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DESIGN AND IMPLEMENTATION OF AN AUTOMATIC FIRE EXTINGUISHING SYSTEM BASED ON FAULT SECURE MULTI-DETECTORS

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Abstract*- Fire disaster is a common threat to lives and property. An automatic fire extinguishing strategy provides real time monitoring, exploration and programmed fire alarm. This paper presents the design of a low cost, robust and secure fire protection system for buildings .It sends early alarm when the fire occurs and helps to reduce the fire damage. This system consists of a smoke detector and a temperature sensor whose outputs are connected to the controller. The system takes into account the density of smoke and thus the probability of false alarms can be avoided. A PIC16F84A microcontroller is considered here to control the total arrangement and the test results through hardware prototype show that the validity of proposed approach which achieves design requirements as well as increase system reliability.*

Keywords: Fire extinguisher, Detectors, Controller, Fault tolerance, Sensitivity.

1. INTRODUCTION

In our country fire accident is a very common phenomenon. Many wealth and lives are fallen in danger. As a developing country we have no modern technology to solve this problem. The main sector of fire brigade has limitation to overcome it. Sometimes police, military come to the firing spot to help them. But this is not enough. If an automatic fire extinguishing system available, offers greater flexibility [1].

In conventional automatic fire-extinguishing systems utilizing a fire-extinguishing gas, a bomb containing a fire-extinguishing gas, such as halon gas, under pressure is provided at a location. Several gas jetting nozzles are arranged at desired locations within a region when a fire occurs therein. The gas jetting nozzles are connected through a valve and a pipe to the bomb. Fire sensors are arranged at desired locations within the region. In response to a fire signal from the fire sensors, the valve is opened to cause fire-extinguishing gas to jet from the gas jetting nozzles into the region so that automatic extinguishing can be effected therein [2].

However, since such conventional automatic fire-extinguishing systems require a complicated system of gas pipes from a gas bomb to the gas jetting nozzles, the cost and installation of the pipes is expensive. Moreover, since the gas pipes are fixedly arranged in the walls, ceiling etc., of a room defining a region, it is not easy to remove the gas pipes and to change the arrangement of the gas jetting nozzles. Furthermore, the gas bomb to be used must have a capacity comparable with the space of the region and therefore, gas bombs having different capacities must be prepared for different regions. This is very uneconomical.

To eliminate the drawbacks of the above-mentioned conventional fire extinguishing system a Portable automatic fire protection system is disclosed comprising battery powered ,independent suppressor units, each including a supply of fire extinguishing fluid and a fire detector. The connection of the individual unit's control circuits provides a control circuit network that automatically initiates an extinguishing fluid discharge from all units in response to fire detection by any single unit [3].

The main object of this paper is to provide an automatic fire-extinguishing system which eliminates the above described disadvantages of the prior arts, and to enable easy installation or removal of the system in or from a region wherein automatic fire-extinguishing should be effected [4] and to allow a flexible arrangement of gas jetting nozzles according to the size and shape of the region.

The main part of this task is the involvement of a microcontroller [5] which may be considered to be the nucleus of the whole system. We established a closed loop feedback system with microcontroller which senses the temperature sensor, smoke detector signal and send it to the solenoid valve through some control circuits to maintain the magnitude of temperature to a certain level.

This paper is illustrated as follows: Section 2 describes the brief overview of fire extinguisher. Automatic control method of fire extinguisher is presented in section 3. Results and analysis is demonstrated in section 4. Finally conclusions are drawn in section 5.

2. FIRE EXTINGUISHER

A fire extinguisher is an active fire protection device used to extinguish or control small fires, often in emergency situations. Typically, a fire extinguisher consists of a hand-held cylindrical pressure vessel containing an agent which can be discharged to extinguish a fire.

There are two main types of fire extinguishers: Stored pressure and generated pressure [6]. In stored pressure units, the expellant is stored in the same chamber as the firefighting agent itself. Depending on the agent used, different propellants are used. With dry chemical extinguishers, nitrogen is typically used; water and foam are pressurized with air. Stored pressure is the most common type of fire extinguisher. Cartridge-operated extinguishers contain the expellant gas in a separate cartridge that is punctured prior to discharge, exposing the propellant to the agent. These types are not as common, used primarily in areas such as industrial facilities, where they receive higher-than-average use. They have the advantage of simple and prompt recharge, allowing an operator to discharge the extinguisher, recharge it, and return to the fire in a reasonable amount of time. Unlike stored pressure types, these extinguishers utilize compressed carbon dioxide instead of nitrogen, although nitrogen cartridges are used on low temperature (-60 rated) models. Cartridge operated types are available in dry chemical and dry powder in the US and water, wetting agent, foam, and dry powder (ABC, BC, or D) in the rest of the world Fire extinguishers are further divided into handheld and cart-mounted, also called wheeled extinguishers. Handheld extinguishers weigh from 0.5 to 14 kilograms (1 to 30 pounds), and are hence easily portable by hand. Cart-mounted units typically weigh 23+ kilograms (50+ pounds). These wheeled models are most commonly found at construction sites, airport runways, heliports, as well as docks and marinas. Internationally there are several accepted classification methods for hand-held fire extinguishers. Each classification is useful in fighting fires with a particular group of fuel [7].

According to the standard BS EN 3, fire extinguishers in the United Kingdom as all throughout Europe are red RAL 3000, and a band or circle of a second color covering between 5-10% of the surface area of the extinguisher indicates the contents. Before 1997, the entire body of the fire extinguisher was color coded according to the type of extinguishing agent.

The UK recognizes five fire classes:

Class A fires involve organic solids such as paper and wood.

Class B fires involve flammable liquids and liquefiable solids.

Class C fires involve flammable gases.

Class D fires involve metals.

Class F fires involve cooking fat and oil.

Fire extinguishing performance per fire class is displayed using numbers and letters such as 13A, 55B.EN3 does not recognize a separate electrical class - however there is an additional feature requiring special testing (35 kVA dielectric test per EN 3-7:2004). A powder or CO_2 extinguisher will bear an electrical pictogram as standard signifying that it can be used on live electrical fires (given the symbol E in the table). If a water-based extinguisher has passed the 35 kVA test it will also bear the same electrical pictogram however, any water-based extinguisher is only recommended for inadvertent use on electrical fires [8].

We use Powder based agent fire extinguisher for this performance. As in our system ABC type of fire extinguisher is used, it is suitable for a combination of class A, B and C fires which is shown in Fig.1.

Parts of a fire extinguisher:

Handle and operating lever
Locking pin
Pressure gauge
Discharge nozzle
#Label

Fig.1: overview of fire extinguisher

Specification:

Model no.	VPA 1
Capacity	1 kg
Range	2.5 m
Pressure	1.5 M pa
Height	33 cm

This is the multipurpose dry chemical extinguisher. The ABC type is filled with mono ammonium phosphate, a yellow powder that leaves a sticky residue that may be damaging to electrical appliances such as a computer. Dry chemical extinguishers have an advantage since they leave a non-flammable substance on the extinguished material, reducing the likelihood of re-ignition.

3. CONTROL ALGORITHM

Fig.2 shows the total control technique. One automatic fire-extinguisher placed at a desired location within a region wherein automatic extinguishing should be effected when fire occurs therein, one fire-extinguisher including integrally a bomb containing a fire-extinguishing gas under pressure and a gas jetting nozzle connected through a valve to bomb; one fire

sensor arranged at a desired location within said region; and an intermediate electric power supply source connected to said automatic fire-extinguishing system, said one fire extinguisher being provided with a relay to receive an actuation signal from outside and an electro-mechanical means for opening said valve, a gas jetting detecting switch for detecting gas pressure in bomb and a unit control circuit for controlling the actuation of said fire-extinguisher, said unit control circuit comprising a series circuit provided with an electric actuation circuit of said opening means and an on-off switch, which is controlled by said relay in a condition of connecting in a series, a terminal of series circuit connected to a terminal of intermediate power supply source, a switch means of gas jetting detecting switch for interrupting power supply to series circuit in response to reduction of internal gas pressure in said bomb and for simultaneously out-putting an electric potential of the other terminal of intermediate power supply source to an output terminal of unit control circuit, switch means connected to the other terminal of said series circuit and the other terminal of said intermediate power supply source, relay of said fire-extinguisher being capable of receiving a fire signal issued from fire sensor.

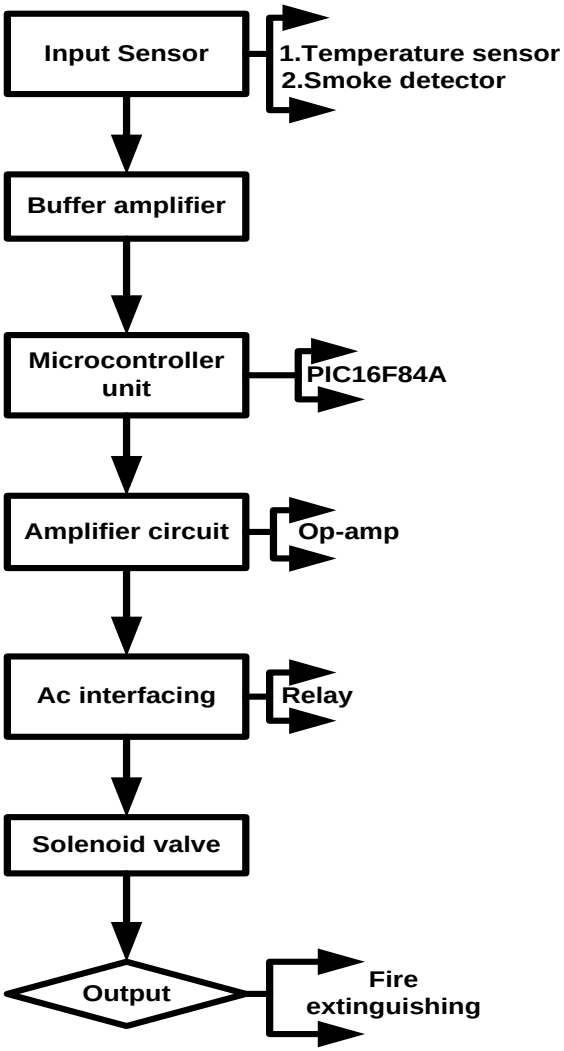

Fig. 2: Flow chart of whole control

3.1 Temperature Sensor

A heat flux sensor is a commonly used name for a transducer generating a signal that is proportional to the local heat flux. This heat flux can have different origins; in principle convective, radioactive as well as conductive heat can be measured.

3.2 Smoke Detector

A LDR was placed in the smoke duct. As smoke passes through the duct, LDR resistance changes accordingly. This resistance change was used by suitable circuitry to sense the presence of smoke[9].

3.3 Solenoid Valve

A solenoid valve shown in Fig.3 is an electromechanical valve for use with liquid or gas controlled by running or stopping an electric current through a solenoid, which is a coil of wire, thus changing the state of the valve. The operation of a solenoid valve is similar to that of a light switch, but typically controls the flow of air or water, whereas a light switch typically controls the flow of electricity [10].

Fig.3: Schematic view of a Solenoid valve

3.4 Relay

A relay is an electrical switch that opens and closes under the control of another electrical circuit. In the original form, the switch is operated by an electromagnet to open or close one or many sets of contacts [11].

3.5 Microcontroller

In our project we use one of PIC family microcontroller. The PIC16F84A is an 8 bit microcontroller. It contains 1K words of FLASH program memory, 68 bytes of data RAM, and 64 bytes of data EEPROM. While this seems like an extremely limited amount of code and data space, the PIC's incredibly compact code makes the most of it. 1024 instruction word memory actually means 1024 instructions, no less. Even immediate-mode instructions, where an operand is part of the instruction itself, takes only one memory location, as do CALL and GOTO instructions [12].

We used MPLAB IDE v7.41 to generate, simulate and compile the coding to be loaded in the PIC. It also generates the Hexadecimal (HEX) code and EPICWIN to load the program into the microcontroller.

3.6Signal conditioning and interfacing

The signal conditioning circuit is comprised with a led, transistor and a 741 operational amplifier. The connection diagram of the circuit is shown in Fig.4. As seen the output of the temperature sensor is the input of the operational amplifier. The output of the temperature sensor is low; it amplifies the output into a larger voltage signal. The dc voltage derived from the circuit is then passed through a capacitor to reduce the ripple.

The voltage is further reduced by a resistance to make it a measurable quantity for the comparator circuit. A reference voltage is set to the non inverting input of the op-amp. The output voltage is increased by amplifier as microcontroller senses the signal.

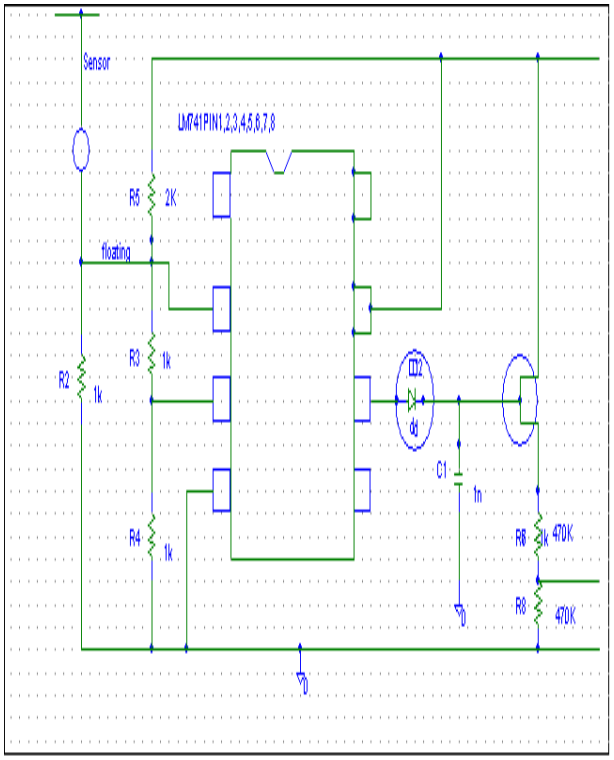

Fig. 4: Signal conditioning circuit diagram

We used two output pin and two input pin of PIC16F84A to interface with the amplifier circuit. This is summarized as follows:

Pin 6&7configured as output

Pin 4&17 configured as input (interrupt)

Pin 15 & 16 is connected with a 4MHz crystal oscillator.

Pin 14 is V_{CC} & pin 5 is connected as ground.

Interfacing is the final and most important part of the project. As there are various types of circuits introduced throughout the project it is also important to interface each circuit very carefully as each one has its own purpose. The final interfacing of the whole system is shown in the Fig.5.

At the top of the figure is shown a regulated power supply circuit which provides 5V & 12V dc for the rest of the circuit. Next the signal conditioning circuit connected with the solenoid valve is shown. The feedback path is clearly seen as whenever there is a temperature variation, there is an output pulse results from the comparator circuit. This output is coupled to the microcontroller thereby send a signal to the Buzzer and relay.

It is clear that this circuit abjectly does the job of an automatic control and it does so without any manual compensation that's why it is an Automatic fire extinguishing system.

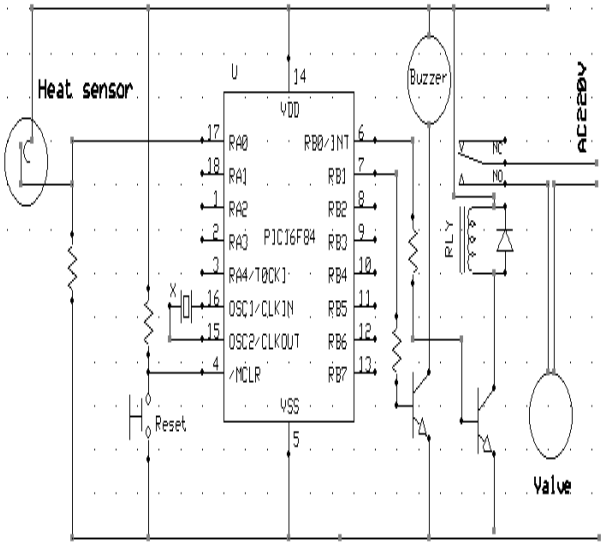

Fig. 5: Interfacing circuit diagram

4. RESULTS AND ANALYSIS

4.1 Sensing Capability

The performance of a fire fighting system greatly depends on the sensing capability of the smoke and temperature sensor. When ports get signal alarms operate otherwise it is wait for 1s. For removing false signal reset is introduced. Microcontroller produced satisfactory result shown in table 1 and table 2. Table 3 presents the minimum number of portable fire extinguishers in area basis. The total cost of proposed project is shown in table4

Table 1: levels of sensors' adjustments

Level name	Value, degree
normal	10-28
attention	35
danger	40
fire	Over 50

Table 2: Variation between temperature and operating time

Temperature, degree	Types of operation
10	No operation
20	No operation
30	Room temperature, no operation
40	Operation on 2 second
50	After operation room temp. again 30 degree

Table 3: Area calculation

Area	No.of extinguisher	Nominal capacity
1000 square feet	2	5 kg
1000 square feet	3	3 kg
200 square feet	1	1 kg

4.2 Technical Calculations

If premises are single occupancy and not larger than 100 sq meters with an upper floor area of not more than 100 sq meters then it will require a minimum fire test rating of 13A (which is the equivalent to 1 x 9L Water or greater than a 4Kg powder or greater than a 2Litre Foam) plus it should also have a fire extinguisher to cover any specific risks (i.e. CO_2 for electrical risks or possibility of liquid fires). If building is larger than 400sq meters then there should be a minimum of 2 fire extinguishers per floor and each floor should not have less than a fire test rating of 26 A (2 x 9 L Water or 2 x greater than a 4Kg powder or 2 x greater than a 2 litre Foam) plus it should also have a fire extinguisher to cover any specific risks (i.e. CO_2 for electrical risks or possibility of liquid fires). The formula is 0.065 x floor area (in square meters) and that will give the Class A fire test rating that needs as a minimum. If in special circumstances, feel unsure or feel that it may be a high risk please contact the local fire services (Fire Officer).

4.3 Recommendations and prospects

Fires cause the greatest loss of life and property in urban areas.Urban fires have devastating impact on communities. Unplanned urbanization has intensified the problem further. The number of fire incidents in Bangladesh was 9,196in 2007, 9,310 in 2008, and 12,182 in 2009 (Bangladesh Fire Service and Civil Defense).While floods have the greatest impact to the country's population as a whole, fires cause the greatest loss of life and property in the urban areas. Fires broke out at Rahattarpul and Badurtala in Chittagong on 10thMarch, 2006, burnt assets worth about Tk.7 lakh, the fire officials said (The New Age, March 11, 2006) [1]. On 13March, 2009 the top floors of the Bashundhara City Complex were damaged by a fire. According to the mal authorities, the incident cost a loss of Tk200 crore. In 2012, fire accident occured in garments factory in Ashulia, Dhaka. At least 112 workers were killed and over 200 were injured in the devastating fire that broke out at Ashulia's Tazreen Fashions Limited making a tragic history in country's readymade garment sector. A properly designed, installed, operated, and maintained fire fighting system can reduce these losses associated with an unwanted fire in any building [13].

The automatic fire extinguisher constructed based on microcontroller may be taken as a good model of automatic fire extinguishing system design. This fire extinguishing system is completely adjustable for our country. The maintenance of this system ensures system reliability and inexpensive to install for simple.

The sensing capability of this system is lowered because of the restricted disposition of the fire detector upon each independent suppressor. Since each suppressor is provided with the own-battery, if a number of suppressors are utilized for the fire-extinguishing system, the cost of the batteries becomes high. There is a possibility of gas leakage after disposition of the fire-extinguishers in the region to be protected. It's a problem to refill the cylinder after using once. A gas reservoir can mitigate the problem.

Table 4: Cost Estimation of proposed method

Component name	Number	cost in TK
Fire extinguisher	1	650.00
Solenoid Valve	1	600.00
Heat Sensor ,smoke detector	1+1	48
Microcontroller	1	220.00
Relay	1	30.00
AC/DC Adapter	1	120.00
Led	3	4.50
Ic regulator	1	12.00
Resistance	5	5.00
Capacitor	2	3.00
Diode	1	1.50
	Total	1694 tk

5. CONCLUSION

The microcontroller based adjustable fire extinguishing system has been introduced. Experimental results showed that the microcontroller is a reliable instrument to control the fire extinguisher. This system is applicable to different sizes of fire extinguisher and high controlling capability over them. The simple design of it allows minimum of maintenance work. There is a greatly reduced of malfunction, as no moving parts the risk of false alarm is also reduced. The price performance relationship is cost effective.

The overall performance of microcontroller based fire extinguishing system is determined by following factor:

MCU speed
MCU timing granularity
MCU I/O features
Accuracy and stability of the fire sensor used.

Despite of having a narrow range of difficulty the popularity of microcontroller based system design is increasing day by day; besides improved and advanced technologies are replacing the older versions which is keep enhancing the system efficiency.

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