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Smart Automated Menstrual Pads Incinerating Disposer Hybrid Assembly

Kushal M[1], HP Rahulkrishna[2], Nagendra Manjunath Hegde[3], Namith S[4], Sangeetha V[5]
[1,2,3,4,5]*Department of Electronics and Communication Engineering, K. S. Institute of Technology, Bengaluru, Karnataka, India*

Abstract: ***This paper presents the development of an automated system for the hygienic disposal of used menstrual pads through controlled electrical incineration. The system uses an ESP32-S3 microcontroller to manage user detection, door locking, and the overall operating process. A VL53LDK Time-of-Flight sensor detects the presence of a user and triggers the electromagnetic door lock to open, allowing 15 seconds for pad insertion. The system is designed to collect two pads per batch before automatically starting the incineration process. A ceramic heater operates for a preset duration of 14 minutes, reaching a maximum reported temperature of approximately 420 °C. The smoke generated during incineration is directed through a filtration unit containing activated carbon and HEPA filters, while the resulting ash is collected in a separate ash tray. The developed prototype integrates automated pad loading, batch-based incineration, smoke filtration, and ash collection into a single disposal system.***

Keywords: Automated Menstrual Pad Disposal, ESP32-S3, Time-of-Flight Sensor, Electrical Incineration, Electromagnetic Lock, Smoke Filtration, HEPA Filter, Ash Collection.

I. INTRODUCTION

The proper disposal of used menstrual pads is an important aspect of maintaining hygiene and managing sanitary waste. In many places, such as educational institutions, workplaces, hospitals, and public washrooms, used pads are often discarded along with general waste. This can lead to unpleasant odours, hygiene concerns, and difficulties during waste collection and handling. Since sanitary pads contain absorbent materials and synthetic components, they also take a considerable amount of time to decompose naturally. These challenges highlight the need for an effective and controlled disposal system.

The proposed Smart Automated Menstrual Pads Incinerating Disposer Hybrid Assembly is designed to address these issues through an automated electrical incineration process. The system uses an ESP32-S3 microcontroller as its main control unit, along with a VL53LDK Time-of-Flight sensor, an electromagnetic door-locking mechanism, and a TFT display. When a user approaches the disposal unit, the sensor detects their presence and sends a signal to the microcontroller. The controller then unlocks the feed door, allowing the user to insert a used menstrual pad within a predefined time interval of 15 seconds. Once the interval expires, the door is automatically locked.

The system follows a batch-based disposal approach in which two pads are collected before the incineration process begins automatically. A ceramic heater is used to provide heat inside the combustion chamber and operates for a preset duration of 14 minutes, reaching a maximum reported temperature of approximately 420 °C. The feed door remains locked throughout the heating process to prevent access to the chamber during operation. To manage the smoke generated during incineration, the system incorporates a separate filtration unit containing activated carbon and HEPA filters. An exhaust fan helps direct the smoke through the filtration arrangement before it is released through the outlet. The resulting ash is collected in a dedicated ash tray for further handling.The developed prototype brings together automated user detection, controlled pad insertion, batch-based incineration, smoke filtration, and ash collection into a single system. It aims to provide a more organized approach to menstrual waste disposal while reducing the need for direct handling of used sanitary pads.

II. RELATED WORK

Research related to automated menstrual pad disposal covers different areas, including sanitary waste incineration, automated pad handling, air filtration, and emission monitoring. Several researchers have explored microcontroller-based incinerators, automated disposal mechanisms, and filtration systems using HEPA filters and activated carbon. Other studies have focused on identifying harmful gases released during incineration and monitoring the performance of filtration materials. These existing works provide a foundation for developing an automated menstrual pad disposal system and help identify areas that require further improvement.

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A. Automated Sanitary Waste Incineration

Pranav K. G. et al. [2] developed a sanitary waste incinerator that uses microcontroller-based temperature control along with thermoelectric energy recovery. Mariaraja et al. [6] designed an automatic incinerator using an ATmega328P microcontroller, temperature sensors, and a heating coil. Similarly, SabariPriya et al. [7] proposed an automated sanitary napkin incinerator that uses infrared sensing and a multi-stage exhaust arrangement. These studies highlight the importance of automation, controlled heating, and proper exhaust management in sanitary waste disposal.

B. Integrated Sanitary Pad Disposal Systems

Gawande et al. [4] developed a combined sanitary napkin dispenser and incinerator controlled using an Arduino microcontroller. Rajole et al. [9] proposed Agni Dita, an electronic sanitary napkin disposal system that combines thermal treatment with exhaust-gas treatment. These systems demonstrate how pad handling and disposal can be integrated into a single unit. The proposed system follows a similar approach by combining controlled feed-door access, batch-based pad loading, and timed thermal treatment.

C. Emission Monitoring and Filter Assessment

Manisha and Thakare [12] studied the toxic gases released by existing and proposed IoT-based sanitary napkin incinerators, including carbon monoxide, chlorine, nitrogen dioxide, and phosgene. Cerro et al. [15] developed a microsensor-based platform to monitor the remaining useful life of activated-carbon filters using electrical impedance measurements. These studies highlight the importance of monitoring emissions and evaluating filtration performance. For the proposed system, these aspects remain important areas for future testing, as the actual emission levels and filtration efficiency have not yet been established.

D. Research Gap

The reviewed studies cover automated sanitary waste incineration [2], [6], [7], integrated pad disposal systems [4], [9], air filtration [1], [3], [8], and emission or filter monitoring [12], [15]. However, these studies use different system configurations and do not establish the performance of the particular combination implemented in the proposed prototype.

The proposed system brings together ToF-based user detection, electromagnetic feed-door locking, batch counting, timed ceramic heating, TFT-based user guidance, and activated-carbon and HEPA filtration in a single unit. It is configured to handle up to two pads per batch, with a 15-second loading interval and a preset heating duration of 14 minutes. Further testing is necessary to evaluate thermal-treatment performance, filtration efficiency, emissions, operational safety, and residual-material handling.

TABLE I
COMPARISON OF SELECTED RELATED WORKS

Ref.	Key feature	Limitation
[1], [3], [8]	HEPA-based air purification	Not designed for pad disposal
[2], [6]	Automated sanitary waste incineration	Different heating and control methods
[4], [9]	Integrated pad disposal systems	Different loading and treatment designs
[7]	IR-based incineration with exhaust treatment	Different system configuration
[12], [15]	Gas emission and filter-life monitoring	Focus on evaluation and monitoring
Proposed	Automated access, batch loading, timed heating, display, and filtration	Requires performance and safety validation

III.PROBLEM IDENTIFICATION AND OBJECTIVES

A. Problem identification

The disposal of used menstrual pads remains a challenge in many public and private spaces. Conventional disposal methods generally depend on waste bins and manual collection, which can lead to improper waste segregation, hygiene concerns, and unpleasant odours. Handling used sanitary products during collection also creates additional difficulties.

Another concern is the lack of controlled access and a structured disposal process in conventional systems. Most disposal arrangements do not provide automated loading control or a mechanism to manage the quantity of waste before treatment. In addition, uncontrolled burning may release smoke and harmful substances into the surrounding environment.

To address these issues, there is a need for an automated disposal system that provides controlled pad insertion, batch management, automatic door locking, and electrical incineration. The system should also include a smoke-filtration arrangement to help treat the smoke generated during the process. The thermal performance, filtration efficiency, and operational safety of the developed system must be evaluated through appropriate testing.

B. Objectives

The primary objective of the project is to develop an automated system for the controlled disposal of used menstrual pads through electrical incineration.

The specific objectives are:

- To implement the overall system control using an ESP32-S3 microcontroller.
- To detect user presence using a Time-of-Flight (ToF) sensor and control access to the feed door.
- To provide a predefined 15-second loading interval and manage batches of up to two sanitary pads.
- To automatically initiate a preset 14-minute ceramic-heater cycle once the batch limit is reached.
- To keep the feed door locked throughout the incineration process to restrict access to the heating chamber.
- To display operating-status messages and instructions through a TFT display.
- To incorporate activated-carbon and HEPA filters into the smoke-filtration arrangement.
- To integrate the different subsystems into a functional prototype for further performance and safety evaluation.

IV. PROPOSED SYSTEM ARCHITECTURE

The proposed Smart Automated Menstrual Pads Incinerating Disposer Hybrid Assembly is organized into four major functional sections: the power supply, microcontroller and control unit, collection and combustion chamber, and smoke-filtration chamber. These sections work together to automate pad insertion, control the incineration process, and manage the smoke generated during operation.

The ESP32-S3 microcontroller acts as the central control unit, coordinating user detection, door access, pad counting, heating operation, and display messages. The overall arrangement of these components is illustrated in Fig. 1.

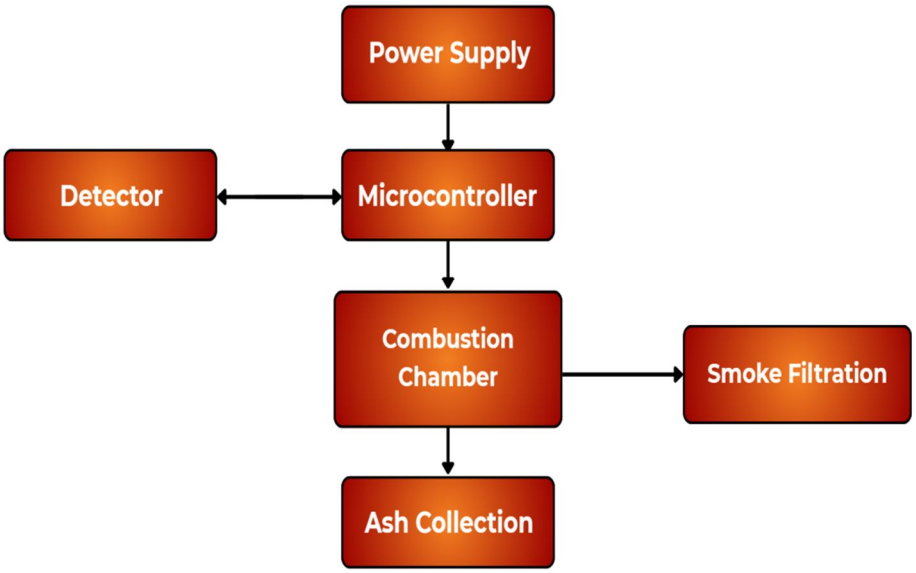


Fig. 1 Block Diagram of the Proposed System

A. Power Supply

The power supply provides the electrical energy required for operating the different components of the system. The prototype uses a 12 V, 2 A Switched-Mode Power Supply (SMPS), which converts the AC mains input into a regulated DC output. It supplies power to compatible components, including the electromagnetic door-locking mechanism. The power supply acts as the electrical interface between the input source and the connected system components. All connected loads must operate within the specified electrical ratings of the supply.

B. Microcontroller and Control Unit

The ESP32-S3 microcontroller serves as the central processing unit of the proposed system. It receives input from the VL53LDK Time-of-Flight (ToF) sensor and controls the overall operating sequence.When the sensor detects a user near the feed door, the microcontroller deactivates the electromagnetic lock to allow pad insertion. It maintains the door in an unlocked state for 15 seconds, after which the door is locked again and the pad counter is updated. The controller checks the pad count and initiates the incineration cycle when the configured batch limit of two pads is reached.The microcontroller also controls the TFT display, which provides instructions and status messages during different stages of operation. The control program is developed and uploaded using Arduino IDE 2.3.6.

C. Collection and Combustion Chamber

The collection and combustion chamber is designed to accommodate used menstrual pads and carry out the thermal treatment process. The feed door is controlled by an electromagnetic locking mechanism connected to the ESP32-S3 microcontroller. When a user is detected, the door unlocks for 15 seconds to allow pad insertion. Once the interval expires, the door locks automatically, and the pad counter is incremented. This process continues until the configured batch limit of two pads is reached. After the batch limit is reached, the ceramic heater is activated for a preset duration of 14 minutes. The maximum reported operating temperature of the prototype is approximately 420 °C. During the entire heating cycle, the feed door remains locked to restrict access to the combustion chamber.

D. Smoke Filtration Chamber

The smoke-filtration chamber is positioned above the incinerator and is designed to treat the smoke generated during the combustion process. It incorporates two filtration media: activated carbon and a High-Efficiency Particulate Air (HEPA) filter. The activated-carbon filter is intended to adsorb certain gaseous compounds and odour-producing substances, while the HEPA filter is used to capture airborne particles. An exhaust fan helps move the generated smoke through the filtration arrangement towards the outlet. This filtration arrangement forms an important part of the overall system. However, its actual filtration efficiency and ability to reduce emissions have not yet been established through quantitative testing and require further evaluation.

V. METHODOLOGY

The proposed system operates through a predefined sequence controlled by the ESP32-S3 microcontroller. When the power supply is switched on, the electronic circuit initializes, and the system enters its ready state. The VL53LDK Time-of-Flight (ToF) sensor continuously monitors the area near the feed door to detect the presence of a user. When an object is detected within the configured range, the microcontroller deactivates the electromagnetic lock and opens the feed door for a predefined interval of 15 seconds.

During this interval, the user can insert a used menstrual pad, while the TFT display provides the necessary instructions and operating-status information. Once the 15-second interval expires, the electromagnetic lock is activated again, and the pad counter is incremented according to the programmed sequence. The controller then checks whether the configured batch limit of two pads has been reached. If the count is below two, the system returns to the detection stage and waits for the next user interaction.

When the pad count reaches two, the microcontroller keeps the feed door locked and initiates the incineration process. The ceramic heater operates for a preset duration of 14 minutes, with a maximum reported operating temperature of approximately 420 °C. During this process, the generated smoke is directed towards the filtration chamber containing activated carbon and HEPA filters. An exhaust fan helps move the smoke through the filtration unit towards the outlet. The ash produced during the process is collected in a separate ash tray.

After the programmed heating interval is completed, the incineration cycle ends, and the system returns to its ready state to begin the next batch. The complete sequence of operations, including user detection, timed pad insertion, batch counting, incineration, smoke filtration, and ash collection, is illustrated in the flowchart shown in Fig. 2.

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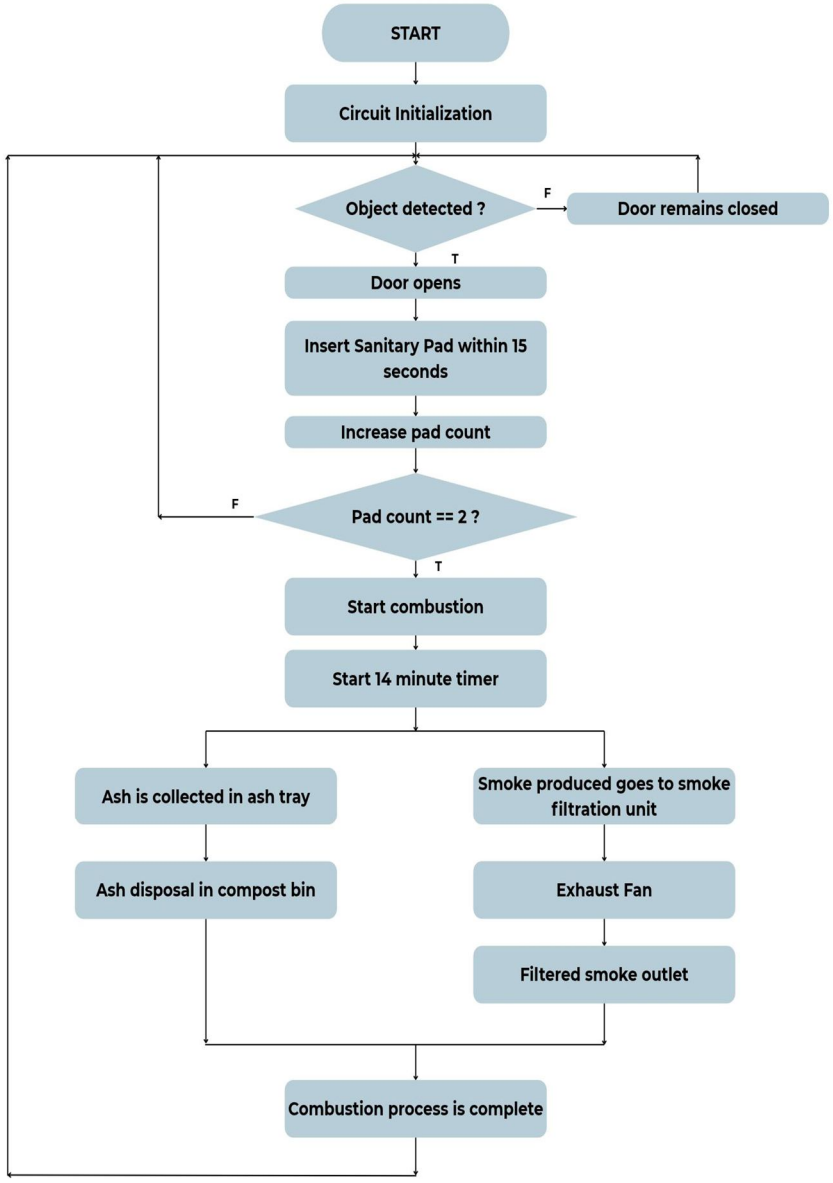


Fig. 2 Flowchart of the Proposed System Operation

VI. EXPECTED BENEFITS AND LIMITATIONS

A. Expected Benefits

The proposed system offers a more organized approach to menstrual pad disposal by combining automated access control, timed pad insertion, and batch-based incineration. Unlike conventional disposal methods that generally depend on manual handling, the developed prototype uses an electromagnetic door lock to regulate access to the combustion chamber.

The 15-second loading interval provides a predefined time for pad insertion, while the batch-counting mechanism ensures that the incineration process begins only after two pads have been collected. The TFT display also provides operating instructions and status messages, helping users understand the different stages of operation.

The system additionally incorporates a smoke-filtration arrangement consisting of activated carbon and HEPA filters. These features demonstrate the integration of automated control, thermal treatment, and smoke filtration within a single disposal unit.

TABLE III
DESIGN COMPARISON WITH CONVENTIONAL SYSTEMS

Aspect	Conventional Systems	Proposed System
Access Control	General open access	Electromagnetic lock
Loading	Manual handling	15-second insertion interval
Batch management	Conventional waste collection	Up to two pads per batch

The prototype demonstrates the programmed control sequence and integration of its major functional units. However, the actual effectiveness of thermal treatment and smoke filtration requires further quantitative evaluation.

B. Limitations and Future Work

The current prototype operates with a preset heating duration of 14 minutes and has a maximum reported operating temperature of approximately 420 °C. However, the extent of waste decomposition and the actual performance of the thermal-treatment process have not yet been established through detailed experimental testing. Similarly, the smoke-filtration arrangement uses activated carbon and HEPA filters, but its filtration efficiency and ability to reduce harmful emissions have not been quantitatively verified. Future improvements should focus on detailed temperature measurements, emission analysis, filtration-performance testing, and repeated-cycle reliability assessment. Further evaluation of the resulting ash is also necessary to determine the appropriate handling and disposal methods. These improvements and tests are important for establishing the operational safety, reliability, and suitability of the developed prototype for practical use.

VII. RESULTS AND DISCUSSION

The proposed Smart Automated Menstrual Pads Incinerating Disposer Hybrid Assembly was physically assembled by integrating the combustion chamber, feed-door mechanism, control electronics, and smoke-filtration arrangement into a single prototype. The developed system combines user detection through a VL53LDK Time-of-Flight sensor, electromagnetic door locking, timed pad insertion, batch counting, and a TFT display for providing operating-status information. The ESP32-S3 microcontroller coordinates these functions according to the programmed operating sequence.

Physical testing verified the operation of the prototype with a batch limit of two pads and a predefined loading interval of 15 seconds. After the loading interval, the feed door was automatically locked, and the pad counter was updated according to the programmed sequence. Once the configured batch limit was reached, the ceramic heater was activated for a preset duration of 14 minutes.During operation, a maximum temperature of approximately 420 °C was recorded. The feed door remained locked throughout the incineration cycle, restricting access to the combustion chamber. These observations demonstrate the successful implementation of the intended control sequence and the integration of the major system components.

The prototype also incorporates a smoke-filtration chamber containing activated carbon and HEPA filters. An exhaust fan is provided to direct the generated smoke through the filtration arrangement. However, the actual filtration efficiency and reduction in harmful emissions have not yet been established through quantitative testing.

Overall, the physical implementation demonstrates the integration of automated access control, batch-based pad loading, timed thermal treatment, display-based user guidance, and smoke filtration. Further testing is required to evaluate the thermal-treatment performance, emission levels, filtration effectiveness, and long-term operational safety.



Fig. 3 Assembled Prototype of the Proposed Menstrual Pad Disposal System

VIII. CONCLUSIONS

The Smart Automated Menstrual Pads Incinerating Disposer Hybrid Assembly was successfully developed as a prototype for the automated disposal of used menstrual pads. The system integrates user detection, electromagnetic door locking, timed pad insertion, batch counting, electrical incineration, and smoke filtration into a single unit. The ESP32-S3 microcontroller coordinates the overall operation, while the TFT display provides instructions and operating-status information to the user.

Physical testing verified the programmed operating sequence with a batch capacity of two pads, a 15-second loading interval, and a preset incineration duration of 14 minutes. During operation, a maximum temperature of approximately 420 °C was recorded, and the feed door remained locked throughout the heating cycle. The system also incorporates activated-carbon and HEPA filters to support the treatment of smoke generated during incineration.

The developed prototype demonstrates the practical integration of sensing, control, heating, and filtration technologies for menstrual waste disposal. However, further experimental evaluation is required to establish the effectiveness of thermal treatment, filtration performance, emission levels, and overall operational safety. Future improvements can focus on enhancing system reliability, verifying actual pad insertion, and conducting detailed performance and safety assessments.

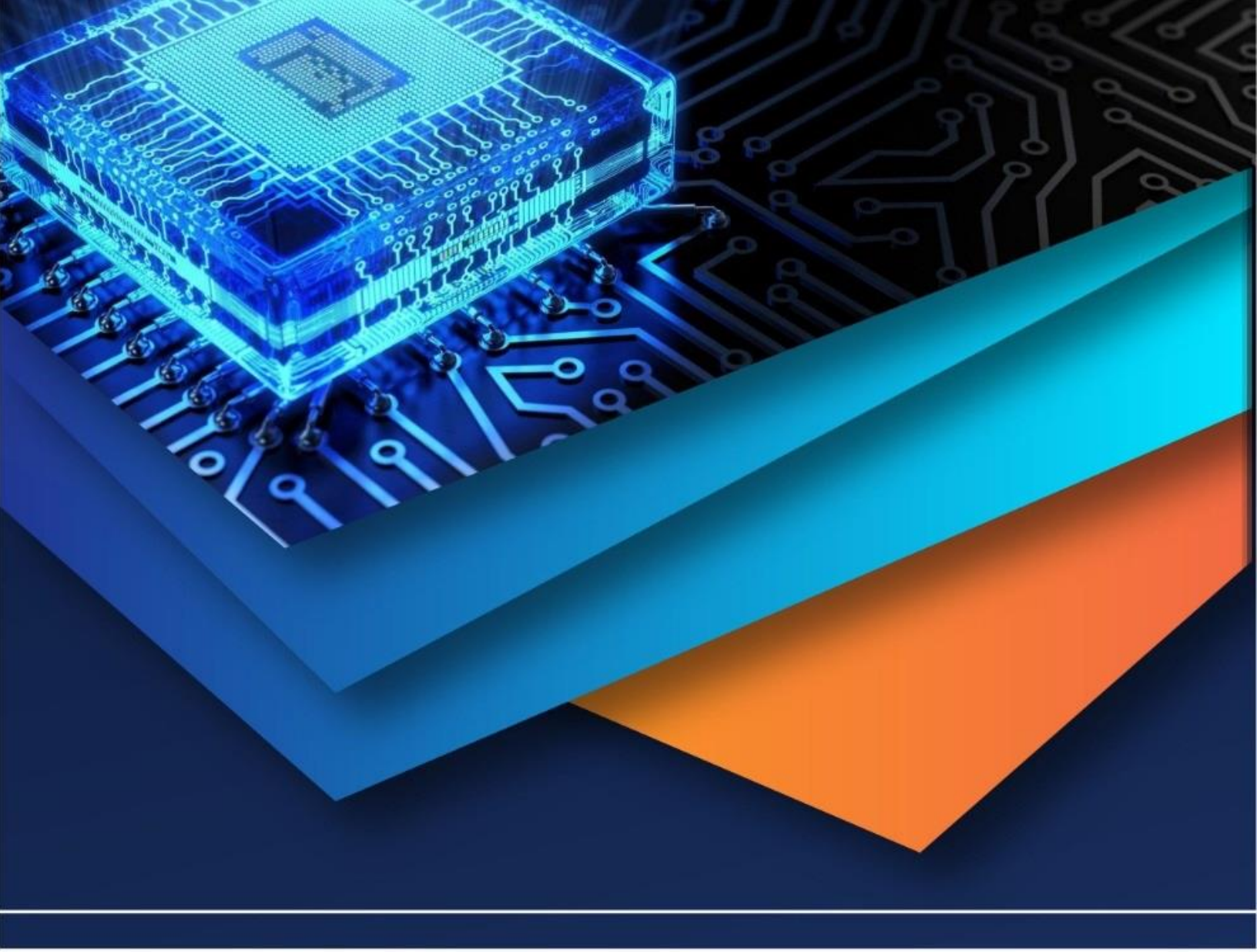
IX. ACKNOWLEDGMENT

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