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The Design and Analysis of a Micro Controller Based Fire Alarm System with Water Sprinkler

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ABSTRACT

A microcontroller-based fire alarm system with a water sprinkler was designed and analyzed. The objective was to enhance the traditional fire alarm system's detection and quenching process, which is still widely utilized by several institutions in Africa. Furthermore, a microcontroller-based system was to take the place of the traditional fire alarm system. Traditional fire alarm systems, with their constraints of rapid warning and automatic fire control, have not shown to be as successful in reducing the number of people killed and property destroyed by fires. As a result, with the development of technology, the requirement for a trustworthy, effective fire alarm system with automated water sprinkler procedures has become crucial. It is possible to detect flame, turn on pumps, and keep an eye on the water level. The work was constructed with an embedded microcontroller system that was linked to sensors that can measure water level and detect flames. The water level sensor was required to keep an eye on the water level and guarantee that the pump produces water. When it detected a flame, the system sounded an alert for a brief period while it waited to see if the flame was out or if the alarm was set off by mistake. After the brief period, if the fire was still there, a signal was given to the pump to start pumping water to the sprinkler, which sprinkles water to put it out. The alarm system went off when the fire was extinguished, signaling that no more fire had been found. Consequently, a micro controller based fire alarm system with a water sprinkler was proposed.

Keywords: *Micro Controller, Sensor, System, Automatic alarm, Water sprinkler*

1.0 INTRODUCTION

Societies had to fight flames as they started before humanity discovered how to use electricity (Ifeagwu *et al.*, 2017). Caesar Augustus established the Corps of Vigiles in 6 AD as a response to the many fires that plagued ancient Rome (Sandler, 2010). Since there was no alternative way to detect or prevent fires, this strategy concentrated on putting out fires as they started (Ifeagwu, Edeko and Emagbetere, 2015). Fires could only be discovered after the structure had sustained most of its damage, and they could only be put out as they got worse (Bruce Dressel, 2020).

A number of 19th-century innovations significantly improved the state of fire detection (Sandler, 2010). After Samuel Morse created the telegraph in 1837, others quickly exploited this early method of long-distance communication (Enebe *et al.*, 2017a). This approach transformed the concept of a "central bell tower" into a "central station." In essence, an operating center located in the middle of the neighborhood received a notification from a box there. The central station would ring the bell tower in response to a fire alarm and notify first responders of the precise neighborhood from whence the signal came (Enebe *et al.*, 2017b). The capacity to locate a fire accurately led to the first-ever significant improvement in dispatch times (Sandler, 2010).

According to Ifeagwu *et al.* (2015), vocal evacuation system might notify residents of the location of a fire, the appropriate evacuation protocol, and the fact that the alarm was not a rehearsal, in place of the same light flashes and sirens going off for every distinct fire incident. The ability to leave buildings during an alert event was made even more effective by personalizing the evacuation protocol, which helped to reduce the number of victims in fire-related incidents (Dressel Bruce, 2020).

It is inconceivable to envision a home or building in today's society without a fire accident detector. Installing fire detectors is a must for modern homes as well as in the workplace (Ifeagwu *et al.*, 2015). Consider a scenario in which a duplex experiences a fire without a detector; everything within the structure, including people, will burn. However, if a fire alarm is installed, everyone within the building will be notified, and fire security authorities will also be notified so that prompt security measures can be taken. The offices and industries are likewise susceptible. A fire alarm system is used to alert residents of any building in the event of a fire. By tracking environmental changes brought on by combustion, an autonomous fire alarm system is intended to identify the unwelcome presence of fire (Bryan and Nicholas 2019). With certain limitations like rapid alarming and automatically handling the fire, traditional fire alarm systems have not proven to be as effective in preventing the loss of lives and property caused by fire outbreaks. These limitations typically result in significant financial losses to properties and lives. As a result, the need for a dependable, efficient fire alarm system with automatic water sprinkler processes has become essential with the advancement of technology. It is possible to

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sense flame, start pumps, and monitor water level. Hence, a design and analysis of a micro controller based fire alarm system with water sprinkler.

2. MATERIALS AND METHOD

2.1 Materials

The Components and materials used in the work are:

1. ***Arduino Nano Microcontroller:*** A programmable microcontroller board used as the core component of the fire alarm system.
2. ***MQ-2 Smoke Sensor:*** A sensor module used to detect smoke and other combustion gasses.
3. ***Vero Board and Breadboard:*** Prototyping boards used for circuit assembly and testing.
4. ***Power Supply:*** A +12V DC power supply and a +15V adaptor charger used to provide power to the system.
5. ***Relay:*** An electromagnetic switch used to control the activation of the water sprinkler system.
6. ***Plastic Casing or Box:*** Enclosure used to house the components and protect them from environmental factors.
7. ***Cables and Jump Wires:*** Wiring used to connect the various components together.
8. ***Soldering Iron and LEDs:*** Tools used for soldering connections and indicating system status.
9. ***Black Sealing Tape, Screwdrivers, LM7805 Transistor:*** Miscellaneous tools and components used for assembly and installation.
10. ***Flame Sensors, Pressure Pump, Submersible DC Pump and Water Tank:*** Components of the water sprinkler system for fire suppression.
11. ***Heater, Sprinkler, Buzzer:*** Additional components for simulating fire conditions and activating alarms.

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12. ***Ultrasonic Sensor, Resistor, Carton, Black Marker, Glue Gun, Cutter, Black Paint:*** Supplementary materials and tools used for specific tasks during the project.

2.2 Method

1. ***Prototype Modeling***: The project employed prototype modeling as the primary technique for development. This approach allows for the creation of a functional prototype at an early stage, facilitating iterative testing and refinement.
2. ***Circuit Design and Assembly:*** The circuitry for the fire alarm system was designed using schematic diagrams and then assembled on the Vero Board and Bread Board. Connections were made using cables and jump wires, and components were soldered in place as necessary.
3. ***Programming:*** The Arduino Nano Microcontroller was programmed to interface with the MQ-2 Smoke Sensor and other components. The code included algorithms for smoke detection, alarm activation, and control of the water sprinkler system.
4. ***Integration of Fire Detection and Suppression Systems:*** The smoke sensor readings were utilized to trigger the alarm system, which, in turn, activated the relay to start the water sprinkler system. This integration ensures rapid response to fire incidents.
5. ***Testing and Validation:*** The prototype underwent rigorous testing to ensure its functionality and reliability. Various scenarios were simulated to evaluate its performance in detecting smoke, activating alarms, and suppressing fires.
6. ***Documentation and Reporting:*** Throughout the project, detailed documentation was maintained, including circuit diagrams, code listings, test results, and observations. This information was used to generate reports and analyze the effectiveness of the fire alarm system.

Furthermore, Prototype modeling is the modeling technique employed in this study. The approach delivers a functional product at an early stage of development. And it employs the prototyping modeling method because the end result effort will be a working prototype. Below is a flowchart of how this method works.

2.3 Flowchart of code:

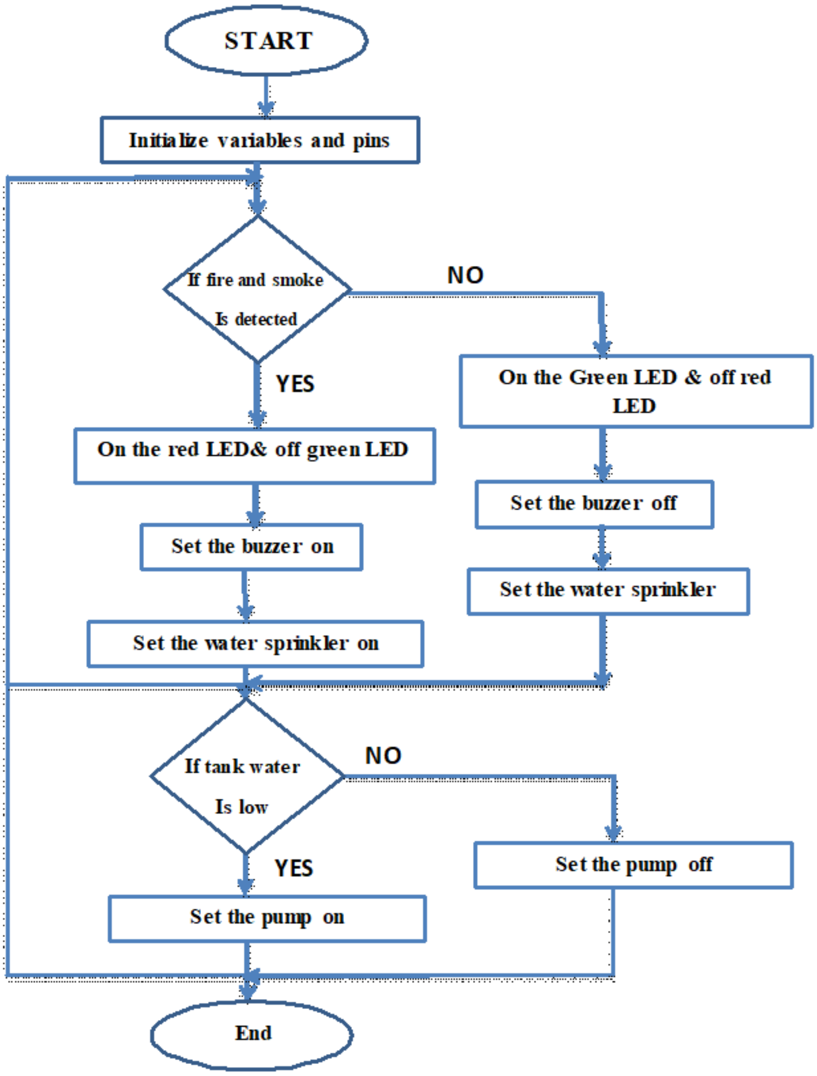

Figure 1: Flowchart of code

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3.0 DESIGN AND ANALYSIS

3.1 Circuit diagram:

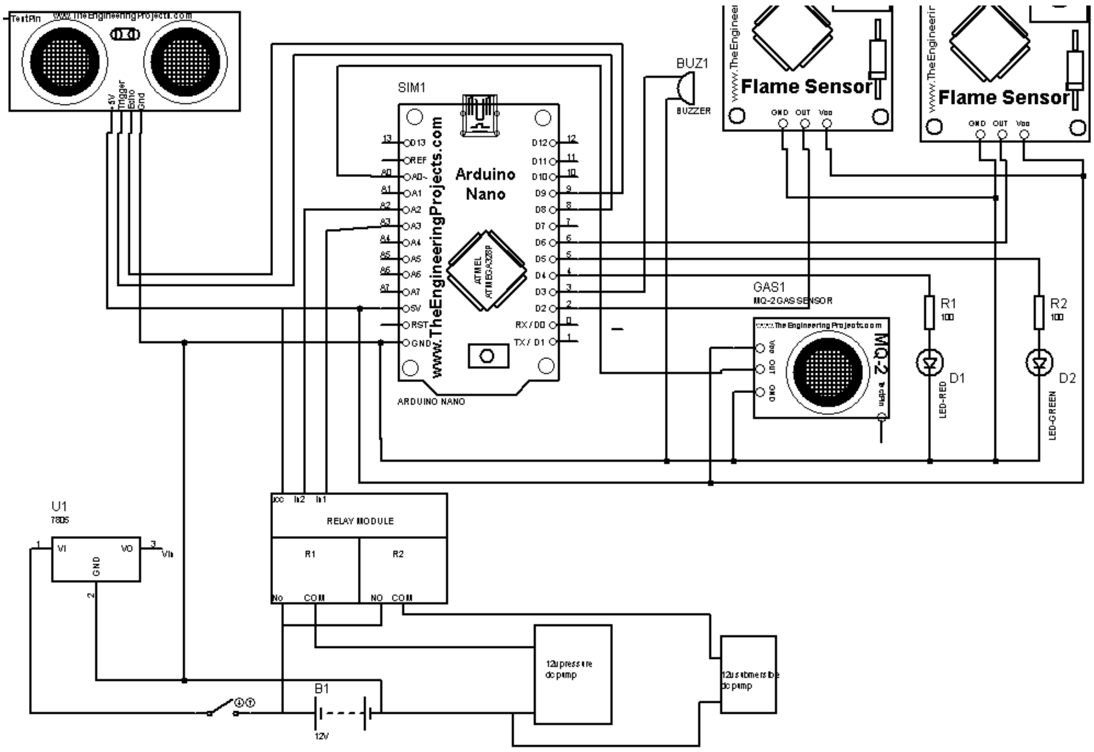

Figure 2: Circuit Diagram Designed with Proteus

3.2 Explanation of The working principle of the systems circuit in Figure 2:

The microcontroller's 5 volts is connected to the VCC of the flame, smoke, and ultrasonic sensors, and its GND is connected to its GND. To power the sensors, a signal travels from the microcontroller's 5 volt source into them and is then grounded via the GND pin.

The microcontroller's pins D6, D2, and A0 are connected to the sensors' OUTs and pins A0 is connected to the smoke sensors OUT. The microcontroller's D8 and D9 pins are linked to the ultrasonic sensor's TRIG and ECHO pins. Thus, these pins are used by the sensors to transmit signals back to the microcontroller when they function.

One end of the pumps is connected to the 2 COMMON (COMs) of the 2 channel relay. The other ends of the pumps are connected to the negative end of the 12V DC battery used. The 12V DC battery is connected to an LM7805 transistor which is then connected to the VIN and ground and the microcontroller. The ports of the relay (VCC, IN1, and IN2) are connected to the microcontroller via pins 5V, A3, A2 respectively.

3.3 Algorithm of the construction:

Step 1: Supply Power to the entire circuit.

Step 2: While the sensors (flame sensors, smoke sensor and temperature sensor are set up at strategic points in the prototype box, if there is detection of fire and smoke together, signals will be sent to the microcontroller (Arduino).

Step 3: The microcontroller (Arduino) will send a signal to the GSM Module and Buzzer to indicate that there is a fire outbreak.

Step 4: The Microcontroller (Arduino) will send a signal to the pump to pump water from the prototype tank.

Step 5: While pumping water from the tank to the sprinkler, if there is a low level of water in the tank, the water level sensor sends a signal to the microcontroller (Arduino).

Step 6: The Microcontroller (Arduino) sends a signal to the dc pump to pump water from the prototype underground reservoir into the prototype tank.

THIS IS TO ENSURE THAT WATER IS Always READY AVAILABLE.

Step 7: After the fire and smoke is quenched, the alarm (buzzer) stops beeping and the fire indicator turns green.

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4.0 SYSTEM TESTING AND RESULTS

Unit Test 1: Detection of Fire Outbreak in the system
Test Objective: To detect the outbreak of fire and give out an indication for an outbreak.

Table 2: Detection of Fire Outbreak in the system

NO	TEST CASE	EXPECTED RESULT	RESULT
1	Detection of fire outbreak in the system	Successful detection of fire	Pass 95%

Unit Test 2: Detection of Smoke in the system
Test Objective: To detect smoke and give out an indication for an outbreak.

Table 3: Detection of Smoke in the system

NO	TEST CASE	EXPECTED RESULT	RESULT
1	Detection of smoke in the system	Successful detection of smoke	Pass 60%

Unit Test 3: Sprinkling of water to quench Fire
Test Objective: To Sprinkle water continuously until the fire is put out.

Table 3: Sprinkling of water to quench Fire

NO	TEST CASE	EXPECTED RESULT	RESULT
1	Sprinkling of water to quench Fire	Successful release of water to put out the fire.	Pass 97%
2	Pumping of water when water is low	Successfully pumping water into the reservoir tank when its water level is low	Pass 99%

Unit Test 4: Charging of battery
Test Objective: To charge the 12V DC battery with a 15v adapter.

Table 4: Charging of battery

NO	TEST CASE	EXPECTED RESULT	RESULT
1	Charging of battery	Successful charging of 12v DC battery	Pass 96%

Unit Test 5: Working of the entire system
Test Objective: To check for efficiency and performance of the system.

Table 5: Working of the entire system

NO	TEST CASE	EXPECTED RESULT	RESULT	
			EFF.	PERF.
1	Working of the entire system	Proper working of the system without any error	90%	99%

CONCLUSION

The purpose of this study was to design a microcontroller-based fire alarm system with a water sprinkler to enhance the traditional fire alarm system's detection and quenching process, which is still widely utilized by several institutions in Africa. Furthermore, a microcontroller-based system was to take the place of the traditional fire alarm system. Traditional fire alarm systems, with their constraints of rapid warning and automatic fire control, have not shown to be as successful in reducing the number of people killed and property destroyed by fires. In conclusion, the classic fire alarm system, which is still extensively used by many institutions, notably in Africa, will be replaced with a microcontroller based system. The goal of this system is to improve the accuracy, convenience, efficiency, and dependability of the entire fire detection and quenching procedure. In addition, the use of water spraying technologies will lessen the number of people killed in the event of an outbreak.

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