85 degrees, the accuracy is up to +-0.5 degrees. This sensor can fulfill all requirements needed for this project.

Requirements	**Verification**
1. The accuracy of the Temperature sensor should be within +- 0.5 Celsius degrees. 2. Should be able to work along with other sensors(blocks) which share the same power unit. The input voltage will be between 3.0V to 5.5V at all times and the sensor should be working under these conditions. 3. The frequency of 1 reading every 10 seconds is expected when the pet water fountain is fully functional.	1. Setting up 3 tanks of water each with different temperatures. Temperature will be measured using the sensor as well as a thermometer (a liquid-in-glass Hg thermometer with accuracy level of 0.5 Celsius degrees) [8]. The results will be compared, and certain calibration will be made. 2. Various input voltages (3.0V, 3.5V, 4.0V, 4.5V, 5.0V and 5.5V) will be tested using power supply and test the working conditions for the sensor. 3. In each of the solutions, readings will be acquired every 10 seconds for 1 hour consecutively. The overall deviation between the sensor and the thermometer should be <= 0.5 Celsius degrees overall. And less than 1 outlier (data with relatively higher or lower value) should be reported in ten readings to ensure the overall accuracy.

3.1.2 pH-sensor

pH value is a valued indicator of water quality. This pH-sensor [9] works with 5V voltage, which is also compatible with the temperature sensor. It can measure the pH value from 0 to 14 with an accuracy of +- 0.1 at the temperature of 25 degrees.

Requirements	**Verification**
1. The pH-sensor should be able to measure pH-values from 0-14. In addition, accurate measurement for solutions with pH-value between 5.0 to 8.5 needs to be achieved. Most daily use water has pH-value sitting in this range so an accuracy up to +- 0.3 is sought for. 2. The pH-value claims a <=1 minute response time. When the pet water fountain is working fully functional, pH-values are expected to be reported every minute.	1. A digital pH meter [10] will be used as a reference to verify the accuracy of the pH-sensor. Solutions will be used: lemon juice(pH~2), tomato juice(pH~4), black coffee(pH~5), water(pH~7), bleach (pH up to 13). These solutions are listed based on their pH-value from low to high. And pH values reported from the sensor and the digital pH meter will be compared and necessary calibration will be carried out. 2. pH-values for the 5 solutions mentioned above will be obtained at the fastest possible rate (< 1min per reading). And the readings will be reported consecutively for 1 hour. After confirming the accuracy and the frequency of reading, calibrations will be made to make reading frequency stable.

3.1.3 Conductivity sensor

Conductivity sensor is also part of the water quality assessment. The input voltage is from 3.0 to 5.0V. The error is small, +-5% F.S. The measurement value ranges from 0 to 20 ms/cm which is enough for water quality monitoring [11].

Requirements	**Verification**
1. The measurement range is expected to be accurate within 5% range from 0 to 10ms/cm. 2. A rate of 1 reading per minute is expected for this sensor.	1. Three different kinds of water will be prepared to verify the functions of this sensor: tap water, spring water and distilled water will be used. The result from the sensor will be compared with the results from a digital conductivity meter [12] which has an accuracy of 2% for conductivity from 0 to 9990 us/cm. 2. The conductivity sensor will be programmed to measure for a reading at its fastest rate of 2

	readings per minute for one hour for each of the solutions mentioned. After comparing the results with the digital conductivity meter, ensuring the accuracy of the readings, the sensor will then be calibrated to have stable reading frequency.

3.1.4 Liquid Level Sensor

This sensor [13] is responsible for reflecting how much freshwater is left in the water tank. When the water level is low, fresh water will be pumped to the water tank to ensure the water fountain keeps running with freshwater. This sensor is 0.5 Watts. For water level from 0 to 9 inches, the corresponding sensor outputs readings from 0 to 1.6. From that, the quantity of freshwater left can be determined.

Requirements	**Verification**
1. Alert when the water level is below 1 inch depth. 2. Regarding the overall dimension of the freshwater tank (depth around 4 inches). The accuracy of the sensor from depth of 1 inch to 4 inch should be controlled less than 1cm (a maximum error of 1% at maximum depth of 4 inches).	1. As this sensor is not sensitive when the water level is less than 1 inch, it will be tested with arbitrary water depth multiple times with proper calibration before finally being implemented onto the freshwater tank. 2. A yardstick shall be used to accurately measure the true depth of water. 10 arbitrary volumes of water will be added to the water tank and this sensor is going to be used to measure the water level. Comparing it with the actual reading from the yardstick, the accuracy can be determined.

3.2 Display Unit

3.2.1 Screen

The screen will be used to display the readings from the sensors in a real-time manner [14]. In addition, other necessary information will also be displayed. As described in the sensor part, the water quality and remaining water quantity will be displayed. The screen will be programmed for users to easily read the information.

This 20*4 LCD display screens functions to display the relevant information. After programming the screen, a conclusion of water quality (Good, Average, Poor) will be displayed along with the remaining water level.

Requirement	Verification
1. Display real time water quality level in the format of ‘Water Quality: Good/Average/Poor’ with at most 22 characters.	1. Use an LCD with an incoming buffer that stores at most 80 characters. 2. Program with arduino-compatible AVR ATMega328p chip to display real time water quality through I2C address.

3.3 Power Supply Unit

3.3.1 Voltage Regulator

The integrated circuit will regulate the power supply for each module to maintain their functionality. This chip [15] must be able to handle the maximum voltage supplied by the battery (3.60V ± 0.5V) while ensuring the voltage at each module does not exceed its limit.

Requirements	Verification
1. Can handle the maximum voltage supplied by the power outlet (110V±10V). 2. Can regulate the input voltage to voltage the range required by all the components. 3. Convert the supplied AC to DC. 4. Can operate under environment temperature 5-35°C.	1. Set the input voltage to the regulator to 100V, 110V, and 120V and check the functionality of the regulator. 2. Measure the output to each component on the integrated circuit through a voltmeter. The voltage should be regulated so that all the sensors would fully function and not be damaged. 3. Monitor the output to each component on the integrated circuit through an oscilloscope. All outputs should be direct current to prevent damage to sensors. 4. Test the system under 5°C, 25°C, and 35°C. Measure the output to each component on the integrated circuit through a voltmeter.

3.4 Mechanical Unit

3.4.1 Fountain Pump

The fountain pump [16] must maintain a continuous water supply through the fountain mechanism. The pump must work 24 hours a day, 7 days a week unless the user manually turns off the power supply.

Requirements	Verification
1. The fountain pump should have an operational condition around 3V, 200mA. 2. Can lift a cylindrical water stream of diameter 6mm for a height of 400mm. 3. The fountain pump must serve for a duration of 2 years without maintenance or replacement under heavy workload.	1. Power the pump with a 3V power supply. Measure the current through a multimeter to ensure a 200mA current in the system. 2. Attach a cylindrical pipe of 400mm to the water outlet of the pump. The pipe should be placed vertically upward. When powered with a 3V voltage source, water should be able to fill the pipe.

3.4.2 Supply Pump

The supply pump must function when a low water level alert is raised. While no water supply is requested, the pump must prevent water flow between the main supply and the fountain.

Requirement	Verification
1. The supply pump should have an operational condition around 3V, 200mA. 2. must prevent water flow between the main supply and the fountain when no instruction is received.	1. Power the pump with a 3V power supply. Measure the current through a multimeter to ensure a 200mA current in the system. 2. Place the pump in the product and start filling the main supply. When the supply pump is not operating, water level in the main supply and storage should not change significantly.

3.4.3 Filter

The filter must maintain the water quality through controlling the pH value and conductivity of the water.

Requirement	Verification

Filtered water must have a quality level of “average” under the designed water quality algorithm.	Let water polluted with dust flow through the filter. Test the resultant water with the designed water quality algorithm. A test result of “average” should be emphasized.

3.5 Control Unit

This unit contains the control unit which does the following things:

- When the weight sensor reports a weight less than the minimum weight setting, the control unit will send an alert signal to the user and then control the water supply unit to refill the water fountain with a certain amount of water.
- Computes the water quality with data transferred from the three sensors in the water quality module and sends the result in terms of “Good”, “Average” or “Bad” to the user.
- If the water quality is “Bad”, the control unit will control the drain module to drain the water in the fountain and then control the water supply to refill.
- Water quality results are displayed on the LCD screen as described above in the display unit.

3.5.1 Microcontroller

We choose ATmega328 - TQFP [17] as our microcontroller. We will program the chip to compute water quality and display the result on the LCD screen. It also controls the use of water pumps and valves.

Requirement	**Verification**
1. Can transmit data over I2C to the LCD. 2. Can receive data from the temperature sensor, pH-value sensor, and water conductivity sensor simultaneously. 3. Can output high/low signals directly to the supply pump and the draining system [18] motor.	1. Connect microcontroller to LCD with SDA(PC4) and SCL(PC5) pins. 2. Connect each sensor to the microcontroller through Port A input pins. 3. Connect the two output port pins with the supply pump and the draining system motor, respectively. High/low signals are transferred through each of the pins to control the devices.

4 Tolerance Analysis

The most important tolerance in our project is the evaluation of water quality. We determined the Poor, Average and Good ranges for the temperature, pH-value, and water conductivity.

	Poor	Average	Good
Temperature (°C)	Temp < 5, Temp > 30	5 < Temp < 30	15 < Temp < 25
pH-Value	pH < 6.5, pH < 8.5	6.5 < pH < 7, 8 <pH < 8.5	7 < pH < 8
Conductivity (mS/cm)	Cond > 1mS/cm	Cond < 1ms/Cm	Cond < 0.5mS/cm

The tolerance of all three sensors is calibrated to $\pm$5%.

Another tolerance is about the water level measurement. We use a liquid level sensor that outputs resistance as an indicator of the water level. The output resistance is inversely proportional to the water level. According to the datasheet, the output resistance has ±10% tolerance. We set the alerting water level to 1 inch which corresponds to 1.5 Kohms. With the ±10% tolerance, the lower bound resistance at 1 inch can be $1500 \times (1 - 0.1) \ = 1350\Omega$. The resistance gradient is $140\Omega/inch\ (56\Omega/cm), \pm 10\%$. Then the water level with 1350 Ohms is $\frac{1500\Omega - 1350\Omega}{140\Omega/inch} = 1.07\ inches$. So, there is a buffering water level region up to 1.07 inches.

5 Cost and Schedule

5.1 Cost Analysis

The estimated hour labor cost for our group is $30/hour, 10 hours/week for three people. The remaining semester will be used for project development, thus 8 weeks in total. The total labor cost is then calculated as

3*($30/hr)*(10hr/week)*8(weeks)*2.5 = $18,000

Required parts and corresponding costs are listed below, with the total cost calculated.

Part	Cost (Prototype)	Quantity
Temperature sensor - Waterproof (sparkfun; DS18B20)	$11.95	1
Analog pH Sensor (Gravity; SEN0169)	$56.90	1
Analog Electrical Conductivity Sensor (Gravity; DFR0300)	$69.90	1
Liquid Level Sensor (sparkfun; SEN-10221)	$39.95	1
SparkFun 20*4 SerLCD (sparkfun; LCD-16398)	$24.95	1
Submersible 3V DC Water Pump (adafruit; 4547)	$1.95	2
Solenoid Valve (Digi-Key; 1568-1365-ND)	$7.95	1
Microcontroller (Sparkfun; ATmega328 - TQFP)	$4.25	1
AC/DC Voltage Regulator (Digi-Key; ECS45US15)	$31.93	1
Total	$251.68	N/A

The total cost of this project, including labor and parts, is thus calculated as $18,251.68.

5.2 Schedule

Week	Yu Fen (yuf3)	David Wu (wenyuw3)	Ziqin Zhang (ziqinz2)
3/8/2021	Design Review; Sensor Selection	Design Review; Sensor Selection	Design Review; Sensor Ordering
3/15/2021	Overall Construction	Overall Construction	PCB Design
3/22/2021	Improve Project Design	Improve Project Design	Order parts
3/29/2021	Test on arrived parts	Test on arrived parts	Updata PCB Design
4/5/2021	Sensor Calibration; PCB Soldering	Sensor Calibration; PCB Soldering	Microcontroller Programming;
4/12/2021	Integrate all parts	Integrate all parts	Debug and test with sensors
4/19/2021	Water quality testing; Mock Demo	Water quality testing; Mock Demo	Water quality testing; Mock Demo
4/26/2021	Final Improvement	Final Improvement	Final Improvement

6 Ethics and Safety

6.1 IEEE Code of Ethics I-1

Quoted from IEEE Code of Ethics [18]: “To hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, to protect the privacy of others, and to disclose promptly factors that might endanger the public or the environment.”

We will carefully choose the materials used to build the container. Non-toxic are sure to be used. We will prefer using reusable materials. In addition, the users can choose to buy reusable bottles of water for the freshwater supply for the pet water fountain. Those universal water bottles are safe and reusable. A special connector will be designed, and the universal connection is planned. After the water in the bottle is used up, this reusable bottle can be recycled and reused. This is the most environmentally friendly solution and complies with the IEEE Code of Ethics #I-1. It not only improves the practicality, convenience, and reduces the future cost when using the pet water fountain.

6.2 IEEE Code of Ethics II

Quoted from IEEE Code of Ethics: “II. To treat all persons fairly and with respect, to not engage in harassment or discrimination, and to avoid injuring others.”

As mentioned in the previous section, the mechanical unit involves electronic components that are physically placed in the water tank. The consequence can be serious if the leak proofing is not performed properly. To maintain a safe, convenient using experience, we will be responsible for testing and ensuring all containers meet the demand. These actions must be taken to ensure the safety of using the pet water fountain and protect the others.

6.3 IEEE Code of Ethics I-6

Quoted from IEEE Code of Ethics: “to maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations.”

All team members involved in the development of the pet water fountain have completed “Laboratory Safety training” and have gained required and necessary knowledge in dealing with emergency situations. In case of accidents, proper reaction will be made to ensure the safety of people and property to the largest extent.

7 Citation

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