



Low-Cost Fire Safety System Design for Low-cost Houses in India

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Abstract—The majority of lower-income family houses in India measure around 400 square feet. This paper proposes a low-cost fire safety design for small houses measuring around 300-400 square feet in area. On an average around 10,000 fire accidents are reported in India annually and many more do not get reported. Thousands of people succumb to fire accidents every year. The usage of non-standard electric equipment and wiring is leading to many fire accidents apart from the kitchen and open fire-related accidents. With just 3000 fire stations across the country and slow response time, it is grossly inadequate to cover the entire population with public fire services. Building codes and fire safety norms are followed by very few high-rise buildings. Low-cost housing schemes seldom implement safety features. Design in this paper is based on components and equipment built as per Indian Standards Institution specifications. Low-cost and reliable fire sensors and warning systems are proposed along with fire safety and firefighting equipment. Prototypes of fire alarms are built with readily available components and results are reported. Detailed design instructions are provided so that local building contractors can procure, build and install low-cost fire alarm systems. The system design proposed in this paper can easily be implemented and it is a low-cost high-impact safety feature that can save lives and stop economic loss to lower-income families.

Keywords—Fire Safety, Low-income households, Low-cost housing, Low-cost fire alarms, Fire safety design.

1.0 Introduction

Between 2016-2020 on average 35 people died every day in India due to fire-related incidents (Business Standard 2022).

High-rise buildings in urban areas are under the constant gaze of civic authorities to follow the building code and fire safety norms. However, the majority of Indians live in small independent houses on the ground floor or a couple of floors above the ground level. These houses measure around 300-400 square feet accommodating around five occupants (Kumar, n.d.).

Small houses are usually built by local masons with raw materials available locally. Designs are traditional and do not incorporate any fire safety features. Due to lax supervision and intervention, these dwellings get occupied and people start living without any formal occupancy certificate or clearance from civic authorities. Poor electrical wiring and usage of non-standard electric gadgets are making these houses vulnerable to fire accidents. The advent of electric vehicles and charging them inside the house is causing many fire accidents apart from the traditional kitchen and open flame fires (The Times of India 2022).

India has just 3,000 fire stations grossly inadequate to protect a large and densely populated country. In urban and semi-urban locations traffic moves at a snail's pace. All these factors lead to a very late response from fire stations (The Indian Express 2016) (Onmanorama News 2022). Non-life insurance penetration that includes fire insurance as a percentage of GDP is less than 1%. Fire accidents lead to great financial loss to households which are not insured (IBEF, n.d.).

This is really a burning problem! It is important for designers to come up with cost-effective solutions suitable for low-cost houses not only to save lives but also to protect their meager resources to ensure their livelihood.

1.1 Types of fires

Classification of fires is not universal and is country-specific (“Fire Class” 2022). This paper presents the classification relevant to India as per Indian Standards institute IS 2190 and related specifications for the fire-fighting equipment (BUREAU OF INDIAN STANDARDS 2004,) (Tricone Solutions PVT.LTD., n.d.).

Class A: Fire involves solid combustible materials of organic nature such as wood, paper, rubber, plastic, etc where the cooling effect of water is essential for the extinction of fire. Suitable extinguishers– Water, Foam, ABC dry powder, and clean agent*.

Class B: Fires involving flammable liquids or liquefiable solids or like where a blanketing effect is essential. Suitable extinguishers– Foam, Dry powder, clean agent, and carbon dioxide.

Class C: Fire involving flammable gases under pressure including LPG, where it is necessary to inhibit the burning gas at a fast rate with inert gas, powder, or vaporizing liquid for extinguishment. Suitable extinguishers–Dry powder, clean agent and carbon dioxide.

Class D: Fire involving combustible metals such as magnesium, aluminum, zinc, sodium, potassium, etc. where the burning metal reacts with water co₂, and halogenated hydrocarbons. Suitable extinguishers - Special dry powder extinguishers

* A clean agent is any type of fire extinguishing agent that is electrically non-conductive, volatile, or gaseous, and that does not leave a residue upon evaporation. Clean agent fire suppression systems make use of an inert gas or chemical that is stored in a container and discharged when a fire is detected.

1.2 Fire Triangle

It is very important to understand the classic ‘fire triangle’ before attempting any fire safety design. Any fire will occur only when all three vertices of the triangle are present. The essential components to sustain fire are- heat (for ignition), fuel (combustible fuel), and Oxygen (to sustain the fire). A fire can be prevented or extinguished by effectively removing any of these vital components represented by the fire triangle (“Fire triangle” 2022).

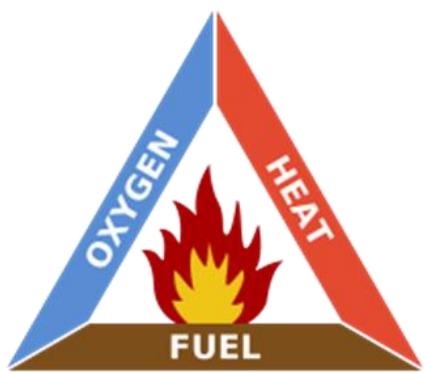


Figure 1: Fire Triangle (“Fire triangle” 2022)

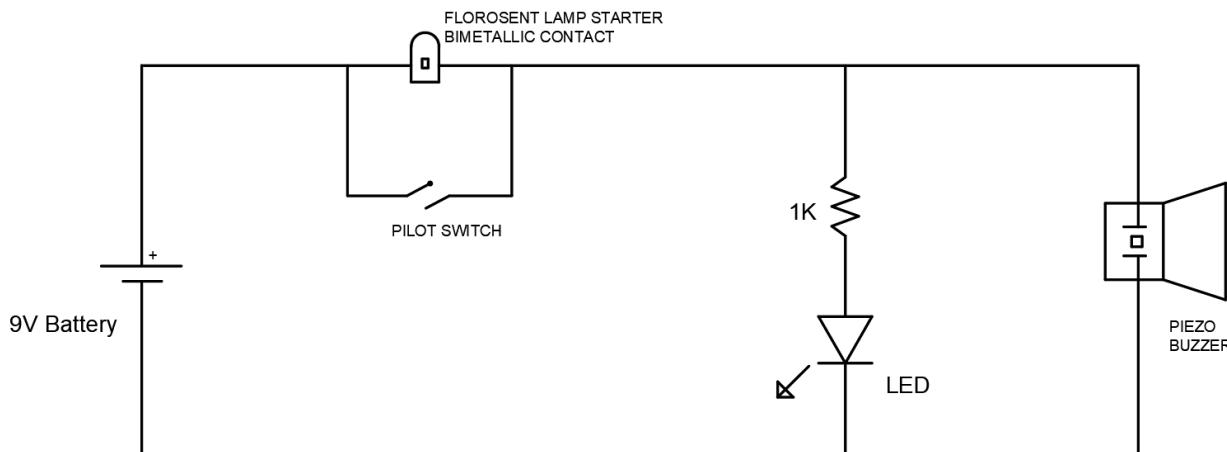
2.0 Low-cost Fire Alarms

The market is flooded with very sophisticated and expensive fire alarms which are internet (IOT-Internet of things-enabled) enabled. Most of them are designed to be fixed in large buildings and get integrated with the central monitoring system. Prohibitive costs, availability of uninterrupted electric power supply/internet connectivity, and non-availability of trained technicians to install/maintain such systems is a major challenge to implement any design based on such devices. This paper proposes few very simple fire alarm systems with readily available components in the spirit of DIY-(do it yourself!). The intention is to equip local electricians with the required know-how to make and maintain simple fire alarms.

2.1 Fire Alarm based on Tube Light (Fluorescent lamp) Starter (Internal Bimetallic contact)

DIY enthusiasts have built a simple fire alarm based on Tube Light starter internal part. Tube Light starter consists of a gas-filled tube that contains a bimetallic contact which is normally open and closes when the glass tube is heated within an electric current or by applying external heat. This component can be easily extracted from any old Tube Light starter. Millions of traditional tube lights are becoming obsolete and are being replaced by LED-based lamps. Building a fire alarm using tube light starter parts will lead to recycling of electronic waste effectively. The schematic diagram is shown below in Circuit Diagram 1. (Bhatt, n.d.) (DIY & TECh HuB 2017)

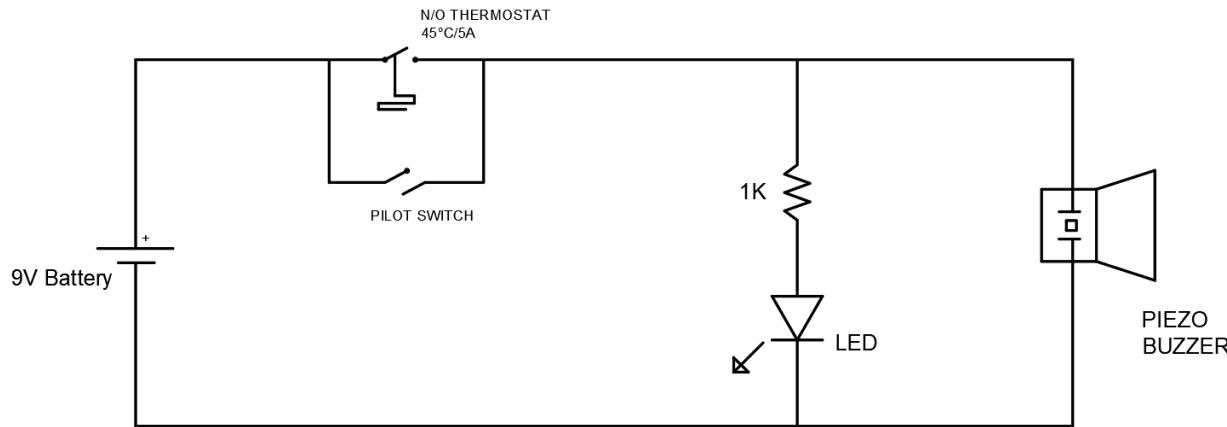
This device operates on a standard 9 Volt Alkaline battery. The circuit is normally in sleep mode and does not draw any current from the battery during normal conditions. The circuit draws current only when the ambient temperature exceeds 50 Degrees Celsius emitting a loud alarm to warn the occupants regarding an impending fire hazard. The circuit configuration results in a very long life of several years. A pilot switch is provided to ensure that the alarm is checked periodically so that it is ready to alert any fire-related incident.



CIRCUIT DIAGRAM 1

2.2 Fire Alarm based on Normally Open Contact Bimetallic Thermostat Switch

Bimetallic switches are mass produced to protect various electrical devices. These components are inexpensive and very reliable. The schematic diagram is shown in Circuit Diagram 2. The circuit operates in sleep mode like the configuration shown in section 2.1 to ensure long battery life.

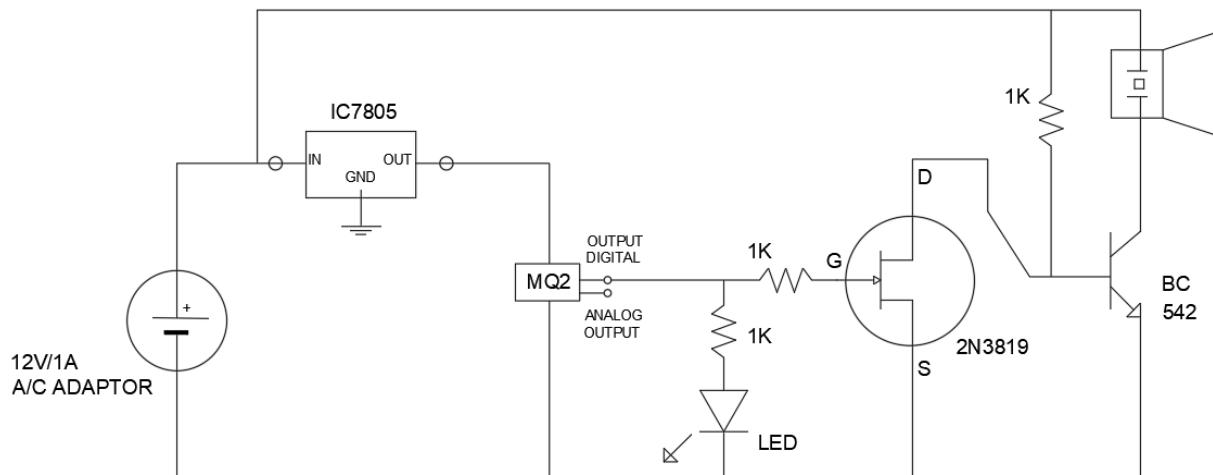


CIRCUIT DIAGRAM 2

2.3 Smoke Detector Alarm

A simple inexpensive smoke detector alarm based on proven and reliable sensor MQ2 is proposed in the Circuit Diagram 3. Smoke alarms are prone to give many false alarms in Indian household conditions. Firwood stoves, burning incense sticks kitchen seasoning fumes, stubble/garbage burning in the neighborhood are few common reasons for false alarms. However, if used prudently they can alert the occupants in advance regarding any major fire. MQ2 sensor operates on 5V dc power supply. It has two outputs. Analog output gives out voltage signal proportional to the presence of flammable gases in the vicinity. Digital output of the sensor, normally gives a high level TTL logic signal and low level TTL logic signal when flammable gases are present in the room. Threshold level of flammable gases can be adjusted by a variable potentiometer (Wikipedia 2022).

The prototype is built using the digital output. A field effect transistor 2N3819 is driven by digital output of the sensor. It pulls down the base drive of transistor BC 547 under normal conditions keeping the alarm in silent mode. When MQ2 senses inflammable gases, digital output goes to low level and BC547 transistor gets activated and drives the piezo electric buzzer alerting the people around.



CIRCUIT DIAGRAM 3

2.4 Bill of material for Fire Alarms

The following table gives the bill of material for the proposed fire safety devices.

Component	Circuit 1	Circuit 2	Circuit 3	Price Rs.
9 V PP3 Battery	✓	✓	-	50
9V/1A DC adopter	-	-	✓	100
Glass Tube bimetallic Contact	✓			3
N/O Bimetallic Thermostat Contact		✓		200
MQ2 Sensor			✓	80
LED	✓	✓	✓	1
Piezo Buzzer	✓	✓	✓	25
Enclosure	✓	✓	✓	50
MISC. Electronic components	✓	✓	✓	25

It can be concluded that a fire alarm can be made within Rs 154 to Rs. 351 and a smoke detector within Rs.281. It is a very low investment when compared to the benefits of safety to human life and property.

3.0 Low-Cost Fire Protection System

High-rise buildings and industrial establishments which have high fire hazards install water hydrant systems. Hydrant systems consist of high-pressure water piping distributed around the facility. An independent diesel engine-driven high-pressure pump will be an integral part of such a system. These systems are very expensive and require highly trained operators to always keep them in operational readiness. Water sprinkler systems require elaborate plumbing and the availability of high-pressure water storage and circulation systems. These systems are highly desirable. However, they are beyond the reach of any low-cost housing units.

This paper proposes a minimalist fire protection system that can be easily procured and installed. Three low-cost high-impact components are proposed

- Fire Bucket with Stand
- Fire Blanket
- Powder-based standalone fire extinguisher for A/B/C type fires.

A simple combination of Sand and Water, fire bucket placed in one corner of the house can very effective in putting out small fires. Dry Sand can be used to prevent and extinguish fire caused by burning liquids like oils, paints, and electric equipment. A water bucket can effective in extinguishing A-class fires caused by organic materials like wood, paper, and textiles. After any fire incident, replacement of sand and water is simple and does not cost any expenses. Fire buckets are very old, low-technology fire protection equipment. They are relevant even today. Petrol bunks, railway stations, and many offices use them as standby equipment in effectively fighting small fires (FRIMedia, n.d.).

Fire Blankets are handy and inexpensive and can prevent kitchen fires and also deal with clothes catching fire. Fire blanket works on the principle of starving the fire by starving the oxygen supply by blanketing operation. It removes 'Oxygen' the vital element of the fire triangle and extinguishes fire. Modern fire blankets are made of fiberglass; operators should be careful while using the same. The use of a mask and hand gloves will prevent any irritation caused by loose falling glass fibers.

Powder-based Fire extinguishers made to the specifications of Indian standards Institution mounted on the wall are the most essential piece of equipment in dealing with any fires and act as a primary defense against fire accidents. However, some expenditure is involved to recharge it periodically or after any fire incident.

The Bill of material for the low-cost fire protection components is given below:

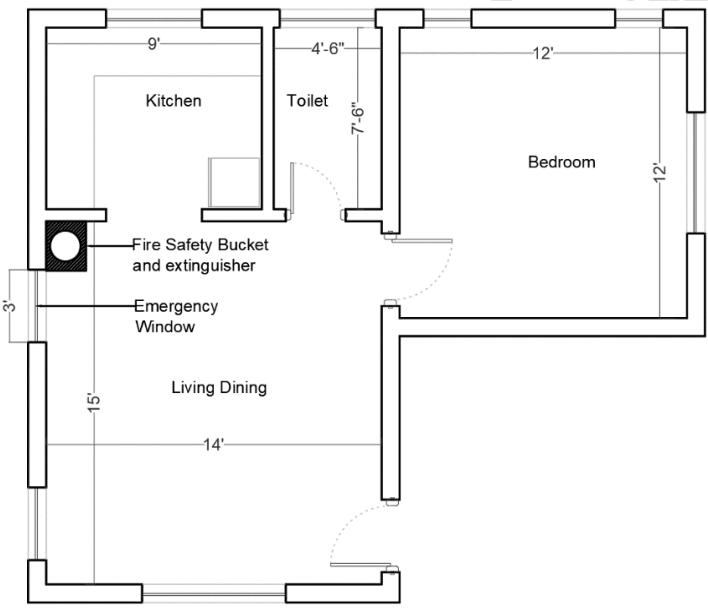
DESCRIPTION	APPROXIMATE PRICE Rs
Fire Bucket and stand	900
Fire Blanket	750
Small Powder based ABC Fire Type extinguisher	650



4.0 Design Solution

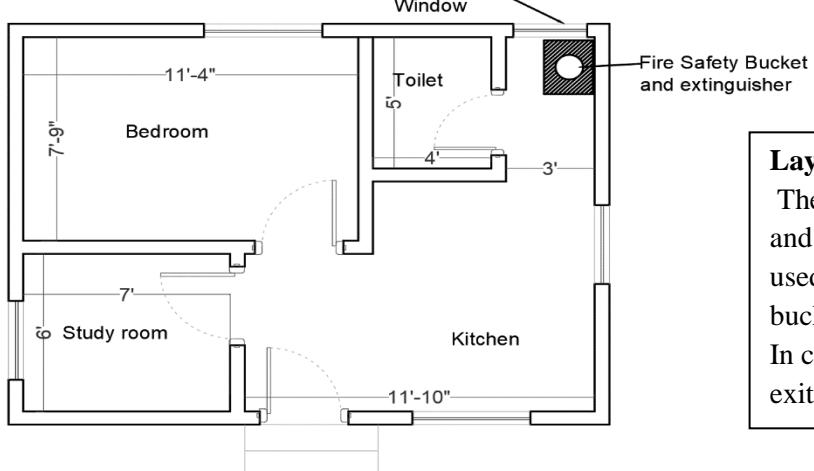
Typical 300 SFT and 400 SFT low-cost layouts are presented and a design solution for the placement of low-cost fire protection equipment is presented below.

Low cost houses typically have just one entrance. In case of any fire accident, an obstruction to the entrance can trap the occupants inside the house. It is very important to provide at least one additional emergency exit point for occupants to escape and also fire fighters to break into the house for rescue operation. A simple re-design of a window can convert it into an emergency exit.



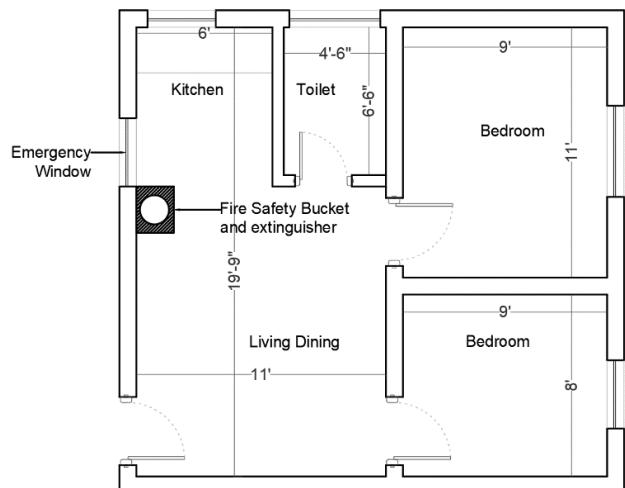
Layout A:

The Fire exit and equipment is located in the Living/Dining area close to the kitchen. In case of an emergency the occupants have immediate access to exiting the place in case of fire. Also in case of a minor emergency situation, the emergency equipment is within reach.



Layout B:

The Fire exit is located in the back Toilet area and the narrow space close to the toilet area is used to store emergency equipment like the fire bucket and extinguishers. In case of an emergency the occupants have 2 exit points, the main entry and the emergency

**Layout C:**

The Fire exit is located in the Kitchen area. There is also provision to store emergency equipment like the fire bucket and extinguishers.

In case of an emergency the occupants have 2 exit points, the main entry and the emergency window in the kitchen.

Placing of firefighting equipment at strategic locations within the house is very important so that under normal conditions, it does not obstruct the occupants and during any fire related incident, it is easy to access and use them.

- Fire extinguisher can be placed close to kitchen or close to high ampere power points where people connect high powered electric devices
- Fire buckets and fire blanket can be located close to the main entrance of the house.

5. 0 Experimental Results



Prototypes of two types of fire alarms and one smoke detector are built. Fire alarms were tested using a lighted candle. Bringing the lighted candle near the thermostat triggered the alarm within 10 seconds. A lighted incense stick triggered the smoke alarm within 10 seconds.

6.0 Conclusion

Standalone low-cost fire protection system is an absolute necessity in small-budget houses. The design solution proposed in this paper costs less than Rs.3,000/. This is low investment high-impact building service that will go long way in saving human life and precious belongings of low-income households.

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