بسم الله الرحمن الرحيم

SUDAN UNIVERSITY OF SCIENCE & TECHNOLOGY
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FIRE ALARM SYSTEM USING SMOKE AND HEAT DETECTORS WITH PLC

نظام إنذار الحريق بإستخدام كاشفات الحرارة والدخان مع المتحكمات المنطقية المبرمجة

A thesis submitted for partial fulfillments of the requirement of the degree of science master in physics

Submitted by :

Amna Ahmed Abdalla Ahmed .

Supervisor :

Dr. Rawia Abd Elgani Elobaid Mohammed.

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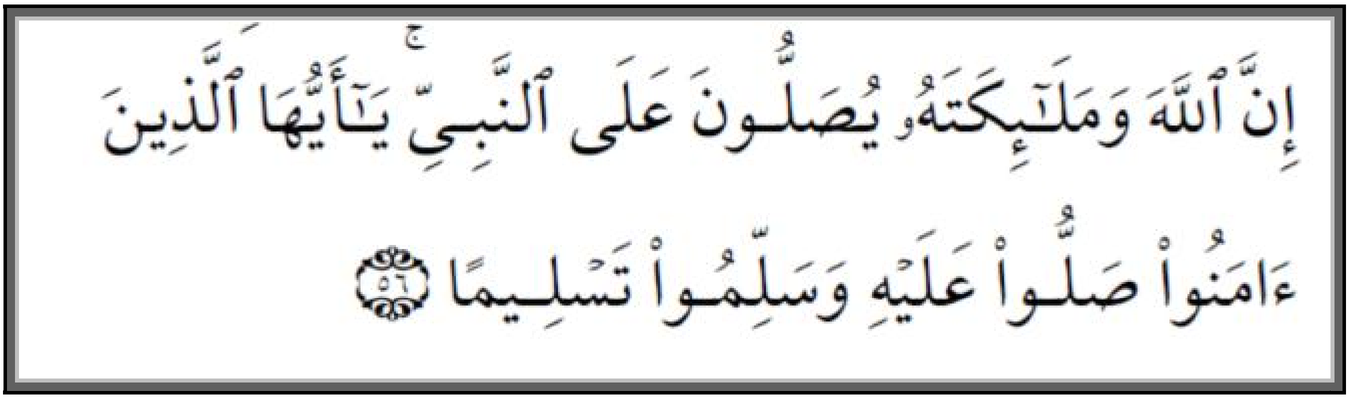
بسم الله الرحمن الرحيم

قال تعالى :



إِنَّ ٱللَّهَ وَمَلَٰٓئِكَتَهُۥ يُصَلُّونَ عَلَى ٱلنَّبِيِّۚ يَٰٓأَيُّهَا ٱلَّذِينَ
ءَامَنُواْ صَلُّواْ عَلَيْهِ وَسَلِّمُواْ تَسْلِيمًا ٥٦

صدق الله العظيم

سورة الاحزاب (الاية 56)

Dedication

To the great prophet Mohammed

“Peace & prayers be upon him”

To whom we love for their

Encouragement

And

Support

Acknowledgement

To who are point me in the right direction with this project through the guidance, my supervisor: Dr. Rawia Abd Elgani Elobaid, my deep thanks and appreciation for her encouragement, time criticism and advices.

I would like to express my deepest gratitude to my teachers for their help, kindness and friendship.

Special thanks to my mother and my father.

Abstract

The technology of twenty century covers the side of safety and security system field in a very compressing steps, because the development was so fast.

In this research the electronic mechanism used in certain places; the application used was simply detectors "sensors" especially of heat and gas.

The sensors of heat and gas depend mainly on sensitivity of them; and so the effect reflects on the circuit.

The best choice was PLC testing; the signal found was treated using ladder diagram "programming language".

When output is found the devices directly gives "buzzer / lamp" signal.

المستخلص

تكنولوجيا القرن العشرين شملت جانب حقل نظام الأمن والسلامه في خطوات جدا مختصرة بسبب التطور السريع .

في هذا البحث الآلية الكترونية المستخدمة ; والتطبيق المستخدم هي كواشف بسيطة "حساسات" للحرارة والغاز .

حساسات الحرارة والغاز تعتمد بشكل اساسي على حساسية كل منهما ; والتأثير المنعكس على الدائره .

الأختيار الأفضل هو اختبار المتحكمات المنطقية المبرمجة ; حيث ان الأشارة المتحصلة تعالج بواسطة المخطط السلمي "لغة برمجة".

تخرج الأشارة مباشرة في شكل "ضوء وصوت" .

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Chapter One

Introduction

1.1 Prelude

Fire is a rapid chemical reaction that gives off energy and products of combustion that are very different in composition from the fuel and oxygen that combined to produce them. To understand the reaction we call fire, how it grows, and its products (products of combustion), we need to look at some basic concepts from physical science. *Physical science* is the study of the physical world around us and includes the sciences of chemistry and physics and the laws related to matter and energy. The basic science information in this section is referred to throughout this chapter [1].

1.2 Measurement Systems

Any scientific discussion presents information using numbers. Firefighters use numbers frequently while performing their jobs. They regularly use a numerical system to describe the house lines they use to attack fires 1.7-inch (45 mm) — or the capacity of the pump on an engine — 1,500 gpm (5 678 L/min) — or the length of a ladder — 24 feet (7.3 m). For these numbers to make any sense, they must be used with some unit of measurement that describes what is being measured — distance, mass, or time, for instance. The units are based on a measurement system. In the United States the *English* or *Customary System* is commonly used. Most other nations and the scientific community use a form of the metric system called the *International System of Units* or *SI* (after the French System International). Each system defines specific units of measure..A large variety of derived units are generated from these base units. For example, the base unit for length in SI is the *meter (m)*. From this base unit, you can derive measurements for area in square meters (m^2) and volume in cubic meters (m^3). Measurements for speed can be derived from length and time and described in feet per second or meters per second (fps or m/s). In the discussion of fire behavior that follows, the derived units for heat, energy, work, and power will be introduced and discussed. Other units used in the SI are *hour (h)* and *liter (L)*. While they are not considered base units, they are widely accepted and used. While mass is considered a base unit, weight is not. *Weight* is the measurement of the gravitational attraction on a specific mass. In the Customary system, the unit for weight is the *pound (lb)*. In the SI, weight is considered to be a force and is measured in *newtons (N)*. Both Customary and SI units are provided throughout the chapter. One reason why the scientific community uses the SI is that it is a very logical and simple system based on powers of 10. This allows for the manipulation and conversion of units without the fractions needed with the Customary System. For example, in the Customary System the unit of length is the foot. The other recognized units are the inch (1/12 th of a foot), the yard (36 inches or 3 feet), and the mile (5,280 feet or 1,760 yards). In the SI, the unit of length is the meter. To express length in larger or smaller terms, thus, a centimeter is 1/100 th of a meter, and a kilometer is 1,000 meters [1].

1.3 Energy and Work

In any science, energy is one of the most important concepts. *Energy* is simply defined as the capacity to perform work. Work occurs when a force is applied to an object over a distance .In other words, *work* is the transformation of energy from one form to another. The SI unit for work is the *joule (J).* The joule is a derived unit based on a force in expressed newtons (also a derived unit — kg m/s^2) and distance in meters. In the Customary System the unit for work is the *foot-pound (ft-lb).*The many types of energy found in nature include the following:

- **Chemical**— Energy released as a result of a chemical reaction such as combustion.
- **Mechanical** — Energy an object in motion possesses such as a rock rolling down a hill.
- **Electrical**— Energy developed when electrons flow through a conductor.

- **Heat**— Energy transferred between two bodies of differing temperature such as the sun and the earth.
- **Light**— Visible radiation produced at the atomic level such as a flame produce during the combustion reaction.
- **Nuclear**— Energy released when atoms are split (fission) or joined together (fusion); nuclear power plants generate power as a result of the fission of uranium-235 Energy exists in two states: kinetic and potential. *Kinetic energy* is the energy possessed by a moving object. *Potential energy* is the energy possessed by an object that can be released in the future. A rock on the edge of a cliff possesses potential mechanical energy. When the rock falls from the cliff, the potential energy is converted to kinetic energy. In a fire, fuel has potential chemical energy. As the fuel burns, the chemical energy is converted to kinetic energy in the form of heat and light [1].

1.4 Power

Power is an amount of energy delivered over a given period of time. Throughout history, people have used fire to generate power in many ways. A fuel’s potential energy is released during combustion and converted to kinetic energy to run a generator or turn a shaft that “powers” a machine. The derived units for power are *horsepower (hp)* in the Customary System and *watts (W)* in SI. In the study of fire behavior, researchers frequently address power when they consider the rate at which various fuels or fuel packages (groups of fuels) release heat as they burn. During the last several decades, researchers at the National Institute of Standards and Technology (NIST) have compiled a great deal of information on the heat release rates (HRRs) of many fuels and fuel packages. This information is very useful in the study of fire behavior because it provides data on just how much energy is released over time when various types of fuels are burned. Heat release rates for specific fuel packages are discussed in more detail in the Fire Development section later in the chapter.

1.5 Heat and Temperature

Anyone who has ever fought or even watched a fire fighting operation knows a tremendous amount of heat is generated. *Heat* is the energy transferred from one body to another when the temperatures of the bodies are different. Heat is the most common form of energy encountered on earth. *Temperature* is an indicator of heat and is the measure of the warmth or coldness of an object based on some standard. In most cases today, the standard is based on the freezing (32°F and 0°C) and boiling points (212°F and 100°C) of water. Temperature is measured using *degrees Celsius (°C)* in SI and *degrees Fahrenheit (°F)* in the Customary System. The approved SI unit for all forms of energy including heat is the *joule*. While joules are used to describe heat in current literature, heat was described in terms of calories (Cal) or British thermal units (Btu) for many years. A *calorie* is the amount of heat required to raise the temperature of 1 gram of water 1 degree Celsius. The *British thermal unit* is the amount of heat required to raise the temperature of 1 pound of water 1 degree Fahrenheit. The calorie and the Btu are not approved SI units but are still frequently used. The relationship between the calorie and the joule is called the *mechanical equivalent of heat*, where 1 calorie equals 4.187 joules and a Btu equals 1,055 joules [1].

1.6 Transmission of Heat

The transfer of heat from one point or object to another is a basic concept in the study of fire. The transfer of heat from the initial fuel package to other fuels in and beyond the area of fire origin controls the growth of any fire. Firefighters use their knowledge of heat transfer to estimate the size of a fire before attacking it and to evaluate the effectiveness of an attack. The definition of heat makes it clear that for heat to be transferred from one body to another, the two bodies must be at different temperatures. Heat moves from warmer objects to those that are cooler. The rate at which heat is transferred is related to the temperature differential of the bodies. The greater the temperature differences between the bodies, the greater the transfer rate. The transfer of heat from body to body is measured as energy flow (heat) over time. In the SI, heat transfer is measured in *kilo watts (kW).* In the Customary System, the units are *Btu per second (Btu/s).* Both units (kW and Btu/s) are expressions that relate to power. Heat can be transferred from one body to another by three mechanisms: *conduction, convection,* and *radiation*. Each of these is discussed in some detail in the following sections [1].

1. 7Conduction

When a piece of metal rod is heated at one end with a flame, the heat travels throughout the rod this transfer of energy is due to the increased activity of atoms within the object. As heat is applied to one end of the rod, atoms in that area begin to move faster than their neighbors. This activity causes an increase in the collisions between the atoms. Each collision transfers energy to the atom being hit. The energy, in the form of heat, is transferred throughout the rod. This type of heat transfer is called conduction. *Conduction* is the point-to-point transmission of heat energy. Conduction occurs when a body is heated as a result of direct contact with a heat source. Heat cannot be conducted through a vacuum because there is no medium for point-to-point contact. In general, heat transfer early in the development of all fires is almost entirely due to conduction. Later, as the fire grows, hot gases begin to flow over objects some distance away from the point of ignition and conduction again becomes a factor. The heat from the gases in direct contact with structural components or other fuel packages is transferred to the object by conduction. Heat insulation is closely related to conduction. Insulating materials do their jobs primarily by slowing the conduction of heat between two bodies. Good insulators are materials that do not conduct heat well because of their physical makeup and thus disrupt the point-to-point transfer of heat energy. The best commercial insulators used in building construction are those made of fine particles or fibers with void spaces between them filled with a gas such as air.

1.8 Convection

As a fire begins to grow, the air around it is heated by conduction. The hot air and products of combustion rise. If you hold your hand over a flame, you are able to feel the heat even though your hand is not in direct contact with the flame. The heat is being transferred to your hand by convection. *Convection* is the transfer of heat energy by the movement of heated liquids or gases. When heat is transferred by convection, there is movement or circulation of a fluid (any substance — liquid or gas — that will flow) from one place to another. As with all heat transfer, the flow of heat is from the warmer area to the cooler area [1].

1.9 Radiation

If you hold your hand a few inches (millimeters) to the side of the small fire used as an example in the preceding section, you would also be able to feel heat. This heat reaches your hand by radiation. *Radiation* is the transmission of energy as an electromagnetic wave (such as light waves, radio waves, or X rays) without an intervening medium. Because it is an electromagnetic wave, the energy travels in a straight line at the speed of light. All warm objects will radiate heat. The best example of heat transfer by radiation is the sun’s heat. The energy travels at the speed of light from the sun through space (a vacuum) and warms the earth's surface. Radiation is the cause of most exposure fires (fires ignited in fuel packages or buildings that are remote from the fuel package or building of origin). As a fire grows, it radiates more and more energy in the form of heat. In large fires, it is possible for the radiated heat to ignite buildings or other fuel packages some distance away. Heat energy being transmitted by radiation travels through vacuums and substantial air spaces that would normally disrupt conduction and convection. Materials that reflect radiated energy will disrupt the transmission of heat [1].

1.10 Matter

As you look at the world around you, the physical materials you see are called *matter*. It is said that matter is the “stuff” that makes up our universe. *Matter* is anything that occupies space and has mass. Matter can be described by its physical appearance or more technically by its physical properties such as mass, size, or volume. In addition to those properties that can be measured, matter also possesses properties that can be observed such as its physical state (solid, liquid, or gas), color, or smell. One of the best and most common examples of the physical states of matter is water. At normal atmospheric pressure (the pressure exerted by our atmosphere on all objects) and temperatures above 32°F (0°C), water is found as a liquid. At sea level *atmospheric pressure* is defined as 760 mm of mercury measured on a barometer. When the temperature of water falls below 32°F (0°C) and the pressure remains the same, water changes state and becomes a solid called *ice.* At temperatures above its boiling point, water changes state to a gas called *steam.* Temperature, however, is not the only factor that determines when a change of state will occur. The other factor is pressure. As the pressure on the surface of a substance decreases, so does the temperature at which it boils. The opposite is also true. If the pressure on the surface increases, so will the boiling point. This is the principle used in pressure cookers. The boiling point of the liquid increases as the pressure inside the vessel increases. Thus, foods cook faster in the device because the temperature of the boiling water is greater than 212°F (100°C). Matter can also be described using terms derived from its physical properties of mass and volume. *Density* is a measure of how tightly the molecules of a solid substance are packed together .Density is determined by dividing the mass of a substance by its volume. It is expressed as kg/m^3 in SI and lb/ft^3 in the Customary System. The common description for liquids is specific gravity. *Specific gravity* is the ratio of the mass of a given volume of a liquid compared with the mass of an equal volume of water. Thus, water has a specific gravity of 1. Liquids with a specific gravity less than 1 are lighter than water, while those with a specific gravity greater than 1 are heavier than water. The description for gases is vapor density. *Vapor density* is defined as the density of gas or vapor in relation to air. Since air is used for the comparison, it has a vapor density of 1 (as with specific gravity and liquids). Gases with a vapor density of less than 1 will rise, and those with vapor densities greater than 1 will fall.

1.11 Conservation of Mass and Energy

As fire consumes a fuel, its mass is reduced. What happens to this material? Where does it go? The answer to these questions is one of the basic concepts of modern physical science: the *Law of Conservation of Mass-Energy* (commonly shortened to the *Law of Conservation of Mass*). The law states: *Mass and energy may be converted from onto another, but there is never any net loss of total mass-energy*. In other words, mass and energy are neither created nor destroyed. The law is fundamental to the science of fire. The reduction in the mass of a fuel results in the release of energy in the form of light and heat. This principle enables researchers to calculate the heat release rate of materials by using instruments that determine mass loss and temperature gain when a fuel is burned. The firefighter should be aware of this concept during preplanning operations and size-up (initial evaluation of a situation) at fires. The more fuel available to burn, the more potential there is for greater amounts of energy being released as heat during a fire. The more heat released, the more extinguishing agent needed to control a fire [1].

1.12 Chemical Reactions

Before we begin the discussion of combustion and fire growth, it is important to understand the concept of chemical reactions. Whenever matter is transformed from one state to another or a new substance is produced, chemists describe the transformation as a *chemical reaction*. The simplest of these reactions occurs when matter changes state, which is called a *physical change*. In a physical change the chemical makeup of the substance is not altered. The change of state that occurs when water freezes is a physical change. A more complex reaction occurs when substances are transformed into new substances with different physical and chemical properties. These changes are defined as *chemical changes*. The change that occurs when hydrogen and oxygen are combined to form water is a chemical change. In this case, the chemical and physical properties of the materials being combined are altered. Two materials that are normally gases (hydrogen and oxygen) at room temperature are converted into a substance that is a clear liquid (water) at room temperature. Chemical and physical changes almost always involve an exchange of energy. Reactions that give off energy as they occur are called *exothermic.* Reactions that absorb energy as they occur are called *endothermic.* When fuels are burned in air, the fuel vapors chemically react with the oxygen in the air, and both heat and light energies are released in an exothermic reaction. Water changing state from liquid to gas (steam) requires the input of energy, thus the conversion is endothermic. One of the more common chemical reactions on earth is oxidation. *Oxidation* is the formation of a chemical bond between oxygen and another element. Oxygen is one of the more common elements on earth (our atmosphere is composed of 21% percent oxygen) and reacts with almost every other element found on the planet. The oxidation reaction releases energy or is exothermic. The most familiar example of an oxidation reaction is rusting of iron. The combination of oxygen and iron produces a flaky red compound called *iron oxide* or, more commonly, *rust.* Because this is an exothermic process, it always produces heat. Normally, the process is very slow, and the heat dissipates before it is noticed. If the material that is rusting is in a confined space and the heat is not allowed to dissipate, the oxidation process will cause the temperature in the space to increase. One of the most common examples of heat production in confined spaces is in cargo ships loaded with iron filings. Oxidization of the filings confined within the hold of the ship generates heat that cannot be dissipated because of its location. This heat is conducted to the hull and subsequently to the water outside the ship. When the vessel is in motion, the heat is transferred to the water the ship is moving through and goes unnoticed. When the ship is stationary, however, the fact that heat is being conducted to the surrounding water becomes apparent when the water near the ship begins to boil. While the temperature does not usually increase to the point that flaming ignition (fire) occurs, the condition can be quite dramatic [1].

1.13 Combustion

[NFPA 1001: 3.3.10(a); 4-3.2(b)]

Fire and combustion are terms that are often used interchangeably. Technically, however, fire is a form of combustion. *Combustion is a self-sustaining chemical reaction yielding energy or products that cause further reactions of the same kind* Combustion is, using the term discussed earlier, an exothermic reaction. *Fire is a rapid, self-sustaining oxidization process accompanied by the evolution of heat and light of varying intensities* The time it takes a reaction to occur determines the type of reaction that is observed. At the very slow end of the time spectrum is oxidation, where the reaction is too gradual to be observed. At the faster end of the spectrum are explosions that result from the very rapid reaction of a fuel and an oxidizer. These reactions release a large amount of energy over a very short time.

1.14 Fire Tetrahedron

For many years, the fire triangle (oxygen, fuel, and heat) was used to teach the components of fire. While this simple example is useful, it is not technically correct. For combustion to occur, four components are necessary:

- Oxygen (oxidizing agent).
- Fuel.
- Heat.
- Self-sustained chemical reaction.

These components can be graphically described as the *fire tetrahedron*. Each component of the tetrahedron must be in place for combustion to occur. This concept is extremely important to students of fire suppression, prevention, and investigation. Remove any one of the four components and combustion will not occur. If ignition has already occurred, the fire is extinguished when one of the components is removed from the reaction. To better explain fire and its behavior, each of the components of the tetrahedron is discussed in the following sections [1].

1.14.1 Oxygen (Oxidizing Agent)

Oxidizing agents are those materials that yield oxygen or other oxidizing gases during the course of a chemical reaction. Oxidizers are not themselves combustible, but they support combustion when combined with a fuel. While oxygen is the most common oxidizer, other substances also fall into the category. For the purposes of this discussion, the oxygen in the air around us is considered the primary oxidizing agent. Normally, air consists of about 21% percent oxygen. At room temperature (70°F or 21°C), combustion is supported at oxygen concentrations as low as 14% percent. Research shows, however, that as temperatures in a compartment fire increase, lower concentrations of oxygen are needed to support flaming combustion. In studies of compartment fires, flaming combustion has been observed at post-flashover temperature conditions (the fully developed and decay stages) when oxygen concentrations have been very low. Some research indicates the concentration can be less than 2% percent. When oxygen concentrations exceed 21% percent, the atmosphere is said to be *oxygen enriched.* Under these conditions, materials exhibit very different burning characteristics. Materials that burn at normal oxygen levels burn more rapidly in oxygen-enriched atmospheres and may ignite much easier than normal. Some petroleum-based materials will auto ignite in oxygen-enriched atmospheres. Many materials that do not burn at normal oxygen levels burn readily in oxygen-enriched atmospheres, one such material is Nomex fire resistant material, which is used to construct much of the protective clothing worn by firefighters. At normal oxygen levels, Nomex does not burn. When placed in an oxygen enriched atmosphere of approximately 31% percent oxygen, however, Nomex ignites and burns vigorously. Fires in oxygen-enriched atmospheres are more difficult to extinguish and present a potential safety hazard to firefighters operating in them. These conditions can be found in health care facilities, industrial occupancies, and even private homes where occupants use oxygen breathing equipment [1].

1.14.2 Fuel

Fuel is the material or substance being oxidized or burned in the combustion process. In scientific terms, the fuel in a combustion reaction is known as the *reducing agent.* Most common fuels contain carbon along with combinations of hydrogen and oxygen. These fuels can be further broken down into hydrocarbon-based fuels (such as gasoline, fuel oil, and plastics) and cellulose-based materials (such as wood and paper). Other fuels that are less complex in their chemical makeup include hydrogen gas and combustible metals such as magnesium and sodium. The combustion process involves two key fuel-related factors: the physical state of the fuel and its distribution. These factors are discussed in the following paragraphs. From the earlier discussion on matter, it should be understood that a fuel may be found in any of three states of matter: solid, liquid, or gas. To burn, however, fuels must normally be in the gaseous state. For solids and liquids, energy must be expended to cause these state changes. Fuel gases are evolved from solid fuels by paralysis. *Paralysis is* the chemical decomposition of a substance through the action of heat. Simply stated, as solid fuels are heated, combustible materials are driven from the substance. If there is sufficient fuel and heat, the process of paralysis generates sufficient quantities of burnable gases to ignite if the other elements of the fire tetrahedron are present .Because of their nature; solid fuels have a definite shape and size. This property significantly affects their ease of ignition. Of primary consideration is the surface-to-mass ratio of the fuel. The *surface-to-mass ratio* is the surface area of the fuel in proportion to the mass. One of the best examples of the surface-to-mass ratio is wood. To produce usable materials, a tree must be cut into a log. The mass of this log is very high, but the surface area is relatively low, thus the surface-to-mass ratio is low. The log is then milled into boards. The result of this process is to reduce the mass of the individual boards as compared to the log, but the resulting surface area is increased, thus increasing the surface-to -mass ratio. The sawdust that is produced as the lumber is milled has an even higher surface-to -mass ratio. If the boards are sanded, the resulting dust has the highest surface-to-mass ratio of any of the examples. As this ratio increases, the fuel particles become smaller (more finely divided — for example, sawdust as opposed to logs), and their ignitability increases tremendously As the surface area increases, more of the material is exposed to the heat and thus generates more burnable gases due to paralysis. A solid fuel’s actual position also affects the way it burns. If the solid fuel is in a vertical position, fire spread will be more rapid than if it is in a horizontal position. For example, if you were to ignite a sheet of 1/8-inch plywood paneling that was laying horizontally on two saw horses; the fire would consume the fuel at a relatively slow rate. Fire the same type of paneling in the vertical position burns much more rapidly. The rapidity of fire spread is due to increased heat transfer through convection as well as conduction and radiation for liquids, fuel gases are generated by process called vaporization, in scientific terms, *vaporization* is the transformation of a liquid to its vapor or gaseous state. The transformation from liquid to vapor or gas occurs as molecules of the substance escape from the liquid’s surface into the surrounding atmosphere. In order for the molecules to break free of the liquid’s surface, there must be some energy input. In most cases, this energy is provided in the form of heat. For example, water left in a pan eventually evaporates. The energy required for this process comes from the sun or surrounding environment. Water in the same pan placed on stove and heated to boiling vaporizes much more rapidly because there is more energy being applied to the system. The rate of vaporization is determinedly the substance and the amount of heat energy applied to it. Vaporization of liquid fuels generally requires less energy input than doe’s paralysis for solid fuels. This is primarily caused by the different densities of substances in solid and liquid states and by the fact that molecules of a substance in the liquid state have more energy than when they are in the solid state. Solids also absorb more of the energy because of their mass. The volatility or ease with which a liquid gives off vapor influences its ignitability. All liquids give off vapors to a greater or lesser degree in the form of simple evaporation [1].

Liquids that easily give off quantities of flammable or combustible vapors can be dangerous. Like the surface-to mass ratio for solid fuels, the surface-to-volume ratio of liquids is an important factor in their ignitability. A liquid assumes the shape of its container. Thus, when a spill or release occurs, the liquid assumes the shape of the ground (flat), flows, and accumulates in low areas. When contained, the specific volume of a liquid has a relatively low surface-to volume ratio. When it is released, this ratio increases significantly as does the amount of fuel vaporized from the surface. Gaseous fuels can be the most dangerous of all fuel types because they are already in the natural state required for ignition. No paralysis or vaporization is needed to ready the fuel and less energy is required for ignition For combustion to occur after a fuel has been converted into a gaseous state, it must be mixed with air (oxidizer) in the proper ratio. The range of concentrations of the fuel vapor and air (oxidizer) is called the *flammable (explosive) range.* The flammable range of a fuel is reported using the percent by volume of gas or vapor in air for the lower flammable limit (LFL) and for the upper flammable limit (UFL). The *lower flammable limit* is the minimum concentration of fuel vapor and air that supports combustion. Concentrations that are below the LFL are said to be *too lean* to burn. The *upper flammable limit* is the concentration above which combustion cannot take place. Concentrations that are above the UFL are said to be *too rich* to burn. The flammable limits for combustible gases are presented in chemical handbooks and documents such as National Fire Protection Association (NFPA) Standard 49, *Hazardous Chemicals Data,* and NFPA 325, *Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids*. The limits are normally reported at ambient temperatures and atmospheric pressures. Variations in temperature and pressure can cause the flammable range to vary considerably. Generally, increases in temperature or pressure broaden the range and decreases narrow it [1].

1.14.3 Heat

Heat is the energy component of the fire tetrahedron. When heat comes into contact with a fuel, the energy supports the combustion reaction in the following ways:

- Causes the paralysis or vaporization of solid and liquid fuels and the production of ignitable vapors or gases.
- Provides the energy necessary for ignition.
- Causes the continuous production and ignition of fuel vapors or gases so that the combustion reaction can continue Most of the energy types discussed earlier in the chapter produce heat. For our discussion of fire and its behavior, however, chemical, electrical, and mechanical energy are the most common sources of heat that result in the ignition of a fuel. Each of these sources is discussed in depth in this section.

Chemical, Chemical heat energy is the most common source of heat in combustion reactions. When any combustible is in contact with oxygen, oxidation occurs. This process almost always results in the production of heat. The heat generated when a common match burns is an example of chemical heat energy. *Self-heating* (also known as spontaneous heating) is a form of chemical heat energy that occurs when a material increases in temperature without the addition of external heat. Normally the heat is produced slowly by oxidation and is lost to the surroundings almost as fast as it is generated. In order for self-heating to progress to spontaneous ignition, the material must be heated to its ignition temperature (minimum temperature at which self-sustained combustion occurs for a specific substance). For spontaneous ignition to occur, the following events must occur:

- The rate of heat production must be great enough to raise the temperature of the material to its ignition temperature.
- The available air supply (ventilation) in and around the material being heated

must be adequate to support combustion.

- The insulation properties of the material immediately surrounding the fuel must be such that the heat being generated does not dissipate. An example of a situation that could lead to spontaneous ignition would be a number of oil soaked rags that are rolled into a ball and thrown into a corner. If the heat generated by the natural oxidation of the oil and cloth is not allowed to dissipate, either by movement of air around the rags or some other method of heat transfer, the temperature of the cloth will eventually become sufficient to cause ignition. The rate of the oxidation reaction, and thus the heat production, increases as more heat is generated and held by the materials insulating the fuel. In fact, the rate at which most chemical reactions occur doubles with each 18°F increase in the temperature of the reacting materials. The more heat generated and absorbed by the fuel, the faster the reaction causing the heat generation. When the heat generated by a self-heating reaction exceeds the heat being lost, the material may reach its ignition temperature and ignite spontaneously Lists some common materials that are subject to self-heating.

Electrical, Electrical heat energy can generate temperatures high enough to ignite any combustible materials near the heated area. Electrical heating can occur in several ways, including the Following:

- Current flow through a resistance.
- Over current or overload.
- Arcing.
- Sparking.
- Static.
- Lightning.

Mechanical, Mechanical heat energy is generated by friction and compression. *Heat of friction* is created by the movement of two surfaces against each other. This movement results in heat and/or sparks being generated. *Heat of compression* is generated when a gas is compressed. Diesel engines use this principle to ignite fuel vapor without a spark plug. The principle is also the reason that self-contained breathing apparatus (SCBA) cylinders feel warm to the touch after they have been filled.

Nuclear, Nuclear heat energy is generated when atoms either split apart (fission) or combine (fusion). In a controlled setting, fission heats water to drive steam turbines and produce electricity. Fusion reactions cannot be contained at this time and have no commercial use. The sun’s heat (solar energy) is a product of a fusion reaction and thus is a form of nuclear energy[1].

1.15 Self Sustained Chemical Reaction

Combustion is a complex reaction that requires a fuel (in the gaseous or vapor state), an oxidizer, and heat energy to come together in a very specific way. Once flaming combustion or fire occurs, it can only continue when enough heat energy is produced to cause the continued development of fuel vapors or gases. Scientists call this type of reaction chain reaction. A *chain reaction* is a series of reactions that occur in sequence with the results of each individual reaction being added to the rest. An excellent illustration of a chain reaction is given by Faughn, Chang, and Turk in their textbook *Physical Science: An example of a chemical chain reaction is a forest fire. The heat from one tree may initiate the reaction (burning) of a second tree, which, in turn ignites a third, and so on. The fire will then go on at a steady rate. But if one burning tree ignites, say, two others, and each of these two ignite two more, for a total of four, and soon, the rate of burning speeds rapidly. Such uncontrolled, runaway chain reactions are at the heart of nuclear bombs.* The self-sustained chemical reaction and the related rapid growth are the factors that separate fire from slower oxidation reactions. Slow oxidation reactions do not produce heat fast enough to reach ignition, and they never generate sufficient heat to become self-sustained. Examples of slow oxidations are the rusting of iron (mentioned earlier) and the yellowing of paper [1].

1.16 Fire Development

When the four components of the fire tetrahedron come together, ignition occurs. For a fire to grow beyond the first material ignited, heat must be transmitted beyond the first material to additional fuel packages. In the early development of a fire, heat rises and forms a plume of hot gas. If a fire is in the open (outside or in a large building), the fire plume rises unobstructed, and air is drawn (entrained) into it as it rises. Because the air being pulled into the plume is cooler than the fire gases, this action has a cooling effect on the gases above the fire. The spread of fire in an open area is primarily due to heat energy that is transmitted from the plume to nearby fuels. Fire spread in outside fires can be increased by wind and sloping terrain that allow exposed fuels to be preheated The development of fires in a compartment is more complex than those in the open. For the purposes of this discussion, a *compartment* is an enclosed room or space within a building. The term *compartment fire* is defined as a fire that occurs within such a space. The growth and development of a compartment fire is usually controlled by the availability of fuel and oxygen. When the amount of fuel available to burn is limited, the fire is said to be *fuel controlled.* When the amount of available oxygen is limited, the condition is said to be: *ventilation controlled.* Recently, researchers have attempted to describe compartment fires in terms of stages or phases that occur as the fire develops. These stages are as follows:

- Ignition.
- Growth.
- Flashover.
- Fully developed.
- Decay.

It should be noted that the stages are an attempt to describe the complex reaction that occurs as a fire develops in a space with no suppression action taken. The ignition and development of a compartment fire is very complex and influenced by many variables. As a result, all fires may not develop through each of the stages described. The information is presented to depict fire as a dynamic event that is dependent on many factors for its growth and development [1].

1.16.1 Ignition

Ignition describes the period when the four elements of the fire tetrahedron come together and combustion begins. The physical act of ignition can be *piloted* (caused by a spark or flame) or *no piloted* (caused when a material reaches its ignition temperature as the result of self-heating) such as spontaneous ignition. At this point, the fire is small and generally confined to the material (fuel) first ignited. All fires — in an open area or within a compartment — occur as a result of some type of ignition.

1.16.2 Growth

Shortly after ignition, a fire plume begins to form above the burning fuel. As the plume develops, it begins to draw or entrain air from the surrounding space into the column. The initial growth is similar to that of an outside unconfined fire, with the growth a function of the fuel first ignited. Unlike an unconfined fire, however, the plume in a compartment is rapidly affected by the ceiling and walls of the space. The first impact is the amount of air that is entrained into the plume. Because the air is cooler than the hot gases generated by the fire, the air has a cooling effect on the *temperatures within the plume.* The location of the fuel package in relation to the compartment walls determines the amount of air that is entrained and thus the amount of cooling that takes place. Fuel packages near walls entrain less air and thus have higher plume temperatures. Fuel packages in corners entrain even less air and have the highest plume temperatures. This factor significantly affects the temperatures in the developing hot-gas layer above the fire. As the hot gases rise, they begin to spread outward when they hit the ceiling. The gases continue to spread until they reach the walls of the compartment. The depth of the gas layer then begins to increase. The temperatures in the compartment during this period depend on the amount of heat conducted into the compartment ceiling and walls as the gases flow over them and on the location of the initial fuel package and the resulting air entrainment. Research shows that the gas temperatures decrease as the distance from the of the plume increases The growth stage will continue if enough fuel and oxygen are available. Compartment fires in the growth stage are generally fuel controlled. As the fire grows, the overall temperature in the compartment increases as does the temperature of the gas layer at the ceiling level [1].

1.16.3 Flashover

Flashover is the transition between the growth and the fully developed fire stages and is not a specific event such as ignition. During flashover, conditions in the compartment change very rapidly as the fire changes from one that is dominated by the burning of the materials first ignited to one that involves all of the *exposed combustible surfaces* within the compartment. The hot-gas layer that develops at the ceiling level during the growth stage causes radiant heating of combustible materials remote from the origin of the fire. Typically, radiant energy (heat flux) from the hot-gas layer exceeds 20kW/m^2 when flashover occurs. This radiant heating causes paralysis in the combustible materials in the compartment. The gases generated during this time are heated to their ignition temperature by the radiant energy from the gas layer at the ceiling while scientists define flashover in many ways; most base their definition on the temperature in a compartment that results in the simultaneous ignition of all of the combustible contents in the space. While no exact temperature is associated with this occurrence, a range from approximately 900°F to 1,200°F (483°C to 649°C) is widely used. This range correlates with the ignition temperature of carbon monoxide (CO) (1,128°F or 609°C), one of the most common gases given off from paralysis Just prior to flashover, several things are happening within the burning compartment: The temperatures are rapidly increasing, additional fuel packages are becoming involved, and the fuel packages in the compartment are giving off combustible gases as a result of paralysis. As flashover occurs, the combustible materials in the compartment and the gases given off from paralysis ignite. The result is full-room involvement. The heat release from a fully developed room at flashover can be on the order of 10,000 kW or more. Occupants who have not escaped from a compartment before flashover occurs are not likely to survive. Firefighters who find themselves in a compartment at flashover are at extreme risk even while wearing their personal protective equipment [1].

1.16.4 Fully Development

The fully developed fire stage occurs when all combustible materials in the compartment are involved in fire. During this period of time, the burning fuels in the compartment are releasing the maximum amount of heat possible for the available fuel packages and producing large volumes of fire gases. The heat released and the volume of fire gases produced depends on the number and size of the ventilation openings in the compartment. The fire frequently becomes ventilation controlled, and thus large volumes of unburned gases are produced. During this stage, hot unburned fire gases are likely to begin flowing from the compartment of origin into adjacent spaces or compartment. These gases ignite as they enter a space where air is more abundant [1].

1.16.5 Decay

As the fire consumes the available fuel in the compartment, the rate of heat release begins to decline. Once again the fire becomes fuel controlled, the amount of fire diminishes, and the temperatures within the compartment begin to. Decline, the remaining mass of glowing embers can, however, result in moderately high temperatures in the compartment for some time.

1.17 Factors That Affect Fire Development

As the fire progresses from ignition to decay, several factors affect its behavior and development within the compartment:

- Size, number, and arrangement of ventilation openings.
- Volume of the compartment.
- Thermal properties of the compartment enclosures.

• Ceiling height of the compartment.

• Size, composition, and location of the fuel package that is first ignited.

• Availability and locations of additional fuel packages (target fuels) for a fire to develop, enough air to support burning beyond the ignition stage must be available. The size and number of ventilation openings in a compartment determine how the fire develops within the space. The compartment's size and shape and ceiling height determine if a significant hot-gas layer will form. The location of the initial fuel package is also very important in the development of the hot-gas layer. The plumes of burning fuel packages in the center of a compartment entrain more air and are cooler than those against walls or in corners of the compartment. The temperatures that develop in a burning compartment are the direct result of the energy released as the fuels burn. Because matter and energy are conserved, any loss in mass caused by the fire is converted to energy. In a fire, the resulting energy is in the form of heat and light. The amount of heat energy released over time in a fire is called the *heat release rate* (HRR). HRR is measured in Btu/s or kilowatts (kW). The heat release rate is directly related to the amount of fuel being consumed over time and the heat of combustion (the amount of heat a specific mass of a substance gives off when burned) of the fuel being burned. This information gives representative numbers for typical fuel items Firefighters should be able to recognize potential fuel packages in a building or compartment and use this information to estimate the fire growth potential for the building or space. Materials with high heat release rates such as polyurethane foam-padded furniture, polyurethane foam mattresses, or stacks of wooden pallets, for example, would be expected to burn rapidly once ignition occurs. Fires in materials with lower heat release rates would be expected to take longer to develop. In general, low-density materials (such as polyurethane foam) burn faster (have a higher HRR) than higher density materials (cotton padding) of similar makeup. One final relationship between the heat generated in a fire and fuel packages is the ignition of additional fuel packages that are remote from the first package ignited. The heat generated in a compartment fire is transmitted from the initial fuel package to other fuels in the space by all three modes of heat transfer. The heat rising in the initial fire plume is transported by convection. As the hot gases travel over surfaces of other fuels in the compartment, heat is transferred to them by conduction. Radiation plays a significant role in the transition from a growing fire to a fully developed fire in a room. As the hot-gas layer forms at the ceiling, hot particles in the smoke begin to radiate energy to the other fuel packages in the compartment. These remote fuel packages are sometimes called *target fuels.* As the radiant energy increases, the target fuels begin paralysis and start to give off ignitable gases. When the temperature in the compartment reaches the ignition temperature of these gases, the entire room becomes involved in fire (flashover).

1.18 Special Consideration

*[NFPA 1001:3-3.10(a); 3-3.11(*a*)]*

Several conditions or situations that occur during a fire’s growth and development should be discussed. This section provides an overview of these conditions and the potential safety concerns for each [1].

1.18.1 Flame Over / Rollover

The terms *flame over* and *rollover* describes a condition where flames move through or across the unburned gases during a fire’s progression. Flame over is distinguished from flashover by its involvement of only the fire gases and not the surfaces of other fuel packages within a compartment. This condition may occur during the growth stage as the hot-gas layer forms at the ceiling of the compartment. Flames may be observed in the layer when the combustible gases reach their ignition temperature. While the flames add to the total heat generated in the compartment, this condition is not flashover. Flame over may also be observed when unburned fire gases vent from a compartment during the growth and fully develop stages of a fire’s development. As these hot gases vent from the burning compartment into the adjacent space, they mix with oxygen; if they are at their ignition temperature, flames often become visible in the layer [1].

1.18.2 Thermal Layering of Gases

The *thermal layering* of gases is the tendency of gases to form into layers according to temperature. Other terms sometimes used to describe this tendency are *heat stratification* and *thermal balance*. The hottest gases tend to be in the top layer, while the cooler gases form the lower layers. Smoke, a heated mixture of air, gases, and particles, rises. If a hole is made in a roof, smoke will rise from the building or room to the outside. Thermal layering is critical to fire fighting activities. As long as the hottest air and gases are allowed to rise, the lower levels will be safer for firefighters. This normal layering of the hottest gases to the top and out the ventilation opening can be disrupted if water is applied directly into the layer. When water is applied to the upper level of the layer, where the temperatures are highest, the rapid conversion to steam can cause the gases to mix rapidly. This swirling mixture of smoke and steam disrupts normal thermal layering, and hot gases mix throughout the compartment, this process is sometimes referred to as *disrupting the thermal balance* or *creating a thermal imbalance*. Many firefighters have been burned when thermal layering was disrupted. Once the normal layering is disrupted, forced ventilation procedures (such as using fans) must be used to clear the area. The proper procedure under these, conditions is to ventilate the compartment, allow the hot gases to escape, and direct the fire stream at the base of the fire, keeping it out of the hot upper layers of gases [1].

1.18.3 Back Draft

Firefighters operating at fires in buildings must use care when opening a building to gain entry or to provide horizontal ventilation (opening doors or windows). As the fire grows in a compartment, large volumes of hot, unburned fire gases can collect in unventilated spaces. These gases may be at or above their ignition temperature but have insufficient oxygen available to actually ignite. Any action during fire fighting operations that allows air to mix with these hot gases can result in an explosive ignition called *back draft* many firefighters have been killed or injured as a result of back drafts. The potential for back draft can be reduced with proper vertical ventilation (opening at highest point) because the unburned gases rise. Opening the building or space at the highest possible point allows them to escape before entry is made. The following conditions may indicate the potential for a back draft:

- Pressurized smoke exiting small openings.
- Black smoke becoming dense gray yellow.
- Confinement and excessive heat.
- Little or no visible flame.
- Smoke leaving the building in puffs or at intervals (appearance of breathing).
- Smoke-stained windows.

1.18.4 Products of Combustion

As a fuel burns, the chemical composition of the material changes, this change results in the production of new substances and the generation of energy as a fuel is burned, some of it is actually consumed. The Law of Conservation of Mass tells us that any mass lost converts to energy. In the case of fire, this energy is in the form of light and heat. Burning also results in the generation of airborne fire gases, particles, and liquids. These materials have been referred to throughout this chapter as products of combustion or smoke. The heat generated during a fire is one of the products of combustion. In addition to being responsible for the spread of a fire, heat also causes burns, dehydration, heat exhaustion, and injury to a person's respiratory tract. While the heat energy from a fire is a danger to anyone directly exposed to it, smoke causes most deaths in fires. The materials that make up smoke vary from fuel to fuel, but generally all smoke can be considered toxic. The smoke generated in a fire contains narcotic (asphyxiate) gases and irritants. Narcotic or asphyxiate gases are those products of combustion that cause central nervous system depression, which results in reduced awareness, intoxication, and can lead to loss of consciousness and death. The most common narcotic gases found in smoke are carbon monoxide (CO), hydrogen cyanide (HCN), and carbon dioxide (CO_2). The reduction in oxygen levels as a result of a fire in a compartment will also cause a narcotic effect in humans. Irritants in smoke are those substances that cause breathing discomfort (pulmonary irritants) and inflammation of the eyes, respiratory tract, and skin (sensory irritants). Depending on the fuels involved, smoke will contain numerous substances that can be considered irritants. The most common of the hazardous substances contained in smoke is carbon monoxide. While CO is not the most dangerous of the materials found in smoke, it is almost always present when combustion occurs. While someone may be killed or injured by breathing a variety of toxic substances in smoke, carbon monoxide is the one that is most easily detected in the blood of fire victims and thus most often reported. Because the substances in smoke from compartment fires are deadly (either alone or in combination), firefighters must use SCBA for protection when operating in smoke. Flame is the visible, luminous body of a burning gas. When a burning gas is mixed with the proper amounts of oxygen, the flame becomes hotter and less luminous. The loss of luminosity is caused by a more complete combustion of the carbon. For these reasons, flame is considered to be a product of combustion. Of course, it is not present in those types of combustion that do not produce a flame such as smoldering fires [1].

1.19 Fire Extinguishment Theory

[NFPA 1001: 3-3.10(a)]

Fire is extinguished by limiting or interrupting one or more of the essential elements in the combustion process (fire tetrahedron). A fire may be extinguished by reducing its temperature, eliminating available fuel or oxygen, or stopping the self-sustained chemical chain reaction [1].

1.19.1 Temperature Reduction

One of the most common methods of extinguishment is cooling with water. This process depends on reducing the temperature of a fuel to a point where it does not produce sufficient vapor to burn. Solid fuels and liquid fuels with high flash points can be extinguished by cooling. However, cooling with water cannot sufficiently reduce vapor production to extinguish fires involving low flash point liquids and flammable gases. The use of water for cooling is also the most effective method available for the extinguishment of smoldering fires. To extinguish a fire by reducing its temperature, enough water must be applied to the burning fuel to absorb the heat being generated by combustion. Types of streams and extinguishing methods are discussed later in the manual.

1.19.2 Fuel Removal

Removing the fuel source effectively extinguishes some fires. The fuel source may be removed by stopping the flow of liquid or gaseous fuel or by removing solid fuel in the path of a fire. Another method of fuel removal is to allow a fire to burn until all fuel is consumed [1].

1.19.3 Oxygen Exclusion

Reducing the oxygen available to the combustion process reduces a fire’s growth and may totally extinguish it over time. In its simplest form, this method is used to extinguish cooking stove fires when a cover is placed over a pan of burning food.the oxygen content can be reduced by flooding an area with an inert gas such as carbon dioxide, which displaces the oxygen and disrupts the combustion process. Oxygen can also be separated from fuel by blanketing the fuel with foam. Of course, neither of these methods works on those rare fuels that are self-oxidizing [1].

1.19.4 Chemical Flame Inhibition

Extinguishing agents such as some dry chemicals and halogenated agents (halons) interrupt the combustion reaction and stop flaming. This method of extinguishment is effective on gas and liquid fuels because they must flame to burn. Smoldering fires are not easily extinguished by these agents. The very high agent concentrations and extended periods of time necessary to extinguish smoldering fires make these agents impractical in these cases. Most ignitable liquids (those that support combustion) have a specific gravity of less than 1. If water is used as an extinguishing agent, the fuel can float on it while continuing to burn. If the fuel is unconfined, using water could unintentionally spread a fire. The solubility (ability of a substance to mix with water) of a liquid fuel in water is also an important factor in extinguishment. Liquids of similar molecular structure tend to be soluble in each other while those with different structures and electrical charges tend not to mix. In chemistry, those liquids that readily mix with water are called *polar solvents.* Alcohol and other polar solvents dissolve in water. If large volumes of water are used, alcohol and other polar solvents may be diluted to the point where they will not burn. As a rule, hydrocarbon liquids (non polar solvents — not soluble in water) do not dissolve in water and float on top of water. This is why water alone cannot wash oil off our hands; the oil does not dissolve in the water. Soap must be added to water to dissolve the oil. Vapor density also affects extinguishment of both ignitable liquids and gaseous fuels. Gases that are less dense than air (vapor densities of less than 1) tend to rise and dissipate when released. Gases or vapors with vapor densities greater than 1 tend to hug the ground and travel as directed by terrain and wind. Common hydrocarbon gases such as ethane and propane have vapor densities greater than air and tend to collect near the surface when released. Natural gas (methane) is an example of a hydrocarbon gas with a vapor density less than air. When released, methane tends to rise and dissipate.

1.20 Classification of Fires

[NFPA 1001: 3-3.15(a)]

The classification of a fire is important to the firefighter when discussing extinguishment. Each class of fire has its own requirements for extinguishment. The four classes of fire are discussed here, along with normal extinguishment methods and problems. These classes will be used throughout the manual when the various extinguishment methods are discussed in greater detail.

1.20.1 Class A Fires

Class A fires involve ordinary combustible materials such as wood, cloth, paper, rubber, and many plastics Water is used to cool or quench the burning material below its ignition temperature. The addition of Class A foams (sometimes referred to as *wet water*) may enhance water's ability to extinguish Class A fires, particularly those that are deep seated in bulk materials (such as piles of hay bales, sawdust piles, etc.). This is because the Class A foam agent reduces the water's surface tension, allowing it to penetrate more easily into piles of the material. Class A fires are difficult to extinguish using oxygen-exclusion methods like CO_2 flooding or coating with foam because those methods do not provide the cooling effect needed for total extinguishment [1].

1.20.2 Class B Fires

Class B fires involve flammable and combustible liquids and gases such as gasoline, oil, lacquer, paint, mineral spirits, and alcohol. The smothering or blanketing effect of oxygen exclusion is most effective for extinguishment and also helps reduce the production of additional vapors. Other extinguishing methods include removal of fuel, temperature reduction when possible, and the interruption of the chain reaction with dry chemical agents such as PurpleK.

1.20.3 Class C Fires

Fires involving energized electrical equipment are Class C fires. Household appliances, computers, transformers, and overhead transmission lines are examples. These fires can sometimes be controlled by a no conducting extinguishing agent such as halon, dry chemical, or carbon dioxide. The fastest extinguishment procedure is to first de-energize high-voltage circuits and then fight the fire appropriately depending upon the fuel involved [1].

1.20.4 Class D Fires

Class D fires involve combustible metals such as aluminum, magnesium, titanium, zirconium, sodium, and potassium these materials are particularly hazardous in their powdered form. Proper airborne concentrations of metal dusts can cause powerful explosions, given a suitable ignition source. The extremely high temperature of some burning metals makes water and other common extinguishing agents ineffective. No single agent effectively controls fires in all combustible metals. Special extinguishing agents are available for control of fire in each of the metals. They are marked specifically for the metal fire they can extinguish. These agents are used to cover the burning material. Firefighters may find these materials in a variety of industrial or storage facilities. It is essential to use caution in a Class D materials fire. Information regarding a material and its characteristics should be reviewed prior to attempting to extinguish a fire. The burning material should be isolated and treated as recommended in its Material Safety Data Sheet (MSDS) or in the *North American Emergency Response Guidebook* (NAERG) from the U.S. Department of Transportation. All personnel operating in the area of the material should be in full protective equipment, and those exposed should be limited to only the people necessary to contain or extinguish the fire.

1.20.5 Class F Fires

Fires' involving commercial cooking appliances with vegetable oils, animal oils or fats at high temperature a wet potassium acetate low PH-based agent is used for this class of fire [1].

1.21 Previous Studies

1.21.1 [A] Design and Implementation of Automatic Fire Alarm System Based on Wireless Sensor Networks

This study was forwarding by Lei Zhang, (School of Computer Science and Technology, Southwest University of Science and Technology, Mianyang, China) and Gaofeng Wang, (Laboratories EM2C, CNRS, Ecole Centrale

Paris, Chatenay-Malabry, France). In this paper, an automatic fire alarm system based on wireless sensor networks is designed and developed with emphasis on the network architecture and communication protocol. Prototype system tests show that the system provides early extinguishing of a fire disaster so that damages will be reduced effectively. It must pre-arrange the installing location of each detector in this system due to localization mechanism is not considered. In order to reduce the installation workload and make the system more convenient, automatic localization mechanism is the focus of our future work.

1.21.2 [B] Automated Fire Detection and Controlling System

These study was forwarding by Kausik Sen, Jeet Sarkar, Sutapa Saha, Anuk rishna Roy, Dipsetu Dey, Sumit Baitalik, Chandra Sekhar Nandi . are Students of Applied Electronics and Instrumentation Engineering Department, University Institute Of Technology, BurdwanUniversity,W.B. India And Faculty of Applied Electronics and Instrumentation Engineering Department, University Institute Of Technology, Burdwan University, W.B. India. In this paper basically a low cost fire detection and control system based on smoke and heat detection is proposed. It is comprised of a combination of electrical/electronic devices/equipments working together to detect the presence of fire and alert people through audio or visual medium after detection. These alarms may be activated from smoke detectors or heat detectors which, when detects fire. Then, it automatically operates a relay which can be used to send Short Message Service (SMS) to the registered mobile numbers and switch on a water sprayer or a Solenoid Pump to spray water or fire ceasing foam.

1.22 Problem Statement

Monitoring of many places by the human to detect fires when happens is dangerous and difficult to manage and need to be more safety and development.

1.23 Project Objective

The objective of this research is to design and built fire alarm system in which two detectors can be detect via heat and smoke sensors with PLC and controlling software.

1.24 Research Outline

Such experimental study composed of four chapters the first chapter tackles the previous studies, the problem of the study and it is importance objective .moreover, it tackles the terminology provided in the study. The second chapter tackles the type of detectors covering definitions of detectors and some types of detectors such as gas detectors, duct detectors, flam detectors, CO detectors, fire –gas detectors, smoke – heat detectors, and combination detectors, air sampling detectors beside the heat and smoke detectors that used in this research. The third chapter includes the definition of PLC and it is components, systems and programs. Eventually, the fourth chapter involves addresses composition of the circuit with emphasis on the designing and diagram titled the (hardware).

1.25 Methodology

An experimental setup will be built , in this setup will be connective to a smoke sensor circuit and heat sensor circuit , a programmable logic controller will be interface to the smoke and heat out puts respectively , a software will be developed to the control , the viewing of seen capture by each at time .

Chapter Two

Detectors

2.1 Introduction

There are a number of reasons for installing fire detection and alarm systems. Each system is designed to fulfill specific needs. The following are recognized functions:

- To notify occupants of a facility to take necessary evasive action to escape the dangers of a hostile fire.
- To summon organized assistance to initiate or to assist in fire control activities.
- To initiate automatic fire control and suppression systems and to sound an alarm.
- To supervise fire control and suppression systems to assure that operational status is maintained.
- To initiate a wide variety of auxiliary functions involving environmental, utility, and process controls Fire detection and alarm systems may incorporate one or all of these features. Such systems may include components that operate mechanically, hydraulically, pneumatically, or electrically, but most state-of-the-art systems operate electronically. Despite advances in other forms of fixed fire protection suppression systems, automatic sprinkler systems remain the most reliable form for commercial, industrial, institutional, residential, and other occupancies. It is proven that fires controlled by sprinklers result in less business interruption and water damage than those that have to be extinguished by traditional fire department methods. In fact, data compiled by Factory Mutual Research Corporation indicates that about 70% percent of all fires are controlled by the activation of five or fewer sprinklers [2].

2.2 Types of Alarm Systems

[NFPA 1001: 4-5.1; 4-5.1(a); 4-5.1(b)]

The most basic alarm system is designed to only be initiated manually. This is a local warning system similar to the type installed in schools or theaters, and the signal alerts occupants of the traditionally called this type a *local system,* contemporary terminology uses *protected premises fire alarm systems*. A wide variety of optional features are available to expand the capabilities of an alarm system. Automatic fire detection devices may be added, allowing the system to sense the presence of a fire and to initiate a signal. Four basic types of automatic alarm-initiating devices are designed to detect heat, smoke, fire gases, and flame. The following sections describe the most common types of devices in use [2].

2.2.1 Heat Detectors

Figure (2.1) Heat Detector

Several different types of heat detection devices, such as fixed-temperature devices and rate of- rise detectors, are discussed in the following sections.

2.2.1.1 Fixed-Temperature Heat Detectors

Figure (2.2) Fix Temperature Heat Detector

Systems using fixed-temperature heat-detection devices are among the oldest types of fire detection systems in use. They are relatively inexpensive compared to other types of systems, and they are least prone to false activations. But heat detectors are also the slowest to activate of all the various types of alarm-initiating devices. Because heat rises, heat detectors must be placed in high portions of a room, usually on the ceiling. Detectors should have an activation temperature rating slightly above the highest ceiling temperatures normally expected in that space. The various types of fixed temperature devices discussed detect heat by one or more of three primary principles of physics:

- Expansion of heated material.
- Melting of heated material.
- Changes in resistance of heated material.

Fusible Devices / Frangible Bulbs, While these two devices are more commonly associated with automatic sprinklers, they are also used in fire detection and signaling systems. The operating principles of these devices are identical to the fusible links and frangible bulbs used with automatic sprinklers; only their applications differ *fusible device* is normally held in place by a solder with a known melting (fusing) temperature. Under normal conditions, the device holds a spring operated contact inside the detector in the open position when a fire raises the ambient temperature to the fusing temperature of the device, the solder melts, allowing the spring to move the contact point. This action completes the alarm circuit, which initiates an alarm signal. Some of these detectors may be restored by replacing the fusible device; others require the entire heat detector to be replaced. A *frangible bulb* in a detection device holds electrical contacts apart, much in the way that a fusible device does. The little glass vial (frangible bulb) contains a liquid with a small air bubble. The bulb is designed to break when the liquid is heated to a predetermined temperature. When the rated temperature is reached, the liquid expands and absorbs the air bubble, the bulb fractures and falls out, and the contacts complete the circuit to initiate an alarm. In order to restore the system, the entire detector must be replaced. While detectors of this type are still in service, their manufacture has been discontinued.

Continuous Line Detector, Most of the detectors *described in this chapter are of the spot type;* that is, they are designed to detect heat only in a relatively small area surrounding the specific spot where they are located. However, *continuous line detection devices* can detect heat over a linear area parallel to the detector. One such device consists of a cable with a conductive metal inner core sheathed with stainless steel tubing. The inner core and the sheath are separated by an electrically insulating semiconductor material that keeps them from touching but allows a small amount of current to flow between the two. This insulation loses some of its electrical resistance capabilities at a predetermined temperature anywhere along the line. When this condition happens, the current flow between the two components increases, initiating an alarm signal through the system control unit, this type of detection device restores itself when the level of heat is reduced. Another type uses two insulated wires within an outer covering. When the rated temperature is reached, the insulation melts and allows the two wires to touch. This action completes the circuit and initiates an alarm signal through the system control unit). To restore this type of line detector, the fused portion of the wires must be cut out and replaced with new wire.

Bimetallic Detector, one type of bimetallic detector uses two metals that have different thermal expansion characteristics. Thin strips of the metals are bonded together, and one or both ends of the strips are attached to the alarm circuit. When heated, one metal expands faster than the other, causing the strip to arch or bend. The deflection of the strip either makes or breaks contact in the alarm circuit, initiating an alarm signal through the system control unit. Another type of bimetallic detector utilizes a snap disk and micro switch). Most bimetallic detectors will reset automatically when cooled. After a fire, however, they do need to be checked to ensure that they were not damage [2].

2.2.1.2 Rate -of- Rise Heat Detectors

Figure (2.3) Rate - of - Rise Heat Detector

A *rate-of-rise heat detector* operates on the principle that the temperature in a room will increase faster from fire than from atmospheric temperature. Typically, rate-of-rise heat detectors are designed to initiate a signal when the rise in temperature exceeds 12 to 15°F (7°C to 8°C) per minute. Because the alarm is initiated by a sudden rise in temperature, regardless of the initial temperature, an alarm can be initiated at a temperature far below that required for a fixed-temperature device. Most rate-of-rise heat detectors are reliable and not subject to false activations. However, if not properly installed, they can be activated under non-fire conditions. For example, a rate-of-rise detector is installed just inside an exterior door in an air-conditioned building. If the door is opened on a hot day, the influx of heated air can rapidly increase the temperature around the detector and cause it to actuate. Relocating the detector farther from the doorway should alleviate the problem. There are several different types of rate-of-rise heat detectors in use; all automatically reset if undamaged. The different types are discussed in more detail in the following paragraphs.

Pneumatic rate -of- Rise Spot Detector, Pneumatic spot detector is the most common type of rate-of-rise detector in use. It consists of a small dome-shaped air chamber with a flexible metal diaphragm in the base. A small metering hole allows air to enter and exit the chamber during the normal rise and fall of atmospheric temperature and barometric pressure. In the heat of a fire, however, the air within the chamber expands faster than it can escape through the metering hole. This expansion causes the pressure within the chamber to increase, forcing the metal diaphragm against contact points in the alarm circuit. An alarm signal to the system control unit results. This type of detector is most often combined in one unit that also has fixed-temperature capability.

Pneumatic Rate -of- Rise Line Detector, the spot detector monitors a small area surrounding its location; however, a lie detector can monitor large areas. A *line detector* consists of a system of tubing arranged over a wide area of coverage the space inside the tubing acts as the air chamber described in the preceding paragraph on spot detectors. The line detector also contains a diaphragm and is vented. When any portion of the tubing is subjected to a rapid increase in temperature, the detector functions in the same manner as the spot detector, the tubing in this system must be limited to about 1,000 feet (300 m) in length. The tubing should be arranged in rows that are not more than 30 feet (9m) apart and 15 feet (5 m) from mages walls.

Rate-Compensated Detector, this detector is designed for use in areas that are normally subject to regular temperature changes that are slower than those under fire conditions. The detector consists of an outer metallic sleeve that encases two bowed struts that have a slower expansion rate than the sleeve. The bowed struts have electrical contacts on them. In the normal position, these contacts do not come together. When the detector is heated rapidly, the outer sleeve expands in length. This expansion reduces the tension on the inner strips and allows the contacts to come together, thus initiating an alarm signal through the system control unit. If the rate of temperature rise is fairly slow, such as 5°F (2°C to 3°C) per minute, the sleeve expands slowly enough to maintain tension on the inner strips. This tension prevents unnecessary system activations. However, regardless of threat of temperature increase, when the surrounding temperature reaches a predetermined point, an alarm signal will be initiated.

Thermoelectric Detector, this rate-of-rise detector operates on the principle that when two wires of dissimilar metals are twisted together and heated at one end, an electrical current is generated at the other end. The rate at which the wires are heated determines the amount of current that is generated. These detectors are designed to "bleed off" or dissipate small amounts of current. This reduces the chance of a small temperature change activating an alarm unnecessarily. Rapid changes in temperature result in larger amounts of current flowing and activation of the alarm system [2].

Rate Compensation will respond regardless of the rate of temperature rise

2.2.2 Smoke Detectors

Figure (2.4) Smoke Detector

Because a smoke detector can respond to smoke produced very early in a fire's development and does not have to wait for heat to be generated, it can initiate an alarm of fire much more quickly than heat detector, for this reason, the smoke detector is the preferred detector in many types of occupancies. The two basic types, photoelectric and ionization are described in the following sections, along with a discussion of power sources for smoke detectors [2].

2.2.2.1 Photoelectric Smoke Detector

A *photoelectric detector,* sometimes called a *visible products-of-combustion detector*, uses a photoelectric cell coupled with a specific light source. The photoelectric cell functions in two ways to detect smoke: beam application and refractory application. The *beam application* type uses a beam of light focused across the area being monitored and onto a photoelectric cell. The cell constantly converts the beam into current, which keeps a switch open. When smoke obscures the path of the light beam, the required amount of current is no longer produced, the switch closes, and an alarm signal is initiated The *refractory photocell* uses a light beam that passes through a small chamber at a point away from the light source. Normally, the light does not strike the photocell, and no current is produced. This allows the switch to remain open. When smoke enters the chamber, it causes the light beam to be refracted (scattered) in all directions. A portion of the scattered light strikes the photocell, causing current to flow. This current causes the switch to close and initiates the alarm signal a photoelectric detector works satisfactorily on all types of fires and automatically resets when the atmosphere is clear. Photoelectric detectors are generally more sensitive to smoldering fires than are ionization detectors [2].

2.2.2.2 Ionization Smoke Detector

During combustion, minute particles and aerosols too small to be seen by the naked eye are produced. These invisible products of combustion can be detected by devices that use a tiny amount of radioactive material (usually americium) to ionize air molecules as they enter a chamber within the detector. These ionized particles allow an electrical current to flow between negative and positive plates within the chamber. When the particulate products of combustion (smoke) enter the chamber, they attach themselves to electrically charged molecules of air (ions), making the air within the chamber less conductive. The decrease in current flowing between the plate's initiates an alarm signal .An ionization detector responds satisfactorily to most fires; however, this detector generally responds faster to flaming fires than to smoldering ones. It automatically resets when the atmosphere has cleared [2].

2.2.2.3 Power Sources

Either batteries or household current can power residential smoke detectors. Battery-operated detectors offer the advantage of easy installation a screwdriver and a few minutes are all that are needed. Battery models are also independent of house power circuits and operate during power failures. Firefighters should be aware of any state/province or local laws that deal with smoke detectors. Such legislation, in addition to spelling out minimum installation requirements for given occupancies (including homes), may designate the power source to be used. Laws requiring hard-wired units were precipitated by statistics showing a growing lack of maintenance in battery operated detectors (worn-out batteries not being replaced). Consequently, many codes requiring detectors in newly constructed homes specify 110- volt, hard-wired units. The detector powered by household current is usually the most reliable mechanism. However, in some rural areas and areas with high thunderstorm occurrence, power failures may be more frequent, and battery-operated units may be more appropriate. It is critical that the specific battery type recommended by the detector's manufacturer be used for replacement. The batteries should be changed at least twice a year or more often if necessary. One way firefighters can get citizens to remember when to change smoke-detector batteries is by suggesting the change be made in the spring and fall at the same time clocks are reset for daylight savings or returned to standard time [2].

2.2.3 Duct Detectors

Photoelectric detector mounted in housing outside the ductwork that has probes that extend into the duct to sample the air inside the duct. Primarily used as a smoke control device to control the flow of air in ductwork [2].

2.2.4 Flame Detectors

There are three basic types of flame detectors (sometimes called *light detectors*).

- Those that detect light in the ultraviolet wave spectrum (UV detectors).
- Those that detect light in the infrared wave spectrum (IR detectors).
- Those that detect both types of light While these types of detectors are among the most sensitive in detecting fires, they are also easily activated by non-fire conditions such as welding, sunlight, and other sources of bright light. They should only be located in areas where these conditions are unlikely. They must be positioned so that they have an unobstructed view of the protected area. If their line of sight is blocked, they will not activate. Because some single-band IR detectors are sensitive to sunlight, they are usually installed in fully enclosed areas. To reduce the likelihood of false alarms, most IR detectors are designed to require the flickering motion of a

flame to initiate an alarm. Ultraviolet detectors are virtually insensitive to sunlight, so they can be used in areas not suitable for IR detectors. However, they are not suitable for areas where arc welding is done or where intense mercury-vapor lamps are used [2].

2.2.5 CO Detection

These detect the smouldering aspect of a fire and provide early warning along with high immunity from nuisance activations from Steam etc. They are not to be used in isolation and must be mixed with standard fire detectors Different combos make the detectors more versatile and more responsive to fire condition.

2.2.6 Fire-Gas Detectors

When a fire burns in a confined space, it changes the makeup of the atmosphere within the space. Depending on the fuel, some of the gases released by a fire may include the following:

- Water vapor (H_2O).
- Carbon dioxide (CO_2).
- Carbon monoxide (CO).
- Hydrogen chloride (HCL).
- Hydrogen cyanide (HCN).
- Hydrogen fluoride (HF).
- Hydrogen sulfide (H_2S).

Only water vapor, carbon dioxide, and carbon monoxide are released from all fires. Other gases released vary with the specific chemical makeup of the fuel. Therefore, it is only practical to monitor the levels of carbon dioxide and carbon monoxide for general fire-detection purposes this type of detector will initiate an alarm signal somewhat faster than a heat detector but not as quickly as a smoke detector. Of more importance than the speed of response is the fact that a fire-gas detector can be more discriminating than other types of detectors. A fire gas detector can be designed to be sensitive only to the gases produced by specific types of hostile fires and to ignore those produced by friendly fires. This detector uses either semiconductors or catalytic elements sense the gas and trigger the alarm. Compared to the number of other types of detectors, few fire-gas detectors are in use [2].

2.2.7 Smoke/ Heat Detection (Multisensory)

This uses a combination of smoke and heat detection to provide optimum fire detection combined with high immunity from nuisance alarms. The intelligent type can be programmed to percentages of each phenomenon and can even change status at night. This would allow heat detection when people are present and smoke detection when they are not [2].

2.2.8 Combination Detectors

Depending on the design of the system, various combinations of the previously described means of detection may be used in a single device .These combinations include fixed temperature/ rate-of-rise heat detectors, combination heat/ smoke detectors, and combination smoke/fire gas detectors. The different combinations make these detectors more versatile and more responsive to fire conditions.

.2.2.9 Air Sampling Detectors

Continuously capture air samples and measure the concentrations of specific gases or products of combustion.

2.3 Indicating Devices

A large assortment of audible and visible alarm indicating devices have also been developed. Some are loud to attract attention in high-noise areas; some generate an electronic tone that is audible in almost any type of environment. Some systems employ bells, horns, or chimes; others use speakers that broadcast prerecorded evacuation instructions To accommodate special circumstances or populations, such as people who must wear personal noise attenuation devices because of very high noise levels in their work areas, visual alarm indicators that employ an extremely high intensity clear strobe may be used. These indicators may be used singularly or in combination with other alarm devices appropriate strobe devices may also be used to meet the requirements of the Americans with Disabilities Act (ADA) in areas where there may be people with hearing impairments [2].

Chapter Three

PLC

3.1 Introduction

3.2 Programmable Logic Controllers

This chapter is an introduction to the programmable logic controller (PLC) and its general function, hardware forms, and internal architecture [3].

3.3 Controllers

What type of task might a control system handle? It might be required to control a sequence of events, maintain some variable constant, or follow some prescribed change. For example, the control system for an automatic drilling machine (Figure 3.1) might be required to start lowering the drill when the work piece is in position, start drilling when the drill reaches the work piece, stop drilling when the drill has produced the required depth of hole, retract the drill, and then switch off and wait for the next work piece to be put in position before repeating the operation. Another control system (Figure 3.1) might be used to control the number of items moving along a conveyor belt and direct them into a packing case. The inputs to such control systems might come from switches being closed or opened; for example, the presence of the work piece might be indicated by it moving against a switch and closing it, or other sensors such as those used for temperature or flow rates. The controller might be required to run a motor to move an object to some position or to turn a valve, or perhaps a heater, on or off. What form might a controller have?! For the automatic drilling machine, we could wire up electrical circuits in which the closing or opening of switches would result in motors being switched on or valves being actuated. Thus we might have the closing of a switch activating relay, which, in turn, switches on the current to a motor and causes the drill to rotate (Figure 3.2). Another switch might be used to activate a relay and switch on the current to a pneumatic or hydraulic valve, which results in pressure being switched to drive a piston in a cylinder and so results in the work piece being pushed into the required position. Such electrical circuits would have to be specific to the automatic drilling machine. For controlling the number of items packed into a packing case, we could likewise wire up electrical circuits involving sensors and motors. However, the controller circuits we devised for these two situations would be different. In the “traditional” form of control system, the rules governing the control system and when actions are initiated are determined by the wiring. When the rules used for the control actions are changed, the wiring has to be changed. Microprocessor-Controlled Systems Instead of hardwiring each control circuit for each control situation, we can use the same basic system for all situations if we use a microprocessor-based system and write a program to instruct the microprocessor how to react to each input signal from, say, switches and give the required outputs to, say, motors and valves. Thus we might have a program of the form: If switch A closes Output to motor circuit if switch B closes Output to valve circuit by changing the instructions in the program, we can use the same microprocessor system to control a wide variety of situations. As an illustration, the modern domestic washing machine uses a microprocessor system. Inputs to it arise from the dials used to select the required wash cycle, a switch to determine [3].

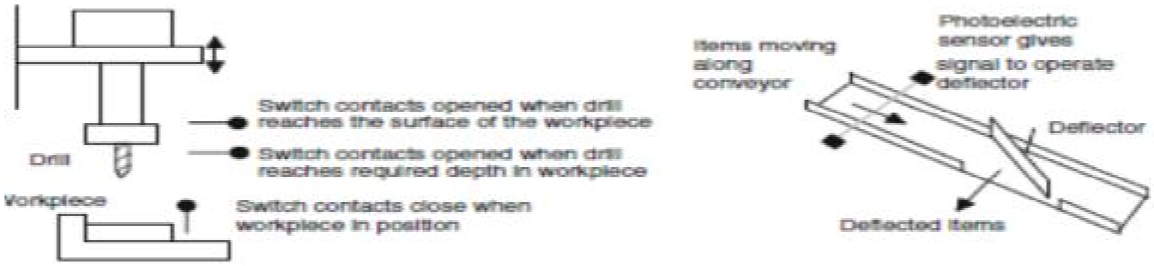


Figure (3.1) An Example of a Control Task and Some Input Sensor (An Automatic Drilling Machine) and a Packing System

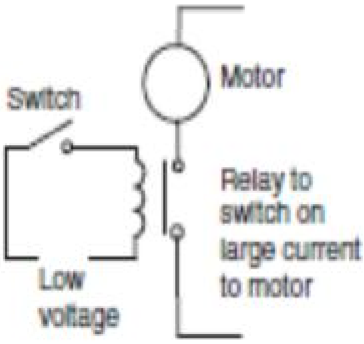


Figure (3.2) a Control Circuit

That the machine door is closed, a temperature sensor to determine the temperature of the water, and a switch to detect the level of the water, On the basis of these inputs the microprocessor is programmed to give outputs that switch on the drum motor and control its speed, open or close cold and hot water valves, switch on the drain pump, control the water heater, and control the door lock so that the machine cannot be opened until the washing cycle is completed [3].

3.4 The Programmable Logic Controller

A programmable logic controller (PLC) is a special form of microprocessor-based controller that uses programmable memory to store instructions and to implement functions such as logic, sequencing, timing, counting, and arithmetic in order to control machines and processes (Figure 3.3). It is designed to be operated by engineers with perhaps a limited knowledge of computers and computing languages. They are not designed so that only computer programmers can set up or change the programs. Thus, the designers of the PLC have preprogrammed it so that the control program can be entered using a simple, rather intuitive form of language. The term logic is used because programming is primarily concerned with implementing logic and switching operations; for example, if A or B occurs, switch on C; if A and B occurs, switch on D. Input devices (that is, sensors such as switches) and output devices (motors, valves, etc.) in the system being controlled are connected to the PLC. The operator then enters a sequence of instructions, a program, into the memory of the PLC. The controller then monitors the inputs and outputs according to this program and carries out the control rules for which it has been programmed. PLCs have the great advantage that the same basic controller can be used with a wide range of control systems. To modify a control system and the rules that are to be used, all that is necessary is for an operator to key in a different set of instructions. There is no need to rewire. The result is a flexible, cost-effective system that can be used with control systems, which vary quite widely in their nature and complexity. PLCs are similar to computers, but whereas computers are optimized for calculation and display tasks, PLCs are optimized for control tasks and the industrial environment. Thus PLCs:

- Are rugged and designed to withstand vibrations, temperature, humidity, and noise.
- Have interfacing for inputs and outputs already inside the controller.

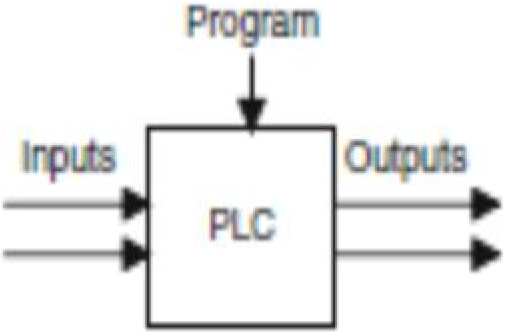


Figure (3.3) a Programmable Logic Controller

- Are easily programmed and have an easily understood programming language that is primarily concerned with logic and switching operations .The first PLC was developed in 1969. PLCs are now widely used and extend from small, self-contained units for use with perhaps 20 digital inputs/outputs to modular systems that can be used for large numbers of inputs/outputs, handle digital or analog inputs/outputs, And carry out proportional-integral-derivative control modes [3].

3.4.1Hardware

Typically a PLC system has the basic functional components of processor unit, memory, power supply unit, input/output interface section, communications interface, and the programming device,(Figure 3.4) shows the basic arrangement.

- The processor unit or central processing unit (CPU) is the unit containing the microprocessor. This unit interprets the input signals and carries out the control actions according to the program stored in its memory, communicating the decisions as action signals to the outputs.
- The power supply unit is needed to convert the mains AC voltage to the low DC voltage (5 V) necessary for the processor and the circuits in the input and output interface modules.
- The programming device is used to enter the required program into the memory of the processor. The program is developed in the device and then transferred to the memory unit of the PLC.
- The memory unit is where the program containing the control actions to be exercised by the microprocessor is stored and where the data is stored from the input for processing and for the output [3].

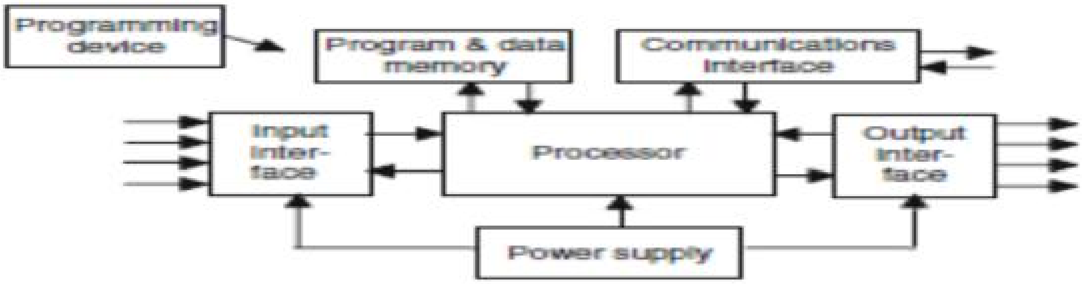


Figure (3.4) The PLC System

Figure (3.5) Signals: Discrete, Digital and Analog

- The input and output sections are where the processor receives information from external devices and communicates information to external devices. The inputs might thus be from switches, as illustrated in (Figure 3.1) with the automatic drill, or other sensors such as photoelectric cells, as in the counter mechanism in (Figure 3.1) temperature sensors, flow sensors, or the like. The outputs might be to motor starter coils, solenoid valves, or similar things. Input and output devices can be classified as giving signals that are discrete, digital or analog (Figure 3.5). Devices giving discrete or digital signals are ones where the signals are either off or on. Thus a switch is a device giving a discrete signal, either no voltage or a voltage. Digital devices can be considered essentially as discrete devices that give a sequence of on/off signals. Analog devices give signals of which the size is proportional to the size of the variable being monitored. For example, a temperature sensor may give a voltage proportional to the temperature.
- The communications interface is used to receive and transmit data on communication networks from or to other remote PLCs (Figure 3.6). It is concerned with such actions as device verification, data acquisition, synchronization between user applications, and connection management [3].

3.4.2Internal Architecture

(Figure 3.7) shows the basic internal architecture of a PLC. It consists of a central processing unit (CPU) containing the system microprocessor, memory, and input/output circuitry. The CPU controls and processes all the operations within the PLC. It is supplied with a clock.

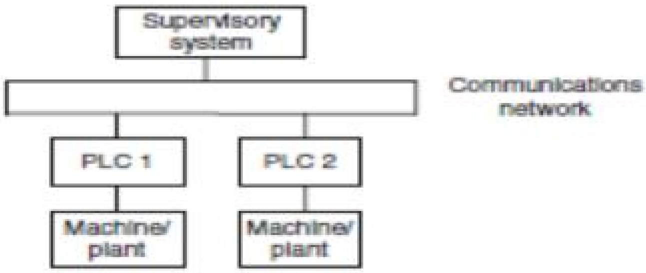


Figure (3.6) Basic Communication Model

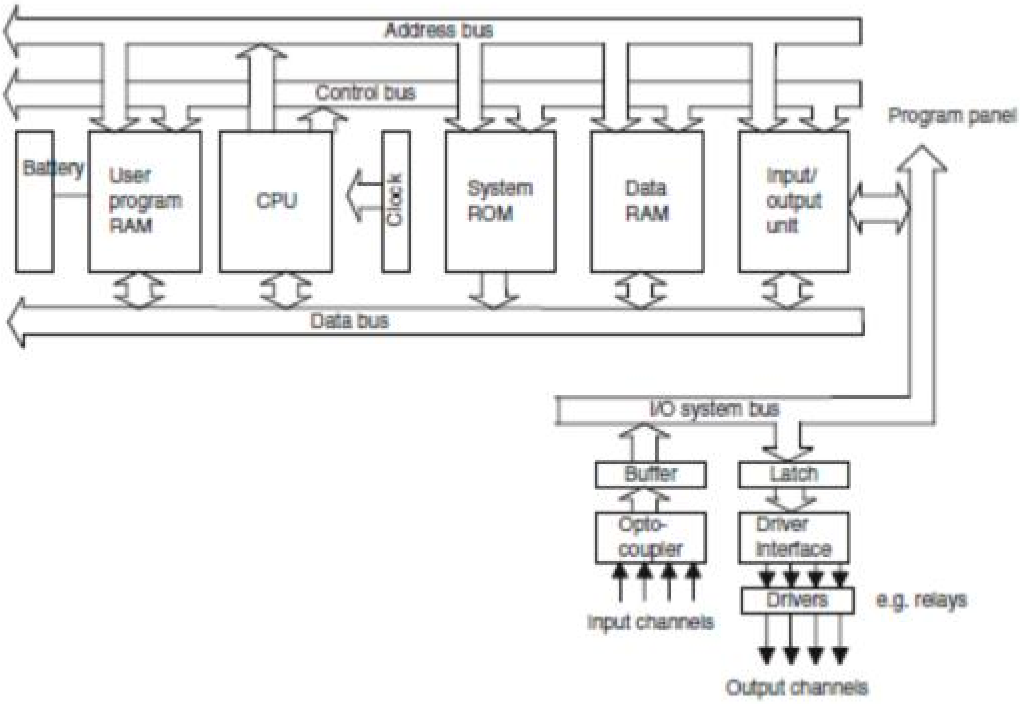


Figure (3.7) Architecture of PLC

That has a frequency of typically between 1 and 8 MHz This frequency determines the operating speed of the PLC and provides the timing and synchronization for all elements in the system. The information within the

PLC is carried by means of digital signals. The internal paths along which digital signals flow are called buses. In the physical sense, a bus is just a number of conductors along which electrical signals can flow. It might be tracks on a printed circuit board or wires in a ribbon cable. The CPU uses the data bus for sending data between the constituent elements, the address bus to send the addresses of locations for accessing stored data, and the control bus for signals relating to internal control actions. The system bus is used for communications between the input/output ports and the input/output unit [3].

3.4.3 The CPU

The internal structure of the CPU depends on the microprocessor concerned. In general, CPUs have the following:

- An arithmetic and logic unit (ALU) that is responsible for data manipulation and carrying out arithmetic operations of addition and subtraction and logic operations of AND, OR, NOT, and EXCLUSIVE-OR .

. • Memory, termed registers, located within the microprocessor and used to store information involved in program execution.

- A control unit that is used to control the timing of operations [3].

3.4.4The Buses

The buses are the paths used for communication within the PLC. The information is transmitted in binary form, that is, as a group of bits, with a bit being a binary digit of 1 or 0, indicating on/off states. The term word is used for the group of bits constituting some information. Thus an 8-bit word might be the binary number 00100110. Each of the bits is communicated simultaneously along its own parallel wire. The system has four buses:

- The data bus carries the data used in the processing done by the CPU. A microprocessor termed as being 8-bit has an internal data bus that can handle 8-bit numbers. It can thus perform operations between 8-bit numbers and deliver results as 8-bit values.
- The address bus is used to carry the addresses of memory locations. So that each word can be located in memory, every memory location is given a

unique address. Just like houses in a town are each given a distinct address so that they can be located, so each word location is given an address so that data stored at a particular location can be accessed by the CPU, either to read data located there or put, that is, write, data there. It is the address bus that carries the information indicating which address is to be accessed. If the address bus consists of eight lines, the number of 8-bit words, and hence number of distinct addresses, is 28 ¼ 256. With 16 address lines, 65,536 addresses are possible.

- The control bus carries the signals used by the CPU for control, such as to inform memory devices whether they are to receive data from an input or output data and to carry timing signals used to synchronize actions.
- The system bus is used for communications between the input/output ports and the input/ output unit [3].

3.4.5 Memory

To operate the PLC system there is a need for it to access the data to be processed and instructions, that is, the program, which informs it how the data is to be processed. Both are stored in the PLC memory for access during processing. There are several memory elements in a PLC system:

- System read-only-memory (ROM) gives permanent storage for the operating system and fixed data used by the CPU.
- Random-access memory (RAM) is used for the user's program.
- Random-access memory (RAM) is used for data. This is where information is stored on the status of input and output devices and the values of timers and counters and other internal devices. The data RAM is sometimes referred to as a data table or register table. Part of this memory, that is, a block of addresses, will be set aside for input and output addresses and the states of those inputs and outputs. Part will be set aside for preset data and part for storing counter values, timer values, and the like.
- Possibly, as a bolt-on extra module, erasable and programmable read-only-memory (EPROM) is used to store programs permanently. The programs and

data in RAM can be changed by the user. All PLCs will have some amount of RAM to store programs that have been developed by the user and program data. However, to prevent the loss of programs when the power supply is switched off, a battery is used in the PLC to maintain the RAM contents for a period of time. After a program has been developed in RAM it may be loaded into an EPROM memory chip, often a bolt-on module to the PLC, and so made permanent. In addition, there are temporary buffer stores for the input/output channels. The storage capacity of a memory unit is determined by the number of binary words that it can store. Thus, if a memory size is 256 words, it can store 256 _ 8 ¼ 2048 bits if 8-bit words are used and 256 _ 16 ¼ 4096 bits if 16-bit words are used. Memory sizes are often specified in terms of the number of storage locations available, with 1K representing the number 210, that is, 1024. Manufacturers supply memory chips with the storage locations grouped in groups of 1, 4, and 8 bits. A 4K _ 1 memory has 4 _ 1 _ 1024 bit locations. A 4K _ 8 memory has 4 _ 8 _ 1024 bit locations. The term byte is used for a word of length 8 bits. Thus the 4K _ 8 memory can store 4096 bytes. With a 16-bit address bus we can have 216 different addresses, and so, with 8-bit words stored at each address, we can have 216 _ 8 storage locations and so use a memory of size 216 _ 8/210 ¼ 64K _ 8, which might be in the form of four 16K _ 8-bit memory chips [3].

3.4.6 Input / Output Unit

The input/output unit provides the interface between the system and the outside world, allowing for connections to be made through input/output channels to input devices such as sensors and output devices such as motors and solenoids. It is also through the input/output unit that programs are entered from a program panel. Every input/output point has a unique address that can be used by the CPU. It is like a row of houses along a road; number 10 might be the “house” used for an input from a particular sensor, whereas number 45 might be the “house” used for the output to a particular motor. The input/output channels provide isolation and signal conditioning functions so that sensors and actuators can often be directly connected to them without the need for other circuitry.

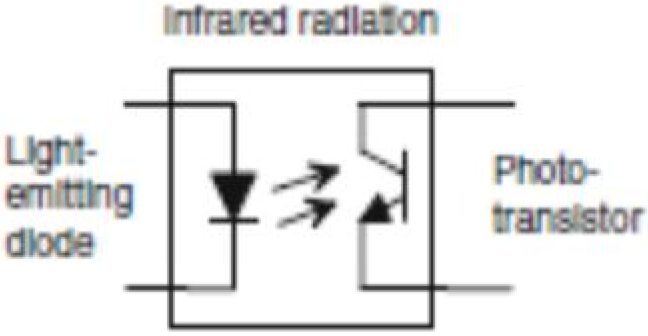


Figure (3.8) An Opt Isolator

Electrical isolation from the external world is usually by means of opt isolators (the term opt coupler is also often used). (Figure 3.8) shows the principle of an opt isolator. When a digital pulse passes through the light-emitting diode, a pulse of infrared radiation is produced. This pulse is detected by the phototransistor and gives rise to a voltage in that circuit. The gap between the light-emitting diode and the phototransistor gives electrical isolation, but the arrangement still allows for a digital pulse in one circuit to give rise to a digital pulse in another circuit. The digital signal that is generally compatible with the microprocessor in the PLC is 5 V DC. However, signal conditioning in the input channel, with isolation, enables a wide range of input signals to be supplied to it. A range of inputs might be available with a larger PLC, such as 5 V, 24 V, 110 V, and 240 V digital/discrete, that is, on/ off, signals (Figure 3.9). A small PLC is likely to have just one form of input, such as 24 V. The output from the input/output unit will be digital with a level of 5 V. However, after signal conditioning with relays, transistors, or triacs, the output from the output channel might be a 24 V, 100 mA switching signal; a DC voltage of 110 V, 1 A; or perhaps 240 V, 1 A AC or 240 V, 2 A AC, from a triac output channel (Figure 3.10). With a small PLC, all the outputs might be of one type, such as 240 V, 1 A AC. With modular PLCs, however, a range of outputs can be accommodated by selection of the modules to be used. Outputs are specified as being of relay type, transistor type, or triac type [3].

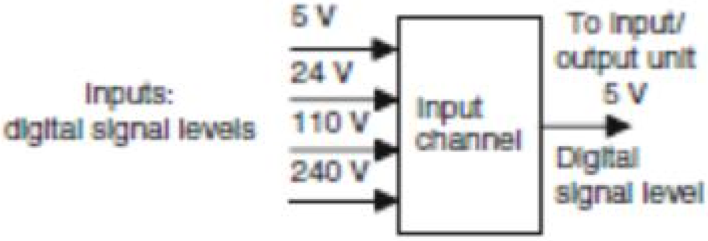


Figure (3.9) Input Levels

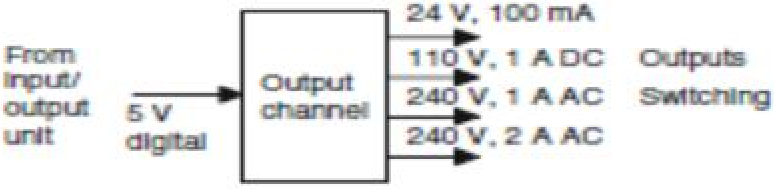


Figure (3.10) Output Levels

- With the relay type, the signal from the PLC output is used to operate a relay and is able to switch currents of the order of a few amperes in an external circuit. The relay not only allows small currents to switch much larger currents but also isolates the PLC from the external circuit. Relays are, however, relatively slow to operate. Relay outputs are suitable for AC and DC switching. They can withstand high surge currents and voltage transients.
- The transistor type of output uses a transistor to switch current through the external circuit. This gives a considerably faster switching action. It is, however, strictly for DC switching and is destroyed by over current and high reverse voltage. For protection, either a fuse or built-in electronic protection is used. Opt isolators are used to provide isolation.
- Triac outputs, with opt isolators for isolation; can be used to control external loads that are connected to the AC power supply. It is strictly for AC operation and is very easily destroyed by over current. Fuses are virtually always included to protect such outputs [3].

3.5 Sourcing and Sinking

The terms sourcing and sinking are used to describe the way in which DC devices are connected to a PLC. With sourcing, using the conventional current flow direction as from positive to negative, an input device receives current from the input module, that is, the input module is the source of the current (Figure 3.11). With sinking, using the conventional current flow direction, an input device supplies current to the input module, that is, the input module is the sink for the current (Figure 3.11). If the current flows from the output module to an output load, the output module is referred to as sourcing (Figure 3.12). If the current flows to the output module from an output load, the output module is referred to as sinking (Figure 3.12) [3].

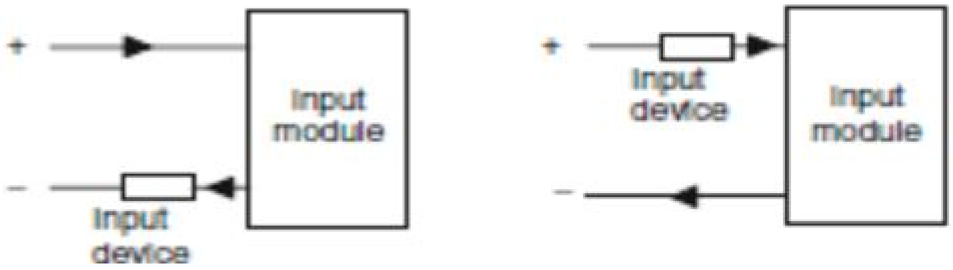


Figure (3.11) Input: Sourcing and Sinking

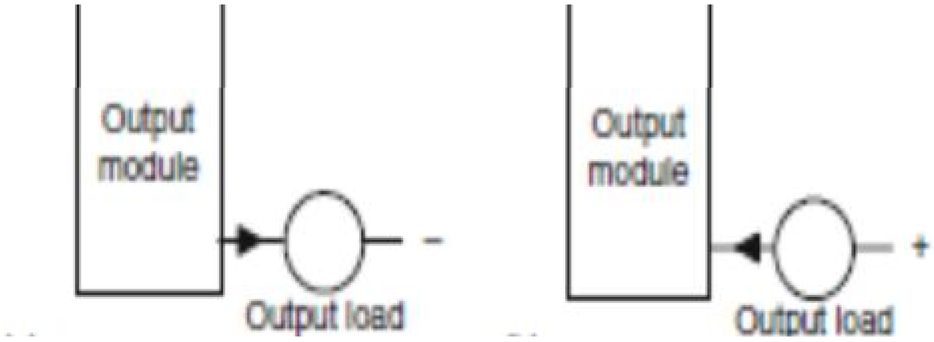


Figure (3.12) Output; Sourcing and Sinking

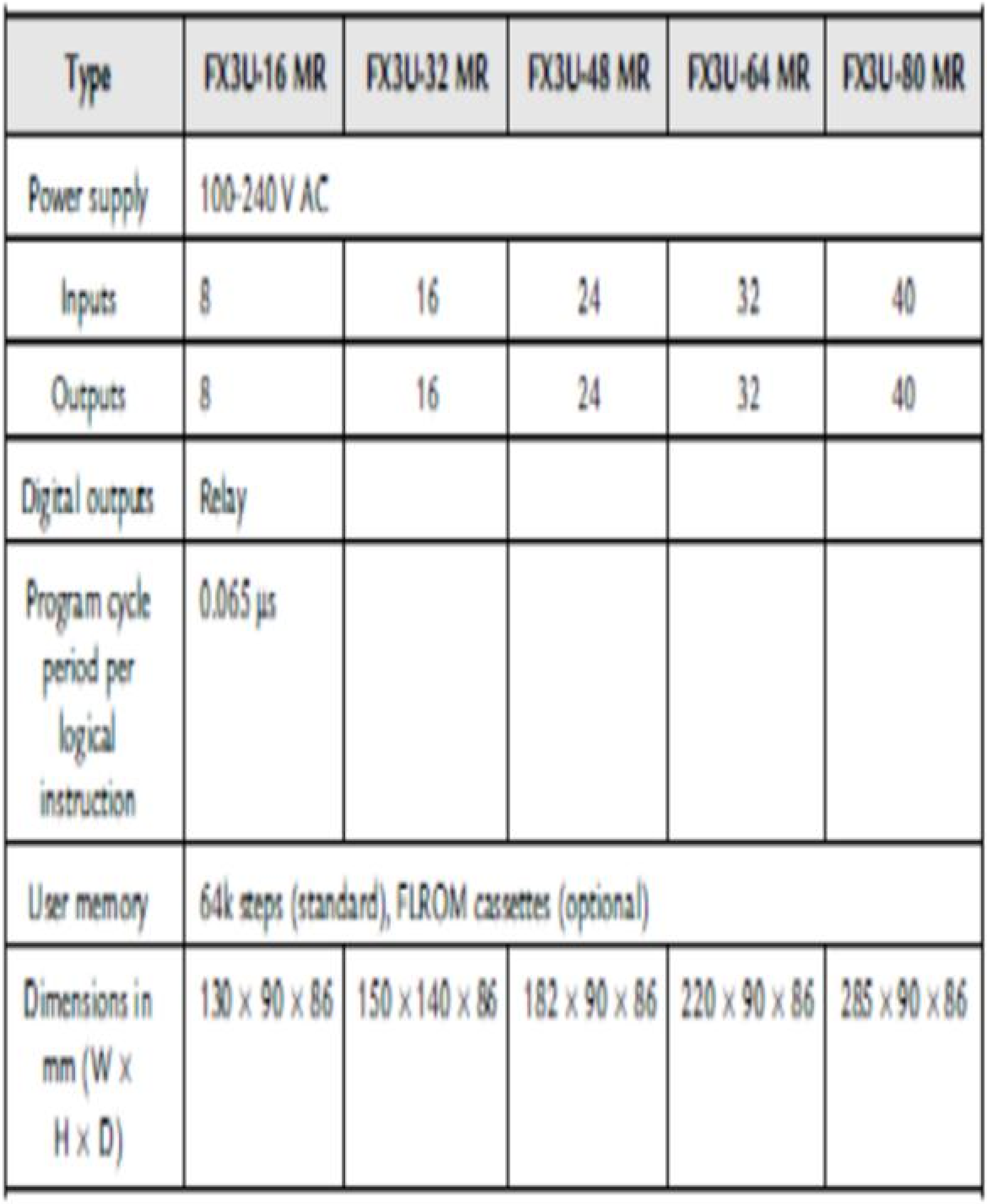
It is important know the type of input or output concerned so that it can be correctly connected to the PLC. Thus, sensors with sourcing outputs should be connected to sinking PLC inputs and sensors with sinking outputs should be connected to sourcing PLC inputs. The interface with the PLC will not function and damage may occur if this guideline is not followed [3].

3.6 PLC Systems

There are two common types of mechanical design for PLC systems—a single box and the modular/rack types. The single-box type (or, as it's sometimes called, a brick) is commonly used for small programmable controllers and is supplied as an integral compact package complete with power supply, processor, memory, and input/output units. Typically such a PLC might have 6, 8, 12, or 24 inputs and 4, 8, or 16 outputs and a memory that can store some 300 to 1000 instructions. (Figure 3.13) shows the Mitsubishi MELSEC FX3U compact (that is, brick) PLC (Table 3.1) gives details of models in that Mitsubishi range. Some brick systems have the capacity to be extended to cope with more inputs and outputs by linking input/output boxes to them. (Figure 3.14) shows such an arrangement with the OMRON CPM1A PLC. The base input/output brick, depending on the model concerned, has 10, 20, 30, or 40 inputs/outputs (I/O). The 10 I/O brick has 6 DC input points and 4 outputs, the 20 I/O brick has 12 DC input points and 8 outputs, the 30 I/O brick has 18 DC input points and 12 outputs, and the 40 I/O brick has 24 DC input points and 16 outputs. However, the 30 and 40 I/O models can be extended to a maximum of 100 inputs/outputs by linking expansion units to the original brick. For example, a 20 I/O expansion module might be added, it having 12 inputs and 8 outputs, the outputs being relays, sinking transistors, or sourcing transistors. Up to three expansion modules can be added. The outputs can be relay or transistor outputs [3].

Figure (3.13) Mitsubishi Compact PLC

Table (3.1) Mitsubishi Compact PLC



Type	FX3U-16 MR	FX3U-32 MR	FX3U-48 MR	FX3U-64 MR	FX3U-80 MR
Power supply	100-240 V AC				
Inputs	8	16	24	32	40
Outputs	8	16	24	32	40
Digital outputs	Relay				
Program cycle period per logical instruction	0.065 µs				
User memory	64k steps (standard), FLROM cassettes (optional)				
Dimensions in mm (W x H x D)	130 x 90 x 86	150 x 140 x 86	182 x 90 x 86	220 x 90 x 86	285 x 90 x 86

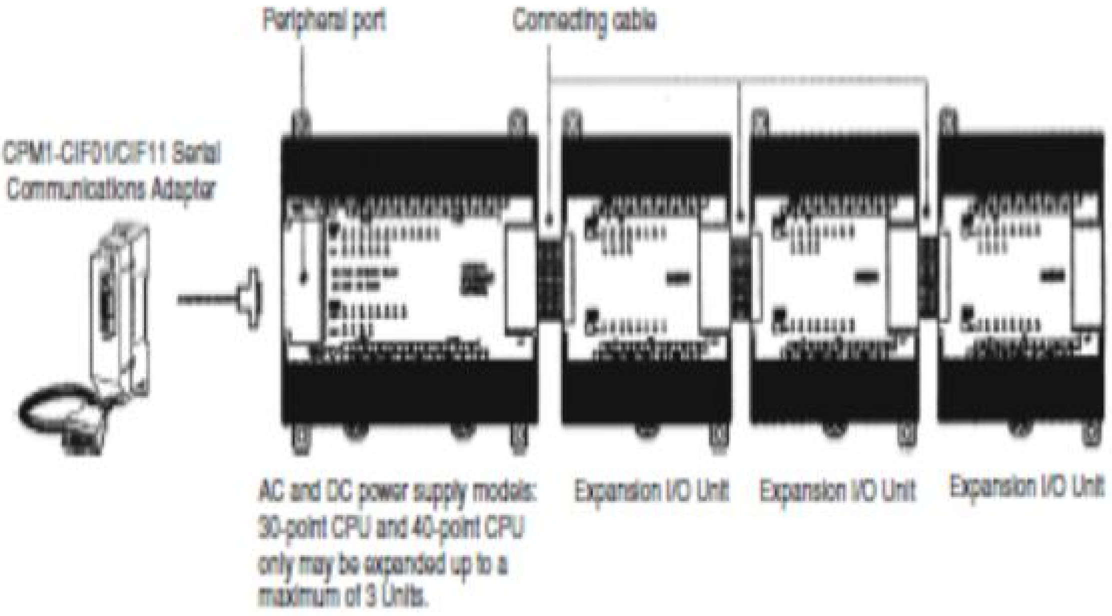


Figure (3.14) Basic Configuration of The OMRON CPM1 PLC

Systems with larger numbers of inputs and outputs are likely to be modular and designed to fit in racks. The modular type consists of separate modules for power supply, processor, and the like, which are often mounted on rails within a metal cabinet. The rack type can be used for all sizes of programmable controllers and has the various functional units packaged in individual modules that can be plugged into sockets in a base rack. The mix of modules required for a particular purpose is decided by the user and the appropriate ones then plugged into the rack. Thus it is comparatively easy to expand the number of I/O connections by simply adding more input/output modules or to expand the memory by adding more memory units. The power and data interfaces for modules in a rack are provided by copper conductors in the backplane of the rack. When modules are slid into a rack, they engage with connectors in the back plane [3].

An example of such a modular system is provided by the Allen-Bradley PLC-5 from Rockwell Automation (Figure 3.15). PLC-5 processors are available in a range of I/O capacity and memory size and can be configured for a variety of communication networks. They are single-slot modules that are placed in the leftmost slot of a 1771 I/O chassis. Some 1771 I/O chassis are built for back-panel mounting and some are built for rack mounting and are available in sizes of 4, 8, 12, or 16 I/O module slots. The 1771 I/O modules are available in densities of 8, 16, or 32 I/O per module. A PLC-5 processor can communicate with I/O across a Device Net or Universal Remote I/O link. A large selection of 1771 I/O modules, both digital and analog, are available for use in the local chassis, and an even larger selection is available for use at locations remote from the processor. Digital I/O modules have digital I/O circuits that interface to on/off sensors such as push-button and limit switches and on/off actuators such as motor starters, pilot lights, and an nunciators. Analog I/O modules perform the required A/D and D/A conversions using up to 16-bit resolution. Analog I/O can be user-configured for the desired fault response state in the event that I/O communication is disrupted. This feature provides a safe reaction/response in case of a fault, limits the extent of faults, and provides a predictable fault response. The 1771 I/O modules include optical coupling and filter circuitry for signal noise reduction. Digital I/O modules cover electrical ranges from 5 to 276 V AC or DC, and relay contact output modules are available for ranges from 0 to 276 V AC or 0 to 175 V DC. A range of analog signal levels can be accommodated, including standard analog inputs and outputs and direct thermocouple and RTD temperature inputs [3].

3.7 Programs

Programs for use with PLCs can be written in a number of formats. To make it easier for engineers with no great knowledge of programming to write programs for PLCs, ladder programming was developed. Most PLC manufacturers adopted this method of writing programs [3].

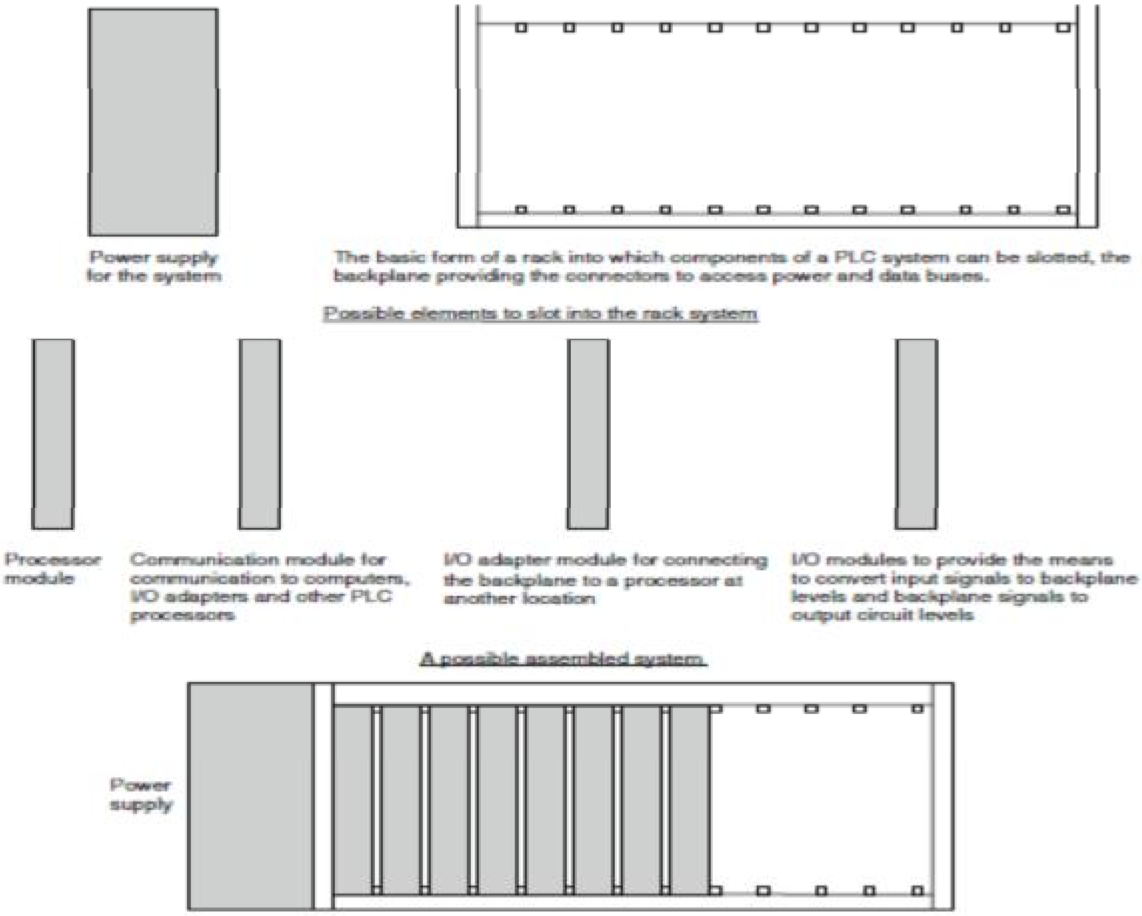


Figure (3.15) Allen Bradley PLC - 5

However, each tended to develop its own versions and so an international standard has been adopted for ladder programming and indeed all the methods used for programming PLCs. The standard, published in 1993, is International Electro technical Commission (IEC) 1131-3, sometimes referred to as IEC 61131-3 [3].

3.8 The IEC Standard

The full IEC 61131 standards covers the complete life cycle of PLCs:

Part 1: General definition of basic terminology and concepts.

Part 2: Electronic and mechanical equipment requirements and verification tests for PLCs and associated equipment.

Part 3: Programming languages. Five languages are defined: ladder diagram (LAD), sequential function charts (SFC), function block diagram (FBD), structured text (ST), and instruction list (IL).

Part 4: Guidance on selection, installation, and maintenance of PLCs.

Part 5: Software facilities needed for communication with other devices based on the Manufacturing Messaging Specification (MMS).

Part 6: Communications via field bus software facilities.

Part 7: Fuzzy control programming.

Part 8: Guidelines for the implementation of PLC programming languages [3].

3.9 Programming PLCs

A programming device can be a handheld device, a desktop console, or a computer. Only when the program has been designed on the programming device and is ready is it transferred to the memory unit of the PLC.

- A handheld programming device normally contains enough memory to allow the unit to retain programs while being carried from one place to another.
- Desktop consoles are likely to have a visual display unit with a full keyboard and screen display.
- Personal computers are widely configured as program development workstations. Some PLCs only require the computer to have appropriate software; others require special communication cards to interface with the PLC. A major advantage of using a computer is that the program can be stored on the hard disk or a CD and copies can be easily made. PLC manufacturers have programming software for their PLCs. For example, Mitsubishi has MELSOFT. The company’s GX Developer supports all MELSEC controllers, from the compact PLCs of the MELSEC FX series to the modular PLCs, including the MELSEC System Q, and uses a Windows-based environment. It supports the programming methods of IL, LD, and SFC languages. You can switch back and forth between IL and LD at will while you are working. You can program your own function blocks, and a wide range of utilities is available for configuring special function modules for the MELSEC System Q; there is no need to program special function modules, you just configure them. The package includes powerful editors and

diagnostics functions for configuring MELSEC networks and hardware, and extensive testing and monitoring functions to help get applications up and running quickly and efficiently. It offers offline Simulation for all PLC types and thus enables simulation of all devices and application responses for realistic testing. As another illustration, Siemens has SIMATIC STEP 7. This fully complies with the international standard IEC 61131-3 for PLC programming languages. With STEP 7, programmers can select from among various programming languages. Besides LAD and FBD, STEP 7 Basis also includes the IL programming language. Other additional options are available for IEC 61131-3 programming languages such as ST, called SIMATIC S7-SCL, or SFC, called SIMATIC S7-Graph, which provides an efficient way to describe sequential control systems graphically. Features of the whole engineering system include system diagnostic capabilities, process diagnostic tools, PLC simulation, remote maintenance, and plant documentation. S7-PLCSIM is an optional package for STEP 7 that allows simulation of a SIMATIC S7 control platform and testing of a user program on a PC, enabling testing and refining prior to physical hardware installation. By testing early in a project's development, overall project quality can be improved. Installation and commissioning can thus be quicker and less expensive because program faults can be detected and corrected early on during development. Likewise, Rockwell Automation manufactures RS Logix for the Allen-Bradley PLC-5 family of PLCs, OMRON has CX-One, and Telemechanique has ProWorx 32 for its Modicum range of PLCs [3].

Chapter Four

The Hardware

4.1 Introduction

An experimental setup will be built , in this setup will be connective to a smoke sensor circuit and heat sensor circuit , a programmable logic controller will be interface to the smoke and heat out puts respectively , a software will be developed to the control , the viewing of seen capture by each at time.

4.2 Design of The Model

Devices of firefighting alarm control system, Devices description as follow:

1. input devices
   - Heat sensor with switching relay.
   - Smoke sensor with switching relay.
2. Programmable logic controller
   - With+ or- 24 V DC power supply and digital input /output channels (work as digital controller).
   - Its type is combined, Mitsubishi program, digital controller.
   - Program type is ladder diagram.
3. Output devices
   - Heat alarm light indicator (lamp, + or – 24 V).
   - Heat alarm sound indicator (Buzzer, + or – 24 V).
   - Smoke alarm light indicator (Lamp, + or- 24 V).
   - Smoke alarm sound indicator (Buzzer, + or- 24 V).

4.3 Heat Detection System

4.3.1 Content

- Heat detector circuit.
- Heat sensor operation and signal flow description.

Note:

CA 3130 comparator working (comparison method) it has work condition as follow:

- If V in > V ref, CA 3130 output = 5 V DC.
- If V in < = V ref, CA 3130 output = 0 V DC.

Table (4.1) heat detector components functions and operation sequence

Electronic Component	Function
Heat combined probe sensor.	Senses the heat and translate it to electrical signal as small value of volt proportional to the heat sensed, considered as V in to comparator.
Circuit power supply.	It deliver supply volt of 5 V to heat sensor, CA 3130 and consider as illumination voltage of work (biasing voltage).
The resistors R1 and R2.	Biasing resistors for CA 3130 comparator work as (voltage divider) with R pot.
Potentiometer (R pot)/ variable resistor.	To control sensing degree of CA 3130 as reference voltage (V ref) At certain value as (sensing degree).
CA 3130 integrated circuit 8 pin.	To compare input voltage (V in) From sense element (probe) with voltage / sensing degree (V ref) then output voltage of 0/5 V to BC -548 transistor amplifier to increase current to 150 mA

	and deliver it to relay 1coil and derive relay 1.
BC – 548 (silicon transistor amplifier).	NPN silicon general purpose transistor as switch and current amplifier to derive relay 1 as relay deriver also amplifier current which comes from CA 3130 to value of 150 mA which goes to relay 1 coil to switch ON or OFF .
Relay 1. Coil = 5V. Switching = (24 V – 28 V).	Makes switching ON / OFF for contact has value of 24 V – 28 V to make ON/OFF signal as heat input signal to the PLC (to interface analog signal and convert it ON /OFF signal).

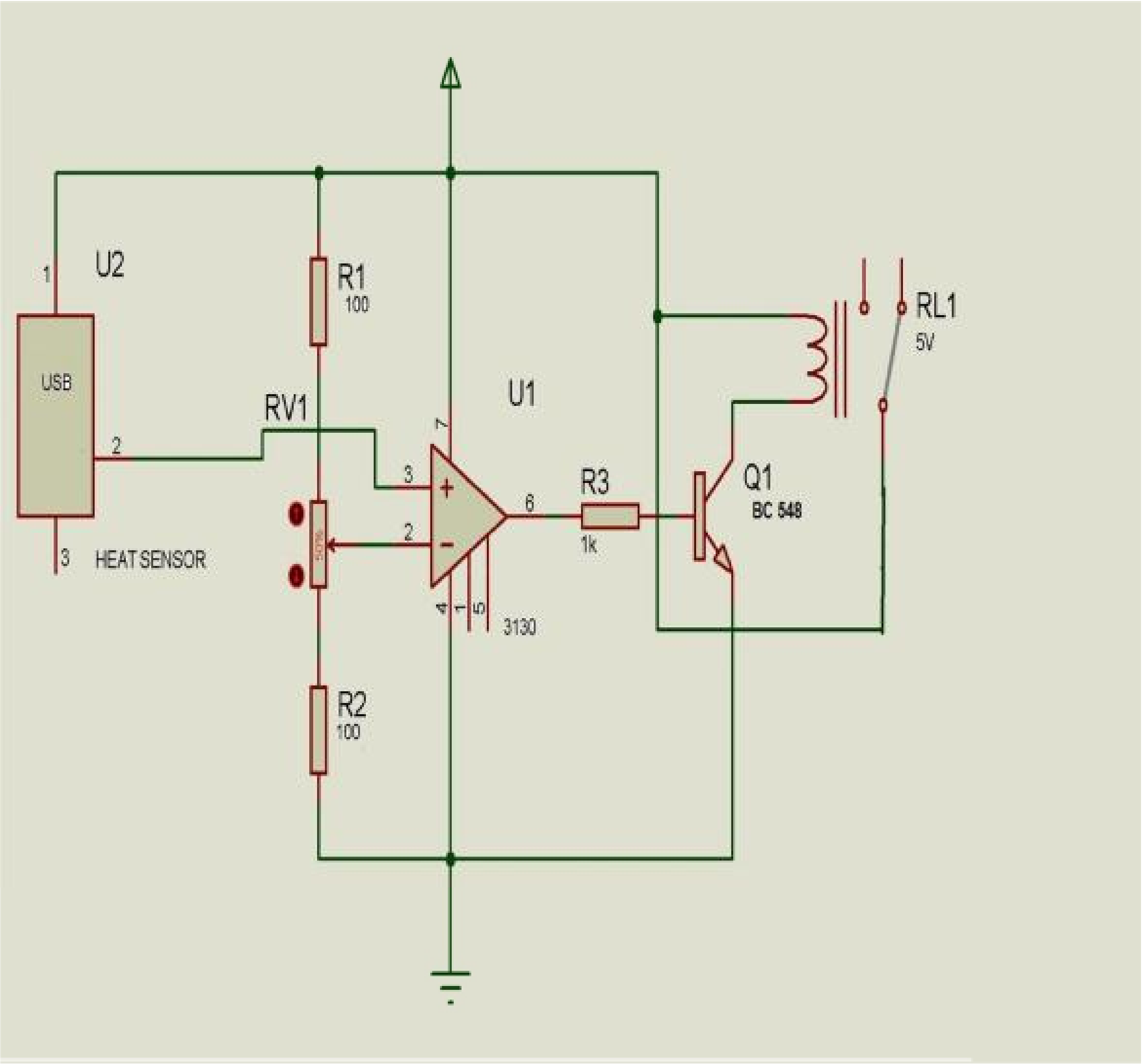


Figure (4.1) Heat Detector Circuit

4.3.2 Heat Detector Operation Steps and Signal Flow

Heat power supply of 5 V applied to the circuit to work and the potentiometer (R pot) is set to v ref as reference voltage of comparator CA 3130 to control sensing degree for heat when heat of fire reach sensor the sensor probe unit convert it to small electrical signal as volt which consider as (I/P)voltage of comparator CA 3130 through pin 3 (V in)(positive terminal of CA 3130) then compared with reference voltage (V ref) the comparison result goes to CA3130 O/P signal as analog signal of (0/5 V DC)with applied to BC -548 (relay driver)which work as current amplifier /relay driver to amplify current to 150 ma then apply it to relay 1 coil in order to switch it's contact (24V-28V) ON/OFF as ON /OFF signal to PLC through digital channel X_0 as heat input.

4.4 Smoke Detection System

4.4.1 Contents

- Smoke detector circuit.
- Smoke sensor operation and signal flow description.

Note:

CA 3130 comparator working (comparison method) it has condition of work as follow:

- If V in > V ref, CA 3130 output =5 V DC.
- If V in = V ref, CA 3130 output = 0V DC.
- If V in < V ref, CA 3130 output = 0V DC.

Therefore CA 3130 output = 0/5 V DC.

Table (4.2) Smoke Detector Components and Functions and Operation Sequence

Electronic Component	Function
Smoke combined probe sensing.	Sense the smoke and translate it to electrical signal as small value of volt which proportional to the smoke sensed, considered as V in to comparators.
The power supply of circuit.	It delivers supply volt of 5V to gas sensor, CA 3130 and ULN 2003 as illuminated voltage to work (biasing voltage).
The resistance R1, R2.	Biasing resistance for CA3130 as reference voltage (V ref) at certain value as sensing degree.
Potentiometer (R pot) (variable resistance).	It is variable resistance to control degree of sensing of CA3130 as

	reference voltage (V ref) at certain value as sensing degree.
CA 3130 integrated circuit 8 pins.	As comparator to compare input voltage from sense element (V in) with reference voltage / sensing degree (V ref) and out voltage of 0/5 V to ULN 2003 for amplify its current and drive relay 2.
ULN 2003 integrated circuit.	Current amplifier / high current drive as relay driver (it amplify its input current and send it to relay coil to generate magnetic field to switching ON/OFF.
Relay 2. Coil = 5V. Switching = (24-28)V.	Make switching ON/OFF for contact has value of (24 – 28) V to make ON/OFF signal as smoke input signal to the PLC (to interface analog signal / convert it to ON/ OFF signal.

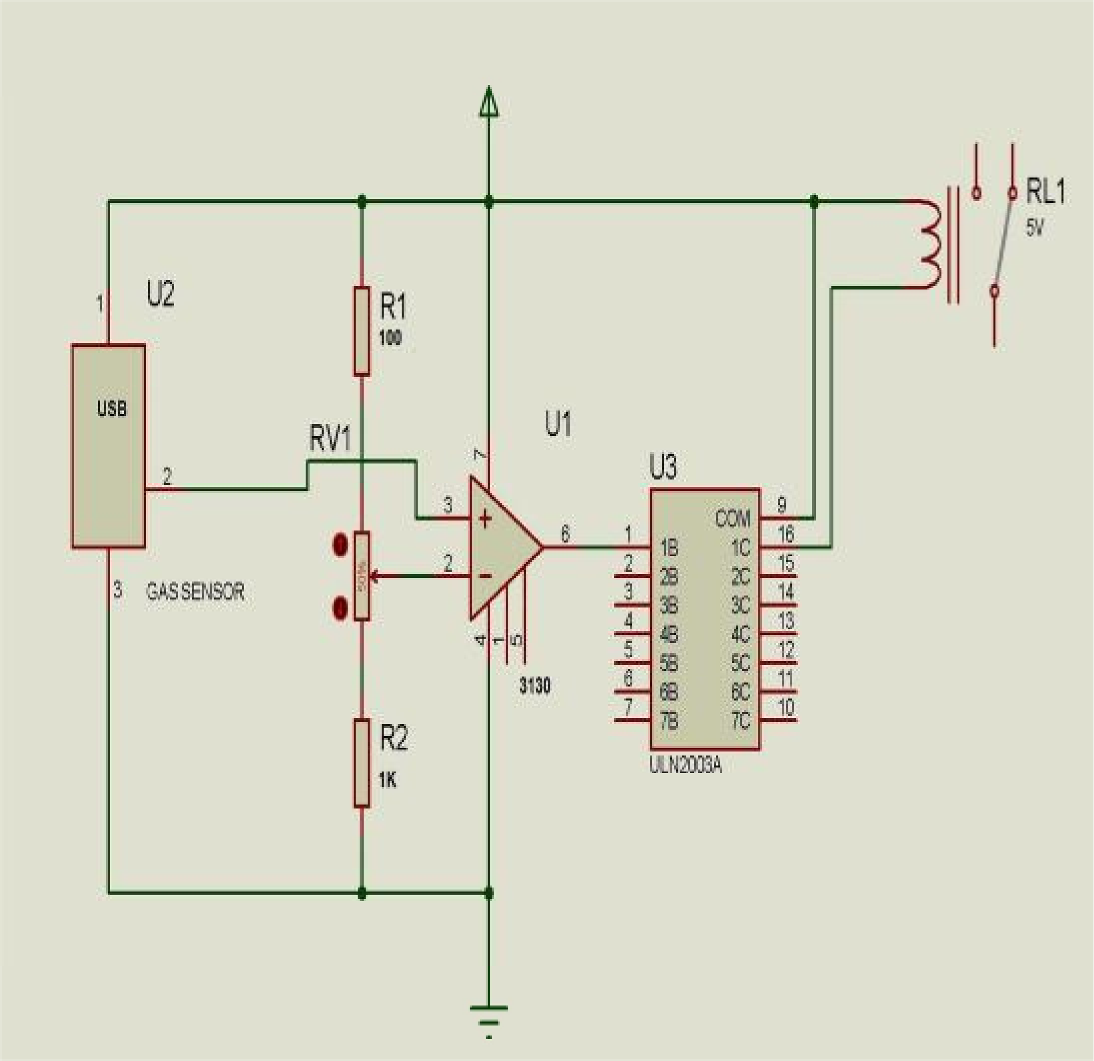


Figure (4.2) Smoke Detector Circuit

4.4.2 Smoke Detector Operation Steps and Signal Flow

The power supply of 5 V applied to the circuit through USB for biasing components to work. The potentiometer (R pot) is set to (V ref) as reference

voltage of comparator CA 3130 to control sensing degree for smoke density , when smoke appear as fire component and become near sensor , it convert it to small electrical signal as volt which consider as I/P voltage of comparator (signal I/P of CA 3130) through pin 3 (non-inverting terminal) positive terminal ,then compared with reference voltage and the comparison result goes as CA3130 O/P signal as analog signal of (0/5 V) which applied to relay driver ULN 2003 which work as current amplifier to 150 m A then applied to the coil of relay 2 as electrical value (5 V, 150 m

A), exist the coil in order to switch relay contact of (24 - 28)V ON /OFF as ON/OFF signal to PLC through digital channel X_1 as smoke input.

4.5 Component of The Circuit

4.5.1 CA 3130 Comparator

- Using as high-input-independence comparators.
- DC supply voltage (between V + and V - terminals) 16V.
- Differential input voltage 8V.
- DC input voltage V+ (+8V) to V- (0.5V).
- Input terminal current 1mA.

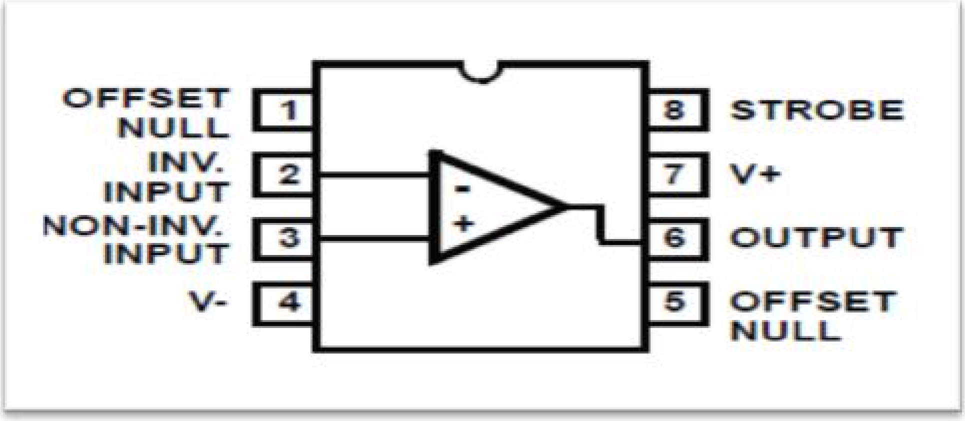


Figure (4.3) CA 3130 Comparator Configuration of Pins

4.5.1.1 Electrical Specifications

- Common mode input voltage range (- 0.5 to + 12) V.

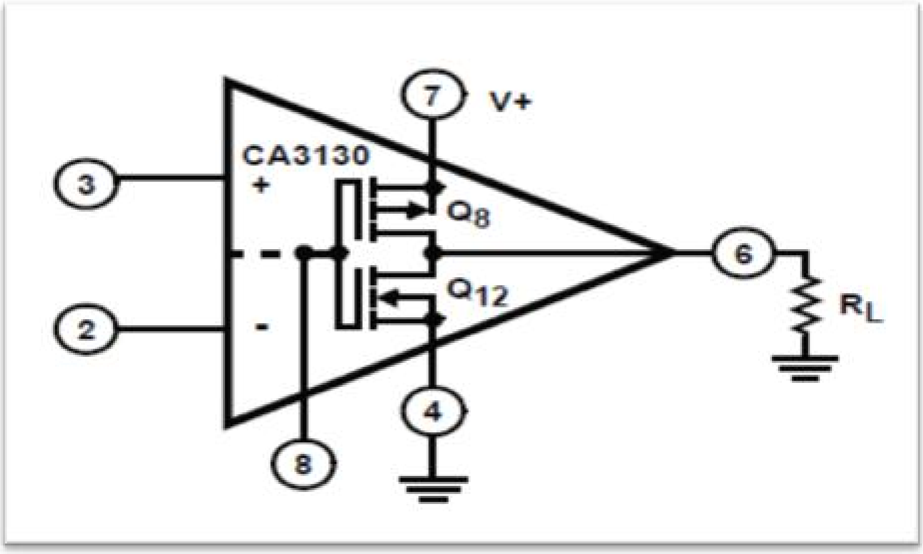


Figure (4.4) Internal Constructions

4.5.2 BC -548 (NPN Silicon General Purposes Amplification Transistors)

- Using as current amplifier and relay driver, Current gain 300/150 m A.

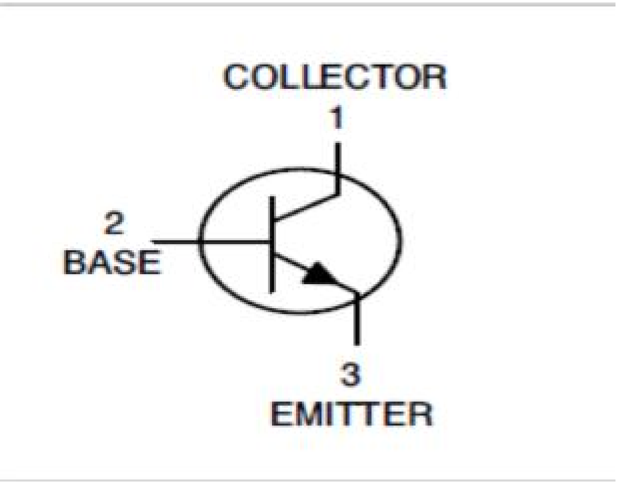


Figure (4. 5) BC-548 Transistor Configuration

4.5.3 ULN 2003 (5V TTL, CMOS)

- Use current.
- High current Darlington driver as relay driver.

4.5.3.1 Description

The ULN3003 integrated circuit is high voltage high current Darlington arrays containing 7 open collectors with common emitters each channel rated at 500mA and connect with stand peak current of 600mA Suppression diodes are included for inductive load driving and the inputs are pinned opposite the outputs to simplify board layout.

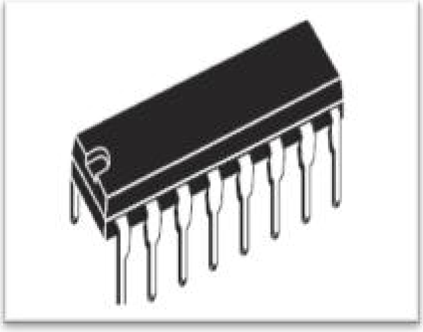


Figure (4.6) ULN 2003

4.5.4 Board Panel

The bread board is ideally for basic design and experiment of analog or digital circuit it can offer end users to perform circuit development in interface or communication field with special universal connector or basic plate.

4.5.5 Lamp

It uses to indicate that there is a heat or smoke in the interrogation zone.

4.5.6 Buzzer

It uses to indicate that there is heat or smoke in the interrogation zone and altering the surveillance system user.

4.5.7 Relay

Relay is an electrical switch that opens and close under the control of another electrical circuit in the original form the switch is operated by an electromagnetic to open or close one or many sets of contacts.

Figure (4.7) Relay

Because a relay is able to control an input circuit of higher power than the input circuit it can be consider to be in aboard sense a form of an electrical amplifier. The current flowing through the coil of the relay create a magnetic field which attracts a level and changes the switch contacts.

4.6 System PLC Ladder Program

The system program generated from method principle and flow chart to design automatic system by using Mitsubishi program and combined digital PLC as controller.

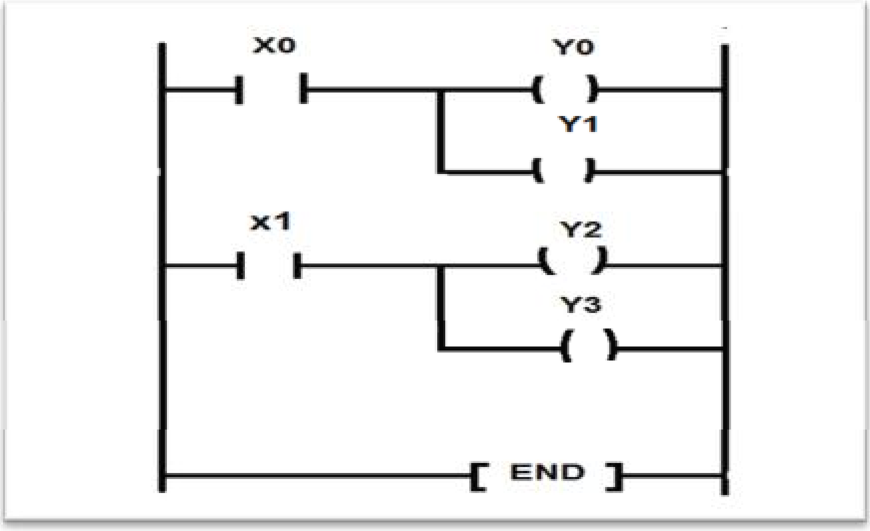


Figure (4.8) Ladder Program

4.7 Flow Chart

The project system designed according to flow chart as follow:

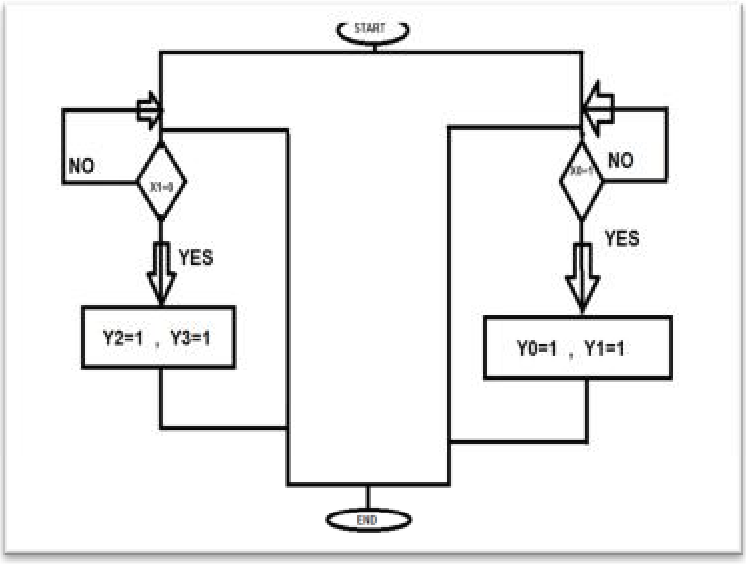


Figure (4.9) System Program Flow Chart

4.8 Calculation

The total respond time for the block diagram of hardware design of the fire detection system illustrated in figure (4.10) is the sum of the times which passing from the sensors (heat and smoke) to the ICs then to PLC then to lamp and buzzer which represented the hardware.

4.8.1 Heat Detector

The total respond time for heat circuit = (T1h+T2h+T3h+T4h+T5h).

Where:

T1h = CA 3130 settling time (1.2µs).

T2h = ULN 2003 turn-on delay time (1µs).

T3h = switching relay time (10ms).

T4h = PLC processing time (CPU) time (0.001ms).

T5h = time as margin (1µs).

4.8.2 Smoke Detector

The total respond time for smoke circuit = (T1s +T2s +T3s +T4s +T5s).

Where:

T1s =CA 3130 settling time (1.2µs).

T2s = BC-548 turn-on delay time (1µs).

T3s = switching relay time (10ms).

T4s = PLC processing time (CPU) time (0.001ms).

T5s = time as margin (1µs).

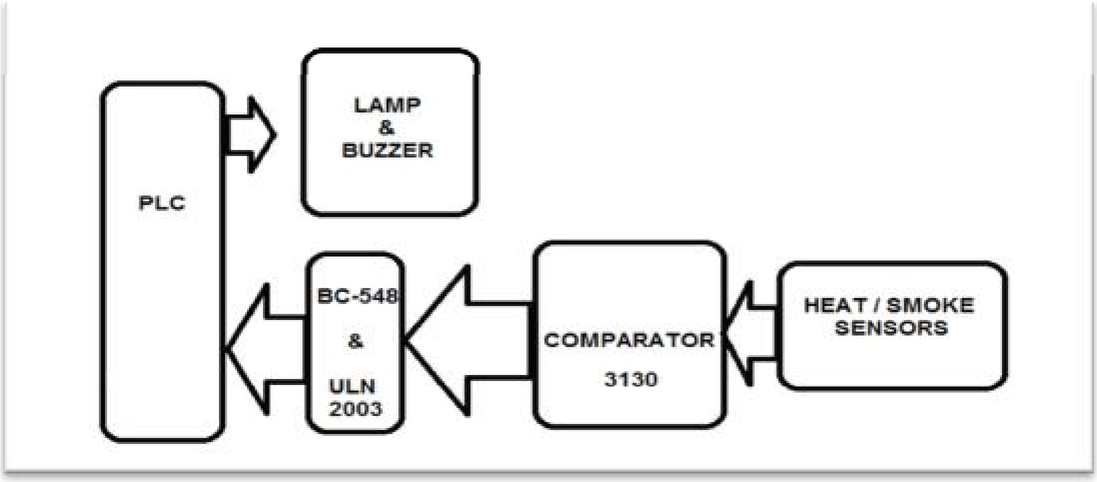


Figure (4.10) The Block Diagram of Calculation Circuit

4.9 Result

when power supply to all system unit as mention the sensing degree of heat and smoke sensors set to desired degree V ref and when heat occur as a result of fire or expected ,the heat sensor probe detect the heat , convert it internally to small electrical signal applied as Vin of comparator CA3130 at positive terminal (pin 3) the comparator CA3130 compare Vin at pin 3 with reference voltage V ref (pin 2) the comparison result is O/P of CA3130 (pin 6) consider as analog signal with value 5 V (according to comparator operation condition). The analog signal (5 V) applied to BC - 548 through resistance / biasing resistance the transistor BC -548 work as current amplifier / relay driver it receive CA3130 0/P signal (analog signal) 5V amplifier it is current to value of 150 mA then pass it to relay 1 coil through collector to switch on the current amplified 150 mA exist relay coil and generate magnetic field. the magnetic field switch relay contact (24 – 28) V close through X_0 which consider as ON signal (X_0 =1(internally) / logic 1 the switching result it is no signal applied to PLC through digital channel X_0 as heat input (X_0) input. PLC ladder diagram scan X_0 input the find it (Logic1) make the internal relay Y_0 and Y_1 at (logic 1) then turn on heat's lamps and buzzer. (Heat lamp generates light as heat light alarm and heat buzzer generates sound as heat sound alarm).

When there is no heat sequence as follow:

There is no detect therefore there is no convert signal (V in) from sensor probe unit and the O/P of CA3130 comparator is 0 V (analog signal = 0V) no current O/P from BC -548 amplifier to relay 1 coil therefore X_o = logic (0) scanned by ladder program inside PLC to internal relay Y_o, Y_1 logic (0) so heat lamp and buzzer are off.

As previous when the smoke probe detect the smoke convert it internally to smoke electrical signal applied as V in of comparator CA3130 at positive terminal (pin 3) it compare it with reference voltage (V ref) at pin 2 the comparison result is O/P of CA3130 (pin 6) consider as analog signal with value of 0 V (according to comparator operation condition) the analog signal (0V) applied to the integrated circuit ULN 2003 through (UNL 2003) PIN 1 as ULN 2003 input. ULN 2003 work as current amplifier / relay driver it receives CA3130 O/P signal (5V), amplifier it is current to value of 150 mA the pass it through (ULN 2003,PIN16) to relay 2 coil to switch on the current amplifier (150 ma) exist relay coil and generate magnetic field the magnetic field switch relay contact (24 V – 28 V)close which consider as on signal through X_1 (X_0 =1 /logic 1)the switching result is on applied to the PLC through digital channel X_1 as smoke input(X_1 input) PLC ladder program scan X_1 input when found (logic1) make the internal relay Y_2 and Y_3 at logic 1 (smoke lamp generate light as smoke light alarm , smoke buzzer generate sound as smoke sound alarm).

When there is no smoke sequence as follow:

There is no detection therefore there is no converter signal (V in) from sensor probe unit the O/P of CA 3130 comparator is 0 V (analog signal = 0V) no current O/P from ULN 2003 amplifier to relay 2 coil therefore X_1 = (logic 0) scanned by ladder program inside relays $Y_{2,}$ Y_3 is (logic 0) so smoke lamp and smoke buzzer is off.

4.10 Discussion

In a smoke circuit the sensor has high sensitivity to LPG gas, natural gas and town gas comparing to the smoke (smoke of cigarettes) and alcohol gas which has small sensitivity.

In the heat sensor it detect temperature in range of (30 – 200) C^0 the fire Detection system has delay time due to the transition of the electrical signal from sensors (heat and smoke) to the comparator and amplifier to the PLC and lastly to the devices.

4.11 Conclusion

I thanks god very much who guide me to do my best to complete this partial research I design a fire detection system that use two sensors (heat and smoke) sensors to send signal if there is heat or density of smoke in the interrogation zone to the PLC that will send a control orders to operate lamp and buzzer to indicate that there is a fire in specific area.

4.12 Recommendation

To improve the fire detection system I recommended to:

- Use sensors with high sensitivity so as to detect fires in short time and that let us out with light loses.
- Increase the number of sensors in specific area to cover wide area and make sure that the area is protected.
- Also attach camera to give absolute sure and give initial information about the fire.
- Connect it to personal computer to have a distance control.

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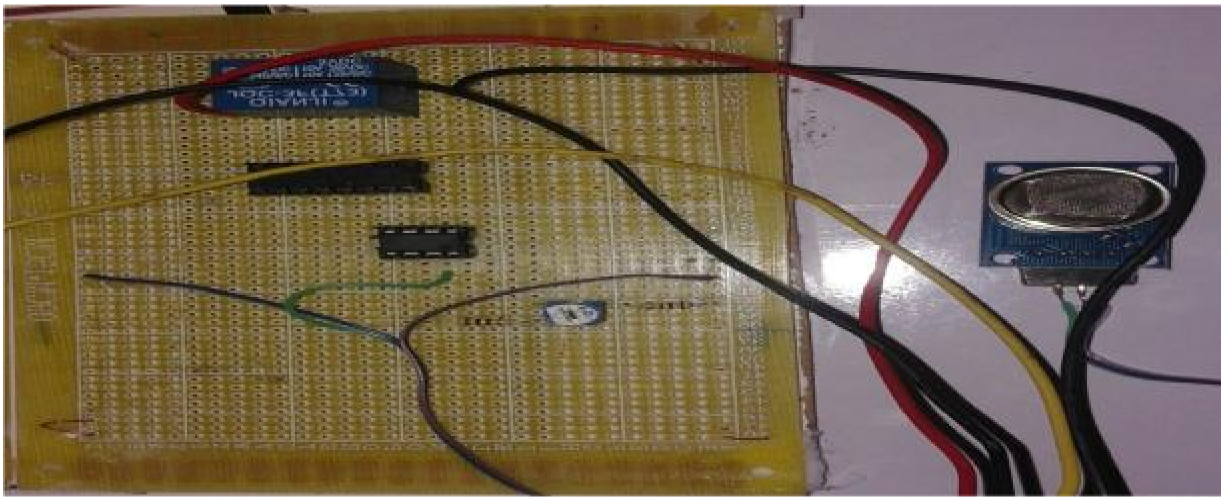
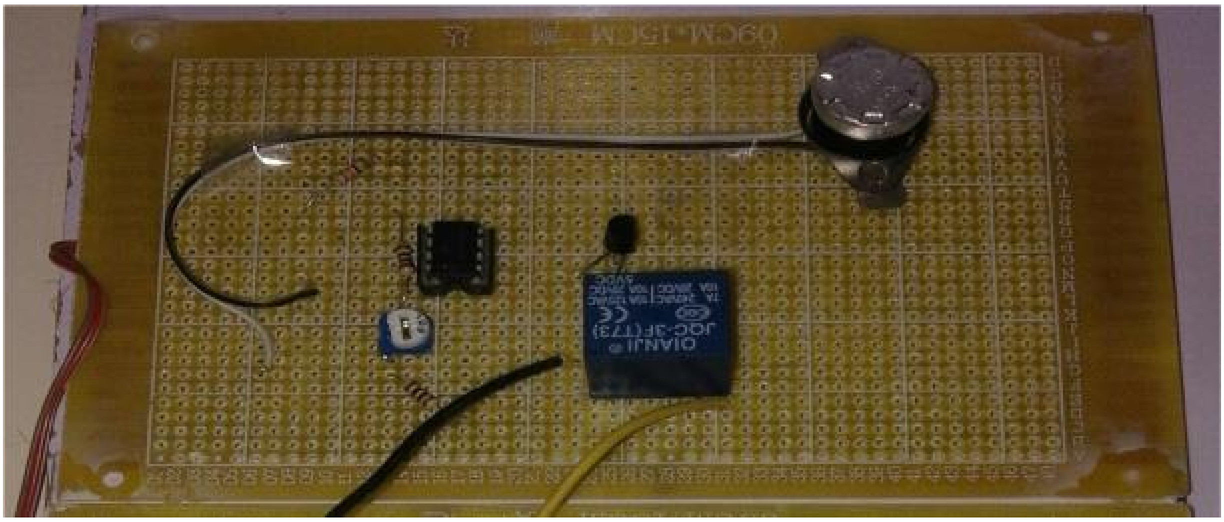
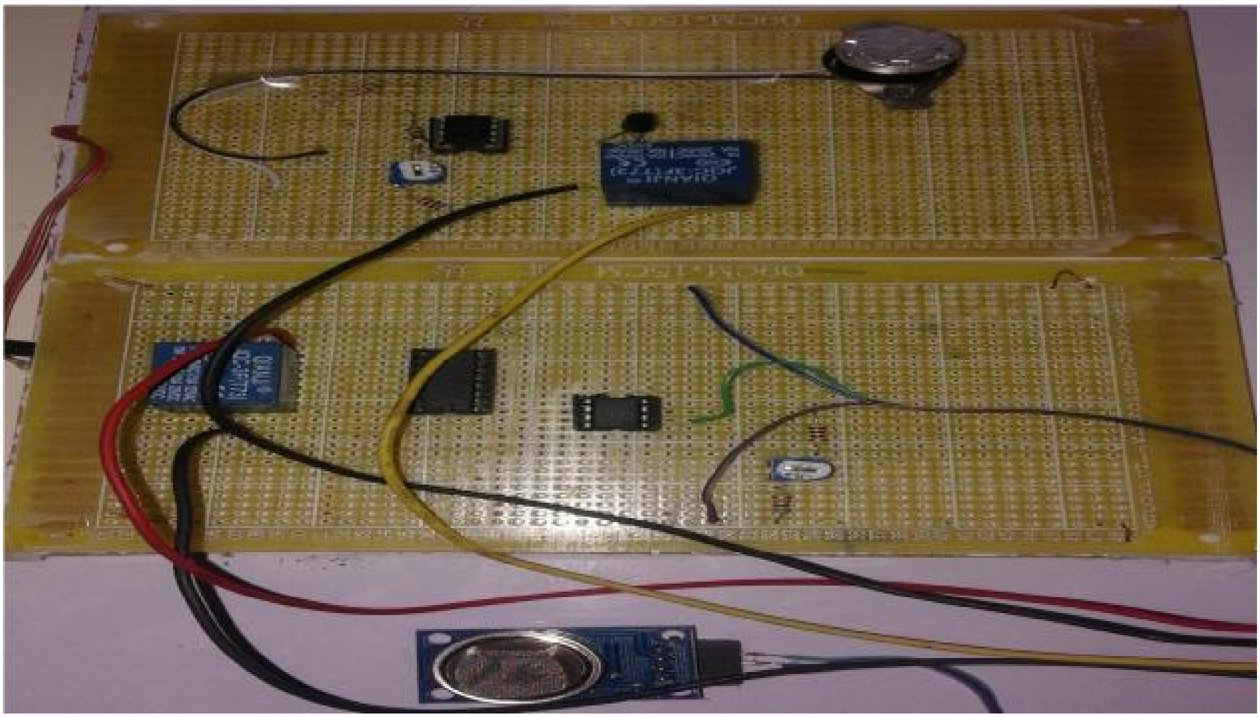
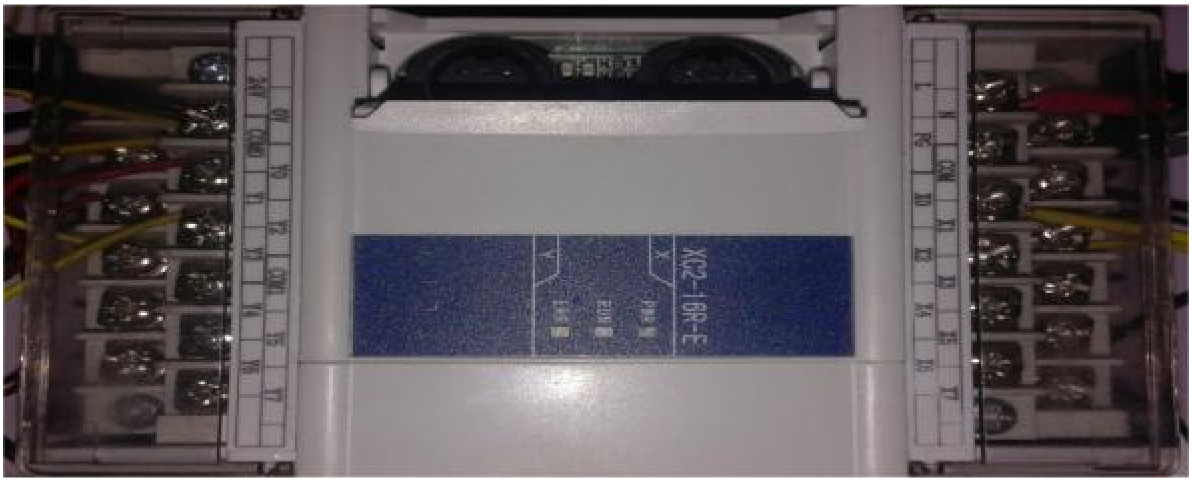
Appendix "A" (Smoke and heat detectors circuits)







Appendix "B"   (Smoke Sensor, Heat Sensor, Relay and The PLC)



Appendix "C"(CA 3130, BC-548, ULN2003 and Potentiometer)