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Development of Fire and Temperature Monitoring Interface in The Engine Room Using Visual Basic Programming

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***Abstract*— The design of the Temperature and Fire Monitoring Interface using Visual Basic Programming aims to detect fires at any time on the ship, especially in the main engine and diesel generator rooms. If the ship's initial conditions in the Main Engine room and diesel generator room are created to cause a fire, the tool will send a fire hazard signal which can be directly monitored by the ship's crew so that prevention can be carried out as early as possible. This design uses two smoke sensors and temperature sensors as inputs, one Arduino Uno microcontroller as a controller, one PC / Laptop as an interface for monitoring temperature and smoke conditions. The result of this system is that if the input temperature sensor and smoke sensor do not detect a fire hazard, the interface output displays a green color. If the temperature and smoke sensor input detects a fire hazard, the interface output will print red, and the buzzer output will light up as set by a visual basic program.**

Keywords— Arduino Uno, Fire detection, Smoke Sensor, Microcontroller, Visual Basic Programming, Temperature Sensor.

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I. INTRODUCTION

The Safety of Life at Sea (SOLAS) Regulations constitute the paramount international framework governing maritime safety[1]. This regulatory regime underwent significant modernization with the adoption of the SOLAS Convention in 1960, which superseded the earlier 1914 convention. Subsequent iterations incorporated comprehensive requirements aimed at enhancing vessel safety, encompassing critical domains such as structural integrity and design, propulsion and electrical systems, fire prevention and suppression measures, lifesaving appliances, and navigational and communication equipment[2]. Continuous refinement of these regulations has been achieved through successive revisions (amendments) to the International Maritime Organization (IMO) convention, enacted in the years 1966, 1967, 1971, and 1973. A fundamental procedural change was introduced with the SOLAS 1974 Convention, establishing a tacit acceptance mechanism whereby amendments automatically enter into force on a predetermined date unless explicitly rejected by a defined threshold of member states or global tonnage holder. Tanker accidents occurred in succession in 1976 and 1977, therefore on the initiative of the President of the United States Jimmy Carter, a special conference was held to recommend additional rules to SOLAS 1974 so that protection of maritime safety would be more effective [1]. The new Global Maritime Distress and Safety System (GMDSS) regulation in 1990 was a fundamental change made by IMO to the maritime communication system, by utilizing technological advances in the field of communication such as satellites, and will be implemented gradually from 1995 to 1999 [3,4]. The basic concept is, that the SAR Agency on land and ships that receive news of a ship accident (vessel in distress) will be immediately alerted to help coordinate the implementation of SAR operations [5].

Various efforts have been made in terms of anticipating fire hazards, such as training on the role of fire and ship leaks or fire training. However, in reality, we often find crew members who still have difficulty in preventing or handling fires. When a fire occurs, there is no early warning for those concerned and the location of the first fire is difficult to detect. The solution to overcome this problem requires a system that can provide early warning to those concerned when a fire occurs so that the losses incurred can be minimized and firefighting equipment in the form of a water sprayer can be added to slow the fire from spreading. The system referred above is a fire extinguishing system including temperature sensors and smoke sensors that can be monitored automatically via a laptop or PC. The purpose of this study is to create an interface design that functions to control or monitor the occurrence of fire hazards in the Engine Control Room, DieselGenerator Room, patrol boat, ship in real-time which is monitored and controlled in the Engine Control Room or patrol boat bridge using visual basic programming [6].

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This study uses USB communication as a means of communication between Arduino and PC and uses Arduino Uno as a device tasked with processing temperature and smoke data. Personnel Computer/Laptop is used for the interface display [7]. This design uses two sensors, namely the MQ2 smoke sensor and the SHT11 temperature sensor [8]. This monitoring system is intended for the ship's engine room and has never been installed or tested on a ship [9].

II. METHOD

This chapter presents the foundational principles underlying fire classification systems and explores the methodologies employed in the design and development of relevant software applications.

A. The Fire Classification

The classification of fires or flames adopted by Indonesia is the classification of fires adopting the National Fire Protection Association (NFPA) system, fires are categorized into[10]:

a. Class A: fires or flames that occur in solid fuels, such as; wood, cloth, paper, cotton, rubber, plastic, and so on.
b. Class B: fires or flames that occur in liquid fuels, such as; gasoline, kerosene, spirits, diesel, jet fuel, and so on.
c. Class C: fires or flames that occur due to failure of electrical equipment.
d. Class D: fires or flames that occur in metal fuels or metals, such as; magnesium, titanium, and aluminum.

B. Sensor

There are four fire extinguishing techniques [11]. Based on the elements and reactions that form the fire, then by removing one of these elements, or the reaction that occurs, the fire can be extinguished. The fire extinguishing techniques are as follows:

a. Smothering (covering), is an extinguishing technique by separating fuel vapor from air.
b. Cooling (cooling), is an extinguishing technique by absorbing heat from the burning fuel, so that the combustion process will be blocked.
c. Starvation (reducing or separating fuel), is an extinguishing technique by cutting off the fuel supply.
d. Breaking chain reaction is an extinguishing technique by breaking the chain of chemical reactions/combustion reactions, or by capturing free radicals such as OH^- and H^+ so that they cannot continue the combustion process of the fire.

The sensor is part of the transducer that functions to sense or "feel and capture" changes in external energy that will enter the input section of the transducer so that changes in the captured energy capacity are immediately sent to the converter section of the transducer to be converted into electrical energy. The following are the types of sensors:

a. A light sensor is a tool used to convert light quantities into electrical quantities. The working principle of this tool is to convert photon energy into electrons. One of its most popular uses is a digital camera.
b. A temperature sensor is a tool used to convert heat quantities into electrical quantities. There are several methods used to make this sensor, one of which is by using a material that changes its resistance to electric current according to its temperature

SHT11 is a type of sensor module for measuring temperature and humidity with digital output [12]. Through a serial connector, the temperature and humidity read have a high level of accuracy. The features of SHT11 are:

a. Temperature ranges from -40°C to +123.8°C
b. Temperature accuracy +/- 0.5°C with an increase of 25°C
c. Humidity ranges from 0 to 100% RH
d. Absolute RH accuracy +/- 3.5% RH
e. Low power consumption (30 μW)

The MQ2 sensor serves as a detection mechanism for cigarette smoke present in the atmosphere[13]. Upon exposure to gases characteristic of cigarette smoke, such as particulate matter, the sensor experiences a decrease in its electrical resistance. This operational principle allows for the identification of smoke gas concentration. Regarding its physical interface, the MQ2 sensor incorporates six pins: three designated for the positive power supply (VCC) operating at +5 volts, which energizes both the internal heater and sensing element; one for the ground connection (VSS); and one serving as the analog or digital output signal pin. Beyond the application of thermal and smoke detection sensors, fire monitoring and suppression systems can also be supplemented by video surveillance systems. [14,15].

C. Microcontroller

A microprocessor is part of the Central Processing Unit (CPU) of a computer, without memory, I/O (input/output), and peripherals needed by a complete system. To work, a microprocessor requires supporting devices such as RAM, ROM, and I/O. If a microprocessor is combined with I/O and memory (RAM/ROM), a microcomputer will be produced, as a breakthrough. This microcomputer can be made in the form of a Single Chip Microcomputer (SCM) which is then referred to as a microcontroller. The difference between a microcomputer and a microcontroller is in the use of I/O devices and program storage media. If a microcomputer uses a diskette or a hard drive, a microcontroller uses PEROM as its program storage. The advantage of a microcontroller compared to a microprocessor is that the microcontroller already has RAM and supporting I/O equipment so there is no need to add it.

A microprocessor constitutes a core component of a computer's Central Processing Unit (CPU), yet lacks the integrated memory, input/output (I/O) capabilities, and peripheral interfaces essential for a fully functional system. The primary advantage of a microcontroller over a microprocessor lies in its inherent integration of RAM and essential I/O support components, thereby eliminating the necessity for their external addition.

Arduino represents an open-source electronics platform, fundamentally comprising a circuit board whose central element is a microcontroller chip, specifically the AVR series manufactured by Atmel[16]. This microcontroller component is an integrated circuit (IC) designed to be programmed via an external computing device. The purpose of embedding a program in a microcontroller is so that the electronic circuit can read the input, process the input, and then produce the desired output [17]. Thus, the microcontroller acts as the 'brain' that controls the input, process, and output of an electronic circuit.

The constituent elements of the Arduino board can be delineated as follows :

a. 14 Digital Input/Output Pins (0-13): These pins are configurable via programming to operate either as inputs or outputs. Six specific pins (3, 5, 6, 9, 10, and 11) additionally provide analog output functionality, permitting programmed adjustment of their output voltage. The analog output level is specified by a discrete value between 0 and 255, corresponding linearly to an output voltage range of 0 to 5 volts DC.
b. USB Port: This interface facilitates three primary operations: transferring program code from a host computer to the board, enabling serial data communication between the board and the computer, and supplying electrical power to the board circuitry.
c. SV1 Connection (Power Source Selection Jumper): This connection, implemented as a jumper, historically allowed manual selection between an external power source and the USB port for board power. Note that this manual selection mechanism is absent in the most recent Arduino board iterations, as power source selection is now performed automatically.
d. Q1 - Crystal Oscillator (16 MHz Quartz Crystal): Functioning analogously to the system's pacemaker, the crystal oscillator generates a precise clock signal essential for microcontroller operation. The selected crystal frequency is 16 million cycles per second (16 MHz), dictating the fundamental timing for processor execution.
e. Reset Button (S1): Activating this button initiates a system reset, causing the currently loaded program to restart execution from its initial state. It is critical to note that this action does not erase the stored program code or clear the microcontroller's memory.
f. In-Circuit Serial Programming (ICSP) Header: This port provides a direct interface for programming the microcontroller's firmware, bypassing the standard bootloader process. While available on the board, the ICSP interface is infrequently utilized by typical Arduino users, who predominantly employ the conventional USB programming method.
g. IC1 – ATmega Microcontroller: Serving as the central processing unit of the Arduino board, this integrated circuit incorporates the core Central Processing Unit (CPU), Read-Only Memory (ROM) for program storage, and Random Access Memory (RAM) for temporary data storage.
h. X1 – External Power Supply Jack: For operation via an external power source, this jack accepts a direct current (DC) voltage input within the range of 9 to 12 volts.
i. Six Analog Input Pins (0-5): These pins are instrumental for acquiring voltage signals generated by analog sensors (e.g., temperature sensors). Through programming, the voltage present at these input pins can be read as a discrete value within the range of 0 to 1023. This value represents a linear conversion of the input voltage, where 0 corresponds to 0 volts and 1023 corresponds to 5 volts DC.

D. Visual Basic(VB)

Microsoft Visual Studio constitutes a comprehensive integrated development environment (IDE) suite designed to facilitate the development of diverse applications. This encompasses business solutions, personal software, and application components, which may be implemented as console applications, Windows-based applications, or web applications [18]. The suite incorporates essential development tools including a compiler, Software Development Kit (SDK), Integrated Development Environment (IDE), and comprehensive documentation (typically provided via the MSDN Library). Compilers integrated within the Visual Studio package encompass Visual C++, Visual C#, Visual Basic, Visual Basic .NET, Visual InterDev, Visual J++, Visual J#, Visual FoxPro, and Visual SourceSafe. Microsoft Visual Studio enables the creation of applications utilizing either native code (compiled into machine language executable directly on the Windows operating system) or managed code (compiled into Microsoft Intermediate Language (MSIL) for execution within the .NET Framework). Furthermore, Visual Studio supports the development of Silverlight applications and applications targeting the Windows Mobile platform (executing on the .NET Compact Framework).

E. Database

A database constitutes a structured framework engineered to systematically organize, store, and facilitate efficient data retrieval. It encompasses digitally formatted data collections methodically arranged for one or more operational purposes. MySQL exemplifies a database management system (DBMS), essential for appending, querying, and manipulating information within computerized databases. Given computers' proficiency in processing voluminous data, DBMSs fulfill a critical function in computing—operating either as autonomous utilities or embedded components within broader applications.

MySQL functions as a relational database management system (RDBMS), wherein data resides in discrete tables to optimize performance and adaptability. Inter-table relationships enable consolidated data extraction from multiple sources via singular queries. The "SQL" designation denotes "Structured Query Language," the predominant lingua franca for database interaction. MySQL's connectivity efficacy, processing velocity, and security protocols render it exceptionally suitable for internet-based database access. Architecturally, it employs a client-server model featuring a multithreaded SQL server supporting diverse backends, heterogeneous client programs and libraries, administrative instruments, and multiple programming interfaces [19]. Additionally, MySQL is distributable as an integrable library for application embedding, while its extensive ecosystem of supplementary software ensures compatibility with numerous preferred applications and programming languages.

III. RESULTS AND DISCUSSION

A. Block Diagram and How the Circuit Works

A block diagram is a sequential relationship between one or more components that have their working units as shown in Figure 1.

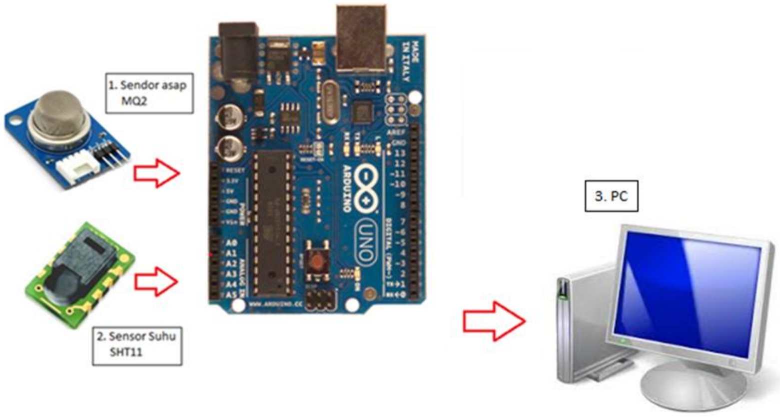

Figure. 1. Block Diagram

The working principle of the automatic fire extinguisher sensor system is that after the smoke sensor and temperature sensor get the input value, the data obtained by the sensor will be translated and then the V_{out} from this sensor will send data to the processor which we have designed with a controller block diagram. The data sent is logical 1 (one) then the processor will activate the buzzer as an alarm or siren. The data we get from the sensor will be displayed on the LCD and in the interface display using a PC with the help of a USB cable.

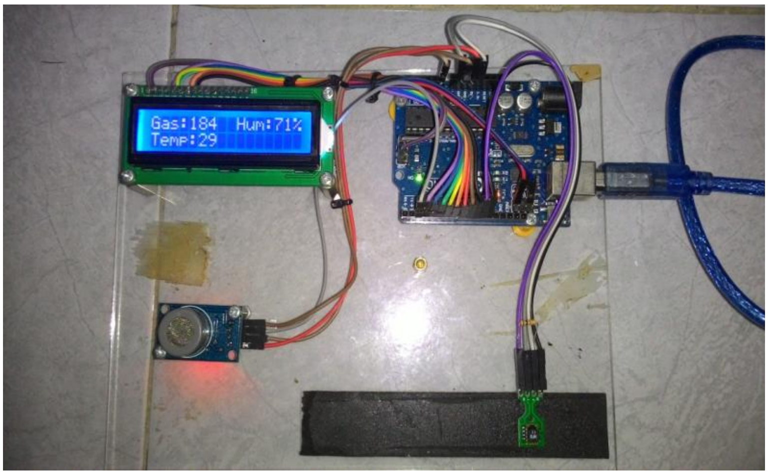

Figure. 2. Temperature and Smoke Sensor Input Circuit

A health condition or normal condition of a room is a condition where the temperature and smoke in the room are in good condition without any disturbance, namely, the normal room temperature of 29ºC and the smoke content in the room is 184 ppm as stated in the LCD as shown in Figure 2, then the data will be processed by Arduino then stored in the internal memory before the data is sent to the display/interface on the laptop/PC via a USB cable. The display on the interface on the laptop shows the condition of the room in a normal state which is indicated by a green image both in the rooms and on the temperature indicator or smoke indicator while the temperature and smoke graph shows the value in a stable condition with the red and blue lines moving straight as shown in Figure 3.

Figure. 3. Interface display in normal condition

Fault Condition

Fault Condition/dangerous condition in a room is a condition where the temperature and smoke levels in the room are not in normal conditions, meaning there is an increase in temperature and smoke levels that can be dangerous.

The Occurrence of Heat

Temperature and humidity sensor testing is carried out by testing the performance of the SHT11 sensor, as well as seeing the reading ability of the SHT11 sensor [20]. Schematic of SHT11 test circuit shown in Figure 4.

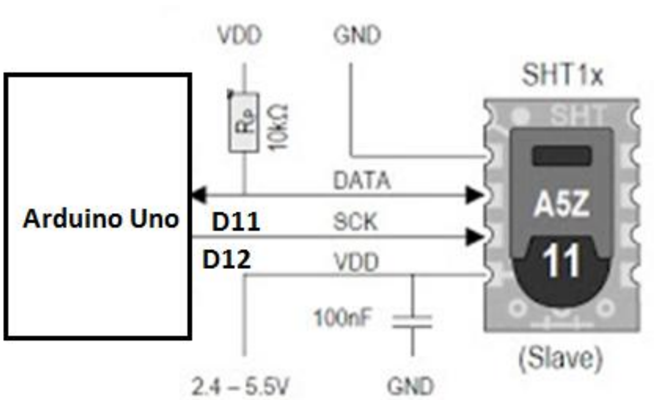

Figure. 4. Schematic of SHT11 test circuit

The SHT11 sensor is a sensor that can detect temperature and humidity with a range of -40°C to 123.8°C or -40°F to 254.9°F, and 0 to 100% RH. There are two pins used on the SHT11 to communicate with the microcontroller, namely the SCK pin and the DATA pin. The SCK pin functions to synchronize communication between the SHT11 and the microcontroller, while the DATA pin functions to transfer data in and out of the SHT11.

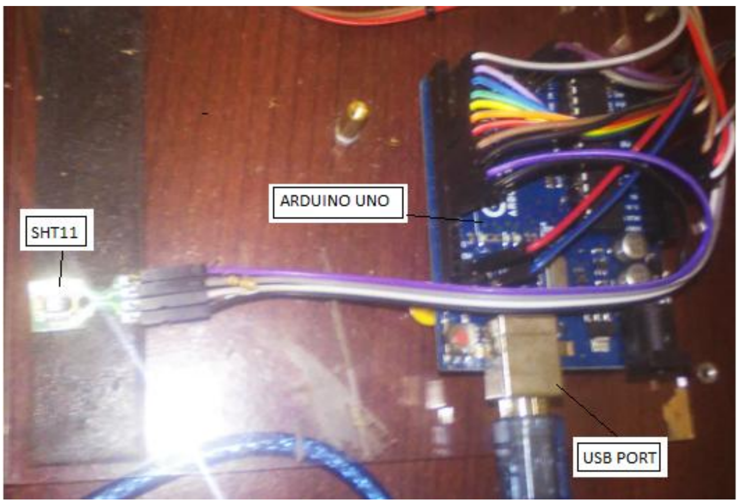

Figure. 5. SHT11 Test Circuit.

Testing Procedures:
1) Connect the SHT11 sensor to the Arduino Uno.
2) Connect the data to pin D11, SCK or clock to D12, Ground to Ground and VDD to +3.3 Vdc
3) Connect the Arduino Uno Board USB Cable
4) Increase the temperature using a lighter.
5) See the temperature and humidity readings on the LCD

The process of testing the temperature and humidity sensor using a match. Supposedly the room conditions are normal with a temperature sensor value of 29ºC, previously we carried out the settings on the set point on the laptop display at the temperature, for example, the initial temperature/initial set point is set to 40ºC, after that light the match then bring it close to the temperature and humidity sensor shown in Figure 5.

Figure. 6. SHT11 Temperature Sensor Test Process with a match

Within a few seconds, there is a change in temperature where the temperature shows a change to 35ºC and a change in the pattern on the temperature graph that increases approaching the initial set point shown on the interface on the laptop. This indicates that there is a fire hazard so that it activates the alert condition which is marked by an orange alarm at the location where the fire hazard is detected as shown in Figure 7.

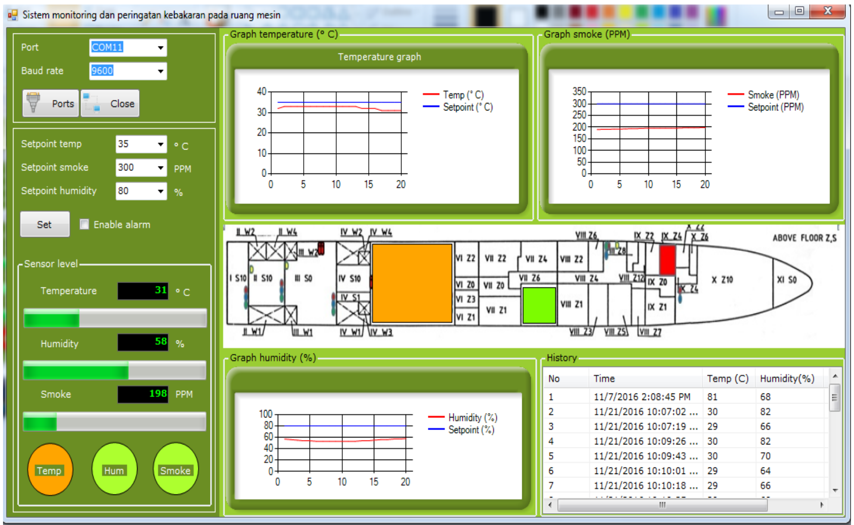

Figure. 7. Standby condition test results on PC Monitor

If during the alert condition, the fire hazard has not been resolved, the situation will be raised to an emergency condition which is marked by the temperature continuing to rise beyond the set point limit set at the beginning, the alarm sound getting faster, and the color changes from orange to red which is displayed on the interface on the laptop. Emergency condition test results on the PC Monitor as shown in Figure 8.

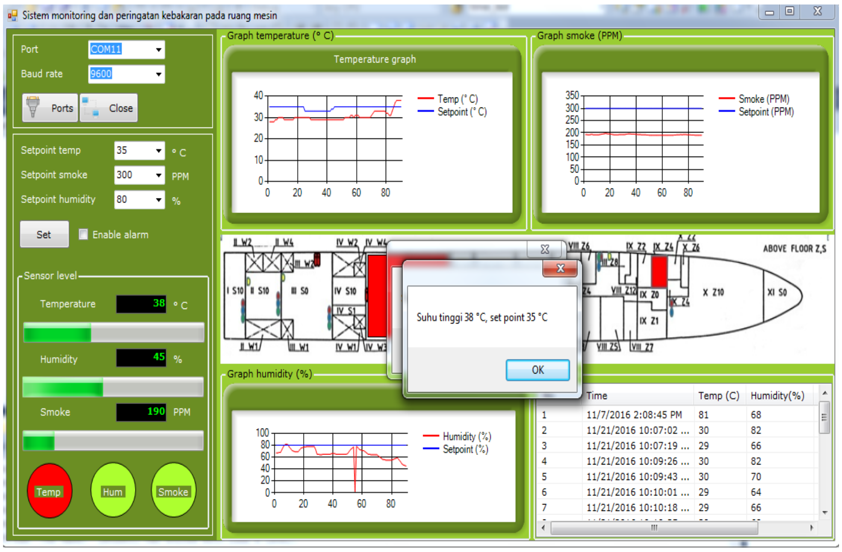

Figure 8. Emergency condition test results on PC Monitor

Occurrence of Smoke

This smoke detector has several properties, including being very sensitive to smoke, if the incoming supply is of the wrong polarity, it will not be damaged and more than one smoke detector can be connected [21]. The design of this system uses a smoke detector, namely the Smoke Detector MQ2. The installation of the smoke detector is shown in Figure 8.

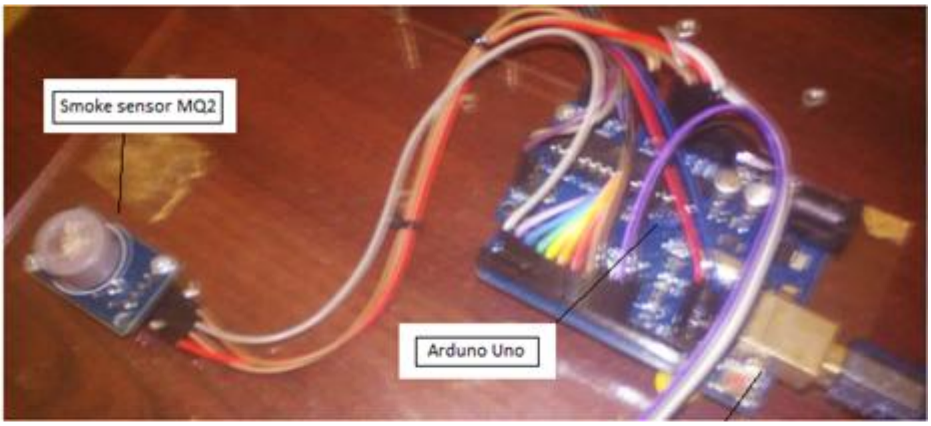

Figure. 9. MQ2 Smoke Sensor Test Circuit

Testing Procedure:
1) Connect Arduino, MQ2, and LCD.
2) Connect MQ2 analog output to Arduino analog input A0.
3) Connect the Limiter output to Arduino pin D2.
4) Download the MQ2 sensor reading program and display the reading result
5) Observe the display on the LCD, and make sure the MQ2 sensor reading data is correct.
6) Smoke testing using glass media with different smoke content

The process of testing the MQ2 smoke sensor using cigarette smoke. The embers on the cigarette are put into a glass and then brought close to the smoke sensor. Within a few seconds, there is a change in the smoke level where the smoke level shows a change to 206 ppm indicating a fire hazard it activates the alert condition which is marked by an alarm and an orange color at the location where the fire hazard is detected (according to Figure 5). If during the alert condition, the fire hazard has not been resolved, the situation will be raised to an emergency condition which is marked by the smoke level continuing to rise beyond the set point value that has been set, the alarm sound getting faster, and the color changes from orange to red which is displayed on the interface on the laptop shown in Figure 10.

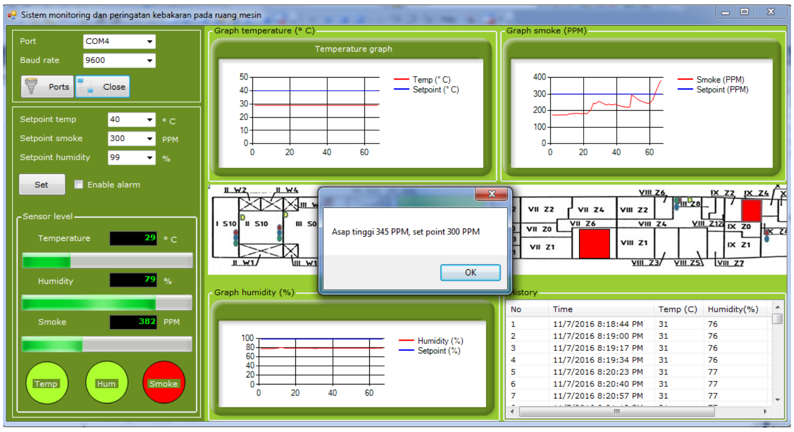

Figure. 10. Emergency condition test results

Occurrence of Heat and Smoke

This condition occurs when the input from both the temperature sensor and the smoke sensor exceeds the normal standard or set point that we determine, then the input value from both sensors will be sent to the Arduino to be processed and then sent to the display/interface on the laptop via a USB cable [21]. For example, the temperature sensor is brought close to a match while the smoke sensor is brought close to cigarette embers resulting in a rapid increase in temperature and smoke, this increase is then forwarded to the Arduino and then sent to the display on the laptop via a USB cable. the input value displayed on the interface exceeds the specified normal standard/set point, it causes various warnings, including continuous alarms, changes in the color of temperature and smoke on each text box from orange to red, and there is a message point display from each sensor.

Figure. 11. Temperature and Smoke Sensor Test Results

The SHT11 sensor test uses a standard tool as a reference, namely a digital thermometer that displays temperature and humidity parameters.

TABLE 1.
SHT11 SENSOR TEST RESULTS UNDER HOT CONDITIONS

Sample	Thermometer		Sensor *SHT 11*		Error (ºC)	Error (%)
	(ºC)	(%)	(ºC)	(%)		
1	32.4	34.4	32	42	0.4	7.6
2	34.7	40.4	33	42	1.7	1.6
3	38.2	42.4	37	40	1.2	2.4
4	41.5	42.4	42	41	0.5	1.4
5	45.1	40.4	48	40	2.9	0.4
6	46.9	40.4	45	39	1.9	1.4
7	50.2	40.4	50	39	0.2	1.4
8	53.3	38.4	55	37	1.7	1.4
9	55.0	36.4	56	36	1.0	0.4
10	55.6	36.4	55	36	0.8	0.4
Mean					1.23	1.84

The use of standard measuring tools aims to compare the readings of the SHT11 sensor with a digital thermometer to determine the level of error in the readings of the SHT11 sensor. This test uses hot conditions using a flame on a candle. The test is carried out with the initial temperature and humidity of the SHT11 and the standard tool on a candle with a distance of 5 cm in a room. Data collection is carried out every three minutes for 30 minutes. The SHT11 sensor can read temperature changes in hot conditions. There is still a difference/error between the sensor and the thermometer. Quantification of measurement accuracy yielded mean errors of 1.23 °C for temperature parameters and 1.84% for relative humidity parameters. Researchers analyzed the possibility that the temperature and humidity sensors in the thermometer are in the plastic casing of the thermometer so that they are less sensitive to the rate of change. This is different from the SHT11 sensor which is directly adjacent to the flame on the candle. The Sensor Circuit can operate by processing and displaying the value of temperature and humidity on the LCD. The SHT11 sensor placed in the Sensor circuit can operate well. The SHT11 sensor can measure the magnitude of high-temperature changes. Then the Arduino Uno microcontroller can process it well and display it on the LCD screen. The SHT11's dual-function environmental monitoring capability functions effectively even at elevated temperatures, a critical factor in sustaining the system's comprehensive operational efficacy.

IV. Conclusion

The SHT11 thermal sensor and MQ2 particulate sensor, when empirically evaluated, show operational efficacy in simultaneous temperature and smoke detection across two discrete compartments. The implementation of the monitoring system using Visual Studio 2010 can run well and the feature side is quite adequate as a fairly reliable monitoring system accompanied by a color change if a fire hazard is detected, namely alert conditions (orange) and emergency conditions (red).

After conducting research and experiments on this automatic fire extinguisher, several things were obtained that can be used as suggestions for further research development, namely:

a. Development for multidrop communication between Arduino devices and PC devices so that communication with Arduino devices that are more than one unit and a longer communication distance can be obtained or can utilize communication using WIFI devices.
b. It is recommended to use more than two types of sensors so that more input value parameters are obtained.
c. This tool is packaged in a safer and more protected form so that its use is more effective.

Addition of action messages so that if a fire hazard is detected, the ABK can immediately take preventive action

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