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DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

OPTION: ELECTRICAL TECHNOLOGY

DESIGN AND IMPLEMENTATION OF A SMART CONTROL SYSTEM FOR WATER SUPPLY TRANSFER PUMPS

Research project submitted in partial fulfillment of the requirements for the award of Advanced Diploma in Electrical Technology of ULK Polytechnic Institute

Submitted By: NGABO Aimable

Roll number: 201950443

Supervisor: Mr. KALISA Jean Bosco

October 2024

DECLARATION A

I, NGABO Aimable declare that this final year project titled **"design and implementation of smart systems for water supply transfer pumps**" is presented in partial fulfillment of the requirements for award of Advanced Diploma. It is entirely my own work and has not been submitted to any other higher education institution, or college as a whole or in part. Where use has been made of the work of other people, it has been fully acknowledged and fully referenced.

Student Name: NGABO Aimable

Roll number: 201950443

Signature………………………………

Date………. /………. /…………….

DECLARATION B

I confirm that the work reported in this research project was carried out by the candidate under my supervision and it has been submitted with my approval as the UPI supervisor.

Supervisor Name: Mr. KALISA Jean Bosco

Sign: ____________________________

Date: _________________

APPROVAL SHEET

This research project entitled " **design and implementation of smart systems for water supply transfer pumps** " prepared and Submitted by NGABO Aimable in partial fulfillment of the requirement for award of advanced diploma (A1) in electrical technology has been examined and

Approved by the panel on oral examination.

Name and Sig. of Chairperson: ____________________________

Date of Comprehensive Examination: ___

DEDICATION

I dedicate this work to:

Almighty GOD,

My family members, our brothers and sisters,

My classmates and friends,

My supervisor for the support he gave me,

All the teaching staff that have helped me during the study.

AKNOWLEDGEMENT

I would like to express my gratitude to the almighty God for blessing me with strength and courage to complete this project. From the beginning until the end of this project, I have so many people who stand by me; gives guidance for every obstacle that stand in my way. Therefore, we would like to express my deepest appreciation to those involved in this project.

I would like to express my gratitude and to my project supervisor Mr. KALISA Jean Bosco who had showered us with ideas and guidance through the whole time the last second. I will never forget all your sacrifices and only God could ever repay that you have done for me.

Finally, yet importantly, I cannot forget to thank ULK Polytechnic institute administration

ABSTRACT

The increasing demand for efficient water management in residential houses, hotels, and hospitals necessitates innovative solutions to ensure reliable water storage while minimizing waste and energy consumption. The goal of this project is to automate the process of transferring water to storage tanks through the design and installation of a smart system for water supply transfer pumps. The system is designed to keep water levels at ideal levels, minimizing the need for human intervention and guaranteeing a steady supply of water under demanding situations.

Real-time water level monitoring and control are achieved by the smart water supply system with the use of relays, water pumps, microcontrollers, and ultrasonic water level sensors. The microprocessor receives data from the ultrasonic sensors, which measure the water level in storage tanks, to decide when to turn on or off the water pumps. The pumps are triggered automatically to replenish the tanks when the water level falls below a certain threshold. In a similar vein, the pumps are turned off to prevent overflow and guarantee effective pump performance when the water level hits the top limit. In settings like homes, hotels, and hospitals where having access to clean water is essential, this system guarantees a steady and dependable supply of water. Particularly in settings with high water demand, automating the water transfer process minimizes human error, improves water conservation, and uses less energy. The system's architecture ensures that it will consistently store water without the need for manual modifications or frequent monitoring. In addition to increasing operational effectiveness, the smart water supply system's deployment promotes environmentally friendly water management techniques. For establishments that need stable and effective water storage solutions, it provides continuous water availability and is a sensible and affordable option.

Keywords: Smart Water Supply System, Water Management, Automation, Real-time Monitoring

Table of Contents

LIST OF FIGURES

LIST OF TABLE

LIST OF ACRONYMS AND ABBREVIATIONS

ADC: Analog to Digital Converter

CPU: Central Processing Unit

DAC: Digital to Analog Converter

HoD: Head of Department

TTL: Transistor Transistor Logic

USB: Universal Serial Bus

DC: Direct Current

PWM: Pulse Width Modulation

CHAPTER 1: GENERAL INTRODUCTION

1.1 Background of the study

Global water management is becoming increasingly important, particularly as urban populations rise and water scarcity is made worse by climate change. Water consumption is increasing globally, and many areas face challenges with insufficient water supply infrastructure. The situation is especially worrying in Africa, where many regions experience recurrent droughts, ineffective water delivery systems, and rapid population increase that puts stress on available resources(By et al., 2002). Similar difficulties are being faced by Rwanda, an East African country that is developing quickly, in supplying its urban and rural residents with a steady supply of water. At the household, institutional, and industrial levels, there is a growing need for creative, effective, and sustainable water management solutions in response to these challenges. Ensuring access to and sustainable management of water and sanitation for all by 2030 is emphasized globally by the United Nations Sustainable Development Goal 6. This emphasizes how critical it is to spend money on intelligent water management systems, which can guarantee effective water use while cutting waste. Across the world, smart water distribution and storage systems are becoming increasingly important, particularly in areas where water supplies are variable. For instance, automation of water distribution networks has already begun to lessen the consequences of uneven distribution systems and water shortages in nations like South Africa and India, giving urban populations more dependable access to water (Ministry of Natural Resources, 2011).

In Africa, it's challenging to guarantee a steady supply of water due to factors including increasing urbanization and erratic rainfall patterns. As part of its Vision 2050 development strategy, the Rwandan government has put ambitious plans into action to enhance the management of water resources. The ultimate goal is to guarantee that everyone has access to clean and dependable water. As per the Ministry of Infrastructure in Rwanda (2020), ensuring water security is of utmost importance, especially for vital industries like healthcare and hotels. Water supply interruptions can have serious repercussions because hotels, hospitals, and residential homes depend on a steady and dependable supply of water for basic operations (Giordano & Shah, 2014).

Thus, Rwanda's adoption of smart water supply systems is a step in the right direction toward meeting the urgent demand for automated and effective water management. By minimizing pump wear and energy consumption, these systems, which make use of automation and sensor technology, can guarantee the uninterrupted transfer of water to storage tanks, prevent overflows, and save operating expenses. Rwanda and other African nations may make great progress toward attaining water security and sustainability with advancements in pump control systems and water level monitoring, especially in urban and high-demand settings like hotels and hospitals(Risk & Profile, n.d.).

1.2 Problem Statement

Inefficient manual water management methods cause irregular water supply in many Rwandan homes, hotels, and hospitals. These conventional techniques frequently result in problems including overflows, pump failures, water waste, and excessive energy use. These issues are made worse by the lack of automation in water transfer and storage systems, which frequently results in water shortages and interferes with key environment operations.

1.3. Objectives of the study

1.3.1. Main objective

The main objective of this research project is to design and implement a smart control system-for water supply transfer pumps**.**

1.3.2. Specific objectives

i. Automate Water Level Monitoring.
ii. Optimize Efficiency in Water Transfer.
iii. Enhance Water Resource Management.

1.4 Research Questions

1. How can the integration of water level sensors improve the accuracy of water level monitoring in storage tanks?
2. What impact does the automation of water transfer processes have on energy consumption and operational efficiency in residential houses, hotels, and hospitals?

3. How does the automated system compare with traditional water management methods in terms of reliability and cost-effectiveness?

1.5 Scope and limitation of the Study

The design and installation of a smart water supply transfer pump system, particularly for Rwandan homes, hotels, and hospitals, is the main emphasis of this project. It includes the incorporation of microcontrollers, relays, water pumps, and ultrasonic water level sensors to automate water transfer and monitoring procedures. The system's ability to improve water management efficacy, lower waste, and guarantee consistent water availability in these crucial locations will be assessed by the research. The scope of this study is restricted to a few urban and rural regions of Rwanda, which may not adequately represent the variety of water management issues that exist throughout the nation. Therefore, it's possible that the results cannot be applied to other areas with different environmental and infrastructure circumstances. Furthermore, the smart water supply transfer pump system will only be implemented in the residential, hotel, and hospital sectors; the agricultural and industrial sectors will not be included. The results' applicability to more general water management scenarios may be limited by this focus. Additionally, it's possible that external considerations like consumer adoption of the technology and maintenance concerns haven't been fully investigated.

1.6 Significance of the Study

The results of this study will help Rwandan water management methods, especially in residential buildings, lodging establishments, and medical facilities. It seeks to increase productivity, cut down on water waste, and save operating expenses by creating a smart water supply transfer pump system. The results will offer insightful information about the advantages of automation in guaranteeing a consistent supply of water, in line with Rwanda's Vision 2050 objectives for sustainability and water security. In the end, this research can promote sustainable development and raise people's standards of living by guaranteeing that communities have access to reliable and clean water supplies.

1.7 Organization of the Study

Chapter one: This chapter provides an overview of the study's focus on design and implementation of smart systems for water supply transfer pumps, explains problem statement, the goals of the research, develops research questions and hypotheses.

Chapter two: The goal of the literature review is explained in this chapter. It reviews prior empirical investigations that are relevant to the current study, identifying gaps and contributions, and summarizes important ideas and points of view from pertinent literature on water supply transfer pumps.

Chapter three: This chapter describes the research process, including the general strategy and techniques employed in water supply transfer pumps. It describes the sampling process, establishes the sample size, and names the target demographic. The chapter also discusses the research instruments that were used to collect the data, evaluates the validity and reliability of those instruments, and defines data collection techniques, analysis strategies, ethical issues, and possible study limits.

Chapter four: The upgraded water supply transfer pumps system's conception and execution are the main topics of this chapter. It includes pertinent computations, schematics of the suggested system, comprehensive specifications for system parts, and a cost analysis of implementation. The system's actual implementation procedure could be covered in detail in an extra section.

Chapter five: In response to the research questions, this chapter offers an overview of the primary discoveries and their ramifications. Based on the research findings, it provides helpful suggestions for enhancing water supply transfer pumps and makes recommendations for future paths that could expand on the current research.

CHAPTER 2: LITERATURE REVIEW

2.0 Introduction

The research and hardware needed to enable the development of our project, "design and implementation of a smart control systems for water supply transfer pumps" are thoroughly reviewed in this chapter. We looked into a number of comparable projects during our study to learn more about pumping system technologies. These sources gave us the fundamental know-how and abilities needed to put efficient detection methods in place. The hardware specifications that other developers of comparable systems employed are also described in this chapter. We selected important strategies and technologies to improve pumping system technologies by looking at earlier research and implementations. This gave us a thorough understanding of the tools and techniques we used in my project.

2.1 Related works

An introduction to industrial automation is given in this book, which covers subjects including actuators, sensors, process control, and programmable logic controllers (PLCs). It is pertinent to your project on automated water pump systems since it examines how microcontrollers are integrated into industrial systems for controlling things like water management. It also discusses communication protocols, real-time data gathering, and human-machine interfaces (HMIs). For smart water systems, the book presents core knowledge in sensor-actuator integration, automation methodologies, and how control logic is implemented to manage complex systems efficiently. Stenerson's work is vital for understanding the basic concepts of automation and the necessity of reliability and efficiency in control system(Kumar et al., 2023).

The use of smart technologies for sustainable water management is covered in this book. It focuses on collecting data, analyzing it, and making decisions in real time to optimize water supply systems. Methods like IoT, data analytics, and sensor integration being investigated to increase the effectiveness of the water supply. Owen tackles important topics including controlling water distribution in urban areas, minimizing water waste, and keeping an eye on the quality of the water. For your project, this book provides insights into how smart water systems can be implemented using automated pump control and sensor technology to regulate water supply in residential and commercial setups, assuring greater resource management and operational efficiency(Aivazidou et al., 2021).

This book focuses on optimizing agricultural water usage with IoT-enabled automation, which can be applied to urban smart water delivery systems. It offers comprehensive guidance on monitoring and managing water distribution through the use of sensors, microcontrollers, and Internet of Things platforms. Although it primarily focuses on agricultural, the methods discussed are readily applicable to other water management systems, such intelligent building water pumps. The book offers helpful insights on how to utilize IoT and automation for resource conservation and operational efficiency, with a focus on using cloud-based platforms and real-time data for effective water management(Barusu et al., 2023).

This book focuses on creative approaches to water resource management, particularly in light of climate change. The use of IoT, AI, and machine learning to forecast water demand, control supply, and cut waste is explored in relation to smart water management systems. My smart water pump control system can benefit from the sensor-based control systems that are highlighted in the book. These systems maximize the performance of water pumps and valves in urban environments. In order to lower carbon footprints and energy expenses, it also discusses the integration of renewable energy sources, such as solar power, into water systems(Krishnan et al., 2022).

This book offers a thorough examination of environmentally friendly options for water distribution systems with a focus on dependability and efficiency. It covers automation techniques such as pressure management, flow monitoring, and the integration of smart controllers for water pumps. The book covers contemporary techniques including variable speed pumps and the application of predictive control algorithms to optimize water distribution, with an emphasis on energy saving. It's really important to your project because it also discusses the environmental impact of water systems and offers creative ways to save energy costs without sacrificing system performance (Abebe, 2024).

2.2 Hardware requirements

2.2.1 Introduction

This part consists of the discussion about the basics of electronic elements and electrical devices that are joined together in order to achieve the desired result during the design and implementation of a smart control systems for water supply transfer pumps. Although there are several electronic and electrical elements and devices, this chapter will focus on those which are included with pumping system technology as the purpose of project. The concept contains both summaries and explanations of complete or current state of knowledge on text, theories related this topic and study made earlier which are similar the descriptions of work done before that found in books upon this subject. The entire system adopted the Arduino Uno Microcontroller Board based on ATMEGA 328. The core functions modules are Arduino Uno, ultrasonic Sensor, pump, relay.

2.2.2 Microcontroller

2.2.2.1 Introduction

Arduino is an open source microcontroller, which can be easily programmed, erased and reprogrammed at any instant of time. Introduced in 2005 the Arduino platform was designed to provide an inexpensive and easy way for hobbyists, Employees and professionals to create devices that interact with their environment using sensors and actuators.

Based on simple microcontroller boards, it is an open source - computing platform that is used for constructing and programming electronic devices. It is also capable of receiving and sending information over the internet with the help of various Arduino shields, which are discussed in this paper. Arduino uses a hardware known as the Arduino development board and software for developing the code known as the Arduino IDE (Integrated Development Environment).

Built in microcontrollers can be programmed easily using the C or C++ language in the Arduino

Figure 1: Arduino Uno (Gianluca Martino)

2.2.2.2 Arduino pins

The Arduino Uno is a microcontroller board based on the ATmega328. It is a programmable micro controller for prototyping electromechanical devices. You can connect Digital and Analog electronic signals:

It has 14 digital Input / output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic Resonator, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features theAtmega16U2 (Atmega8U2up to version R2) programmed as a USB to-serial converter. The name Arduino comes from a bar in Ivrea, Italy, where some of the founders of the project used to meet. The bar was named after Arduino of Ivrea, who was the margrave of the March of Ivrea and King of Italy from 1002 to 1014.

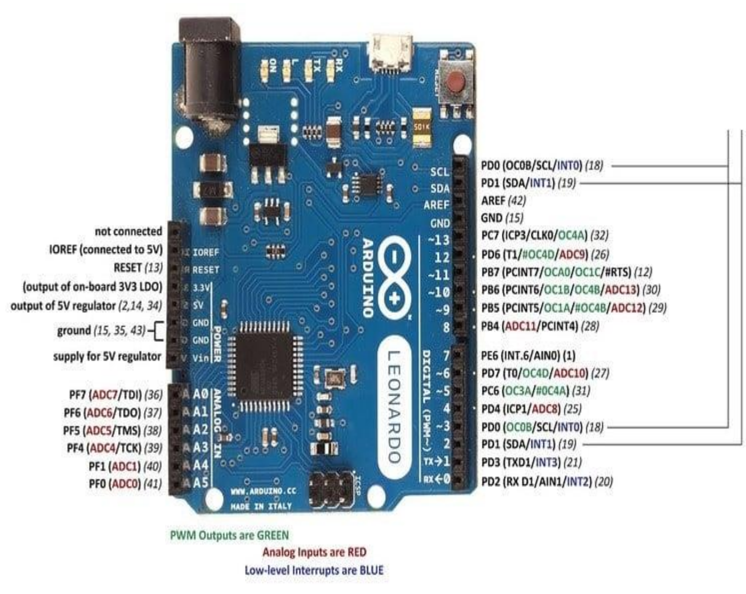

Figure 2: Arduino uno pins

2.2.2.3 Main Pin functions

- LED: There is a built-in LED driven by digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.

- VIN: The input voltage to the Arduino/Genuine board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.
- 5V: This pin outputs a regulated 5V from the regulator on the board. The board can be supplied with power either from the DC power jack (7 - 20V), the USB connector (5V), or the VIN pin of the board (7-20V). Supplying voltage via the 5V or 3.3V pins bypasses the regulator, and can damage the board.
- 3V3: A 3.3-volt supply generated by the on-board regulator. Maximum current draw is 50 mA.
- GND: Ground pins.
- IOREF: This pin on the Arduino/Genuine board provides the voltage reference with which the microcontroller operates. A properly configured shield can read the IOREF pin voltage and select the appropriate power source or enable voltage translators on the outputs to work with the 5V or 3.3V.
- Reset: Typically used to add a reset button to shields which block the one on the board.

2.2.2.4 Special pin Functions

Each of the 14 digital pins and 6 Analog pins on the Uno can be used as an input or output, using pinMode (), digital Write (), and digitalRead() functions. They operate at 5 volts. Each pin can provide or receive 20 mA as recommended operating condition and has an internal pull-up resistor (disconnected by default) of 20-50k ohm. A maximum of 40mA is the value that must not be exceeded on any I/O pin to avoid permanent damage to the microcontroller. The Uno has 6 analog inputs, labeled A0 through A5, each of which provide 10 bits of resolution (i.e. 1024 different values). By default, they measure from ground to 5 volts, though is it possible to change the upper end of their range using the AREF pin and the analog Reference () function.

In addition, some pins have specialized functions:

- Serial: pins 0 (RX) and 1 (TX). Used to receive (RX) and transmit (TX) TTL serial data. These pins are connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip.

- External Interrupts: pins 2 and 3. These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value.
- PWM (Pulse Width Modulation) 3, 5, 6, 9, 10, and 11 Can provide 8-bit PWM output with the analog Write () function.
- SPI (Serial Peripheral Interface): 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK). These pins support SPI communication using the SPI library.
- TWI (Two Wire Interface): A4 or SDA pin and A5 or SCL pin. Support TWI communication using the Wire library.
- AREF (Analog Reference: Reference voltage for the analog inputs.

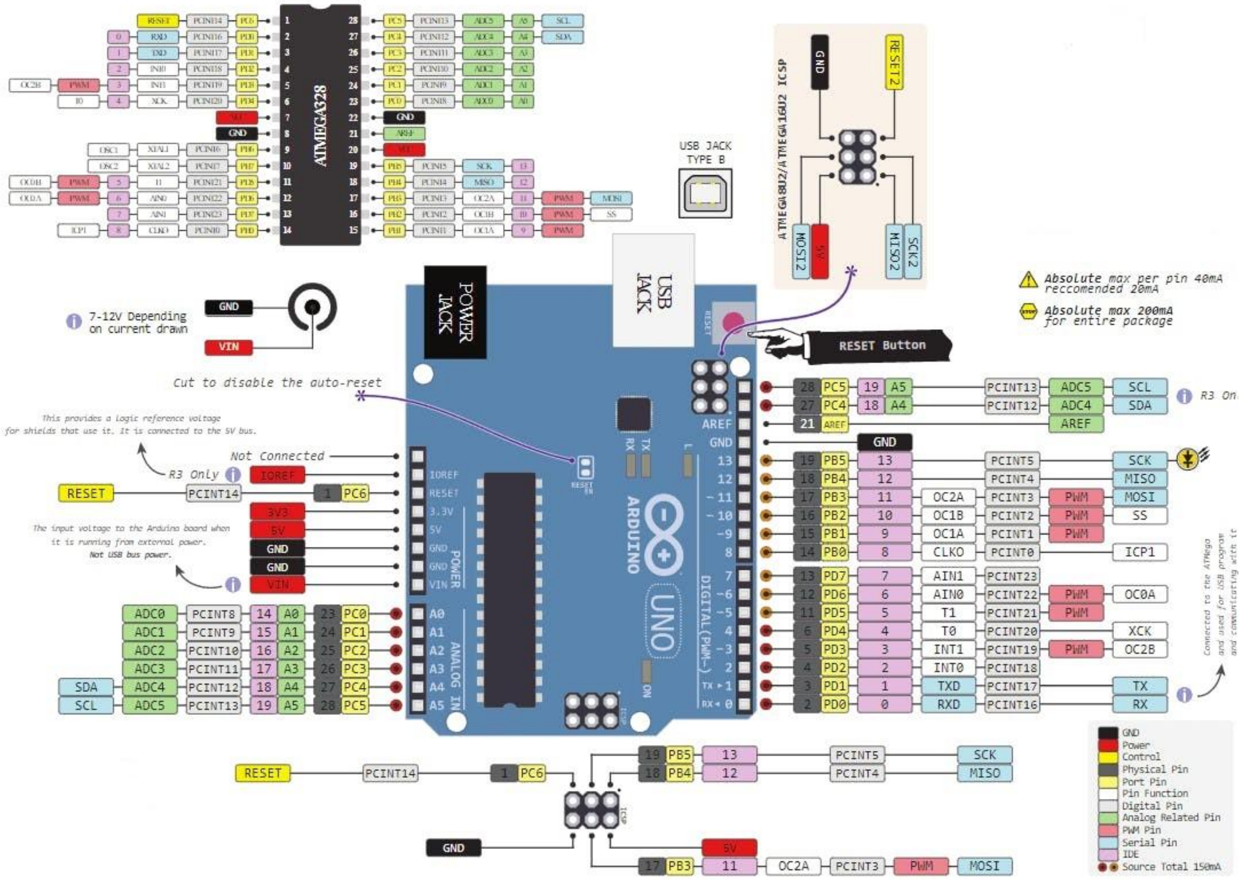

Figure 3: Special pin Functions of Arduino Uno

2.2.3 Ultrasonic sensor

2.2.3.1 Introduction to ultrasonic sensor

The ultrasonic sensor works on the principle of SONAR and RADAR system which is used to determine the distance to an object. An ultrasonic sensor generates high-frequency sound (ultrasound) waves. When this ultrasound hits the object, it reflects as echo which is sensed by the receiver as shown in below figure

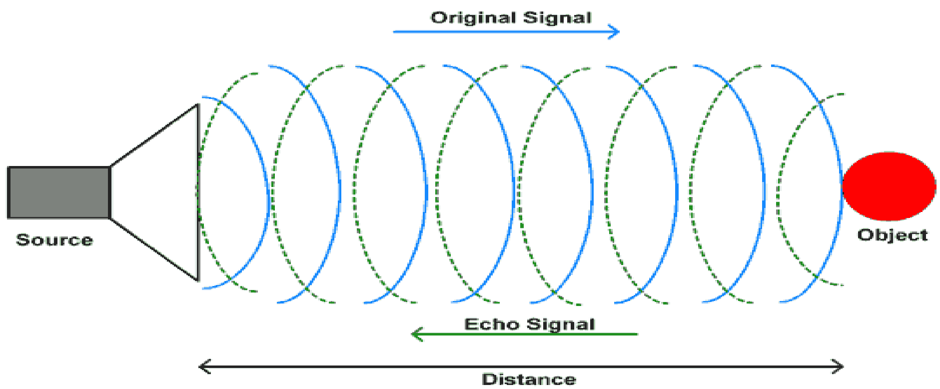

Figure 4: ***Ultrasonic Sensor Working Principle***

By measuring the time required for the echo to reach to the receiver, we can calculate the distance. This is the basic working principle of Ultrasonic module to measure distance.

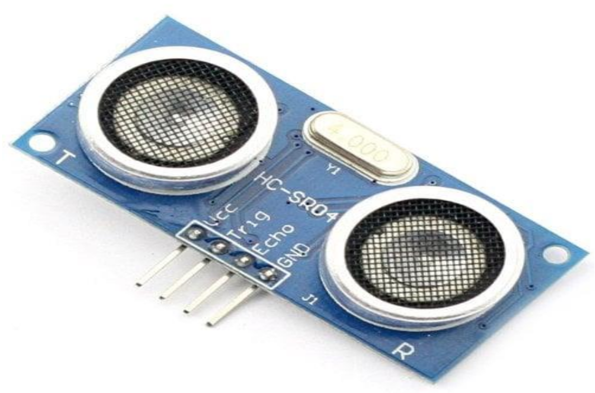

Figure 5: Ultrasonic Module

In the ultrasonic module HCSR04, we have to give trigger pulse, so that it will generate ultrasound of frequency 40 kHz. After generating ultrasound i.e. 8 pulses of 40 kHz, it makes echo pin high. Echo pin remains high until it does not get the echo sound back. So the width of echo pin will be the time for sound to travel to the object and return back. Once we get the time we can calculate distance, as we know the speed of sound.

2.2.3.2 HC-SR04 Pin Description

Figure 6: HC-SR04 Pin Diagram

VCC: +5 V supply

TRIG: Trigger input of sensor. Microcontroller applies 10 us trigger pulse to the HC-SR04 ultrasonic module.

ECHO: Echo output of sensor. Microcontroller reads/monitors this pin to detect the obstacle or to find the distance.

GND: Ground

2.2.3.3 Ultrasonic Sensor HC-SR04 Working Principle

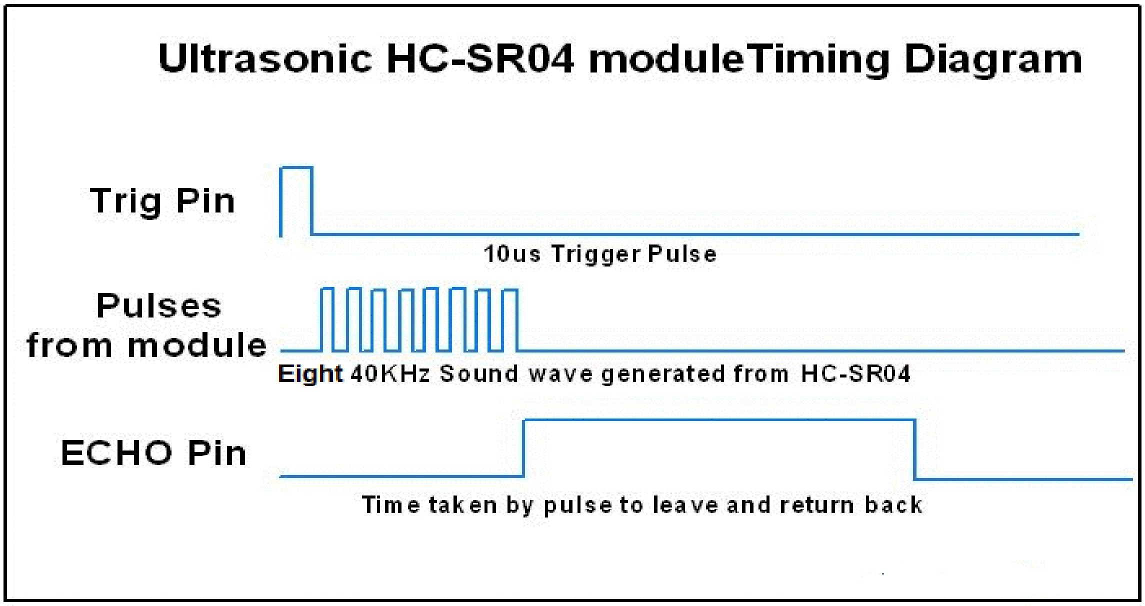

Figure 7: HC-SR04 Ultrasonic Module Timing Diagram

We need to transmit trigger pulse of at least 10 us to the HC-SR04 Trig Pin. Then the HC-SR04 automatically sends Eight 40 kHz sound wave and wait for rising edge output at Echo pin. When the rising edge capture occurs at Echo pin, start the Timer and wait for falling edge on Echo pin. As soon as the falling edge is captured at the Echo pin, read the count of the Timer. This time count is the time required by the sensor to detect an object and return back from an object

2.2.3.4 Formula to calculate distance

We know that, distance (D) = speed(S) time (T) Then, the speed of sound waves is 343 m/s.

So, Total distance (D) = 343xtime of High (Echo) pulse/2

Total distance is divided by 2 because signal travels from HC-SR04 to object and returns to the module HC-SR-04

2.2.4. DC Water pump

A water pump is a mechanical device designed to move water from one location to another by creating a pressure difference. It operates by drawing water into an inlet and expelling it through an outlet, utilizing mechanical force to facilitate the flow. Water pumps are crucial in various applications, including irrigation systems, water supply networks, and industrial processes. They come in different types, such as centrifugal pumps, which use a rotating impeller to move water; diaphragm pumps, which use a flexible diaphragm to create flow; and gear pumps, which use interlocking gears to move fluids. Water pumps can be powered by electricity, gasoline, or other energy sources, depending on the application and required flow rate.

Figure 8: DC water pump

2.2.5 Relay

A relay is an electrically operated switch. It consists of a set of input terminals for a single or multiple control signals, and a set of operating contact terminals. The switch may have any number of contacts in multiple contact forms, such as make contacts, break contacts, or combinations.

Figure 9: relay

Relays are used where it is necessary to control a circuit by an independent low-power signal, or where several circuits must be controlled by one signal. Relays are electrically operated switches that open and close the circuits by receiving electrical signals from outside sources

2.2.7 PCB (printed Circuit Board)

A printed circuit board (PCB; also printed wiring board or PWB) is a medium used to connect electronic components to one another in a controlled manner. It takes the form of a laminated sandwich structure of conductive and insulating layers: each of the conductive layers is designed with an artwork pattern of traces, planes and other features (similar to wires on a flat surface) etched from one or more sheet layers of copper laminated onto and/or between sheet layers of a non-conductive substrate. Electrical components may be fixed to conductive pads on the outer layers in the shape designed to accept the component's terminals, generally by means of soldering, to both electrically connect and mechanically fasten them to it. Another manufacturing process adds plated-through holes that allow interconnections between layers.

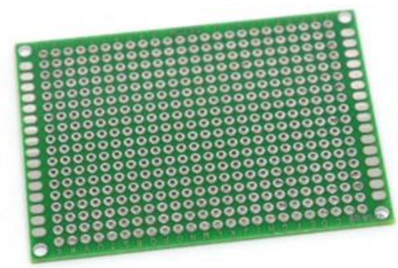

Figure 10: PCB (Printed Circuit Board)

CHAPTER 3. RESEARCH METHODOLOGY

3.1. Introduction

The methodology was a systematic, theoretical analysis of the methods applied to a field of study. It comprises the theoretical analysis of the body of methods and principles associated with a branch of knowledge. While gathering information from different people of how they think my project will resolve, with the help of Class notes, internet, documentation, observation, lecturers' notes, etc. Which they have been mainly to accomplish our project.

3.2. Methodology

The methodology for designing and implementing the smart systems for water supply transfer pumps involves several critical steps. Initially, we select and integrate key components, including the Arduino Uno for processing, ultrasonic sensors for data collection, relays and water pumps for filling water tanks. The project relies on research from technical resources, collaboration with peers, and guidance from instructors and supervisors to refine and validate the system's performance.

3.3 Research design

In order to obtain satisfactory outcomes, we have used different methods and techniques for carrying out this research and data collection. This will be done by taking references and consultation with those having more experiences such as facilitators, classmates, different views done by researchers and internet.

3.4 Research Instrument

In order to collect data, I had used experiment, observation, documentary and internet

3.5 Research choice instrument

3.5.1 Documentary review

Documentation was a data collection instrument based on reading books and other documents related to the research subject in order to get the background of the situation to analyze and find out information of the studies on similar topic. Documents refer to any written material that may be used as source of information about the subject in order to achieve the objective of the study.

I have used this tool in time of collecting data through reading various documents such as, internet, books, and other relevant materials related to this project.

3.5.2 Experimental method

In this research instrument, I had used Arduino programming language and plot as for simulating the design and implementation of smart systems for water supply transfer pumps. Therefore, as my project is based on Arduino microcontroller it is required to develop Arduino program that will help to achieve the research objectives as the researcher have been mentioned in first chapter.

3.5.3 Data gathering procedures

Producing of data in the study I had focused for various resources like library books, class handout, classmates; some websites on the internet, as well as reports done by other researchers. Also, in this section, different researchers have been consulted for their ideas from the field, as we have been used different ideas from other researchers in order to collect all information, after collection those data we have implemented water supply transfer pumps using water level sensor.

3.6 Data analysis and interpretation

To get information on design and implementation of water supply transfer pumps. I have used variety documents to examine my project, books of electrical and electronics and other documents from different websites. In order to get all the relevant data information to this project, some methods of data collection procedures or techniques have been used for the collection of data, interviewers were carried out. The main respondent to these interviews was coming from the electrical and electronic engineering department.

3.7 Ethical consideration

This research project was be conducted by following the guidelines of ULK I therefore to have this project being implemented it will require to follow and to analyses the advices from our supervisor, facilitators, instructors and those who are qualified in electrical and electronic engineering with more experiences.

CHAPTER 4: SYSTEM DESIGN, ANALYSIS AND IMPLEMENTATION

4.1 Introduction

In chapter four I have the design, analysis, and implementation of the Smart Control System for Water Supply Transfer Pumps, focusing on key diagrams and results. It begins with the block diagram, which illustrates the system’s main components and their interactions, followed by the flowchart, which outlines the control logic and decision-making process based on water levels. The circuit diagram provides a detailed representation of the electronic components and connections that enable the system to function. The chapter concludes with the implementation results, where system performance is evaluated through testing, validating the system’s effectiveness in automating water transfer between storage tanks in residential, hotel, and hospital settings.

4.2 Calculation

4.2.1 Ultrasonic Sensor

Voltage: Typically operates at 5V

Current: Approximately 20 mA (0.02 A)

P sensor=V×I=5V×0.02A=0.1 W (100 mW)

4.2.2 Relay Module

Voltage: Typically operates at 5V

Current: Approximately 15 mA (0.015 A) when activated

4.2.3. Water Pump

Voltage: 5V

Current: Depends on the pump; assume 500 mA (0.5 A) for a small pump

P pump=V×I=5V×0.5A=2.5 W

P relay=V×I=5V×0.015A=0.075 W (75 mW)

4.2.4 Arduino Power Consumption

The power consumption of the Arduino depends on the model, but let’s assume you're using a typical Arduino Uno. The relevant specs are:

Operating Voltage: 5V

Current Draw: Approximately 50 mA (0.05 A) when idle.

Power for the Arduino:

P Arduino=V×I=5V×0.05A=0.25W (250mW)

4.3 Block Diagram

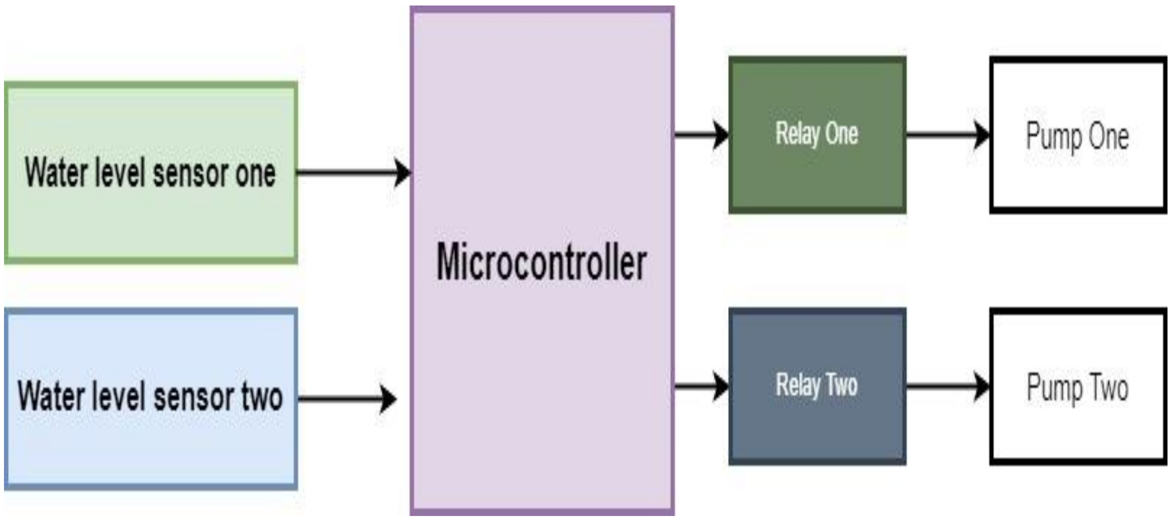

Figure 11: Block Diagram

The block diagram shows the operation of a Smart Control System for Water Supply Transfer Pumps, where have two water level sensors (ultrasonic sensors) to monitor the water levels in two different tanks. The sensors send data to a central microcontroller, which processes the information to determine whether to activate the pumps. The microcontroller controls two relays Relay One and Relay Two that act as switches for Pump One and Pump Two, respectively. When the water level in a tank reaches a predefined threshold, the microcontroller signals the corresponding relay to turn the appropriate pump ON or OFF, enabling automatic water transfer between tanks.

4.4 Flowchart

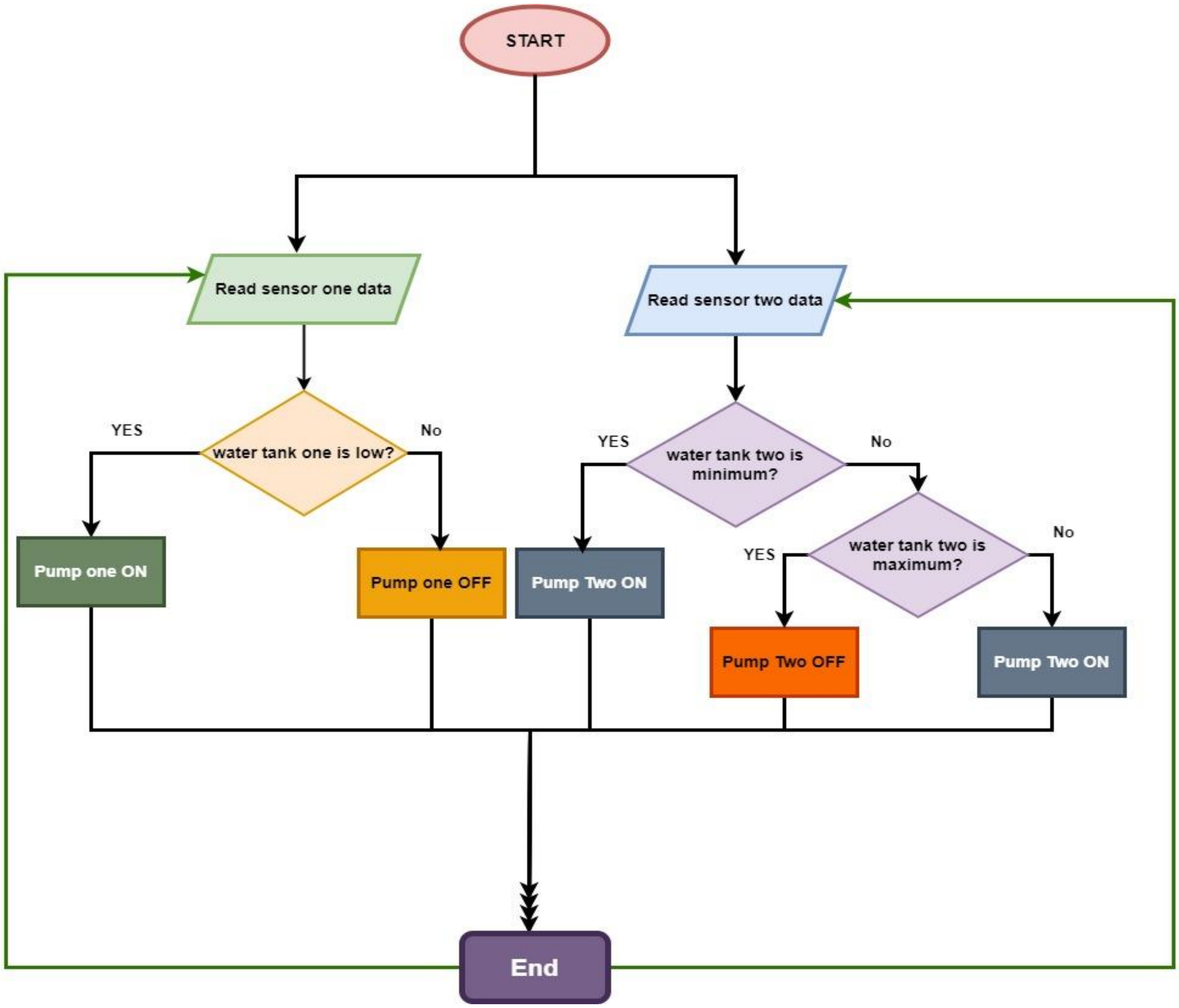

Figure 12: flowchart

The flowchart shows the operation of a smart control system for water supply transfer pumps that monitors and manages water levels in two tanks using sensor data. For tank one, sensor one checks the water level. If the level is low, pump one is activated to refill the tank. If the water level is sufficient, pump one is turned off. For tank two, sensor two monitors its water level. If the level is at a minimum, pump Two is switched on to fill the tank. If the level reaches the maximum, pump two is turned off to prevent overflow. This process runs continuously, ensuring efficient and automated water management for both tanks through real-time sensor data and pump control.

4.5 Circuit Diagram

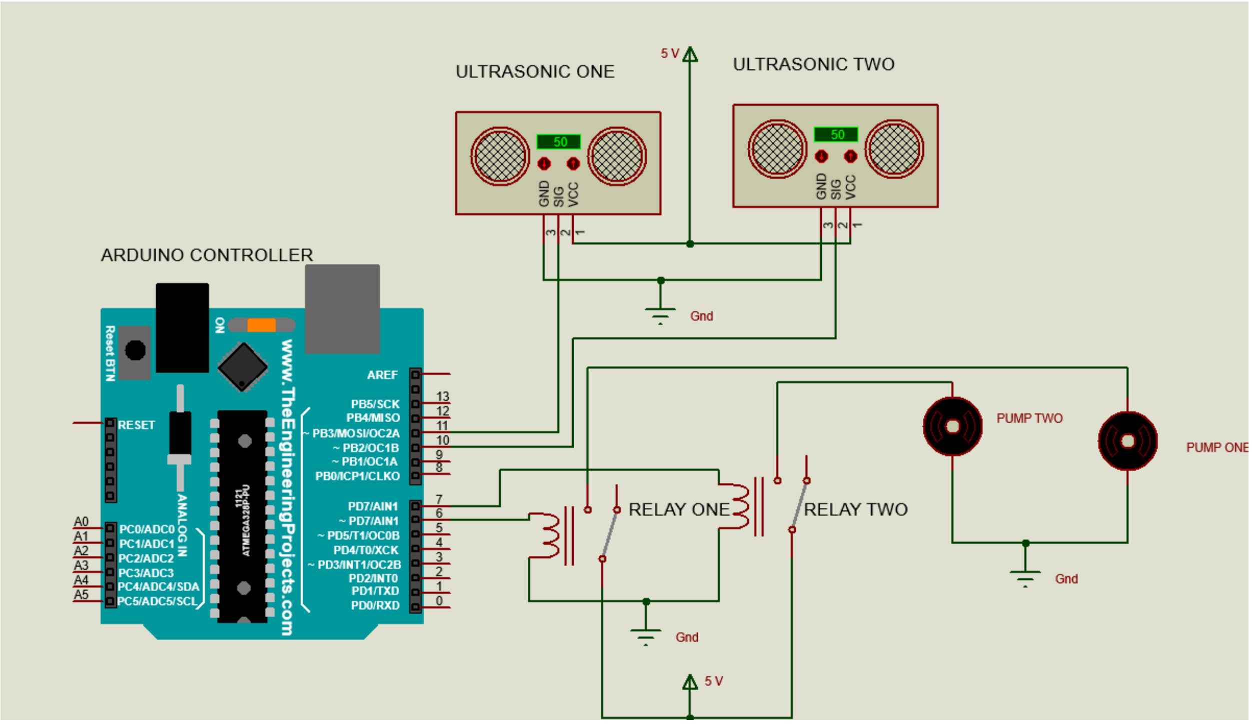

Figure 13: circuit diagram

4.6 Working principle

In the Smart Control System for Water Supply Transfer Pumps, two ultrasonic sensors are used to monitor water levels in separate tanks, and an Arduino microcontroller manages the system's automation. The first ultrasonic sensor (Ultrasonic Sensor One) is powered by the Arduino’s 5V pin, with its signal pin connected to digital pin D11 and its GND connected to the Arduino’s GND pin. Similarly, Ultrasonic Sensor Two is powered through the same 5V pin, with its signal pin connected to digital pin D10, and the ground connected to the Arduino’s GND. These ultrasonic sensors measure water levels by sending a signal to the Arduino, which then processes the data to determine whether to activate the pumps.

For pump control, the system employs two relays. Relay one, responsible for switching Pump One, is connected to the Arduino's digital pin D7, while Relay Two, which controls Pump Two, is connected to digital pin D6. Both relays receive power from the Arduino’s 5V pin and share the common ground connection. When the sensors detect that the water level in either tank is low, the respective relay is triggered to switch the corresponding pump on. Once the water levels are replenished, the relays deactivate the pumps. This setup ensures efficient, automatic control of the water supply between tanks based on real-time data from the sensors.

4.7. Cost estimations

Table 1: cost estimations

S/N	Material/devices	Specification	quantity	Unity price	Total price
1	Arduino uno	Arduino uno R3 BRD41	1	15000	15,000frw
2	ultrasonic sensor	Ultrasonic Module Sensor – HC-SR04 MOD52	2	4,500	9,000 frw
4	pump	Mini Water / Fluid Pump MOD45	2	5,000	10,000 frw
5	Wires + cables	24 AWG Flexible Silicone Electric Wire Tinned Copper Insulated	1 roll	5000	5000 frw
6	PCB	PCB Board 9*15cm PRO24	1	2000	2000 frw
7	Water pipes	Water pump COM46	4m	2,000	8,000 frw
8	Relay	5V DC Power relay CON36	2	2,000	1,000 frw
Total					**50,000 frw**

4.8 Results and Discussions

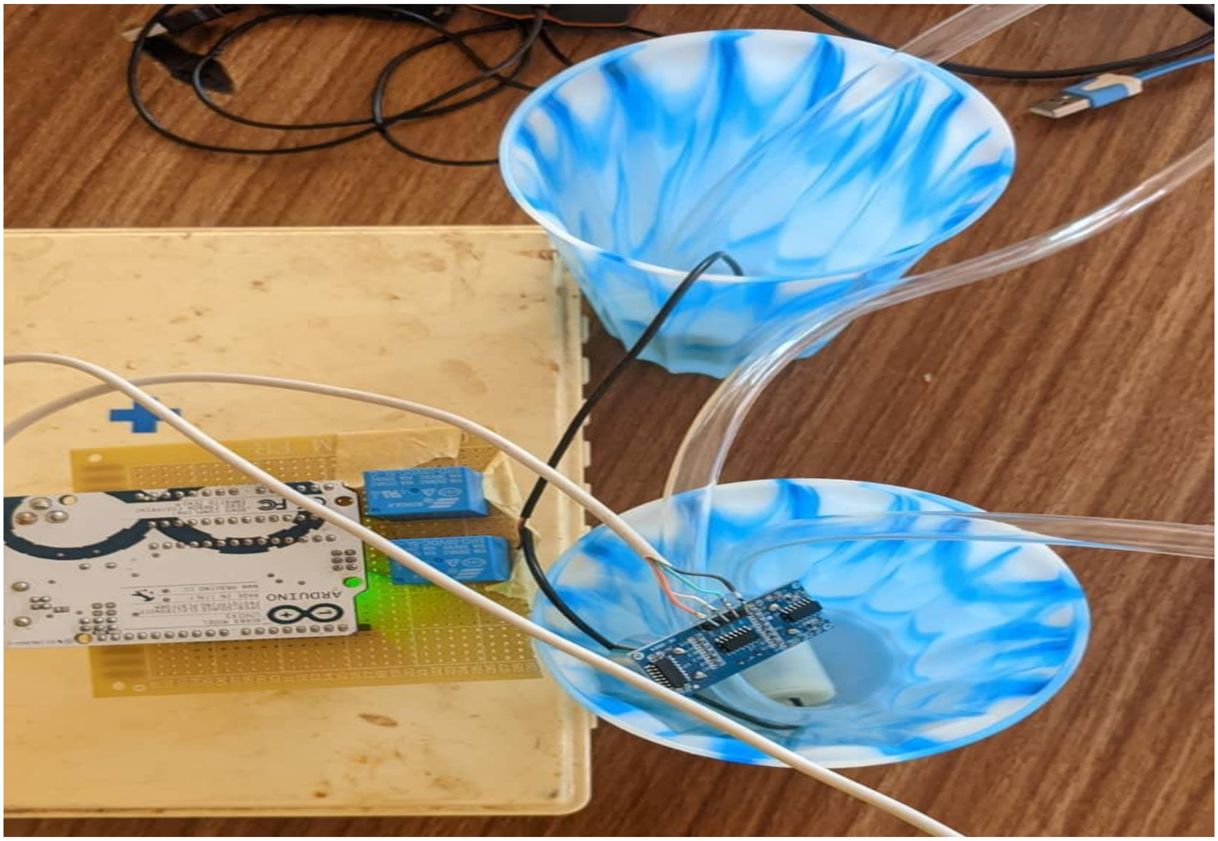

Figure 14: prototype photo

This system features an Arduino controlling a water pump through relays, with a water level sensor monitoring the levels in the container. When the sensor detects a low water level, the Arduino activates the pump to transfer water between containers using plastic tubes. The relays ensure safe power management, automating the process for irrigation or water management applications.

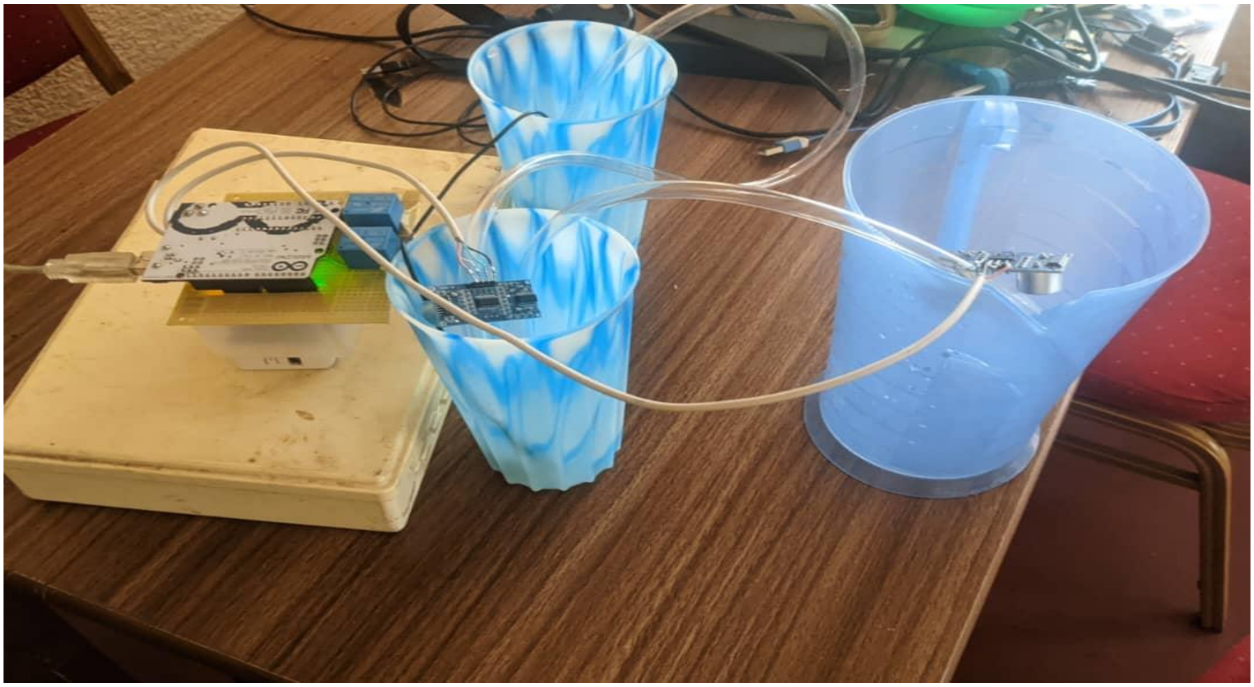

Figure 15: system with three containers

When the sensor detects a low water level, the Arduino activates the pump to transfer water between containers using plastic tubes. The relays ensure safe power management, automating the process for irrigation or water management applications.

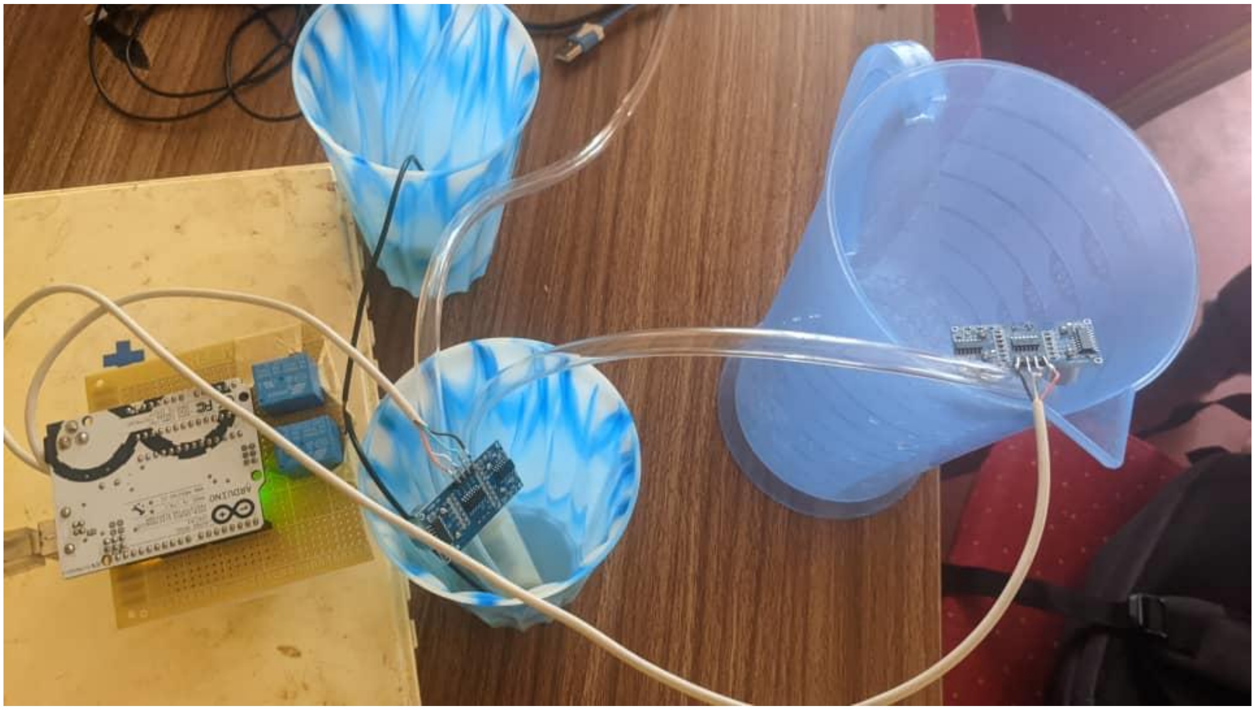

Figure 16: all system

CHAPTER 5. CONCLUSION AND RECOMMANDATION

5.1. Conclusion

The design and implementation of the Smart Control System for Water Supply Transfer Pumps has effectively demonstrated an automated approach to managing water distribution between tanks, particularly relevant for the context of Rwanda. By integrating ultrasonic sensors, relays, and an Arduino microcontroller, the system continuously monitors water levels and activates pumps when necessary, ensuring reliable water transfer. This eliminates the need for manual intervention and optimizes water usage, making it suitable for residential, commercial, and institutional applications throughout the country. The system's ability to operate efficiently based on real-time data showcases the benefits of automation in water management. Overall, the project meets its objective of providing a cost-effective and sustainable solution for automatic water supply control in Rwanda, contributing to improved water resource management in the region.

5.2. Recommendation

To enhance the Smart Control System for Water Supply Transfer Pumps, it is recommended to integrate remote monitoring capabilities via GSM modules or Wi-Fi for greater user convenience. Incorporating additional sensors, such as flow rate sensors, can improve accuracy and prevent overflow. Implementing a data logging feature will help track historical usage patterns. Regular maintenance of the ultrasonic sensors is essential for reliability. Additionally, academic establishments such as ULK Polytechnic Institute are advised to give priority to hands-on training and incorporate practical projects into their curricula. It is imperative that outstanding student projects receive support, including supplying the tools and materials required to address the high cost of parts like microcontrollers and sensors. Collaborating with local agricultural organizations can promote smart water management practices and secure funding to scale this technology across Rwanda.

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APPENDICES

APPENDIX A: Project code

```
int trigPin1 = 8; // Trigger
int echoPin1 = 9; // Echo
long duration1, cm1, inches1;
////////////////////////////////////////////////////
int trigPin2 = 6; // Trigger
int echoPin2 = 7; // Echo
long duration2, cm2, inches2;
int pump1 =6;
int pump2=7;

void setup() {
//Serial Port begin
Serial.begin (9600);
//Define inputs and outputs
pinMode(trigPin1, OUTPUT);
pinMode(echoPin1, INPUT);
pinMode(trigPin2, OUTPUT);
pinMode(echoPin2, INPUT);
pinMode(pump1, OUTPUT);
pinMode(pump2, OUTPUT);
}

void loop() {
// The sensor is triggered by a HIGH pulse of 10 or more microseconds.
// Give a short LOW pulse beforehand to ensure a clean HIGH pulse:
digitalWrite(trigPin1, LOW);
delayMicroseconds(5);
digitalWrite(trigPin1, HIGH);
delayMicroseconds(10);
```

```
digitalWrite(trigPin1, LOW);
pinMode(echoPin1, INPUT);
duration1 = pulseIn(echoPin1, HIGH);
digitalWrite(trigPin2, LOW);
delayMicroseconds(5);
digitalWrite(trigPin2, HIGH);
delayMicroseconds(10);
digitalWrite(trigPin2, LOW);
pinMode(echoPin2, INPUT);
duration2 = pulseIn(echoPin2, HIGH);


cm1 = (duration1/2) / 29.1; // Divide by 29.1 or multiply by 0.0343
inches1 = (duration1/2) / 74; // Divide by 74 or multiply by 0.0135
cm2 = (duration2/2) / 29.1; // Divide by 29.1 or multiply by 0.0343
inches2 = (duration2/2) / 74; // Divide by 74 or multiply by 0.0135
if(cm1>50){
  digitalWrite(pump1, HIGH);
  }
  else {  digitalWrite(pump1, LOW);}
  if(cm2>50){
  digitalWrite(pump2, HIGH);
  }
  else {  digitalWrite(pump2, LOW);}
Serial.print("Distance1: ");
Serial.print(inches1);
Serial.print(" inches\t");
Serial.print(cm1);
Serial.print("cm");
Serial.println();
```

```
delay(1000);
Serial.print("Distance2: ");
Serial.print(inches2);
Serial.print(" inches\t");
Serial.print(cm2);
Serial.print("cm");
Serial.println();

delay(1000);
}
```