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A Cost Effective IOT Solutions for Energy Usage Management

Prof. Prachiti Adghulkar[1], Shreya P.Bangde[2], Khushi A.Kokode[3], Khushi G.Urade[4], Vaishnavi R.Kharwade[5], Sonam K.Bhoriya[6]

[1, 2]*AssistantProfessor,* [3, 4, 5, 6]*ResearchScholar, Department of Information Technology, Govindrao Wanjari College Of Engineering and Technology, Nagpur, Maharashtra, India*

Abstract: ***Thepaperfocusonthedevelopmentofan'ACostEffectiveIOTSolutionsforEnergyUsageManagement '. With the growing demand of electricity its somewhere hard to manage the efficient energy. Traditional Meterswhichisfoundineverywhere nowadays requiremanualreadingandoftenleadtoerrorsanddelayin billing.Asmartenergyaddressedtheseissuesbyenablingreal-timemonitoring and automated-billing. Bythe use of smart energy meter, it allow users to track their energy and get updated all time through an app or a web dashboard. The smart meter is recharged with the help of Esp module. In smart energy meter, energy utilizationand thecorrespondingamountwillbedisplayedonthe LCDasaremainder. Thefeedbackfromtheuserhelp sinidentifyingtheusagesbetweenauthorizedandunauthorizeduserswhichhelpsincontrollingthe power wastage. Esp module is used for sending messages to the local authorities regarding user power consumptions. Also they canmonitor themeterreadingsregularly withoutmakingeffor tstovisiteachhouse fortakingmanualreadings. Thistechnologynotonlyreducethehuman effortsbutalsopromotesenergyconservationby allowing andencouraginguserstomonitorandoptimizetheir energyconsumption.***

Keywords: Espmodule,Arduino,Smartmeter,Display

I. INTRODUCTION

Electricity is an essential part of our daily lives, but managing energy consumption efficiently can be a challenge. Traditional energy meters require manual readings, which can lead to errors, delays in billing. With the advancetechnology, cost effective smart energy meters are transforms the way we monitor and manage electricity usage. Our policies of its distribution are partially responsible for this because we are still not able to correctly estimate our exact requirement and still power theft is prevailing. On the other hand, consumers are also not satisfied with the services of power companies. Most of the time they have complaints regarding statistical errors in the monthly bills. With this we can monitor meter and track if any fault is there or not. In previousmeteracircularmetalstrip rotatesand according tothatrotation wecalculatetheconsumption.Butour meter works on pulse which is obtained with the help of LDR sensor according to consumption and we previously connected Arduinoboardwhich monitorthepulseand accordingto pulsethebillisgenerated.Inthis way we can reduce human efforts needed to record the meter readings which are till now recorded by visiting every home individually. Smart energy meter is an electronic device that measures the most accurate amount of electricity consumed by a residence, business or any electrically-powered device. A smart energy meter is a moderndevicethatconnectsto theinternetand allowsusersto track theirelectricity consumption inrealtime. It automaticallyrecordsenergy usageandsendsthedatatoacloud-basedsystem, whichcanbeaccessedthrougha smartphone appor webdashboard. Thismeansuserscan monitor theirenergy consumption anytimeandreceive alerts if they are using too much power. By using IoT-based smart meters, both consumers and electricity providers can save time, reduce costs, and contribute to energy conservation, making our homes and cities smarter and more sustainable. The system can generate usage reports, compare current usage with past consumption, and even suggest ways to reduce energy costs. For industries and commercial buildings, this feature is extremely valuable as it helps identify energy leaks and inefficiencies that would otherwise go unnoticed.Theypromoteenvironmentalsustainability byencouragingenergyconservationandreducingcarbon footprints. With more people adopting renewable energy sources like solar panels, these meters can also track how much energy is being produced and fed back to the grid.

II. LITERATURERE VIEW

Sr. No.	Author(s)	Year	Title	Objective	Features&Scope

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1	A.Smithetal.	2020	An IoT-Based Smart Energy MeterWithReal- Time PowerTracking System	Real-timepower trackingand efficientbilling.	Real-timemanagementfor residential and industrial use.
2	M.Kumar,N.Gupta	2020	A Novel IoT- based Smart Energy Meter for ResidentialEnergy Managementin Smart Grid Infrastructure	Integratesmart grids with energy meters for enhanced energy management.	Load balancing, real-time usage monitoring.
3	IOSRJournals	2020	IoT-BasedEnergy Meter Analysis Using Real-Time Data Monitoring	Improve monitoring accuracyusing IoT.	Real-timedatacollection with cloud integration.
4	E.H.MatSaat Majjid M.A, Noor HasizaAbdul, NorhalidaOthman	2021	SmartElectricity Meter Data Intelligencefor FutureEnergy Systems:ASurvey	Future-ready smart meter solutions.	Dataanalyticsfor predictiveenergy consumption.
5	DevakiMohan anarangam, K.B.Jayanti,Praveen Rajendra	2021	Energy Meter basedWireless MonitoringSystem using IoT in Residential Areas	Provide users with clear energy usage data.	Remote energy monitoringusingwireless networks
6	M.Ali,S.Khan,etal.	2023	Energy Meter BasedWireless MonitoringSystem Using Blynk Application via Smartphone	Smartphone- based energy monitoring.	Wireless energy usage trackingandmonitoring viaapps.
7	Muhammad Aqeeel, Hammad Shahab, Muhammad Haris Naeem, AliShahazad	2023	Asmart home energy management systemusingIoT and big data analytics approach	Optimizedhome energy management	Bigdata-driveninsights forefficientenergyuse.
8	P.Sinha,R.Joshi	2023	IoTEnabledSmart Energy Meter for Energy Management	Improve efficiency in energy management.	Real-time load analysis andcontrolmechanisms.
9	S.Roy,D. Chakraborty	2024	IoT—A PromisingSolutiontoEnergy Managementin SmartBuildings: A Systematic Review	Smartenergy solutions for buildings.	Reduced energy costs, enhancedbuildingenergy efficiency.
10	ManishTejaswini, PrachiParagRane Moin Syed,Oyesh Patel	2024	IOT-BasedSmart Energy MeterforEfficient EnergyUtilization in Smart GRID	Efficientenergy utilization.	Automatedbilling,user notification via GSM.

Table1:LiteratureReview

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III. METHODOLOGY

ARDUINO UNO : The Arduino Uno is an open-source microcontroller board based on the Microchip ATmega328Pmicrocontroller.Theboardhas14digitalI/Opins(sixcapableofPWMoutput),6analogI/Opins, that maybeinterfacedtovariouscircuitsandisprogrammable with theArduinoIDE,via atypeBUSBcable. It can be powered by the USB cable or by an external 9- volt battery, though it accepts voltages between 7and 20 volts.

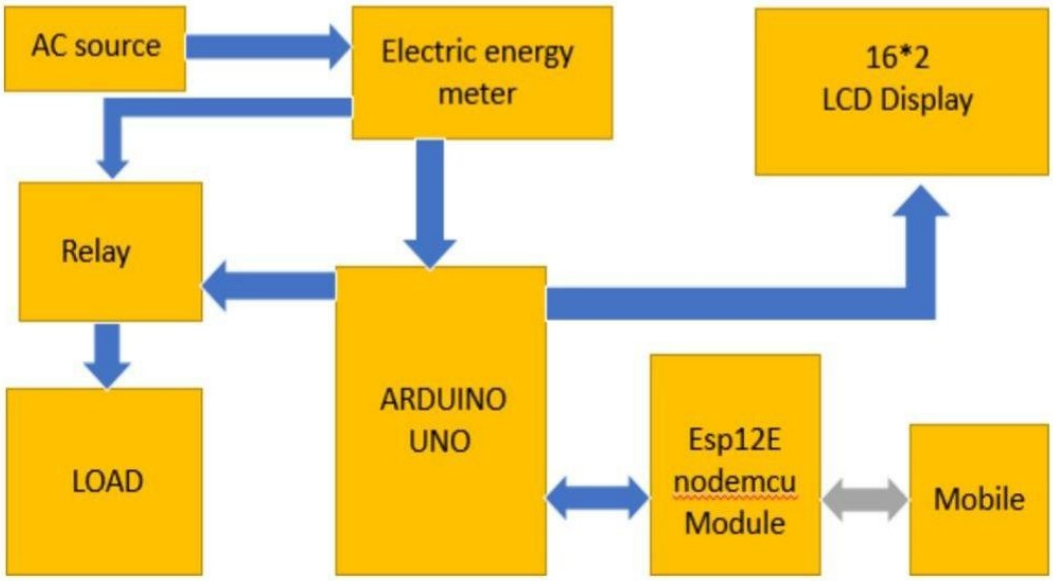
ESP12E NODE MCU MODULE : Node MCU is an open source development board and firmware based in the widely used ESP8266 -12E WiFi module. It allows you to program the ESP8266 WiFi module with the simple and powerful LUA programming language or Arduino IDE. Ai-Thinker's ESP-12E is a Wi-Fi Module based on ESP8266EX So C. The ESP8266EX SoC is a Wi-Fi chip based on Tensilica's L106 Diamond 32-bit Processor and an integrated Wi-Fi MAC, with support for full TCP/IP Stack. Since it has a Microcontroller the ESP-12E canbeusedaseitherastand-alonedevicewithitsWi-FiconnectivityandGPIOPinsoritcanbeusedasa Wi-Fi adapter for other microcontrollers like Arduino, for example, through UART interface.

16x12 LCD : An LCD (Liquid Crystal Display) screen is an electronic display module and has a wide range of applications.A16x2LCDdisplayisverybasicmoduleandisverycommonlyusedinvariousdevicesandcircuits. A 16x2 LCD means it can display 16 characters per line andthereare2suchlines. InthisLCDeachcharacteris displayed in 5x7 pixel matrix. The16x2intelligentalphanumericdotmatrixdisplayiscapableofdisplaying224 different characters and symbols. This LCD has two registers, namely, Command and Data. Command register stores various commands given to the display.

OPTOCOUPLOUR: The4N35isanoptocouplerforgeneralpurposeapplication.Itconsistsof gallium arsenide infrared LED and a silicon NPN photo transistor. Whatanoptocouplerdoesistobreakthe connectionbetween signalsourceandsignalreceiver, soastostopelectricalinterference.Anopto-isolator(alsocalledanoptocoupler, photocoupler, oropticalisolator) isanelectroniccomponentthat transferselectricalsignalsbetweentwoisolated circuitsbyusinglight.Opto-isolatorspreventhighvoltages fromaffectingthesystemreceivingthesignal.

SINGLECHANNELRELAYDRIVER:TheSingleChannelRelayModuleisaconvenientboardwhichcanbeusedtocontrolhighvoltage,hig hcurrentloadsuchasmotor,solenoidvalves,lampsandACload.Itisdesignedto interface with microcontroller such as Arduino, PIC and etc..

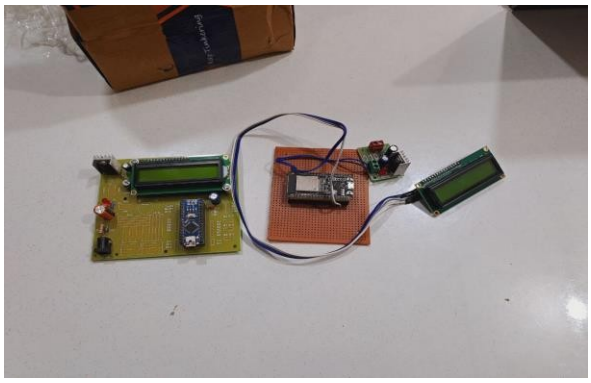
ENERGYMETER:An analog power meter is a device that features a printed display to indicateanyelectrical parameter. An example could be the energy consumed by a typical business, or electrical device. Also called an electromechanicalmeter, theseofferasimpletoreaddisplay. Theenergymeterisanelectricalmeasuringdevice, whichisusedto record Electrical Energy Consumed over a specified period of time in terms of units.



FigNo.1:BlockDiagramofSmartEnergyMeter

1) When the module is started with the initialization of the Wifi module (Esp12E nodemcu) and the LCD takes place first.
2) Thenitwillreadtheamountofbalanceavailableinthemoduleandcheckforthebalance.

3) A threshold value is set in the module here for example we have taken a balance greater than 10. If balance is notgreaterthan10itwillcheckanotherconditionifbalanceislessthan5ornot.Ifthebalanceislessthan5then the power will shut automatically.
4) If thebalance islessthan 10and greater than 5 the setupwill send an alert message to the user via the Esp12E nodemcumodule.Ifbalanceisgreaterthan10therelaywillturnONandunitsofelectricityconsumedsofarand the balance will be shown on the LCD screen.
5) If want the user can send a new message to the setup and add the amount recharged to the balance, if not the process will continue.



FigNo.2:ArduinoESP12E&Wi-fiModule

IV. TECHNOLOGIES

1) ARDUINOIDE:

TheArduinoIntegratedDevelopmentEnvironment-orArduinoSoftware(IDE)-containsatexteditorforwriting code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. The open-sourceArduinoSoftware(IDE)makesiteasytowritecodeanduploadittotheboard.Thissoftwarecanbe used with any Arduino board.

2) MOBILE APPLICATION:

Smartmetersprovide userswith mobileand web-based applicationsfor real-time monitoring,billing,alerts,and reports on energy consumption. These applications are typically designed with user-friendly dashboards. Integrationwithsmartphonesandemail systemsenablesuserstoreceivenotificationswhenenergyconsumption exceeds predefined thresholds or when unusual activity is detected.

3) SMARTBILLING:

Automatedbillingfeaturesenableprecise,realtimebillingbasedonenergyconsumption.Thesystemcandetectdiscrepanciesinreadingsando ffertransparent,up-to-datebillinginformationtousers.Insomeadvancedsystems, blockchain technology may beincorporated to secure and automate transactions, ensureaccurate billing, and allow peer-to-peer energy trading.

4) POWERSUPPLY:

Since energy meters need to be reliable and energy-efficient, the system components (like sensors and wireless communication modules) are designed for low-power consumption, often using battery or energy-harvesting methods for operation.

5) SECURITYTECHNOLOGY:

To ensure secure transmission of data, encryption protocols such as TLS (Transport Layer Security) or AES (Advanced Encryption Standard) are employed to protect data while it's in transit.

V. APPLICATIONS

1) REALTIMEMONITORINGFORENERGYCONSUMPTION:

IoT-based energy meters continuously track and send real-time data about electricity usage to a centralized platform or cloud server.

Users can view their energy consumption patterns in real-time via mobile apps or web dashboards, helping them make energy-efficient decisions.

2) REMOTEMETERREADING:

Utilitycompaniescanremotelyreadenergymeterswithoutrequiringphysicalvisitstoeachlocation.Thisisdonebywirelesslytransmittingdatafromtheenergymetertotheutility'sdatabase.Savesonlaborcosts,reduceshuman error, and ensures accurate billing.

3) AUTOMATICFAULTDETECTIONANDALERT:

IoT-enabled meters can detect faults or anomalies, such as power outages, over-consumption, or faulty connections, and send alerts to users and utility companies. Faster response times to issues, reducing downtime and improving service reliability.

4) LOADMANAGEMENT :

Smartenergymeterscan assistin load balancing by analyzing consumptiondata. They can send informationon peak usage times to utility companies, which can then implement measures like load shedding or load shifting. Ensures a stable supply of energy and helps prevent overloading of the power grid.

5) ENERGYTHIEFPREVENTION:

IoT-basedenergymeterscandetectirregularitiesliketampering,theft,orunauthorizedconsumptionbytracking usage patterns and comparing them to normal behaviour. Helps utility companies identify and prevent energy theft, reducing financial losses.

6) TIME-OF-USEPRICINGANDDYNAMICBILLING :

Smart meters can support time-of-use (ToU) pricing models, where consumers pay different rates based on the timeofdayorseasonwhentheyconsumeelectricity.Encouragesconsumerstouseenergyduringoff-peakhours, balancing the grid and reducing costs.

7) PREDICTIVEMAINTAINANCE:

Smartenergymeterscan collecthistorical data, which canbe analyzedusing AI and machine learning to predict when maintenance is needed before a failure occurs. Reduces downtime and extends the lifespan of energy infrastructure.

8) GRIDOPTIMIZATIONANDSAMRTGRIDINTEGRATION:

The data from smartmeters helps utility companies optimize grid operations by providing insights into demand patterns,enablingmoreaccuratepredictionsandbettergridmanagement.Moreefficientgridoperations,reducing energy waste, and improving grid reliability.

9) INTEGRATIONWITHSMARTHOMESANDBUILDING:

Smartmeterscanintegratewithhomeautomationsystems,allowinguserstocontrolenergyusagethroughsmartdevices,suchasthermostats,lights,andappliances.Enablesseamlessenergymanagement,contributingtogreater convenience and efficiency in home or building management.

10) ENERGYEFFICIENCYANDCONSUMPTIONANALYTICS:

By collecting and analyzing energy usage data, IoT-based meters provide insights into consumption trends and suggestareaswhereenergyefficiencycanbeimproved.Consumerscanoptimizetheirenergyuse,leadingtocost savings and reduced environmental impact.

11) EMVIRONMENTALIMPACTMONITORING:

By monitoring energy usage and comparing it with environmental standards or renewable energy sources, IoT- based meters can help reduce carbon footprints. Supports sustainable practices and compliance with environmental regulations.

12) CONSUMERENGAGEMENT:

IoT-based meters allow consumers to track their energy consumption, set goals, and receive recommendations on how to reduce usage. Promotes energy-saving behaviors and engages consumers in sustainable energy practices.

VI. CONCLUSION

"ACostEffectiveIOTSolutionsfor EnergyManagement",representasignificanttechnologicaladvancementin energy management, offering real-time monitoring, automated billing, and enhanced control over energy consumption. This energy management offer a smart and affordable way to save energy and reduce energy cost. By using connected sensors and smart meters or automations ,businesses and homes can track how much electricitytheyuseondailybasisandavoidenergywastage. Byintegratingwithsmartgrids, artificialintelligence, and data analytics, these meters empower consumers and utilities to make informed decisions, optimize energy usage, and reduce operational costs. This solutions not only help lower power bills but also support greener and moresustainablefuture.WiththefallingcostofIOTdevices andeasyaccesstocloudplatform,anditsnowmore practical then ever to adopt these technologieswithout spending too much. While challenges such as high initial costs, data security concerns, and infrastructure requirements exist, ongoing technological advancements and widespread adoption are expected to overcome these hurdles. Overall, IoT-based smart energy meters have the potentialtorevolutionizeenergy management,contributingto greaterefficiency,sustainability, andthefutureof smart cities. Overall, the IOT is providing to be a powerful and cost-effective tool for managing energy smartly and efficiently.

Furtherresearchcanbeconductedtoimprovethescalabilityofthesystem,makingitadaptableforusenotjust in homes but in large industrial and commercial environments. Integration with smart home devices and IoT- based appliances could automate power management further, allowing the system to control energy consumption intelligently based on user behavior and preferences.

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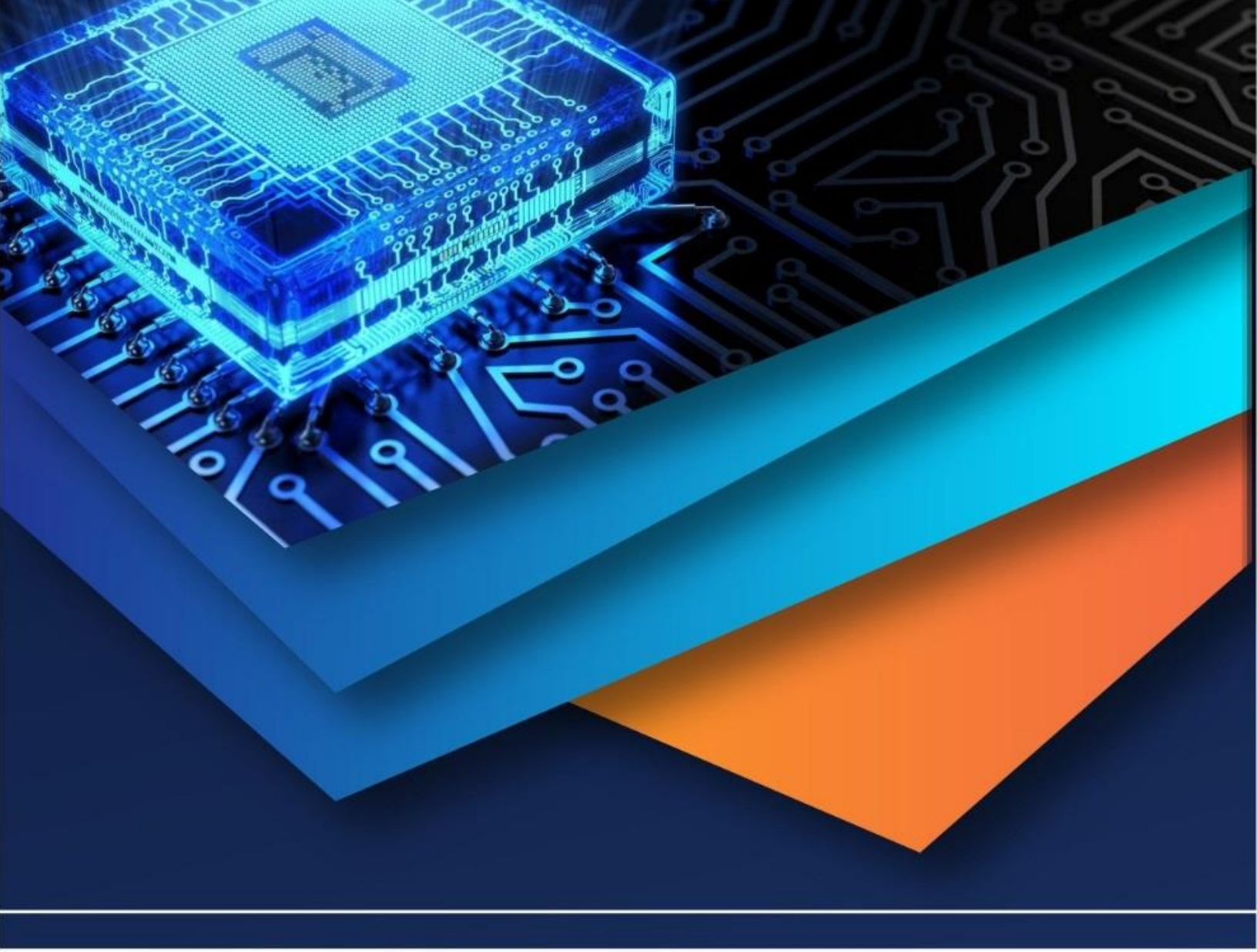

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