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Automated Sanitary Napkin Vending and Smart Incineration with Energy Conservation

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Abstract: ***Access to sanitary napkins and their safe disposal remain practical problems in schools, hospitals, workplaces, and public places, where careless disposal causes odour, poor hygiene, and environmental pollution. This paper presents a prototype that addresses both needs in one system: an automated vending unit, and an incineration unit that recovers part of its waste heat as electricity. The vending unit is built around an ESP32 microcontroller that reads a push button, shows messages on an OLED display, and drives the dispensing mechanism. In the second unit, used napkins are burned in an enclosed chamber heated by an electrical heating element. Thermoelectric generator (TEG) modules in the heat path convert part of the heat into electrical energy through the Seebeck effect, while a cooling arrangement maintains the temperature difference across them. DC-DC converter circuits regulate the output before it is stored in a rechargeable battery through a charging module. In prototype tests, the vending unit demonstrated push-button interaction, display feedback, and servo-driven dispensing, the incinerator burned the napkins placed in it, and the TEG assembly gave a regulated DC output of 4.58–5.01 V after boost conversion. The tests were prototype-level, and payment integration, IoT monitoring, and emission control are left for future work.***

Keywords: Automated vending machine, ESP32, sanitary napkin disposal, incineration, thermoelectric generator, Seebeck effect, waste heat recovery, energy conservation.

I. INTRODUCTION

Menstrual hygiene management depends on two things that are easy to overlook outside the home: having a napkin when it is needed, and having a safe way to dispose of it afterwards. Schools, colleges, hospitals, workplaces, and public places often lack one or both. Where napkins are not within reach, people are inconvenienced; where no disposal facility exists, used napkins are left in open bins or unsuitable places, which creates odour, hygiene problems, and environmental pollution.

Researchers have approached this problem from several directions. Sanitary napkin vending machines have developed from coin-operated dispensers [1] into microcontroller-based, cashless, and cloud-connected designs [2], [3]. Incinerators built for sanitary waste use electrical heating and temperature sensing to burn used napkins on site [4], [5]. Thermoelectric generators (TEGs), which turn a temperature difference into a voltage through the Seebeck effect, have been studied as a way to recover waste heat [6], [7]. Section II reviews this work in more detail.

Most of these studies, however, address only one function at a time. A vending machine does not help with disposal, an incinerator releases its heat into the surroundings, and TEG studies are seldom tied to sanitary waste. To the best of our review, none of the surveyed works combines automated vending, on-site incineration, and heat recovery in one compact system.

This paper presents the design and prototype implementation of such a system. An ESP32 microcontroller runs the vending unit, which takes input from a push button, gives feedback on an OLED display, and drives the dispensing mechanism. A second unit burns used napkins in an enclosed chamber, and TEG modules with a cooling arrangement convert part of the heat into electricity, which is regulated by DC-DC converters and stored in a battery. The contributions of this paper are: (i) an ESP32-based sanitary napkin vending unit; (ii) a heating-element incinerator for used napkins; (iii) TEG-based recovery of waste heat with a cooling arrangement; and (iv) regulated storage of the recovered energy in a rechargeable battery. The rest of the paper is organized as follows. Section II reviews related work, Section III defines the problem and objectives, Section IV describes the system architecture, Section V explains the methodology, Section VI presents the results, and Section VII concludes.

II. RELATED WORK

Earlier work related to this project falls into four groups: vending and dispensing systems, sanitary waste incinerators, thermoelectric heat recovery, and combined systems. This section reviews each group and identifies the gap that the proposed system addresses.

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A. *Vending and Dispensing Systems*

Priya et al. [8] reported a microcontroller-based machine for sanitary napkin vending and disposal. Anitha and Chaithanya [1] built a coin-operated dispenser with infrared stock sensing, which is inexpensive but has no digital payment. Babu et al. [9] added RFID authentication and GSM messages that report stock status, so the machine can be monitored from a distance. Sarat et al. [3] used a Raspberry Pi with QR-code payment and a cloud inventory database for remote stock management, while Aher et al. [2] used an ESP8266 with UPI payment and a motorized dispensing mechanism to obtain a low-cost cashless machine. Charan Kumar et al. [10] controlled transactions with a finite state machine, a keypad and display, and QR payment verification, but their design does not work offline. Hassan et al. [11] combined RFID, mobile payment, and edge computing for faster contactless dispensing, and Rao et al. [12] proposed a solar-powered IoT machine with battery storage and stock alerts for off-grid locations. Harshavardhan et al. [13] used a Raspberry Pi, QR codes, and a camera in a multi-purpose vending machine that includes a Peltier-based locking arrangement for disposal. These works improve payment, inventory handling, and monitoring, but, as described, none of them recovers energy from waste heat.

B. *Sanitary Waste Incinerators*

Gopikadev et al. [4] developed a high-temperature sanitary napkin incinerator with electronic temperature control, which disposes of waste effectively on site. Chettri et al. [5] built a semi-automatic electrical incinerator using an Arduino, a K-type thermocouple, and closed-loop heating, although loading and ignition remain manual. Chourasia et al. [14] produced a portable, low-cost incinerator, and Ugale et al. [15] designed a durable refractory-chamber domestic unit for rural use that operates at about 420 °C; both rely on manual control, and neither filters the exhaust nor recovers heat. Reddy et al. [16] analysed the thermal performance and emissions of sanitary pad incinerators and reported that temperatures above 600 °C are needed to destroy the polymer content completely, which shows why the chamber temperature has to be controlled carefully.

C. *Thermoelectric Heat Recovery*

Zhang et al. [17] reviewed advanced thermoelectric materials and analysed their efficiency in terms of the figure of merit ZT, showing that better materials raise performance, although they did not build a complete system. Park et al. [6] surveyed TEG performance, thermal impedance, and the effect of operating temperature differences; they describe TEGs as durable solid-state converters whose commercial efficiency is still limited. Wang et al. [18] reported efficiency gains of 50–150% from improved cold-side cooling on industrial exhaust, but their approach is complex for a small incinerator. Mishra et al. [7] fitted TEG modules to an incinerator exhaust and showed that useful thermal power generation is feasible; their work, however, is not specific to sanitary waste and has no vending function.

D. *Combined Systems*

Gawande et al. [19] proposed a compact unit that combines a vending machine with an incinerator and IoT monitoring, but it does not recover heat. Shreeshayana and Fathima [20] combined an RFID vending machine with a high-temperature incinerator, giving a dual-function hygiene system, but at the cost of high power consumption and without IoT monitoring or energy recovery.

E. *Research Gap*

Table I compares the most closely related systems with the proposed one. To the best of our review, none of the surveyed works combines (i) automated sanitary napkin vending, (ii) on-site incineration of used napkins, (iii) thermoelectric recovery of the heat produced, and (iv) regulated battery storage of the recovered energy in a single system. This is the gap that the proposed system is designed to fill.

TABLE I
COMPARISON OF SELECTED RELATED WORKS

Ref.	Key feature	Limitation
[19]	Combined vending and incinerator with IoT monitoring	No thermoelectric heat recovery
[20]	RFID vending with high-temperature incinerator	High power consumption; no IoT or energy recovery

Ref.	Key feature	Limitation
[7]	TEG modules on incinerator exhaust	Not specific to sanitary waste; no vending
Proposed	ESP32 vending unit, incinerator, TEG recovery with cooling, battery storage	Prototype-level testing; payment and IoT monitoring not yet implemented

III. PROBLEM IDENTIFICATION AND OBJECTIVES

A. Problem Identification

Sanitary napkins are not always available in public places when they are needed, and traditional distribution depends on manual handling, which is inconvenient. Disposal is a bigger concern: many public places have no dedicated facility for used napkins, so they are discarded improperly, creating unhygienic conditions, unpleasant odour, and environmental pollution. Incineration solves the disposal problem, but the heat it produces is normally released into the surroundings unused. Part of this heat could be recovered as electrical energy, which then has to be regulated and stored before it can be used.

B. Objectives

The objectives of this work are to:

- To develop an automated vending machine using an ESP32 microcontroller for convenient dispensing of sanitary napkins.
- To provide a dedicated incineration facility for the hygienic disposal of used napkins.
- To reduce the volume of sanitary waste through controlled high-temperature combustion.
- To recover a portion of the heat released during incineration using TEG modules and convert it into electrical energy through the Seebeck effect.
- To maintain a suitable temperature difference across the TEG modules using a cooling arrangement.
- To regulate the generated energy and store it in a rechargeable battery, supporting energy conservation and sustainable sanitary waste management.

IV. PROPOSED SYSTEM ARCHITECTURE

Fig. 1 and Fig. 2 show the block diagrams of the proposed system. It has two units: an automated vending unit, and an incineration and energy conservation unit.

A. Vending Unit

The ESP32 microcontroller is the main controller of the vending unit. A push button provides the user input, and an OLED display shows the information the user needs, including the QR-code stage of the transaction. On receiving the input, the ESP32 drives the motor mechanism, which dispenses a napkin through the outlet. A power supply feeds the controller and the other components. The QR display and payment block is drawn with a dashed link in Fig. 1 because the prototype demonstrates the display stage only; full payment verification is left as future work.

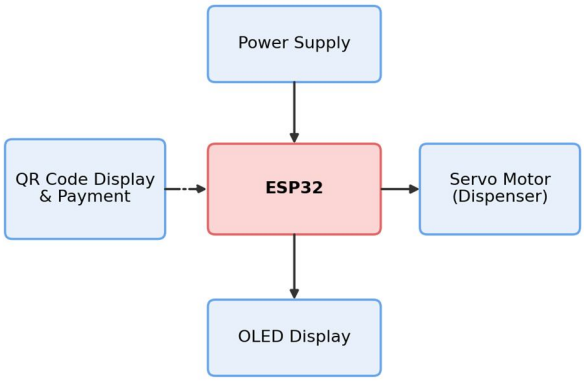

Fig. 1. Block diagram of the vending unit.

B. Incineration and Energy Conservation Unit

The hot unit contains the combustion chamber, a heating element, a manual feed opening, an exhaust fan, and its own power supply. Used napkins are fed in by hand and burned at high temperature. TEG modules sit between the hot unit and a cold unit, so heat flows through them from the chamber side to the cooling side. The cold unit, made up of a fan, a compressor, and a pump for water circulation, keeps the cold side of the modules cool and so maintains the temperature difference needed for the Seebeck effect. The electrical output of the TEG modules is regulated by DC-DC converters and passed to a battery charging module for storage. The exhaust fan carries the combustion gases out of the chamber, and the remaining ash is collected and removed manually after incineration. Together, the two units combine automated dispensing, sanitary waste treatment, thermoelectric energy conversion, and battery storage in one system.

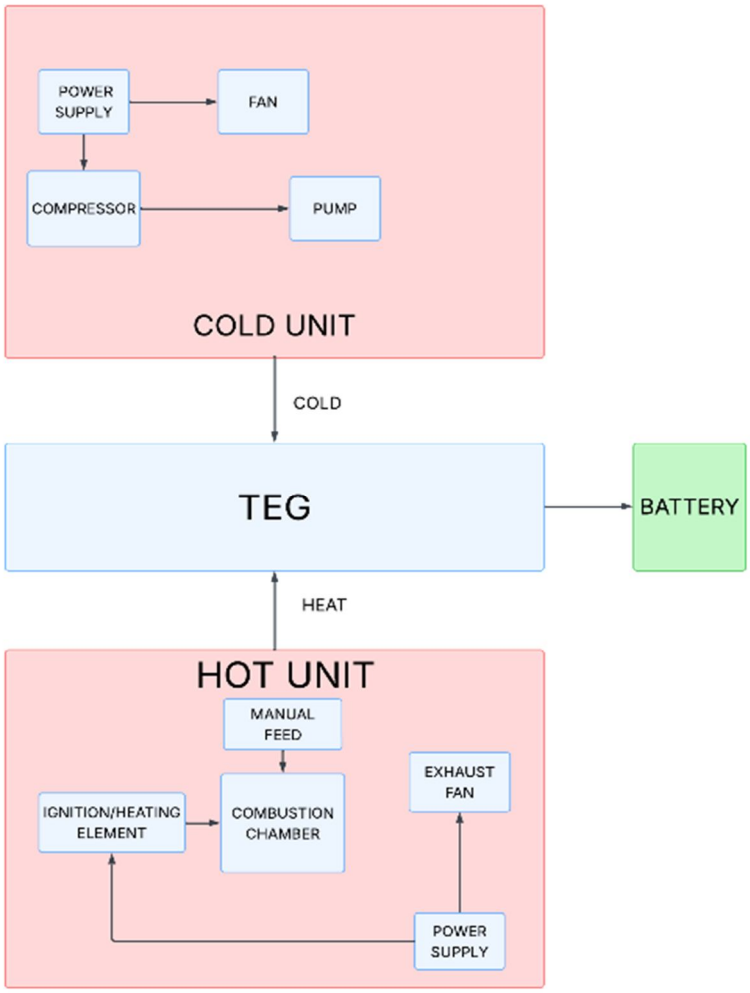

Fig. 2. Block diagram of the incineration and energy conservation unit.

V. METHODOLOGY

The working of the system is summarized by the flowcharts in Fig. 3 and Fig. 4. The two units are designed to be installed together: one dispenses napkins, and the other burns the used ones and recovers energy from the heat.

A. Automated Vending

When the user presses the push button, the ESP32 reads the input and moves to the QR stage. If a QR code is generated, the machine proceeds to payment and then activates the motor mechanism to release a napkin through the outlet; otherwise it reports that the machine is out of stock. The OLED display shows the status at each step (Fig. 3).

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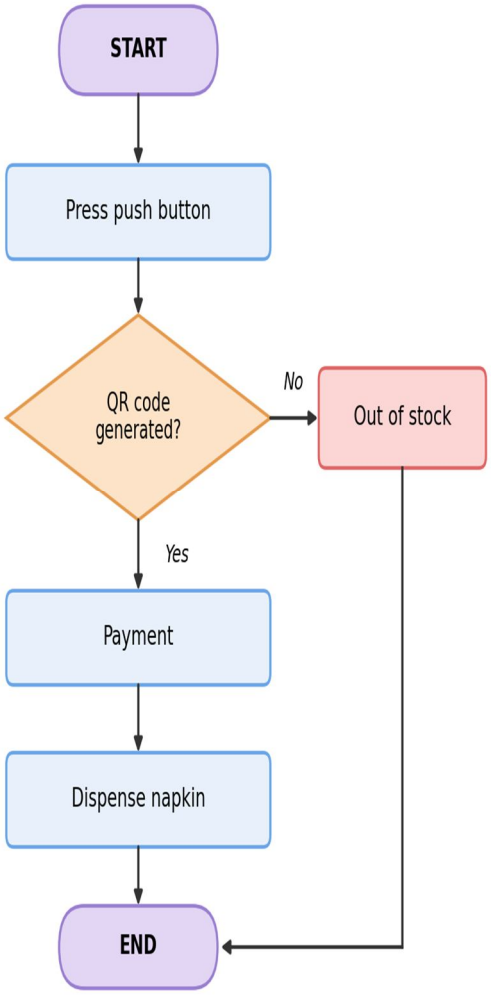

Fig. 3. Flowchart of the vending unit.

B. Incineration Process

After use, the napkin is placed manually inside the combustion chamber. The heating element raises the chamber to the required temperature, and the napkin is burned, which reduces its volume and leaves a small amount of ash (Fig. 4).

C. Thermoelectric Conversion and Cooling

TEG modules in the heat path convert part of the heat into electrical energy based on the Seebeck effect, in which a voltage appears across a material when its two sides are at different temperatures. A cooling arrangement of a heat sink, a cooling fan, and water circulation keeps the cold side cool, so that the temperature difference, and therefore the output, is maintained.

D. Regulation, Storage, and Exhaust Handling

The raw TEG output changes with the temperature difference, so DC-DC converter circuits regulate it to a voltage suitable for battery charging. The regulated output is supplied to the charging module and stored in a rechargeable battery. Combustion gases leave through the exhaust arrangement, and the ash is collected and removed manually after the process.

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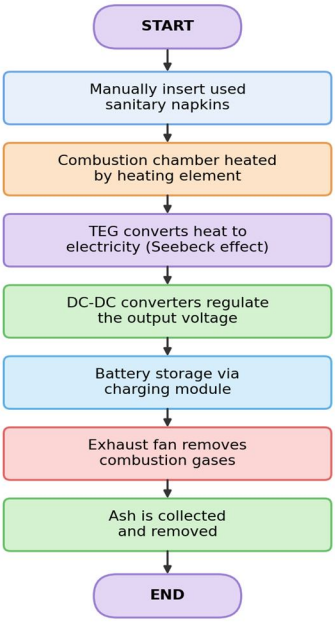

Fig. 4. Flowchart of the incineration and energy conversion unit.

VI. RESULTS AND DISCUSSION

The system was built as a prototype, and its units were tested as separate modules. Fig. 5 shows the vending unit, Fig. 6 shows the incineration setup, and Table II summarizes the observations. The vending unit consists of the ESP32 board, an OLED display, a servo motor that drives the dispensing mechanism, and a push button. The display showed a QR screen (Fig. 5(b)) and a thank-you message (Fig. 5(c)) during operation, and the servo actuated the dispensing mechanism. This confirms the ESP32-based control platform, the display feedback, and the push-button interaction described in Section V.

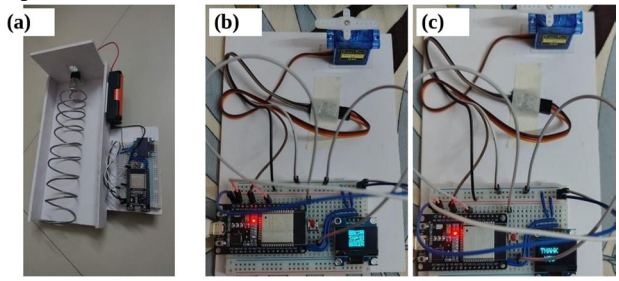

Fig. 5. Vending unit prototype: (a) dispenser with spiral holder, battery, and control board, (b) OLED showing the QR screen, (c) OLED showing the thank-you message.

In the incineration setup, used napkins placed in the perforated metal chamber were burned with the help of the electric heating element (Fig. 6(a) and 6(b)), and a cooling fan assembly was used for the cooling arrangement (Fig. 6(c)). In the thermal-energy experiment, the TEG assembly produced a regulated DC output of 4.58–5.01 V after boost conversion. The spread between these readings shows that the raw output is not constant, which is why regulation is needed before battery charging, and the values are close to the 5 V input commonly used by low-power charging modules.

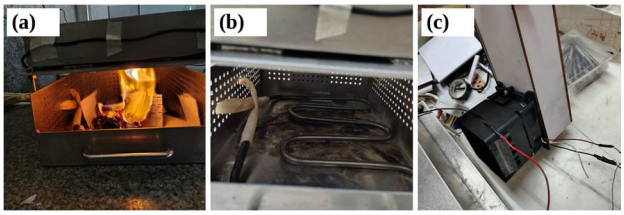

Fig. 6. Incineration setup: (a) napkins burning in the chamber, (b) heating element inside the chamber, (c) cooling fan assembly.

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TABLE II
PROTOTYPE TESTS AND OBSERVATIONS

Test case	Observation
Vending: user input	Push button interaction handled by the ESP32
Vending: display	OLED showed the QR screen and a thank-you message (Fig. 5)
Vending: dispensing	Servo-driven mechanism actuated for dispensing (Fig. 5)
Incineration	Used napkins burned in the heated chamber (Fig. 6)
TEG output	Regulated DC output of 4.58–5.01 V after boost conversion

These are prototype-level observations. The values reported for energy recovery are output voltages; a full characterization of output current, power, and conversion efficiency at different temperature differences, and validation of exhaust emissions, remain for future work.

VII. CONCLUSION AND FUTURE SCOPE

This paper presented the design and prototype implementation of an automated sanitary napkin vending machine combined with a smart incinerator that conserves energy. The vending unit, built around an ESP32, demonstrated push-button interaction, OLED feedback, and servo-driven dispensing. The incineration unit burned used napkins in a heated chamber, and the TEG assembly with boost conversion gave a regulated DC output between 4.58 V and 5.01 V. These results show that automated dispensing, hygienic waste treatment, and waste heat recovery can be brought together on one compact platform, although the tests were prototype-level. The system is suited to schools and colleges, hospitals and clinics, public places and transit facilities, hostels, offices and factories, residential apartments, rural waste-management installations, and smart-city hygiene infrastructure.

In the future, the system can be extended with cloud-based stock monitoring, QR/UPI payment integration, inventory sensing, and load-cell-based triggering of the incinerator. Better temperature control and feedback in the chamber, flue-gas filtration, and validated emission measurements would make it suitable for larger public deployment. The TEG output can be raised by optimizing cold-side cooling and thermal coupling, and a solar photovoltaic hybrid supply could complement the TEG during low-combustion periods. Camera-based machine-learning waste detection could identify napkin insertion and reduce the entry of non-sanitary waste, and a compact sheet-metal enclosure would support commercial-scale deployment.

VIII. ACKNOWLEDEGMENT

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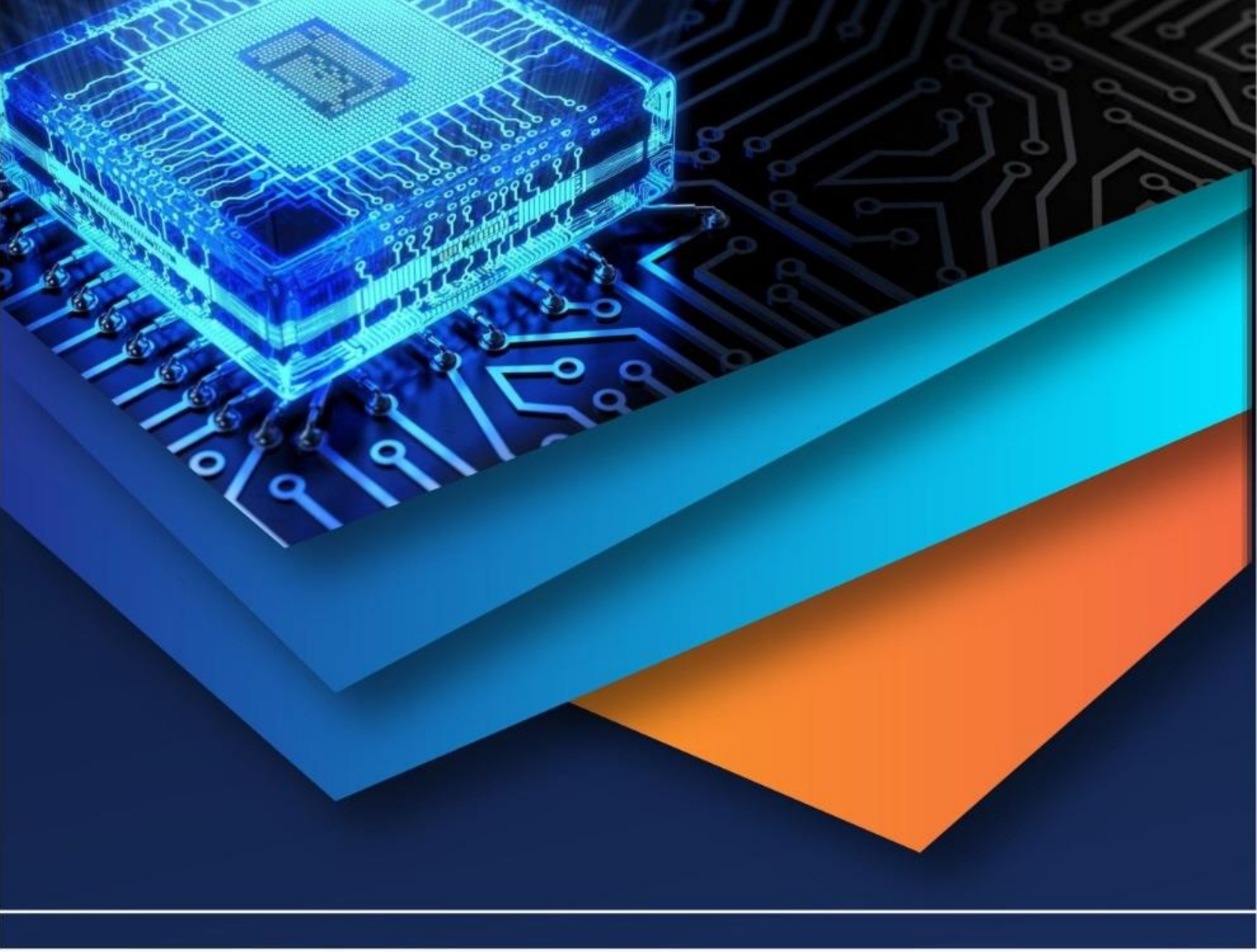

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