iJRASET
International Journal For Research in Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** II **Month of publication:** February 2025

DOI: https://doi.org/10.22214/ijraset.2025.66752

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue II Feb 2025- Available at www.ijraset.com

A Review on the Development of Advanced Fire Safety Robot for Emergency Purposes

Dosti Jaswanth Kumar Reddy[1], Cheepurupalli Anantha Sathya Chandra Sekhar[2], G. Arunkumar[3]
[1, 2, 3]*Dept. of Mech. Engg., Sathyabama Institute of Science and technology., Chennai, Tamil Nadu, India*
[3]*Professor Dept. of Mech. Engg., Sathyabama Institute of Science and technology, Chennai, Tamil Nadu, India*

Abstract: ***This paper presents the design and development of an advanced fire safety robot aimed at improving firefighting operations. Detecting and extinguishing fires is challenging and often puts firefighters' lives at risk. Many firefighters lose their lives each year due to fire accidents while on duty. The robot incorporates Radio Frequency (RF) Operation technology and advanced fire suppression systems to help find and extinguish fires. The location of the fire is detected, and this information is used to control the robot's movements—allowing it to move forward, backward, left, and right. An 8051 Microcontroller is used to manage these functions. The design of the robot focuses on agility, durability, and quick deployment, making it suitable for different terrains, including urban areas. Additionally, it has eco-friendly features, such as electric propulsion and sustainable materials, to reduce its environmental impact. The robot is also equipped with a water tank and a pump that can spray water when needed. The main goal of this advanced fire safety robot is to enhance firefighter safety, reduce response times, and minimize damage during emergencies, ultimately helping to save lives and property.***

Keywords: Microcontroller, Water, Pump, Firefighter, Transmitter, Receiver, RF Controller

I. INTRODUCTION

A robot may be a modified machine that can carry out an assortment of perplexing exercises. Whereas numerous firefighting robots have been created in later a long time, firefighters can control a little number of them electronically [1]. These robots sometimes glitch because of wrong sensor readings, which prevents them from productively putting out fires [2]. In this think about, small depicts an RF (Radio Recurrence) –based fire- fighting robot that can be worked wirelessly conveying superior effectiveness and constancy[3]. Nowadays, robots are more commonly utilized past generation businesses, handling high-risk errands like fire quenching. With this RF-based fire- fighting robot, the chance to human life and property can be essentially decreased, minimizing fire damage[4]. The Fire- Fighting Robot is outlined to function in little spaces, such as within a house, and can quench fires utilizing water. Firefighting could be a physically requesting and perilous errand for firefighters, so this robot offers profitable bolster in unsafe circumstances [5]. Prepared with a water pump associated to an outside water tank through plastic tubing, the robot is designed to handle fire concealment assignments that are also unsafe for people [6]. Robots are perfect for labor-intensive or perilous work and can work in blocked-off situations, diminishing the chance of human life and contributing to lower air pollution [7]. This RF-based Fire- Fighting Robot can move through a demonstrated structure, find a fire, and quench it utilizing water [8]. The paper points of interest the robot's plan, which breaks down the firefighting mission into smaller, proficient assignments. These errands incorporate finding a fire in a particular room, drawing nearer it at a secure separate, and quenching it [9]. One of the key preferences of this robot is its diminished probability of disappointment due to defective sensor readings since an administrator controls it. The RF-based fire-fighting robot effectively checks the whole zone for blazes, identifying and quenching fires sometime recently they spread [10]. This occurs in faster reaction times, avoiding assist damage and ensuring property. A robot is a programmed machine that can carry out a variety of intricate activities [11]. While many firefighting robots have been developed in recent years, firefighters can control a small number of them electronically. These robots occasionally malfunction because of inaccurate sensor readings, which prevents them from efficiently putting out fires [12]. In this study, wee describe an RF (Radio Frequency) –based fire-fighting robot that can be operated wirelessly delivering better efficiency and dependability.

II. PROBLEM STATEMENT

Fire accidents can be unsafe, often putting human lives at risk during rescue and firefighting operations. Firefighters confront challenges such as extraordinarily warm, poisonous smoke, and trouble in getting to fire zones [13]. To move forward with security and proficiency, there's a requirement for a robot that can offer assistance in identifying and battling fires in dangerous ranges. This robot should be able to function remotely, utilizing radio recurrence (RF) innovation, permitting it to be controlled from a secure removal while exploring through smoke, blazes, and impediments [14].

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All fires can be quenched by cooling, covering, starving, or hindering the combustion process to quench the fire. One of the foremost common strategies of quenching a fire is by cooling it with water Expanded Security for Firefighters. Inaccessible Operation in Unsafe Zones. Progressed Get to Hard-to-Reach Regions [15].

III. METHODOLOGY

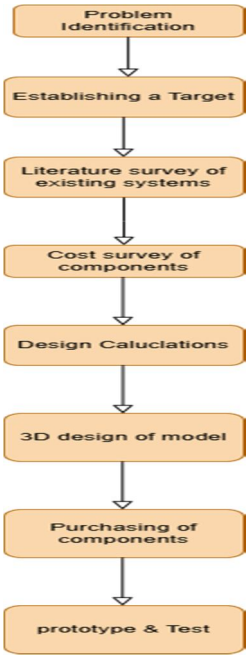


Figure 1: Methodology of development of prototype of fire safety Robot

A. Description of Methodology

To develop a new product, the process begins with problem identification, where the specific issue or need is clearly defined. Next, establishing a target involves setting goals for what the product should achieve, such as performance, safety, and reliability. A literature survey of existing systems helps understand similar products or technologies already in use, ensuring the new design improves on them. The cost survey of components involves researching prices and availability of materials and parts needed for the project to keep it within budget. After that, design calculations are done to ensure the product will perform as intended by considering factors like strength, durability, and functionality. A 3D design of the model is created using CAD software to visualize the product before manufacturing. Once the design is ready, purchasing of components takes place to gather all necessary parts for the prototype. Finally, the prototype is built and tested to check its performance, identify any flaws, and make improvements before launching the final product.

B. Proposed System

The robot will be built from scratch using a plywood framework. Plywood is a good choice because it is strong and stable. The chassis (or base) of the robot should have enough space to hold a water can and all the necessary electronic components. To move, the robot will use four rubber wheels and four DC motors will be fixed at the bottom—one on each side. The water can be placed securely between two plywood frames in the middle of the robot [16]. Sensors will be mounted at the front of the robot to detect flames directly ahead. The circuit will be designed using an RF TX RX module, which will control all the electronic components. All of the electronics, including the RF TX RX, will be securely mounted on the robot. The outlet of the water pump should be fixed at the centre of the robot facing towards the front of the robot [17].

C. Software Development

The robot is implemented using CANVAS software for giving input operations in the microcontroller in C- Language. For communications a modified RF TX RX module is used.

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D. Schematic diagram

The 8051-microcontroller advancement board is utilized in this firefighting automated framework, which is made up of HC-ultrasonic sensors. A fire discovery sensor is utilized to recognize smoke or warmth, activating security alarms expeditiously, a temperature sensor is utilized to screen natural warmth, empowering control and computerization frameworks, and an ultrasonic sensor is utilized to degree separate utilizing sound waves, empowering question discovery [14]. In expansion, for quenching the blazes, it also makes utilize of a water tank and a shower weapon instrument with the help of a 12V pump, water is pumped from the water tank to the water spout [18].

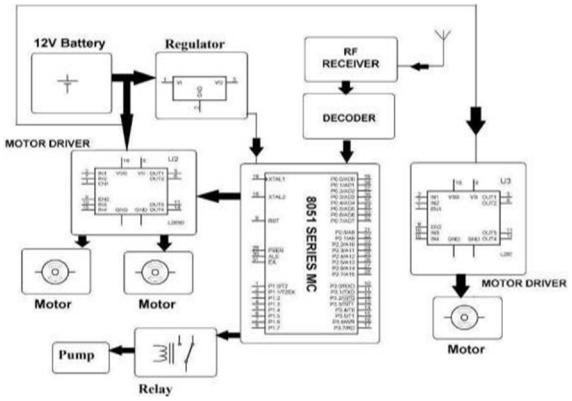


Figure 2: Schematic diagram

IV. COMPONENTS DESCRIPTION & IT'S USES: 4.18051 MICROCONTROLLER

In this project 8051 microcontroller is used as the main controller, in simple 8051 microcontroller is the processor to handle instructions, memory to store information, and input/output ports to connect to other devices like sensors, buttons, or displays.

1851 microcontroller is used to read simple electronics and embedded systems to control small tasks, like turning on lights, controlling motors, or reading data from sensors. Unlike regular computers, which run complex programs, the 8051 is designed to run specific, simple tasks repeatedly and efficiently [19].

Table 1: Specifications of 8051 Microcontroller

Board	Name SKU	8051 Microcontroller A0000066
Microcontroller	ATmega328P	
USB connector	USB-B	
Pins	Built-in LED Pin	13
	Digital I/P Pins	14
Communication	UART	Yes
	12C	Yes
Power	Input Voltage	7-12V
	DC Current Per I/O Pin	20mA
	Power Supply Connector	Barrel Plug
Memory	ATmega328P	2KB SRAM,32KB FlASH,1KB EEPROM



Figure 3: 8051 Microcontroller

A. Fire Detection Sensor

A fire detection sensor is a device that identifies signs of a fire, such as smoke, heat, or flames. It uses these indicators to detect potential fire hazards early, triggering alarms to alert people and sometimes activating safety systems like sprinklers. These sensors are commonly used in homes, offices, and industrial settings to enhance safety by providing early warning and helping prevent fires from spreading.


Figure 4: Fire detection Sensor

B. Temperature Sensor

A temperature sensor that measures the heat or coldness of an object or environment. It converts temperature readings into signals that can be read by electronic systems. These sensorsare used in a wide range of applications, from household appliances like thermostats and ovens toindustrial equipment, where they help monitor and control temperatures to ensure safety, efficiency, and proper functioning.

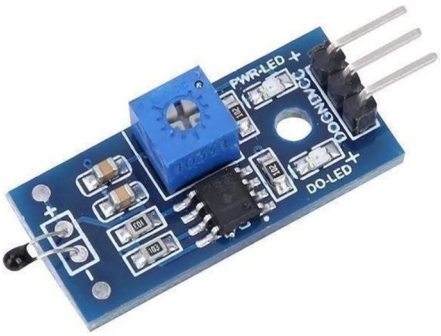


Figure 5: Temperature Sensor

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C. Ultrasonic Sensor

An ultrasonic sensor measures the distance between itself and an object using sound waves. It emits high- frequency sound pulses that bounce off the object and return to the sensor. By calculating the time, it takes for the sound to return, the sensor determines the distance to the object. This technology is used in various applications, such as parking assist systems in cars, obstacle detection in robots, and level measurement in tanks.



Figure 6: Ultrasonic sensor

D. Battery Description

12 Volts 1.3 Amp Sealed Lead Acid Rechargeable Battery
Maintenance-Free Operation Position-Free and Leakage-Free
Clamps are used to hold components like batteries, motors, and other elements rigidly. Here we had taken a standard available L-clamp in the market of thickness 3mm.
Material=Aluminium (here we have considered weight optimization, as we can also adopt steel material but its mass density is more compared)

V. DESIGN, ANALYSIS AND ACTUAL WORK CARRIED OUT OF THE SAME

A. Water Motor Power

Pump power P(kW) in KW is calculated by multiplying the differential pressure p(Pa) in pascal or N/m^2 by 36,000,000 the rate of flow q(m^3/hr) in Kilograms per cubic meter, gravity g in m^2/s, and the pump differential h(m) meter head[20].
Pump Power (kW)=q(m3/hr) ×ρ(kg/m3) ×g(m2/s)×h(m)×p(Pa)/3600000 (1)
Let's assume Q = 2.5 litters/ min = 0.6 m^3 /hr Water Density = 997 kg/m^3
Spraying Arm length = 0.5 m
Assume Head = 1 m from tank to nozzle.

B. Design, Analysis And Actual Work Carried Out For The Same

Circumferential = πr^2.....(2)
G = 9.81 gravity
H = 1m
Assume the Pressure required to supply water from the inlet to the outlet = 2.5 - 3 pascal
Power =0.6∗997∗1∗9.81∗2.53600000=4.0752^-3 Kw
……(3)
Power = 4.0752 watts required to deliver the water from tank to nozzle.
According to availability we will select 4 watts water pump from market

C. Submersible Pump

The standard available motor in the market



Figure 7: Submersible Pump

VI. ANALYTICAL CALCULATION

A. Design of Support or Frame

1) Area of Rectangular

We took a teak wood frame which is available in the market of thickness 4 mm and length, and width according to requirement.

Thickness = 5mm W = 300 mm

L = 400 mm

The total surface area of the rectangular prism is given by:

A = 2(lb + bh + lh).....(4)

= 2((400 x 300) + (300 x 5) + (400 x 5))

= 247000 mm^2

Mass of frame with Material Ply-wood = 0.385 Kg

= 0.127 x 9.81

= 3.776 N

Area = 247000 mm2

= 0.247m2

Moment of Inertia ICM = 1/12 x M (w2 + l2)..... (5)

= 1/12 x 3.776(400^2 + 300^2)

= 78666.6 Nmm^2



Figure 8: Plywood from SolidWorks

Assume load on the frame including all components = 5Kg

Mass of water storage = 2.5-3 litters

=3kg Total mass on frame = 5+3

= 8Kg

= 8*9.81

= 78.48 N

Factor of Safety = 1.5

= 78.48 X 1.5

= 117.72 N

= 120 N

Perpendicular distance = 400 / 2

= 200 mm

Moment = 120 X 200

= 24000 Nmm^2

= 24000 Nmm^2

I = 78666.6 Nmm^2

Y = Distance of the layer at which the bending stress is considered

=5/2

= 2.5 mm

Sigma b = M * Y / (I)..... (6)

= 24000 * 2.5 / (78666.6)

= 0.762 Mpa

0.127 MPa <Plywood 13.8 MPa Ultimate Yield strength Hence Design is safe.

2) Motor Selection On The Total Payload Of Component

Hence total weight on the frame is taken in frame calculation = 120 N

No Motors required= 4 at back side wheels Load is distributed into 4 wheels = 120/4 = 30N

Actual load = total load / no. of Motors

= 120/4

= 30N

The diameter of the inside hole of a wheel is 8mm Torque = ½ Force x Diameter

=1/2x30 x8 mm

=120 N.mm

=0.12 Nm.

=1.22365 Kg-cm torque

Note

Diameter =diameter of the wheel (d= 80mm) standard available in the market, internal diameter (d 10mm).

Force =total force including all components (30N) at each wheel



Figure 9: Motor from SolidWorks

3) Specifications of Motor

Rate base motor RPM = 18000 rpm Rate Speed (RPM) = 200 rpm Operating Voltage(VDC) = 6W18V Voltage = 12V

Rated Torque = 3.9 kg-Cm

Load current max = 900 MA

Motor Diameter = 2.7 mm

Motor Length = 62 mm

4) Clamp for holding motor rigidity

Clamps are used to securely hold components like batteries, motors, and other parts in place. In this case, we selected a standard L-clamp available in the market with a thickness of 3mm. The material chosen is aluminium because it offers weight optimization. Although steel could also be used, aluminium was preferred due to its lower mass density, making it lighter.

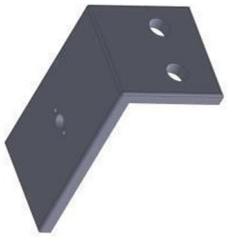


Figure 10: Clamp From SolidWorks

B. Discussion

The selection of appropriate frame material and its dimensions is crucial to ensure the structural stability and durability of the fire-fighting robot. A sturdy frame is essential to support all components, including the clamps for holding motors, which are selected based on strength and compatibility with the frame material. The wheels are chosen to provide optimal mobility on various terrains, ensuring the robot can navigate smoothly during operations. The DC motors, selected for their efficiency and torque, drive the wheels and water pump, ensuring reliable performance. The water pump is selected to provide sufficient pressure for extinguishing fires effectively.

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After conducting a detailed market survey and considering the required specifications, standard components were chosen to meet the design criteria. Therefore, the overall design and preparation of the fire-fighting robot have been completed as per the established standards to ensure functionality, reliability, and safety in firefighting applications.

VII. PROPOSED GEOMETRIC MODEL OF FIRE SAFETY ROBOT

Design has been done using Solid Works. First all the sub-parts are Designed using part design module.
Then all the sub-parts are assembled using the product module in the solid works.
Finally assembled part has been done using Solid Works and saved as a PDF.

VIII. CONCLUSION

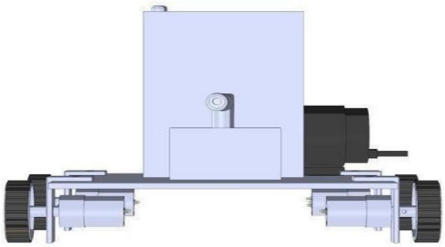


Figure 11: Front View

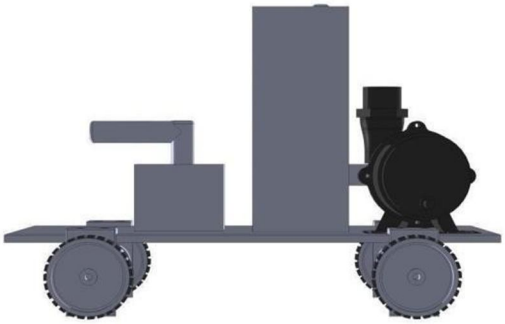


Figure 12: Side view

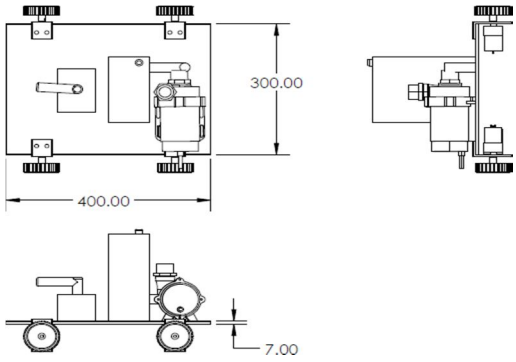
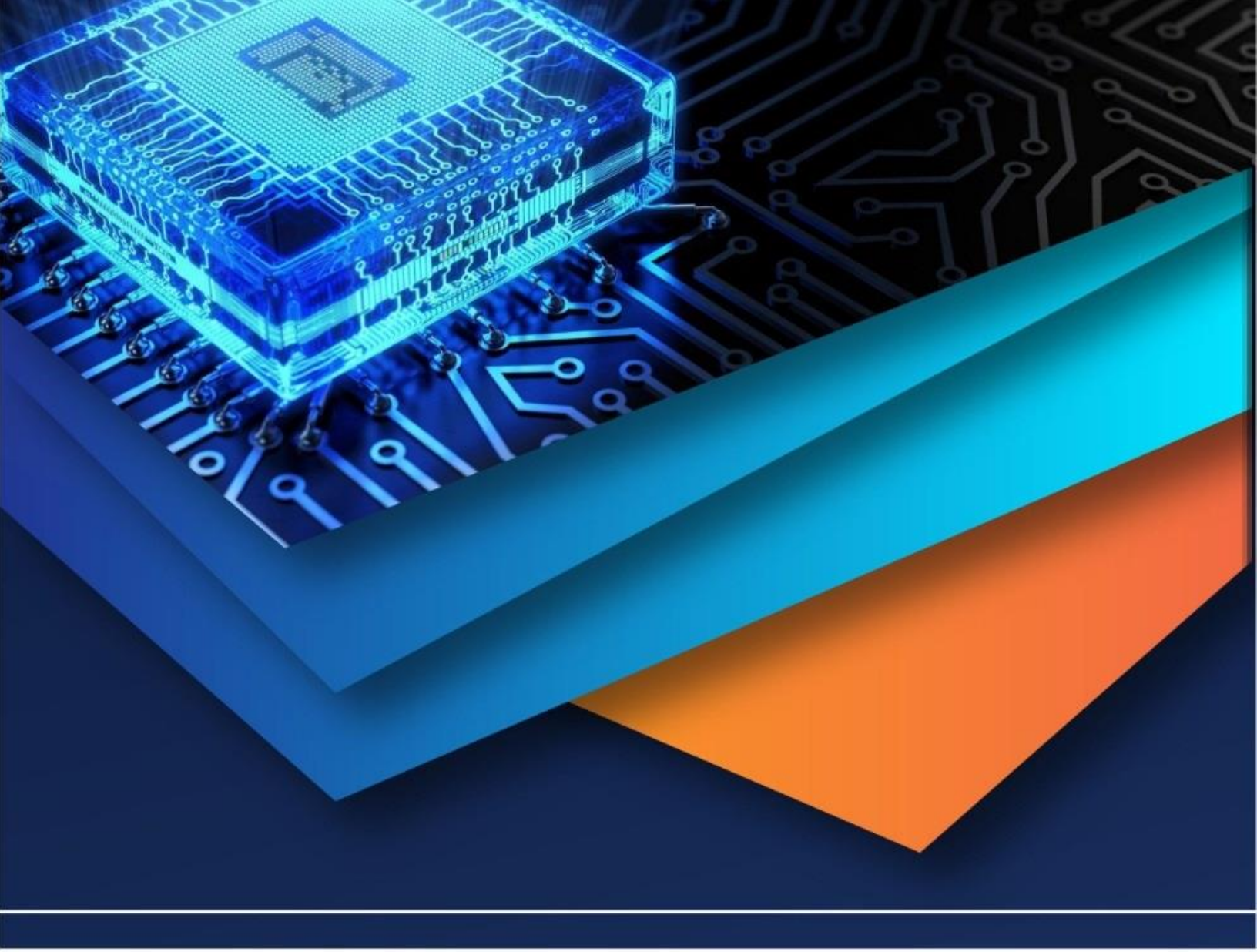


Figure 13: Design of Prototype Model

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