Original Research Article

MODEL OF A CLOSED LOOP CONTROL CIRCUIT DESIGN OF AN AUTOMATIC FIRE SUPPRESSION SYSTEM

ABSTRACT

Automatic control has come about through evolution rather than revolution, an evolution that results from widespread use of the techniques of measurements and control.

Advantages of automatic control has far reaching positive implications to society since human error elimination is key and its one of the positive contributions of use of automatic control. Closed loop of action on automation and reaction operating without human aid would be key.

Hence, for Automatic Fire Suppression system, the system is designed with the input voltage from the smoke detectors, BC107B transistor used as the input, Opto-coupler circuit and photoelectric detector.This design will have a means of detecting a fire outbreak, actuation and delivery of the extinguishing agent.

Keywords: Automatic control, closed loop control, smoke detector, transistor, opto-coupler circuit, photo-electric detector

1.0 INTRODUCTION

1.1 Automatic fire suppression system.

AFS systems control and extinguish fires without human intervention. To do so, they should be designed to have a means of detection, actuation and delivery. [1]

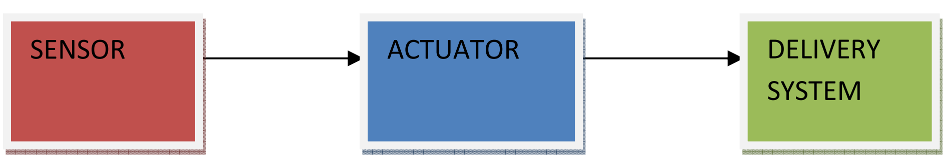

Fig. 1: Automatic Fire Suppression system block diagram [1]

Sensors such as smoke or flame detectors may be employed. To provide actuation this may be done by electrical or mechanical means. Delivery is almost always provided by mechanical means e.g. the rupture of polymer tubing to extinguishers. [2]

1.2 Background

Our poor record in response to fire emergencies has been our major undoing. We have lost many lives by fire outbreaks and property loss in the country through fire has reached unimaginable figure. [3]

The worst cases of loss of lives have happened in our secondary schools: in March, 1998- twenty girls died in their dormitories in Bombolulu and later Kyanguli case where more than 50 students lost their lives left many parents pondering about the option of abolishing boarding in secondary schools.[4]

The most recent case of loss of lives by fire happened in January, 2009 in Nakumatt down-town store where the death toll hit at least 22 people. Then, we had the Faza disaster where thousands of families were left homeless when fire razed down their homes in September, 2009.

Our preparedness for these cases has been very poor and the urgent need for AFS systems implementation can only be underestimated.

Therefore, in this project the intention is to design and build a cheaper AFS system by using modified parts (the water reservoir made of plastic) to help in the improvement of fire outbreak handling and hence reducing on the number of the casualties resulting from the fire incidence.

2.0 LITERATURE REVIEW

2.1 Photo-junction Devices.

A photo-diode is a p-n junction which is operated under reverse bias and in which light energy varies the leakage current by generating electrons and holes in the junction region.

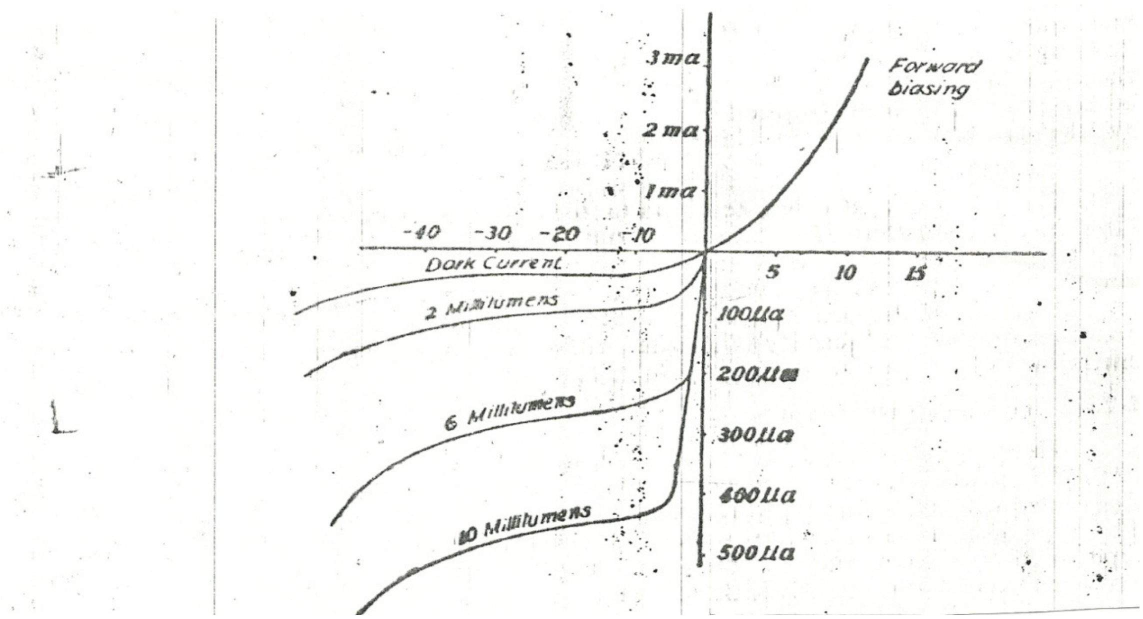

Fig. 2 Characteristics of photodiode.[5]

The typical voltage current characteristic of a photo-diode is shown. It is seen that dark current is approximately 40µ amps at 40 volts.

2.2 Avalanche photo-diode.

These photo-diodes are operated at high reverse bias voltages such that avalanche multiplication takes place.

These are the solid state photo-detectors with internal current gain.

The typical gain values is 10$^{\wedge 4}$ which is the highest available in any type of photodiodes and its response time is quite good at 0.1ns.

Thus a current gain-bandwidth product of 100GHZ is a reality and substantial gain can, therefore, be achieved at microwave frequencies.[6]

In this device the critical problem is the elimination of small areas in which the breakdown voltage is less than that of the junction as a whole.

These small areas are called micro-plasmas. These micro-plasmas can be minimized by using a substrate material of uniform impurity concentration and designing the active area to be no longer than that absolutely necessary to accommodate the incident light beam. Active areas are usually 10µm to 500µm in diameter. The material used is Si or Ge. Avalanche diodes are available with highest SNR of 20 d B.[7]

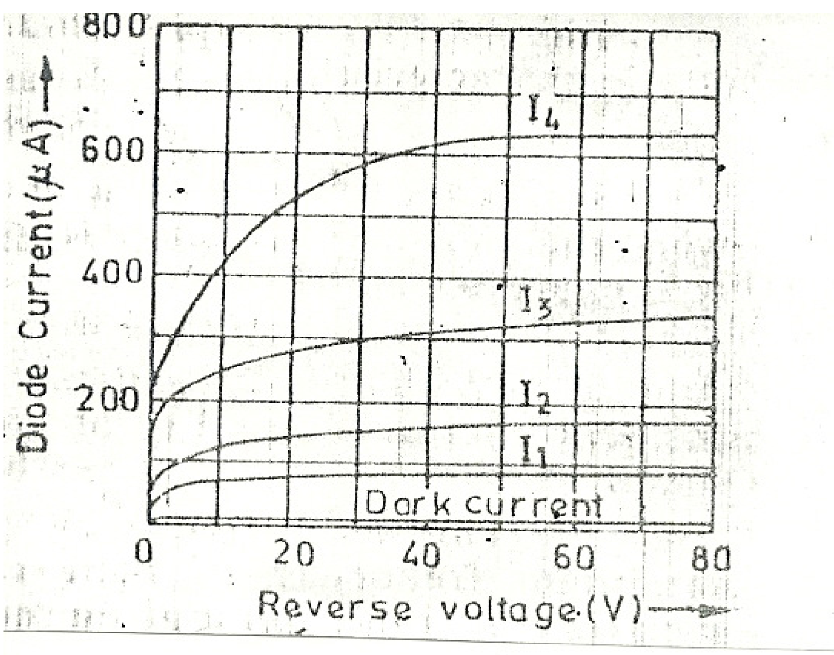

Fig.3 Behaviour of avalnche photodiode.[7]

An important parameter that determines the performance of an avalanche photodiode is the photomultificationfactor , Mph, defined as:

$$M_{ph} = I_{ph} / I_{pho} = I / \left(1 - (V/V_B)^n\right)$$

Where Iph is the multiplied photo-current, Ipho is the photo-current before carrier multiplication takes place, V is the applied voltage, V_B is the breakdown voltage, and n is a constant which is a function of doping profile, the semiconductor material and radiation and wavelength.

The multiplication factor is defined as the ratio of the total current $I = I_{ph} + I_d$, when I_d is the multiplied dark current to the primary current $I_p \left(I_{pho} + I_{do}\right)$, where I_{do} is the dark current before carrier multiplication – same as the reverse saturation current of diode in the absence of light). Therefore,

$$M = I/I_p = \left(I_{ph} + I_d\right)/\left(I_{pho} + I_{do}\right)$$

$$= 1/\left(1 - \left(\left(V - I_R\right)/V_B\right)\right)^n$$

If, now, $I_{pho} >> I_{do}$ and $IR << V_B$, where R is the series resistance plus the space resistance of the diode, then(Mph) optimum is given as:

$$\left(M_{ph}\right)_{opt} = \left(V_B / nI_pR\right)^{1/2}$$

The equation above shows that the optimum photo-multification factor is inversely proportional to the square root of I_p. Recalling that $I_p = I_{pho} + I_{do}$, it is absolutely essential to have as low I_{do} as is possible to get maximum carrier multification and sensitivity.[8]

2.3Time-delay Relay.

Transistor-operated time-delay relays are finding great favor in many industrial applications. The timer aspect of such a relay is dependent on the charge or discharge of a capacitor through an associated resistive network. By changing the associated resistance, we vary the time constant and hence the timing of the circuit.The following circuit utilizes the charge time of capacitor C for its timing characteristics.

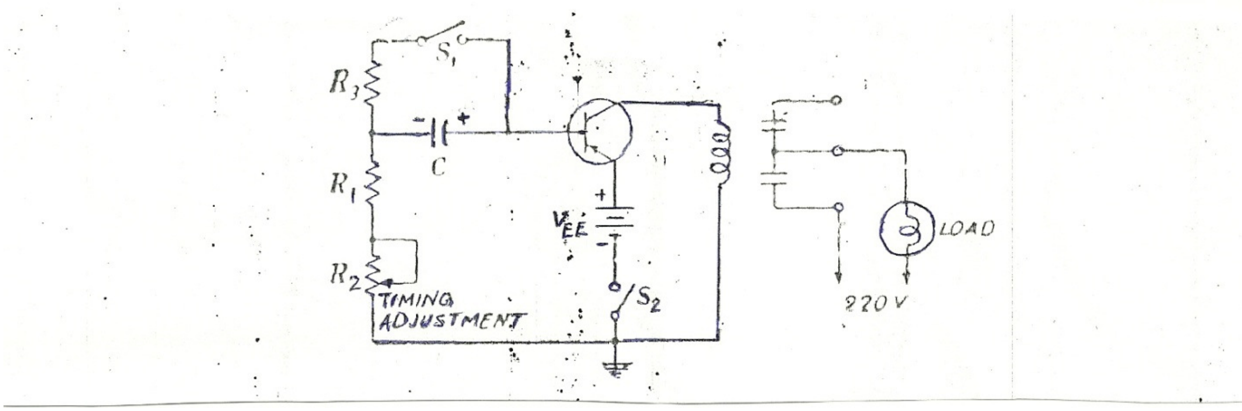

Fig.4 Time-delay utilizing capacitor charge time [9].

The length of time that the relay is energized depends on the time constant C x (R_1 +R_2 +R_{BE}), where R_{BE} is the base-to-emitter resistance; on the value of the battery voltage V_{EE}; and on the characteristics of the relay. By varying $R_{2,}$ we vary the charging time interval [9].

The following figure illustrates a circuit in which the discharge time of a capacitor is used to determine the timing interval. To analyze the operation of this circuit, we assume that switch S_1 is open, that S_2 is in the position shown, and that capacitor C carries no charge on it. When S_1 is closed, the relay remains de-energized since the base-to-emitter bias is zero and keeps the collector current cut off. In order to energize the relay, we provide forward bias for the base-to-emitter circuit. To do this we must first charge capacitor by throwing S_2 to position A.

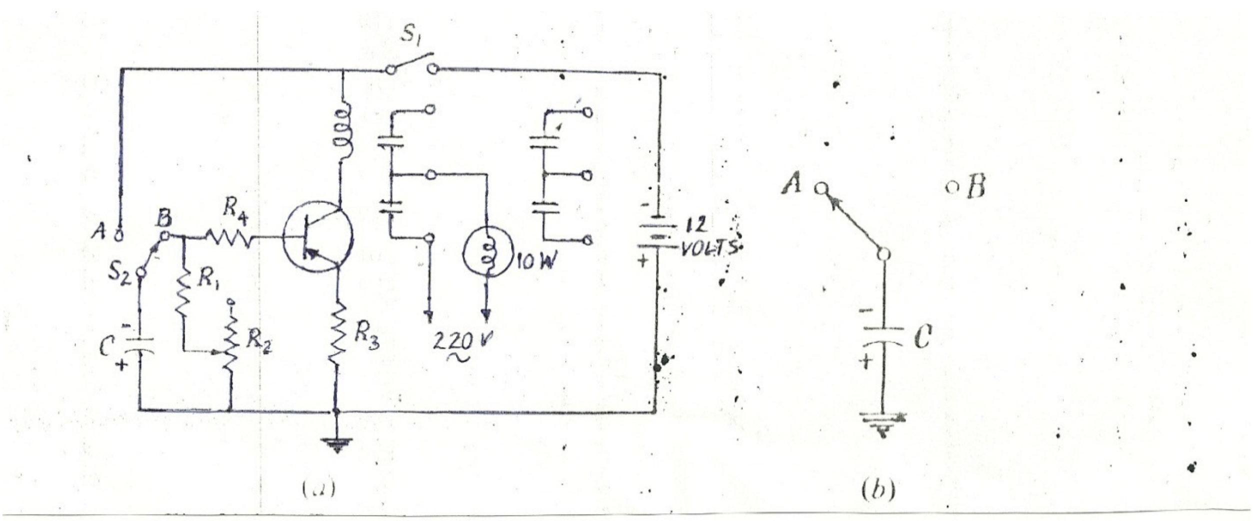

Fig. 5, Time-delay relay utilizing discharge time of the capacitor C for timing interval [9].

The capacitor charges to the supply voltage, with the polarity shown in the fig. Now, when S_2 is thrown to position B, C discharges through two parallel paths. One path is the series resistance R_1 + R_2.

The other path is R_4 +R_{BE} +R_3. The initial discharge current provides sufficient base-to-emitter bias so that the surge of collector current energizes the relay. As the capacitor discharge current is reduced to the point where the relay resets. The length of time that the relay remains energized is proportional to the discharge time constant C x R_P, where R_P is the effective parallel resistance between point B and ground. This time constant may be varied by adjusting R_2.

2.4 UJT controlled SCR Time-delay circuits.

The following figure illustrates a simple and useful time delay circuit and relay. When power is applied, the circuit is started and the following actions take place:

Relay R_{L1} is operated and load 2 is turned on for a time interval't' determined by the time constant

C_1 x (R_1 x R_2) and the characteristics of unijunction transistor Q_1

At the expiration of't' seconds, load 1 is turned on and relay R_{L1} releases, turning off load 2. Load 1 remains on until power is removed by opening S_1. The circuit is restarted by closing S_1. S_1 can be replaced by another time delay circuit so arranged that load 2 are each turned on and off subsequently for preset time intervals.[10]

Operation of the circuit of fig. is as follows:

Before S_1 is closed, there is no power applied. The SCR (Q_2) is off. There is no voltage across the relay, which is also off. The relay contacts make up a single-pole double-throw switch with contacts AB normally closed and AC normally open. The shorted (normally closed) contacts AB are connected across capacitor C_1 so that there is zero-voltage across capacitor C_1 when AB contacts are closed.

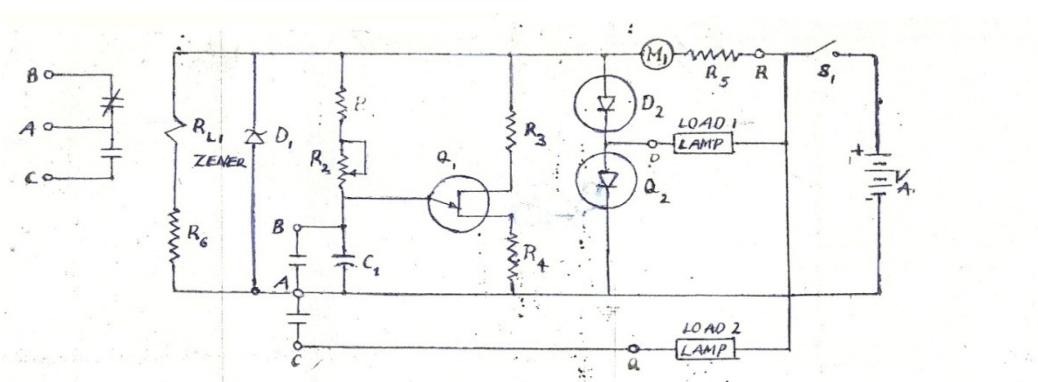

Fig. 6 Circuit of UJT controlled SCR time delay.[10]

The normally open contacts A-C are connected in series with load 2 across the power source V_{AA}. When the relay is set, contacts A-C close and load 2 is energized. Load 1 is energized when the SCR is turned on, because when Q_2 is on, the voltage drop VQ_2 across Q_2 is negligible and V_{AA}-Q_2 is across load 1, supplying power to load 1.

The circuit is cycled by closing switch S_1. V_{AA} is applied to the series combination of zener diode D_1, meter M_1 and R_5.The zener voltage across D_1 appears across the relay coil R_{L1} and R_6. The relay sets, opening switch contacts AB and closing contacts AC. As soon as the relay is set, load2 is energized and the timed interval 't' starts. Capacitor C_1 starts charging through the series combination of R_1 +R_2 toward the zener voltage. When the voltage across C_1 reaches the peak-point voltage of the UJT, it fires. The UJT generates a pulse of current through R_4 and turns on the SCR. When the SCR turns on, load 1, which is in series with the SCR across V_{AA}, is turned on. The SCR is also in series with diode D_2 and resistor R_5 and current flows in this combination. Because of the low forward impedance of D_2 and Q_2, the combined voltage V_{PQ} across D_2 and Q_2 drops to a low value(about 2 volts) and relay R_{L1} drops out, closing contacts AC. Load 2 is therefore de-energized. Load 1 remains ON until switch S_1 is opened.

Normally closed contacts A-B discharge C_1 and assure a constant level, zero voltage from which C_1 will charge. When the SCR is OFF, zener diode D_1 provides a constant voltage level (D_1 maintains a constant voltage across itself in the zener region) towards which C_1 will charge. Timing stability is therefore assured by this means. Holding current for the SCR is provided by D_2 and R_5. Load 1 may therefore be removed or disconnected without affecting the operation of the circuit.

The time delay of the circuit depends on the time constant C_1 x (R_1 + R_2), on the characteristics the of UJT, and on the ambient temperature. The constant may be varied by increasing or decreasing the resistance of R_2.

In the figure, Q_1 does not operate as a relaxation oscillator. The reason is that the voltage toward which C_1 is a critical component in this circuit. For proper operation, it is desirable to use low-leakage type capacitors.

The most preferred method for getting time delay is the UJT controlled SCR time-delay circuit. This is because it provides relative robust control compared with the other two methods.[11]

2.5 DC light sensitive Relay.

We find industrial applications where photocells are used in conjunction with amplifiers and relays in circuits, requiring light-actuated on-off switching circuits. Thus, a photocell amplifier and relay arrangement can be used to switch off the mains before water can be released for extinguishing fire in an Automatic Fire Suppression system.

The following figure is the circuit diagram of a photo relay, which can be used to switch off the mains when the actuating light which is focused on the photocell is switched on. In this case, the load is the mains to be switched off. In the circuit Q_1 is the relay amplifier. The relay coil constitutes the load in the collector of Q_1. The relay here is comparable to a single-pole double-throw switch. In this arrangement two loads are accommodated. In the position shown, the relay is not energized. Contacts 1 and 2 are normally closed and load 1 receives power from the 220-Volt line. When the relay is energized, the power is now applied to the circuit of load 2 and removed from load 1.

The resistance of the photocell pc and R_1 constitutes a voltage divider which forward-biases the emitter-to-base of Q_1. A potentiometer has been selected to provide resistance, R_1 such that when enough light falls on the photocell, its resistance is such as the voltage developed across pc is adequate to drive Q_1 to conduct sufficiently to energize the relay. Therefore, when light shines on pc, the relay is switched on and no A.C power is applied to the load. This happens in that if the constants of the circuit are proper, enough forward bias is developed on the base-to-emitter junction to increase collector current appreciably. The increased collector current energizes the relay and the normally closed relay contacts opens, disconnecting power from the mains.

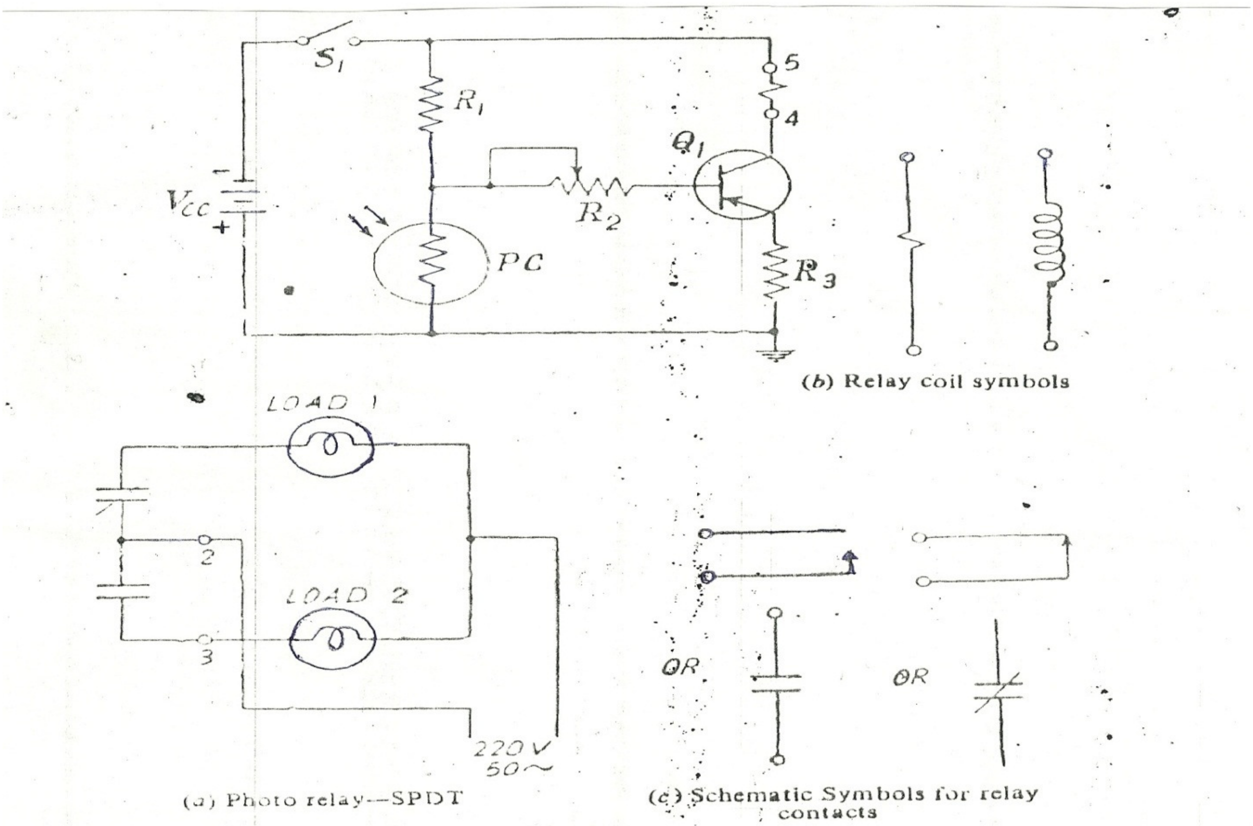

Fig.7: DC light sensitive relay.

3.0 METHODOLOGY

Designed the Automatic Fire Suppression system as per the block diagram below:

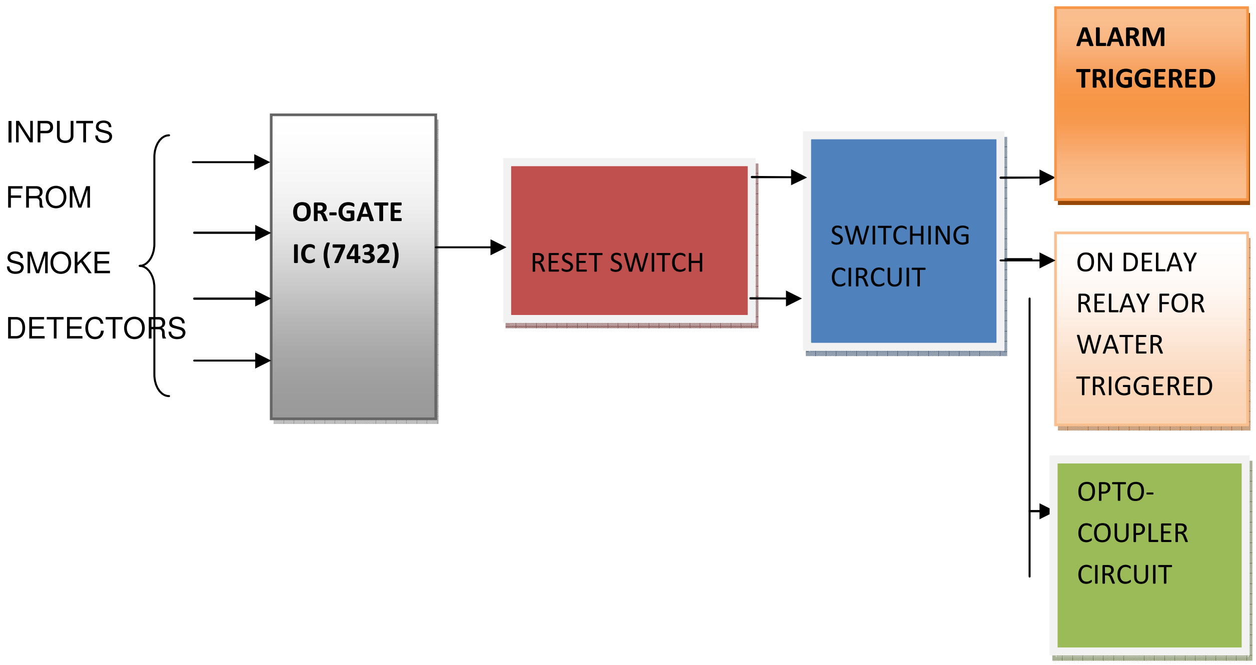

fig.8: Block diagram of the automatic fire suppression system

Main Circuit

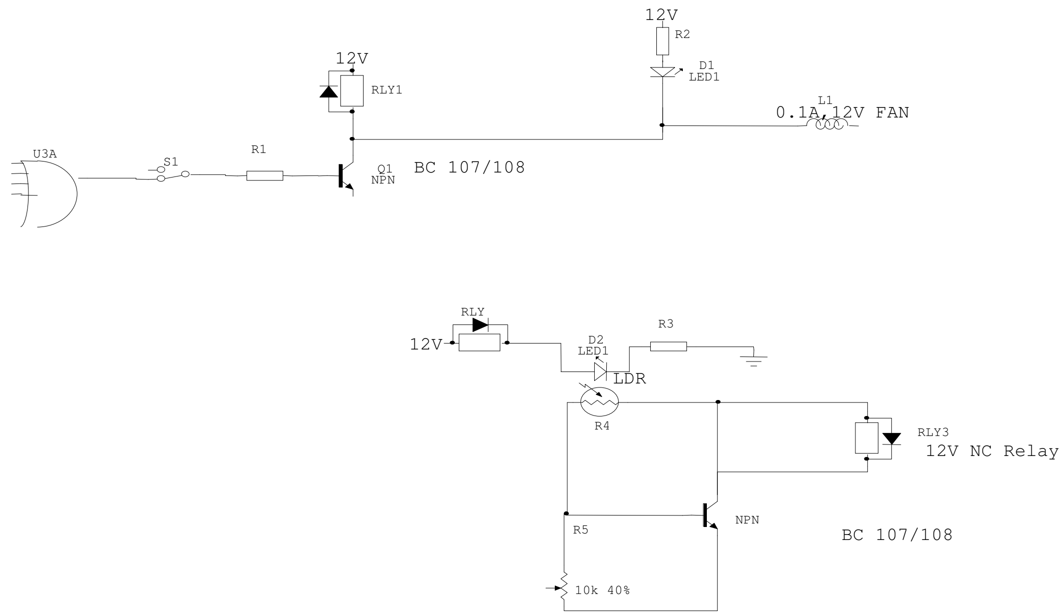

Fig 9: Control circuit for Automatic Fire Suppression system

4.0 RESULTS/DISCUSSION

Design calculations:

With BC107B transistor used at the input which has h_{fe} = 40 m A and the input voltage from the smoke detectors being 9V, Resistance = (Voltage/ current) = 9V/40 m A = 2.25K thus 2.2K, for standard resistors.

Opto-coupler circuit:

The biasing voltage needed to bias the BC107B transistor at this stage is 3V. Light Dependent Resistor and potentiometer usedthus $3V = ((14.4YV_{cc})/(14.4+Y)) = 250V$

Where

14.4Ω - is the resistance of the Light Dependent Resistor when fully illuminated.

Y – is the resistor to be connected with the L.D.R in order to get the voltage divider circuit

Vcc – is voltage at the collector of the BC107B transistor.

A resistance of 250Ω and this can be obtained with a potentiometer.

Photoelectric detector to be implemented that meets the dual parameter approach e.g. obscuration and velocity in unventilated rooms such as:

5.0 CONCLUSION

The Automatic Fire Suppression system is able to detect, actuate the delivery mechanism and deliver the extinguishing agent in order to suppress the fire. It even can switch off the mains before releasing water in order to prevent electrocution. To achieve this: the 9V input from the smoke detector is used to bias the BC107B transistor and this in turn energizes the relay connected at the collector terminal. The relay can then close its NO terminal hence, passing the 12V to switch on the alarm LED, switch on the opto-coupler LED, and finally control the water delivery to suppress the fire.

Non-flaming fires, photoelectric detectors: 1.5-2.5 %/ft and 0.03-0.07 m/s _Input to include OR gates, each terminal picking a signal of 9V.

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