Automatic Water Pump Controller

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Abstract

In countries including Indonesia, Mexico, Guatemala, and El Salvador, a city water authority supplies the clean water and pumps it into large ground-level storage tanks. A resident's water pump then pumps the water to a water tank on top of his/her house. When the water level in the ground-level storage tank becomes too low, the pump siphons air and shuts down, requiring a resident to manually prime the water pump to get it running again. Residents struggle to monitor the water level of the tanks effectively and keep the pump running properly. To remedy the issue, the Automatic Water Pump Controller (AWPC) system monitors the water levels and controls the pump as necessary to prevent breakdown and maximize water storage without overfilling the rooftop tank and wasting water,

Acknowledgments

Thank you to Professor Taufik for developing the idea for this project and helping us progress along the way. Thank you to the Cal Poly SLO Electrical Engineering department for funding this project and allowing access to lab equipment so the project could be successfully built and tested. Finally, thank you to family for all of the support.

Chapter 1: Introduction and Background

Water is an essential element to a person's life. The human body is composed of 75% water in infants and 55% water in the elderly. Not drinking enough water leads to dehydration which can many detrimental effects on the body, both and physical and mental. Studies show dehydration decreases cognitive function in children and increases the risk for delirium in the elderly [13]. Water is also important in maintaining healthy functioning kidneys, gastrointestinal function, and heart function [13].

Water is used for a variety of purposes ranging from bathing and cleaning possessions to drinking and cooking. In the United States and other first world countries, private water developers and private water agencies have constructed thousands of reservoirs to store and distribute water [11]. The water is sourced from both above ground sources such as lakes and rivers, and from underground water supplies. It is then disinfected by water agencies and tested before distribution. This is unless the person has their own private well. In the end, a person is able to turn on the faucet in his/her home and has fresh water whenever needed.

However, this is not the case in many countries around the world. An estimated 884 million people in the world do not have access to safe water supplies [12]. In many developing countries, people must spend hours every day collecting water from distant places because they do not have a nearby water source [12]. It is estimated that by 2025, "1.8 billion people will be living in countries or regions with absolute water scarcity, and two-thirds of the world's population could be living under water stressed conditions [12]."

Water service constitutes a major problem in countries including Indonesia, Mexico, Guatemala, and El Salvador. The water company limits the amount of water it distributes to communities in these countries which makes it very difficult for the residents to know when and how much water they have access to in the future. For example, in El Salvador, the water company provides water to some communities for 4 hours per day or even as little as once every four days. Indonesia, Mexico, and Guatemala, have a similar water supply problem [2]. As a result, people store water in underground reservoirs and residential rooftop water tanks. However, the pipes used to transport water from the city water authorities often do not have enough water pressure to supply water to the rooftop water tanks. Personal water pumps move water from the ground level to the roof level, but if the water pump activates with no water in the reservoir, the pump siphons air and stops working forcing the user to fix it. Without a properly functioning water pump, the underground water reservoir limits the amount of water that can accumulate.

While most people manually attend to the needs of their water system effectively, many people such as the elderly face physical challenges to successfully maintain the functionality of their water pump system. A control system is the solution. This device must monitor the water levels of the reservoir supply as well as the rooftop tank water supply and regulate the flow of water such that water is always supplied to the consumer when available. It needs to be completely autonomous requiring no user input beyond the initial installation. Users need an affordable system that draws little power to ensure low running costs [9]. The system must function accurately so that residents' water tanks can fill as much as possible without pulling air through the pump. Not every pump system requires the same power source, so the control system must support various pumps as well as common voltage sources. Additionally, the Automatic Water Pump Controller (AWPC) system likely resides in an outdoor setting near water necessitating a high level of weather resistance. Lastly, customers need the device small and light for ease of transportation.

Chapter 2: Design Specifications

The Automated Water Pump Controller (AWPC) offers a solution to the problem. Three water level sensors monitor the water level of both the ground-level water reservoir and the rooftop residential water tank. Once the supply of water decreases down to a point of concern, roughly 10% of the tank capacity, the controller turns off the water pump. This prevents the water pump from siphoning air which can result in the water pump's malfunction or complete breakdown [9]. Similarly, the controller turns off the water pump if the rooftop tank reaches a water level of greater than or equal to 95%. This prevents the tank from overflowing and wasting water.

Residents in the situation described above usually own a water pump which is used to transfer their water to the rooftop tank. To accommodate this, the AWPC uses the input power source to power up the water pump. This allows for the controlling of most common water pumps users may own. The AWPC also relies on the same power range as the power source, allowing for use in a variety of regions [3]. Ideally, installation only requires mounting the water sensors in the two water tanks, plugging the water pump into the AWPC, and plugging in the AWPC to the nearest residential power outlet. The system then runs autonomously as a weather resistant control box capable of surviving outdoors for years at a time.

By owning the AWPC, users do not have to worry about checking the water level in the underground water reservoir several times a day. In other words, the AWPC takes care of the tedious routine of preventing the priming and potential malfunctioning of the water pump. The AWPC turns on the water pump when the underground water reservoir reaches full capacity and it turns it off before the water pump can suck in air. This maximizes the water pump life. Table

2-1 summarizes in details the marketing requirements as well as the engineering specifications of the proposed AWPC.

TABLE 2-1
AUTOMATIC WATER PUMP CONTROLLER REQUIREMENTS AND SPECIFICATIONS

Marketing Requirements	**Engineering Specifications**	**Justification**
2,5,7	Meets standards of International Protection code IP51	The unit sits in an outdoor setting exposed to various amounts of dust and condensation. This requires a level of weather resistance.
2,3,4	Deactivates the water pump if the rooftop water tank's water level exceeds 95%	This prevents the rooftop tank from overflowing.
2,3,4	Turns on the water pump when the water level of the water reservoir reaches 100% of the tank's capacity	This will maximizes the amount of water that the user may store.
2,3,4	Turns off the water pump before the water level of the water reservoir drops below 10% of the tank's capacity	This prevents the water pump from sucking in air, resulting in its malfunction
1,5	All materials cost less than $100	This price ceiling keeps the device affordable
2,5	Requires no additional user input beyond initial installation	Residents should not have to worry about operating their water pump system
5,6	Uses and outputs a range of ~80-264Vac within 5% tolerance	This negates the need for an additional power source beyond what already exists. Wall socket voltages include these common voltage ranges.
2,4	Responds to water level with less than 5% error	Pump extracts the maximum amount of water possible without risking malfunction caused by intake of air

1,3,5	Consumes less than 500 mW during standby operation	During its inactive state, it uses minimal power use to maintain efficient function
5,6	Installation takes less than 1 hour for an untrained user	The device comes ready out of the box, requiring only that the user installs the sensors, attaches their pump, and plugs the device in
5,6	Smaller than 8”x5”x3”	This size restraint ensures the device places easily and does not require excessive space
5,6	Weighs less than 5 lbs	A user can more easily carry a lighter device
5	Water level sensors must be made of high density polypropylene	Sensors must not contaminate water supplies or else users may get sick
Marketing Requirements 1. Affordable 2. Completely autonomous 3. Low power consumption 4. Accurate pump control 5. Unobtrusive 6. Easy to install 7. Weather Resistant		

Chapter 3: System Design and Functional Decomposition

Figure 3-1 and Table 3-1 show the level 0 block diagram and the input signals of the AWPC system consecutively. The microcontroller within the AWPC relies on the data from the three water level sensors in order to accurately control the water pump. For simplicity and ease of use, the AC power source provides power to the microcontroller, the user-supplied water pump, and relay. The microcontroller then makes a decision based on the status of the sensors and outputs a flow of water from one tank to the other.

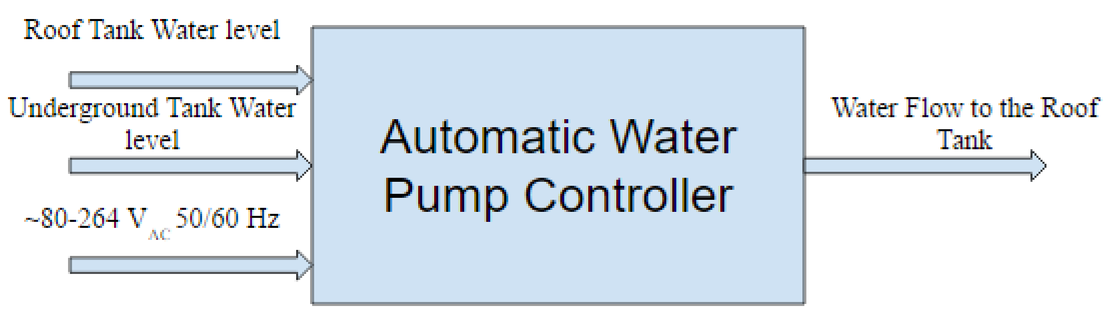

Figure 3-1: Level 0 Black Box Diagram

TABLE 3-1

LEVEL 0 AUTOMATED WATER PUMP CONTROLLER SYSTEM FUNCTIONAL REQUIREMENTS

Module	Automatic Water Pump Controller
Inputs	• Roof Tank Water Level: 0-95% full capacity • Underground Tank Water Level: 10-100% full capacity • Power: ~80-264 V_{AC} 50/60Hz 65W
Outputs	• Water flow to the Roof Tank
Functionality	Turns ON/OFF water pump to transfer water from underground's tank to roof's tank. The input power should be able to handle ~80-264 V_{AC}. The output voltage varies between ~80-264V_{AC}(depending on the input source).

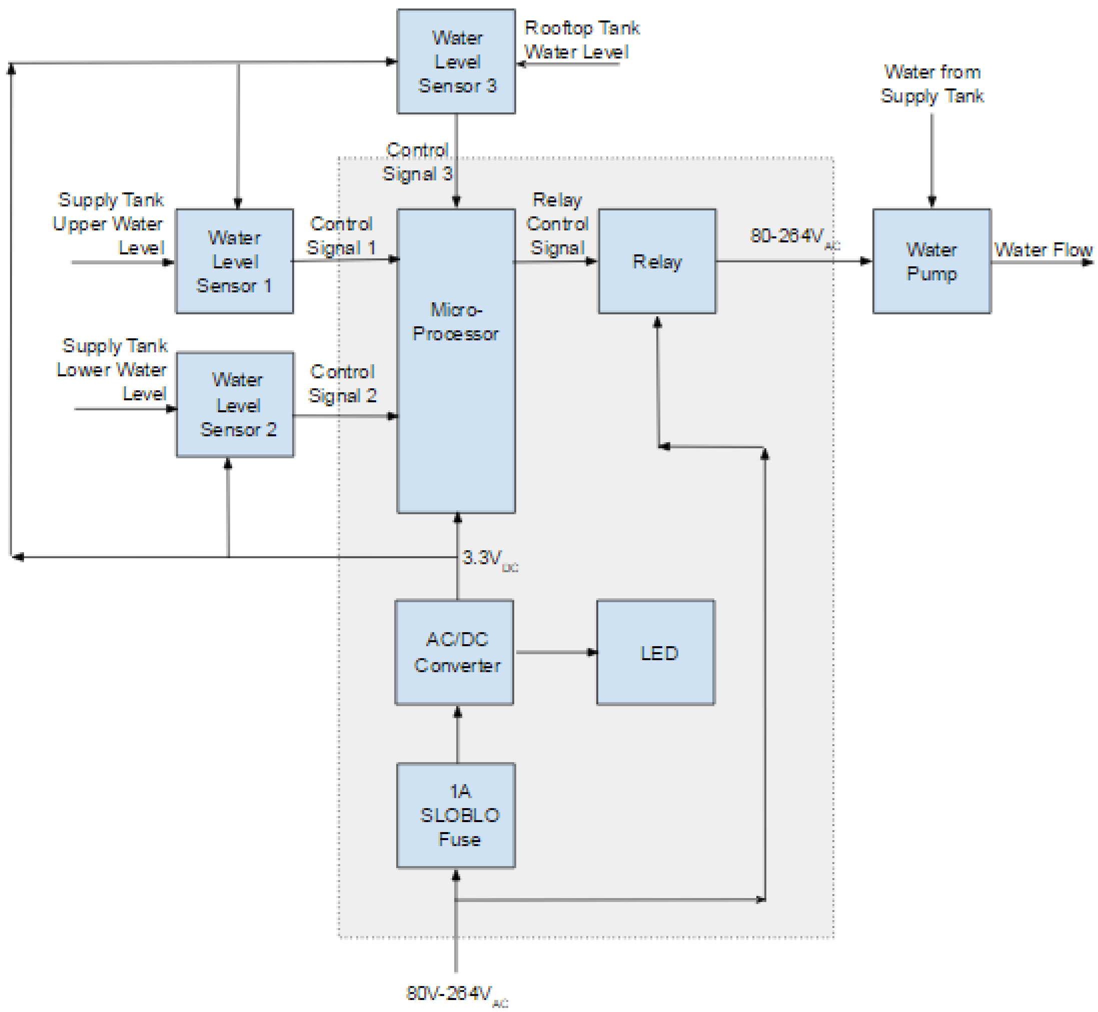

Figure 3-2: Level 1 Black Box Diagram

Figure 3-2 shows the level 1 block diagram of the system which features all of the major modules and their connections. The line voltage feeds into AC/DC power module [4]. The resulting voltage powers the microprocessor and the three sensors. The line voltage splits off to feed the relay which relies on a control signal from the microprocessor to determine whether or not the line voltage passes on to power the water pump.

TABLE 3-2
LEVEL 1 AUTOMATED WATER PUMP – 1A SLOBLO FUSE

Module	1A SLOBLO Fuse
Inputs	• Power: ~80-264 V_{AC} 50/60Hz
Outputs	• Power: ~80-264 V_{AC} 50/60Hz
Functionality	Protect the AC/DC converter from large currents..

Table 3-2 shows information about the 1A SLOBLO fuse. This fuse provides overcurrent protection for the AC/DC converter. It is SLOBLO allowing short surges of current through without blowing the fuse. This is to ensure the components can source the starting current they need.

TABLE 3-3
LEVEL 1 AUTOMATED WATER PUMP – LED

Module	LED
Inputs	• DC: 3.3 V_{DC}
Outputs	• Red Light
Functionality	Produce light signifying the system is powered

Table 3-3 shows information regarding the LED. The LED uses the power output of the AC/DC converter to produce light, signifying there is power to the system.

TABLE 3-4
LEVEL 1 AUTOMATED WATER PUMP – POWER MODULE

Module	AC/DC Converter
Inputs	• Power: ~80-264 V_{AC} 50/60Hz
Outputs	• DC: 3.3 V_{DC}
Functionality	Rectify the AC signal and steps down the DC voltage to 3.3V.

Table 3-4 shows information about the AC/DC Converter module. The AWPC will be designed to accept universal AC input such that the AWPC could be used anywhere regardless the available local residential AC input. In this module the system rectify the AC signal provided by an electricity company, then step down the DC voltage to 3.3V.

TABLE 3-5
LEVEL 1 AUTOMATED WATER PUMP – WATER SENSOR 1 MODULE

Module	Water Level Sensor 1
Inputs	• Supply tank water level: 100% capacity
Outputs	• Control Signal 1: 3.3 V_{DC}
Functionality	Constant measurement of the water level in the supply tank.

TABLE 3-6
LEVEL 1 AUTOMATED WATER PUMP – WATER SENSOR 2 MODULE

Module	Water Sensor 2
Inputs	• Supply tank water level:10% capacity
Outputs	• Control Signal 2: 3.3 V_{DC}
Functionality	Constant measurement of the water level in the supply tank.

TABLE 3-7
LEVEL 1 AUTOMATED WATER PUMP – WATER SENSOR 3 MODULE

Module	Water Sensor 2
Inputs	• Rooftop tank water level: 95% capacity
Outputs	• Control Signal 2: 3.3 V_{DC}
Functionality	Constant measurement of the water level in the rooftop tank.

Tables 3-5, 3-6, and 3-7 are modules for the Water Sensors 1, 2, and 3. The main goal of these modules is to measure the tank's water level. To simplify the design, the three sensors will be selected to be from the same manufacturer. As an example, the sensor will be chosen to have an output signal of 3.3V which will output a control signal to the microcontroller.

TABLE 3-8
LEVEL 1 AUTOMATED WATER PUMP – MICROPROCESSOR MODULE

Module	Microprocessor
Inputs	• Control Signal 1 • Control Signal 2 • Control Signal 3 • Power: 1.8V~3.6 V
Outputs	• Relay Control Signal: 3.3 V_{DC}
Functionality	Process data from the control signals and send out a control signal to the relay.

Table 3-8 shows the input and output signals of the Microcontroller module. The main function of the microcontroller is to process data acquired from the water sensors and send an output signal to either activate or deactivate the relay.

TABLE 3-9
LEVEL 1 AUTOMATED WATER PUMP – RELAY MODULE

Module	Relay
Inputs	• Relay Control Signal • Power: ~80-264 V_{AC} 50/60Hz
Outputs	• Power: ~80-264 V_{AC} 50/60Hz
Functionality	Let signals pass through when the relay is activated.

Table 3-9 shows the input and outputs signals from the relay module. The main function of this module is to close or open the path between the power path signal and the water pump.

TABLE 3-10
LEVEL 1 AUTOMATED WATER PUMP – WATER PUMP MODULE

Module	Water Pump
Inputs	• Water from the supply tank • Power: ~80-264 V_{AC} 50/60Hz
Outputs	• Water flow to the Roof Tank

Functionality	Transfer water from the supply tank to the rooftop tank.

Table 3-10 shows the input and output signals information of the water pump module. The main goal of this module is to wait for the relay to be activated to start (or deactivated to stop) pumping water to the roof tank.

Chapter 4: Implementation and Testing

To allow a water pump to be easily connected to the AWPC, a NEMA 5-15 socket was chosen and mounted to the exterior of a compact plastic 7.5”x4.3”x2.2” enclosure. A rocker switch was chosen to serve as the on/off switch for the device and mounted near the outlet. Finally, a red LED was mounted next to the rocker switch as an indicator showing when the device is on or off. These features can be seen in Figure 4-1. A dremel tool was used to cut the holes necessary to mount the parts and the top of the enclosure secures with self tapping slotted screws.

Figure 4-1: Front of AWPC

Vertical float switches were chosen as sensors to monitor the water level of both the water supply storage and the rooftop water tank. They are simply switches that pass through a voltage based on whether or not the free-moving buoyant piece is in the up or down position. The user is expected to mount the rooftop sensor to the top of their rooftop tank while the other two sensors mount to the top and bottom of the water supply tank.

The user's water pump is to be connected to the power receptacle mounted on the outside of the enclosure. This connects internally to a 40A solid state relay rated for passing 24-380 Vac using a 3-32 Vdc control voltage. This large current rating and wide voltage range is perfect for use with the high current demand of water pumps and supports the 110Vac of some countries and the 220Vac of others.

A Texas Instrument MSP430G2553 microcontroller was chosen to control the relay based on the inputs of the float switches. A 10kΩ pull-up resistor was used for each float switch when connecting to the microcontroller. The MSP430G2553 was especially a good choice for this project as it is very low power consumption and can be powered from as low as 3V. It has more features and I/O than necessary, but we already had a couple in possession from past experiments so it became an ideal choice. The full schematic of the project is shown in Figure 4-2.

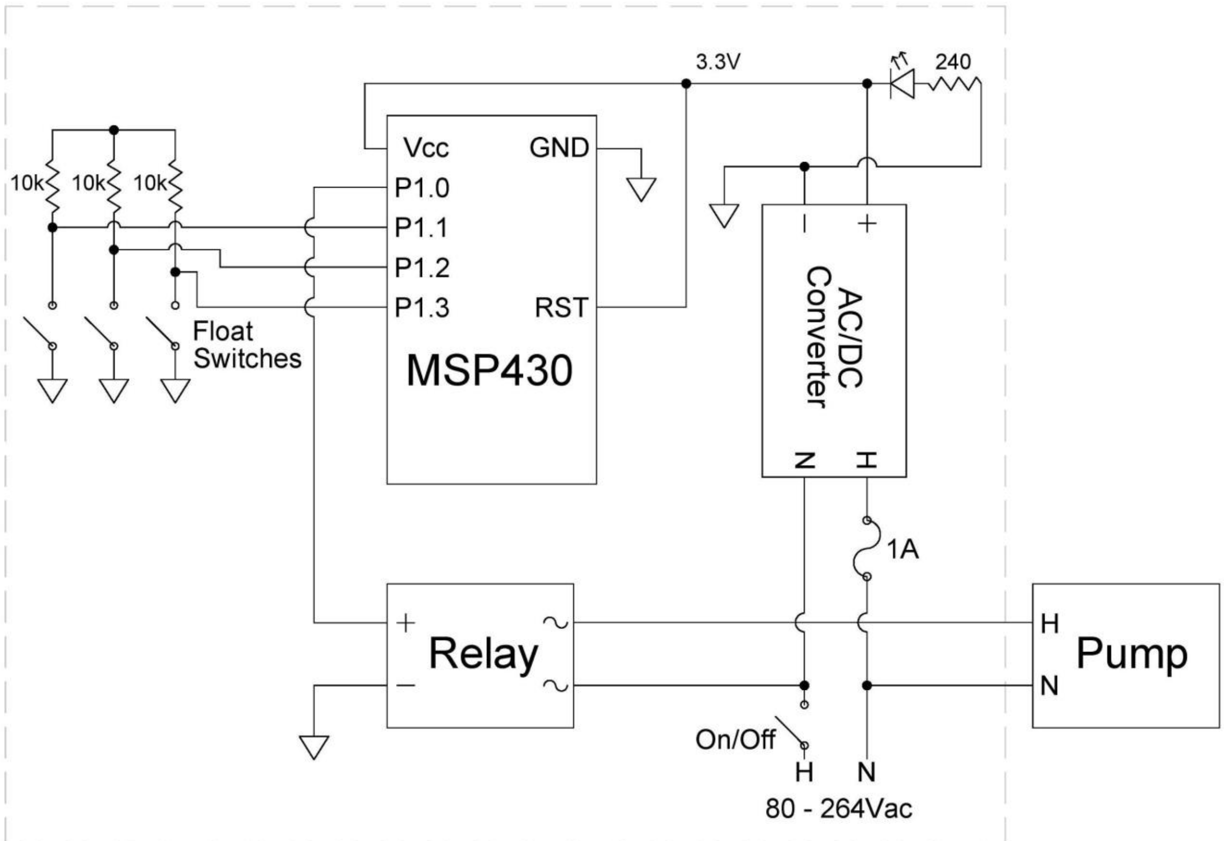

Figure 4-2: Schematic

The microcontroller, the relay, the LED, the pullup resistors, and the AC/DC converter are parts of the project that consume power besides small losses throughout the components' connection. The power consumption of the device is the sum of the microcontroller 230 µA usage, the relay's 6 mA usage, the LED's 17 mA usage, the resistors' total 990µA usage, and the AC/DC converter's maximum 100 mW usage. Therefore, the AWPC consumes an estimated 79.93 mW not including the AC/DC converter, or a grand total of 180 mW assuming worst performance of the converter.

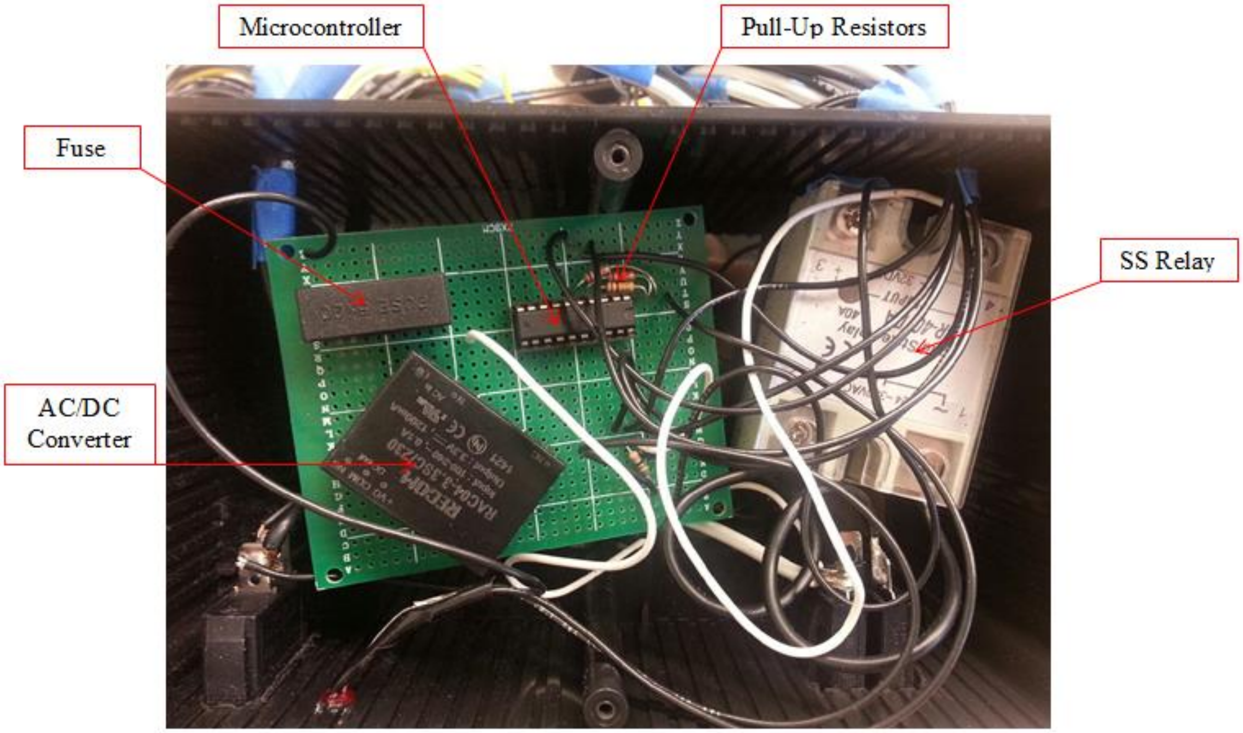

Figure 4-3: Inside of AWPC

Figure 4-3 shows the inside of the device featuring identification of the primary components. In order to test the project, a simply water pump system was created including a ½ HP water pump, two plastic containers, and PVC pipe. The piping was routed from one container into the inlet of the pump, and then from the outlet of the pump to the other container. One container was to serve as a water supply and thus was filled with water and the two corresponding float switches were mounted at the top and bottom of the container. For ease of installation, the float switches were mounted using duct tape. The other container served as a rooftop tank so the corresponding float switch was mounted on top as seen in Figure 4-5. Once the sensors were mounted, the water pump was simple plugged into the AWPC and then we switched the on/off switch to on.

The test needed to check for three events. The pump needed to turn on when the water supply container was near full, turn off when the water supply container was near empty, and turn off when the rooftop tank was full. These three events were successfully confirmed through multiple iterations of the test. The only problem encountered during the testing phase was with the water pump itself. The rotor on the inside has rusted such that it did not move freely when power was supplied to the pump. This required us to open the water pump and dislodge the rotor using WD-40 and a screwdriver. Once this problem was fixed, all tests proceeded without problem.

Figure 4-4: Water "Supply" Storage Container for Testing

Figure 4-4 shows the storage container full of water used for testing.

Figure 4-5: Water "Rooftop Tank" Container For Testing

Figure 4-5 shows the "rooftop" storage container being filled with water for testing.

Chapter 5: Conclusion and Recommendations

The main goal of this project is to provide an autonomous system that will prevent a water pump from syphoning air and maximize the efficiency of water movement from one tank to another. After working on this project, we were able to better understand the difficulties people face when trying to prime a water pump after it has stalled. The AWPC will prevent the water pump from syphoning air and it will be always ready to transfer water to the secondary tank whenever the underground tank is full. The AWPC will be a great device to have in those communities where water is scarce and the need of storing water is a necessity.

All of the specifications listed in Table 2-1 were met including the price constraints. The prices of the components used in the project totaled to $206.70, coming in 13.88%, or $33.30, under budget. The final product met all performance requirement after being tested using a water pump system of PVC pipes and storage containers.

There is still room for future improvements on the AWPC Color coding the sensors would make it even more clear which one goes where. This implementation would make the installation process much easier for the customer by reducing the chances of incorrect installation. The float switches are currently attached to 15 feet of wire each, but can be easily extended is necessary. There is no analog signal being transmitted so interference is not an issue. The enclosure is currently moisture and dust resistant, but for it to thrive in an outdoor setting, it would be beneficial for it to be completely water and dust proof, especially if it is to be placed near bodies of water. Finally, the MSP430g2553 includes a low-power mode that is not utilized in this project. By changing the inputs of the sensors to interrupts, one could leave the microcontroller in low-power mode until it needs to perform an action. This could dramatically reduce its power usage.

Appendices

Appendix A: User's Guide

1. Unscrew the top part of the sensors (as shown in Figure A-1) and install the mounting brackets (Figure A-2)

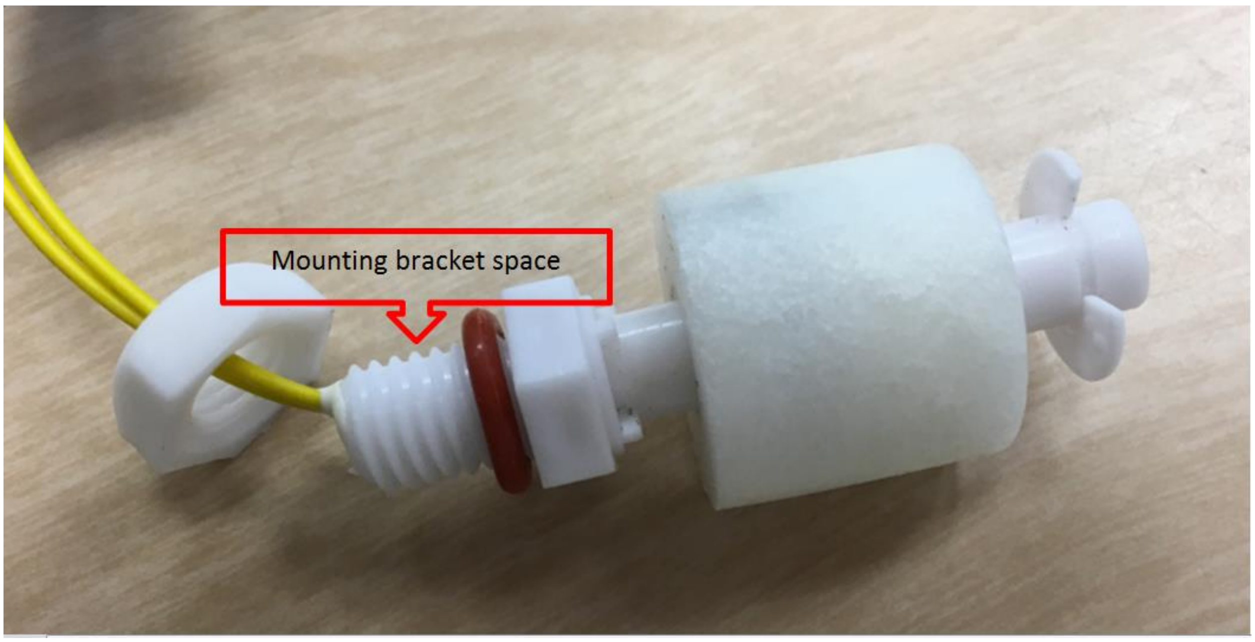

Figure A-1: Sensor - space for the mounting bracket

Figure A-2: Recommended U-type mounting brackets

2. Install the sensor labeled “R” in the water tank located on the roof of the house. The bracket slot should be on top of the flotation portion. It is recommended that this sensor should be mounted at a place of about 95% full capacity of the tank. This will prevent overfilling the water tank.

3. It is recommended to use a waterproof, non-toxic adhesive to glue the mounting brackets to the wall of the water tank. Alternatively, you can use mounting screws if they do not compromise the seal of the tank. Finally, magnet pairs could be used to hold the brackets in place if installed on thin tank walls.

4. Install the water sensor labeled “T” at a place of about 95% full capacity of the underground tank. The bracket slot should be on top of the flotation portion. The water sensor labeled “ B” must be located above the pipe/hose that connects to the water pump. This sensor will prevent that the water level goes below the sensor which will prevent malfunction of the water pump. The flotation portion should be on top of the bracket slot. Note that since this sensor is mounted at the bottom of the tank, it will be upside down compared to the other two sensors.

Figure A-3: Supply Tank Sensors
from left to right: rooftop tank sensor, bottom of supply tank sensor, top of supply tank sensor.

5. After having the sensors installed, connect the AWPC to your wall socket. WARNING: Make you use a power source you would normally use for your water pump. This ensures your pump will run correctly.
6. Connect your water pump to the power socket located on the AWPC. Use an adapter if your plug is not type B.
7. Press the power button to turn the AWPC ON. The LED will turn on as an indicator that the device is ON.

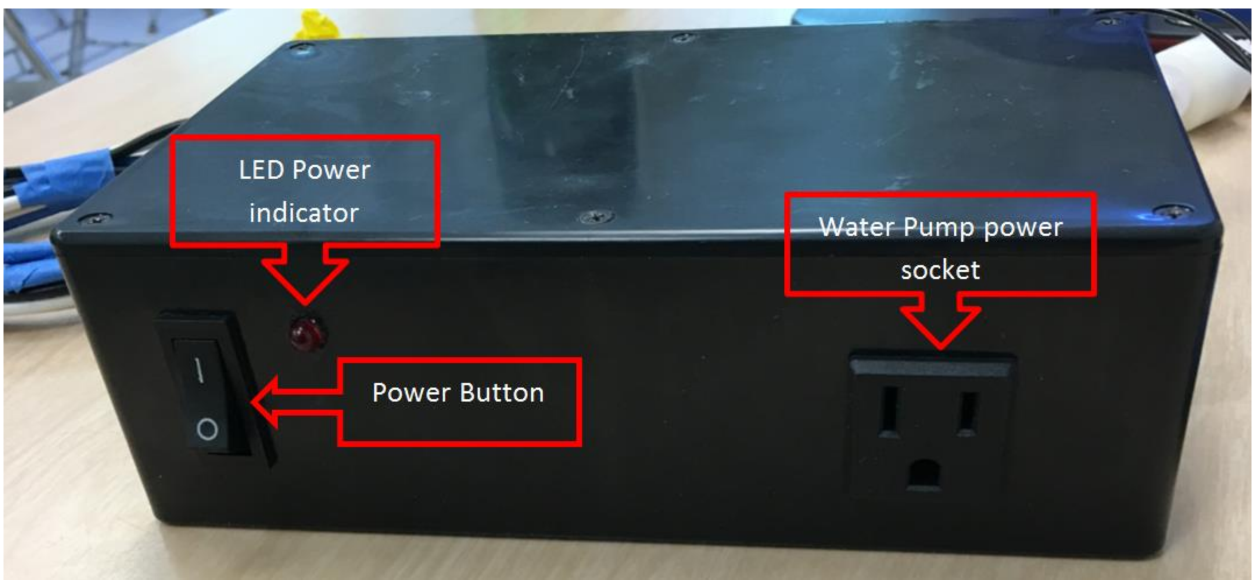

Figure A-4 The Automatic Water Pump Controller

NOTE: In case the system does not turn on, make sure that the system is connected to the power source. Also, check that the fuse is not damaged.

When re-placing the fuse it is recommended to use a 1A Slow Blow fuse. The location of the fuse can be seen in Figure 4-3.

Appendix B: Project Schedule

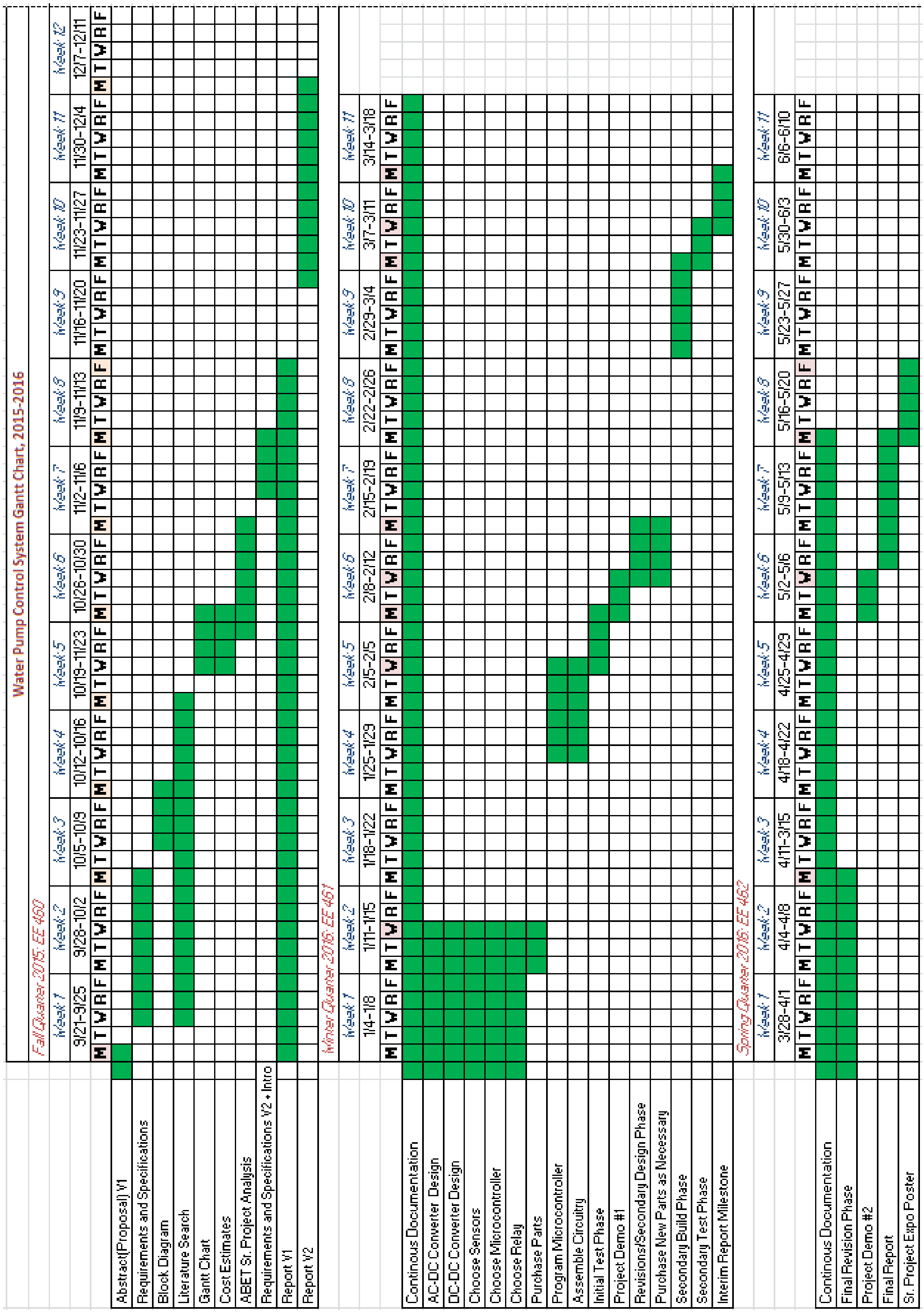

Figure B-1: Project Gantt Chart

Figure 3 shows the scheduling for the major project milestones. This includes two design and build iterations as well as time for ordered parts to arrive.

Appendix C: Planned Estimated Costs

TABLE C-1
ESTIMATED PROJECT COSTS

Cost Estimates		
	Item	Cost
System Parts		
	Enclosure Material	$40
	Controller	$15
	Circuitry & Wires	$30
	Sensors	$25
	Subtotal	**$100**
Testing Parts		
	Water Pump	$100
	Tubing	$20
	Containers	$20
	Subtotal	**$140**
	Grand Total	**$240**

Table C-1 shows the anticipated cost estimates for the Automated Water Pump Controller. Pumping water from one tank to the other during the testing phase requires PVC tubes. Cost estimates include wires and circuit boards because the system requires wires to make connections between components and the circuit board to integrate all of the components. The section labeled other includes tools such as hot glue, and electric tape. And finally, the enclosure material serves as the material cost estimate for the box used to protect all the circuitry from the weather, dust, and water that may endanger the inner circuitry.

Appendix D: Bill of Materials

TABLE D-1
BILL OF MATERIALS

Part	Description	Part #	Quantity	Price (total)
Float Switch pack	5 pack	B0056EWADA	1	$9.80
Relay	min 3Vdc ctrl, rated 24-380Vac	COM-13015	1	$14.66
Water Pump	.5W, 110Vac	50635	1	$30.15
AC to DC converter	80 -264 VAC input, 3.3V output	945-2178-5-ND	1	$15.79
Fuse Holder Lid	For use with 36-4527-ND	36-4527C-ND	1	$0.29
Fuse Holder	for 5mm x 20mm fuses	36-4527-ND	1	$0.71
Fuses	1A, SloBlo	F2419-ND	5	$9.45
Thread Tape	white		1	$1.27
WD 40	Lubricant in can		1	$2.98
Pipe Glue	Adhesive for use with PVC pipes		1	$4.94
Pump Tubing + connectors	1” PVC pipes and 1” threaded connectors		1	$11.54
Check Valve	1” for PVC Tubing		1	$12.18
Large containers for water	intended for storage		2	$18.77
14 AWG wire	white, rated for up to 15A, 25'		1	$6.49
14 AWG wire	Black, rated for up to		1	$6.49

	15A, 25'			
Type B Socket	AC 125V 15A		1	$5.65
Banana Socket pack	2 black, 2 red		1	$6.25
Rocker Switch	5 pack		1	$5.08
Perfboard Set	Variety of sizes		1	$7.99
Microcontroller	3.6V supply,	msp430g2553	1	$2.70
22 AWG Wire	100' Stranded Black Wire		1	$11.86
Enclosure Material	7.5"x4.3"x2.2", black, plastic	1591ESBK ABS	1	$15.81
3 wire Plug	NEMA 5-15 Grounded		1	$5.85
Test Materials Total		**88.08**		
Device Materials Total		**118.62**		
Grand Total		**$206.70**		

Table D-1 shows the list of all materials purchased during the development of the AWPC. The prices listed in blue are parts purchased to use in the AWPC while the prices listed in red are materials purchased to assemble the testing apparatus. These prices include tax and shipping. Certain items or packs of items, like the wire spools, were not used in their entirety and therefore skew the actual price to make the AWPC. Now that it is known what materials work well in this project, it would be easy to reduce shipping costs by consolidating orders. This would push the cost of materials below $100 for the device.

Appendix E: Senior Project Analysis

Summary of Functional Requirements

The Automatic Water Pump Controller (AWPC), an easy to use compact control box, runs off line voltages between ~80-264 V_{AC}. It includes two water level sensors and a cord for power. A user installs one water level sensor in the water supply reservoir, and the other inside their rooftop water storage tank. Then the user plugs their water pump directly into the control box and activates the system. With no further actions necessary, the AWPC monitors the two water levels and activates the pump at times necessary to keep the rooftop storage tank full while preventing the water pump from siphoning air [9]. For a list of all specifications, see Table 2-1.

Primary Constraints

There exist both monetary and location-based constraints associated with this project. The AWPC must function in various countries such as the U.S. which uses 110V or Indonesia which uses 220V. One must also keep in mind the various wall outlet types [3]. Making the system easy to install and independent of the users' water system offers yet another challenge. This may require designing protection circuitry in case a user makes a mistake during installation. For a list of all specifications, see Table 2-1.

Economic Impacts

As with all products, there exist many economic impacts likely to result following the implementation of this project. Many companies benefit from the need for goods and services associated with the project such as shipping, raw materials, parts, manufacturing, and labor. Almost every aspect of the creation of the AWPC requires labor in some shape or form making it an important aspect. Local banks also benefit from the additional purchase made by the businesses and the product user. Users benefit from the AWPC through its elongation of the water pump's lifetime and overall less power usage. With an effective control system in place, the water pump malfunctions far less resulting in less money used for repairs and replacements. Besides the initial investment of buying the product, there exist no upkeep costs beyond its use of power with the exception of repair costs in the event of break-down. This becomes more and more likely throughout the product's lifetime until a replacement becomes necessary. Users have the option of replacing the water level sensors, the only replaceable part, in case they alone fail.

The AWPC requires a user already have a compatible water pump to use in conjunction with the control box. The may require users to purchase a new water pump further stimulating local economy while helping ensure a fully functioning autonomous water pump system for the user. The user of the AWPC, someone who seeks autonomous control of their home water system, pays low overall costs for the affordable product. Not including design or testing cost estimates, the estimated sum of parts totals $100[4]-[7]. Table C-1 lists specific cost estimates. The project takes an estimated 150 hours of development time ending around April of 2016.

If manufactured on a commercial basis

The estimated fixed costs total $9240 to design and development a prototype followed by an estimated $100 per unit plus labor likely meaning $200 per unit. If each unit sells for $250, a positive profit margin would emerge after 185 units sold assuming inefficient manufacturing. Assembling this product through lean manufacturing practices on a production line would result in much lower production costs. However, this would result in higher from the investment necessary to create a manufacturing line. If it costs an estimated $50,000 to create a manufacturing line that reduced production costs to roughly $100 and the selling price remained

$250, it would require 334 units sold to make profit. However, these factories could produce the units at a much faster rate than if not created through lean manufacturing. If 500 units sell per year, the device makes $75,000 yearly profit.

Environmental Impacts

The materials that make up the AWPC include electronics composed of metals mined out of the earth. Sometimes these mining operations impact ecosystems quite seriously due to the overall destruction of the surrounding environment. The manufacturing process uses harsh chemicals, which if not disposed of properly, seep into water supplies contaminating drinking water for humans and animals alike [2]. Like all other electronics, the AWPC consumes power which puts pressure on power generation plants to produce more energy. This requires burning more fossil fuels resulting in more greenhouse gasses emitted into the atmosphere. Greenhouse gasses also accumulate from the increased vehicle presence caused by the need to transport the AWPC. The atmosphere warms as the gasses build up leading to the degradation of various ecosystems reliant on very specific temperatures such as aquatic ecosystems. Once the lifetime of the product has elapsed, the users must properly recycle the waste so it does not decompose quickly and releases toxic chemicals. Often times this waste ends up in developing countries negatively affecting both the people and animals living there.

Manufacturability

The AWPC serves as an easy-to-use control box requiring no user input beyond initial installation. As a result, users likely struggle when attempting to fix malfunctions, and when they occur, instead buy a new unit. While this benefits profit in terms of number of units sold, it also leads to less sustainability as more units require more resources. The AWPC must last a long period of time necessitating a quality build. With no regular maintenance required, the unit requires very little upkeep associated with the product aside from power costs. The product could potentially include easily replaceable internal parts as an upgrade, but this would drive up manufacturing costs. Also, the implementation of the electronics within the AWPC requires the use of rare earth metals. Users can help sustain this resource if they disable the components and recycle them correctly. However, this often does not happen resulting in aggressive non-sustainable consumption of resources.

The modular design of the AWPC allows the individual manufacturing of the modules. The circuitry likely requires the longest manufacturing time due to its small size and precision design. The other components such as the microprocessor and water level sensors come pre-made and ready to integrate into the full assembly. Instillation of the AWPC consists of placing the two level sensors, plugging in the water pump to the AWPC, and supplying power from a nearby wall outlet.

Sustainability

The automated water pump controller’s strives to store water and use it when the water company does not provide water to the costumers. The system needs minimal maintenance for the sensors used to read water levels [7]. The system only requires connection to residential wall-socket voltages in order to perform its functions. In terms of potential improvements, the incorporation of a solar panel to reduce energy usage would make the product greener for the environment. However, the implementation of a solar panel would require a battery to store the resulting charge. The batteries contain chemicals such as sulfuric acid which can harm the environment. The AWPC could also potentially benefit from a wind generated power source depending on average weather conditions of the region.

Ethical Considerations

With respect to the Institute of Electrical and Electronics Engineers (IEEE) code of ethics, the AWPC upholds ethical principles as an ethical device. The designers of said product accept no bribery and discriminate against no persons based on race, religion, gender, disability, age, national origin, sexual orientation, gender identity, or gender expression. Designers perform research when deciding all price estimates and completion time estimates to ensure they honestly reflect likely end costs. Designers make the completed product with the welfare of the public in mind by including warning labels to help prevent incorrect usage. If unforeseen or unintended conflicts arise resulting from the production or use of the device, steps responsible parties must take steps to remedy said conflicts. While the designers of the project have intention to uphold the IEEE code of ethics, the power to do so may lie with different people. If a governing body purchased the AWPC in bulk and distributed them as they see fit, discrimination may become an issue. This applies to the acceptance of bribes and setting fair prices as well.

From a utilitarian perspective, the AWPC can do both good and bad. An individual user utilizing this device gains happiness not having to constantly monitor his/her water system. This allows for optimal water transfer so that the user can enjoy water regularly. If someone only introduces a few devices into a community, those without the AWPC find less water available from time to time due to the more efficient water draw from those with the device. This could cause them unhappiness. However, if all members of a community used the AWPC then all members would benefit equally and the average happiness of the community would rise. With initial successes, the governing body of the area may decide to include the device as part of the water utility spreading the technology for others to benefit from resulting in even more happiness.

Health and Safety Impacts

The use of the AWPC helps users have more efficient access to clean water when they need it. Having a consistent supply of clean water helps maintain public health and safety. In addition, the autonomous nature of the AWPC allows people living with physical disabilities or ailments to forgo the arduous work associated with periodically fixing their water pump system.

Not all aspects of the AWPC benefit people's health. The electronics inside the AWPC require a manufacturing process reliant on harsh chemicals that dangerous to the labor force if work sites do not take proper precautions. As stated in section 5, these chemicals can sometimes leak into water supplies making anyone who uses the water for drinking ill. In addition, the manufacturing setting in general presents a danger for workers due to the large machinery often present. The device itself runs on high voltages which can deliver painful and dangerous shock if irresponsibly tampered with. Because the setting of the system necessitates placement outdoors and near bodies of water, the device has an increased chance of becoming wet and, therefore, higher chance of electric shock to the user. This same high voltage concerns during testing because wrong wire placement can result in electric shock nearby people and damage to surrounding components. Also, any metals the water level sensors contain may rust and compromise the safety of the water and make it harmful to drink [7].

Social and Political Impacts

The AWPC relies on a water system where a reservoir supplies water and needs a pump to move it to a residential storage tank. In countries like Indonesia, the government supplies the supplied water [2]. If they feel like this product gives users an unfair advantage over others with regards to water access, lawmakers may introduce new legislation. Those with expendable money can afford this product giving them more access to water, resulting in less water for those who cannot afford the system. This further solidifies the relationship between money and power. The user benefits directly from a well working water pump system making him/her the main stakeholder. Other stakeholders may include any investors who expect a return of profit. This could potentially cause issues if investors only contribute if they can influence specific changes made to the product. Despite negative concerns, the implementation of the AWPC would introduce technology into a community simplifying otherwise difficult aspects of everyday activities, especially for the physically handicapped. If the governing body in an area decided to purchase the AWPC for all residential buildings in an area, it would help solve the issues of inequality and promote a sense progress in the community. Other stakeholders include companies working to manufacture the AWPC. With high enough demand, the AWPC supplies opportunity for manufacturers to make money and create jobs.

Developmental Comments

The design of the project system has necessitated the research of power electronics, specifically converters between AC and DC voltage and DC to DC step-down [4]. The circuit designs required sensitivity analysis in the form of Monte Carlo simulations. The software chosen, LTspice, warranted research and practice in how to perform the desired analysis. This project required knowledge of new tools such as Gantt charts which helped establish a clear schedule of expected milestones related to the project. Other research conducted includes information on conditions in countries like Indonesia, existing patents related to the AWPC, datasheets for potential components, and worldwide wall-socket voltages. For a complete list of references used in the literature search, see the references section on page 13.

Appendix F: Formatted Code

```
#include <msp430.h>

/*
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 Senior Project
 Cal Poly SLO 2016
*/
void wait(int time)
{
   volatile unsigned int i; // volatile to prevent optimization
   volatile unsigned int k; // volatile to prevent optimization

   i=time;
   while (i > 0) //nested loop to pass time
   {
      k=1400;
      while (k > 0)
      {
         k--;
      }
      i--;
   }
}


int main(void) {
   WDTCTL = WDTPW | WDTHOLD;  // Stop watchdog timer
   P1DIR &= 0x00; // clearing "1" Pin I/O (all inputs)
   P1DIR |= 0x01; // setting BIT0 to output (for ss relay)
   P1OUT &= 0x00; // clearing data bits
   unsigned int waitFlag = 0;

   while(1)
   {
      if(P1IN & BIT2)   //water level at bottom of underground reservoir
      {
         P1OUT &= ~BIT0; //set pin 1 (connected to the on-board LED)
      }
      else if(P1IN & BIT3) //water level at top of rooftop tank
      {
         P1OUT &= ~BIT0; //set pin 1 (connected to the on-board LED)
         waitFlag = 1;
      }
      else if(P1IN & BIT1) //water level at top of underground reservoir
      {
         if(waitFlag)
         {
            wait(10000);// 2min delay
            waitFlag = 0;
         }
         P1OUT |= BIT0; //set pin 1 (connected to the on-board LED and eventually
the relay)
      }
   }
   return 0;
}
```

Appendix G: References

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