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Automated Sensor Network for Monitoring and Detection of Impurity in Drinking Water System

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Abstract-This paper describes a low cost and holistic approach to the water quality monitoring problem for drinking water distribution systems as well as for consumer sites. Our approach is to develop sensor nodes for real time and in-pipe monitoring, assessment of water quality on the fly and to calculate the amount of water delivered. The main sensor node consists of several in-pipe electrochemical and optical sensors and emphasis is given on low cost, lightweight implementation, and reliable long time operation. Such implementation is suitable for large scale deployments enabling a sensor network approach for providing spatiotemporally rich data to water consumers, water companies, and authorities. Based on selected parameters, a sensor array is developed along with several microsystems for analog signal conditioning, processing, logging, and remote presentation of data. Testing are performed to estimate and validate these calculated contamination events of various concentrations of escherichia coli bacteria and heavy metals (arsenic). Experimental results indicate that this inexpensive system is capable of detecting these high impact contaminants at fairly low concentrations.

Keywords:- Water quality monitoring, measurement system, turbidity sensor, multi-sensor system, arsenic&bacterial contamination detection.

I.INTRODUCTION

Drinking Water distribution systems are naturally sensitive to both intentional and accidental contamination. There are many points at which a contaminant may enter the spreading system. Conventional methods of water quality control requires the manual collection of water samples at various locations and at different times, followed by research lab analytical techniques in order to qualify the water tone. Such attacks are no longer considered efficient. Although, the actual methodology allows a thorough analysis including chemical and biological agents, it has several drawbacks. Contaminated water sources may contain traces of metals such as copper (Cu), zinc (Zn), lead (Pb), mercury (Hg), nickel (Ni), cobalt (Co) etc. and other major ions such as nitrate ($NO-3$), phosphate ($PO3-4$), ammonium ($NH4+$) etc. IN this paper, the magnetic field and electric field of the sensor are reactive to the metals and other major ions. Formal methods for detecting bacterial micro-organism are culture-based, requiring conventional laboratory settings utilizing bacterial surrogates or indicators, such as total coli form bacterium, fecal coli form bacterium or Escherichia coli. Hence there is a clear need for continuous on-line water tone supervising with efficient comprehensive resolution. The independent decision was that lots of the chemical and biological contaminants used bear an impression on many water parameters monitored including Turbidity (TU), Oxidation Reduction Potential (ORP), Electrical Conductivity (EC) and pH. Therefore, it is executable to monitor and infer the water tone by observing changes in such parameters. The main part of this paper is to formulate a low cost system that can be used at the prefaces of consumers to continuously monitor qualitative water parameters and fuse multi-parametric sensor response in order to evaluate the water consumption hazard. The contributions regarding the low cost system is the design and development of low cost networked embedded systems as well as optical sensors(turbidity) for water tone monitoring, the development of event detection algorithms using fusion techniques, database evaluation and proof of system performance in various concentrations of microbiologically (E.coli) and chemically (Arsenic) contaminated drinking water.

II. RELATED WORK

A preliminary version of this article has appeared in [1].In this article, we present an improved hardware platform, develop a new advanced contamination event detection algorithm and provide an experimental evaluation and validation of system and event detection algorithms in the presence of real microbiological and chemical contamination events. A limited number of on-line, reagentfree water monitoring systems are commercially available [2] (e.g. Hach HST Guardian Blue [3], J-MAR Bio Sentry [4], etc), but these systems are bulky (sensors are installed in flow cells located in cabinets) and remain cost prohibitive for large scale deployments (cost tens of thousands of dollars per unit). It is worth mentioning that cost is mostly attributed not to sensing probes but to instrumentation-automation controllers (analyzers) and panels. Such systems can take frequent samples of the water quality at a very limited number of locations. However, substantial proportion of contamination problems is attributable to problems within distribution systems and due to the limited spatio-temporal sampling, it is impossible for the water companies and consumers to know the quality of potable water delivered to consumer households. A number of bare multi-parametric sensor arrays have been developed and presented in the literature based on various sensor technologies. A recent review on multi-parametric solid-state sensors for water quality is given [5]. A chemical sensor array for water quality monitoring based on thick film technology is presented in [6], [7], [8], and [9], these sensors are very low cost, though they have limited lifetime (few months) and require a conventional glass reference electrode to operate accurately. Along similar lines, a multiparametric sensor array based on semiconductor ruthenium oxide nanostructures is presented in [3] and [9]. In addition, several water monitoring microsystems (sensor nodes) have been developed for large scale water monitoring based on wireless sensor networks (WSNs) technology. In a sensor node is developed for monitoring salinity in ground waters as well as the water temperature in surface waters.

III. METHODS

Normally the drinking water tone measures are determined according to World Health Organization (WHO) [10] guidelines for drinking-water tone as well as other pertinent systems. These systems set the standards for drinking water tone parameters and indicate which microbiological, chemical and indicator parameters must be monitored and examined regularly in order to protect the health of the consumers and to make sure the water is healthy and clean. Chief mechanism that is currently available to mitigate or reduce the effects of a contamination event in the distribution system is a contamination warning system (CWS). A contamination warning system is a combination of monitors, institutional arrangements, analysis tools, emergency protocols, and response mechanisms designed to provide early warning of contaminants in order to minimize customer exposure. The contamination warning system operation is given as follows.

A. Supervision and assessment

The basic factors of online water tone monitoring, sampling and analysis, enhanced security supervising, consumer complaint surveillance, and public health surveillance takes place on a routine basis, in near-real time until an anomaly or deviation from the baseline or base state is noticed.

B. Credible determination

Credibility finding procedures are performed using information from all contamination warning system elements as well as external resources when available and relevant. Whenever contamination is determined to be believable, additional confirmatory and response actions are originated.

C. Confirmed decision

In this stage of consequence management, additional information is gathered and assessed to confirm drinking water contamination. Response actions initiated during credible determination are expanded and additional response activities may be implemented.

D. Treatment and Retrievals

Once contamination has been confirmed, and the immediate crisis has been addressed through response (e.g., flushing, emergency warnings, etc.), remediation and recovery actions defined in the consequence management plan are performed to restore the system to normal operations. On-line monitors or sensors are widely considered as the primary means of detecting a potential pollution event in a distribution system. In order to reliably and efficiently notice potential contaminants, the monitors must be tender to the presence of a wide range of factors and there must be a sufficient number of appropriate monitors so that detection occurs in a timely manner. Historically, monitoring sites were taken primarily on the basis of informal selection criteria that reflected the representativeness and accessibility of the sites and the specific purpose(s) of the supervising system. The table in [1] shows the parameter to be measured. Convectional combined electrodes (for ORP and pH) have been widely used due to their good sensitivity, electivity, stability and long lifetime. Still convectional pH glass electrodes have various disadvantages due to the intrinsic nature of the glass membrane.

IV. DESIGN PROCESS

A. System and Sensors Development

The overall system architecture under discussion in presented in Fig. 1 and is comprised of the following three subsystems: a central measurement node (PIC16 MCU based board) that collects water quality measurements from sensors, and transmits data to other nodes, a control node ARM/Linux based platform) that stores measurement data received from the central measurement node in a local database and provides gateway to the internet, visualize data (charts), and sends email/sms alerts and finally a tiny notification node(s) (PIC MCU based board) that receives information from the central measurement node through an interconnected ZigBee RF transceiver and provides local water tank notifications to the user (water consumer) via several interfaced peripherals (LED, LCD,Buzzer).solenoid valve is used to close the main water valve from storage tank in case of any impurities found. The central measurement node serves as the sensor node. The idea is to install these sensor nodes in many consumer sites in a spatially-distributed manner to form a WSN that will monitor the drinking water quality in the water distribution system from the source to the tap.

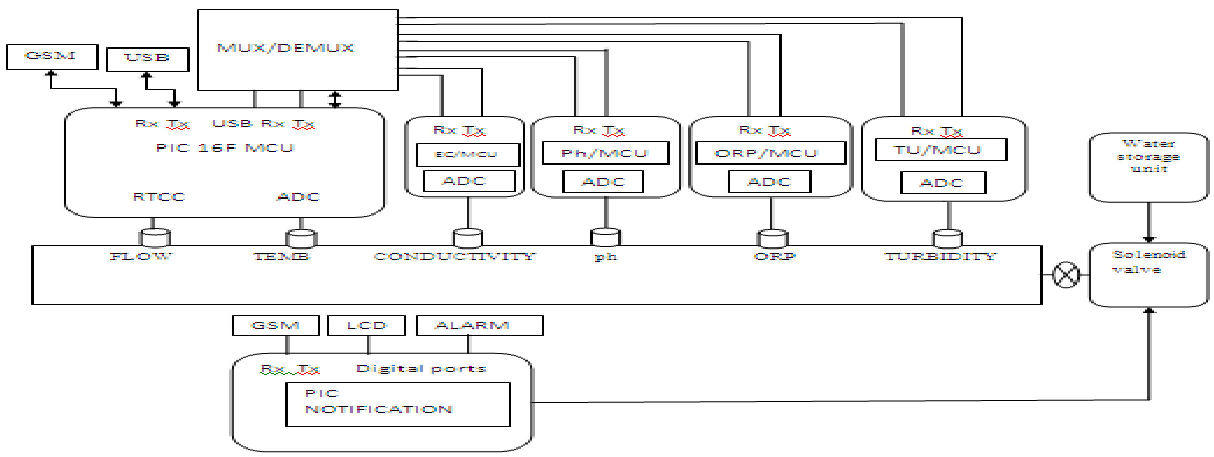

Fig-1.Overview of the system

The central measurement node is interfaced to multi-parameter sensor array comprised of Turbidity (TU), ORP, pH, Electrical Conductivity (EC) and Temperature (T) sensors. The inpipe Turbidity sensor is constructed from scratch based on our previous work [1] while the other sensor probes obtained from SensoreX Corp. The pH sensor embeds an RTD sensor which is used for temperature sensing and temperature compensation of pH and EC measurements. TU, ORP, pH and toroidal EC sensors have flat measuring surfaces for cost effective self-cleaning. The photo of the complete system with Turbidity (TU), ORP, pH, Electrical Conductivity (EC) and Temperature (T) sensors.Fig-2. Show different sensors.

A B C D

Fig-2. A.Turbidity sensor . B. Flat surface PTFE housing. C. Inline Tee fitting. D. Probe board.

B. Sensor development

Generally different type of turbidity measuring instruments existing on the market at the moment, most of them are expensive and not directly compatible with in-pipe, in-line requirements as well as WSNs technology. Therefore, the goal is to develop a low cost, easy to use and accurate enough turbidity sensor for continuous in pipe turbidity monitoring in water distribution systems using commercial off-the self-components. The turbidity sensor development was based on the ratio turbid meter design where both transmitted and scattered light intensities are measured to eliminate errors (interferences) due to IR emitter intensity drift and sample absorption characteristic. An infrared (860nm) narrow beam LED emits light through an optical gap to the water sample and two IR photodiodes separated around 1cm from the emitter receive simultaneously the 90o scattered and 0o transmitted light. The

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photodiodes spectral sensitivity is selected to fit with that of the IR light source. The instrumentation and analog signal conditioning of the sensor is as follows: The IR emitter is pulsed at 1 kHz with a square wave signal and the photodiodes convert the light directly into electrical current, then a high-gain, low-noise CMOS (Complementary metal-oxide-semiconductor) Trans impedance amplifier with background light rejection is used to convert the each photocurrent to voltage output. The ac output of each Trans impedance amplifier is then converted to a dc signal using a precision active peak detector. Finally the 90o Scattered dc signal is further conditioned by an instrumentation amplifier for 0 NTU offset nulling and additional amplification. The conditioned voltage outputs are then sampled by a 10 bit A/D converter with reference voltage of 1.1V and the sensor output voltage V = V90oc.V0o is given as the signal ratio of the scattered V90o to the transmitted V0o voltage, c is calibration coefficient. An indirect method for the sensor calibration was employed, in order to avoid the use of the carcinogen and expensive chemical formazin solutions. Therefore, a number of samples were created and the turbidity of each sample is measured both by the turbidity sensor under calibration and by a laboratory turbid meter (Lutron TU-2016) used as reference. Then the relationship between turbidity (in NTU) and the voltage output (in mV) of the turbidity sensor is extracted and given by TU = 0.1035V − 0.292. The sensor generates an output voltage proportional to the turbidity or suspended particles and has a linear response in the range of 0-100 NTU with 0.1 NTU resolutions. A dedicated PIC based Microsystems is developed for each parameter to accomplish this task. The first process of analog signal conditioning circuitry for each parameter is presented in Fig. 3.

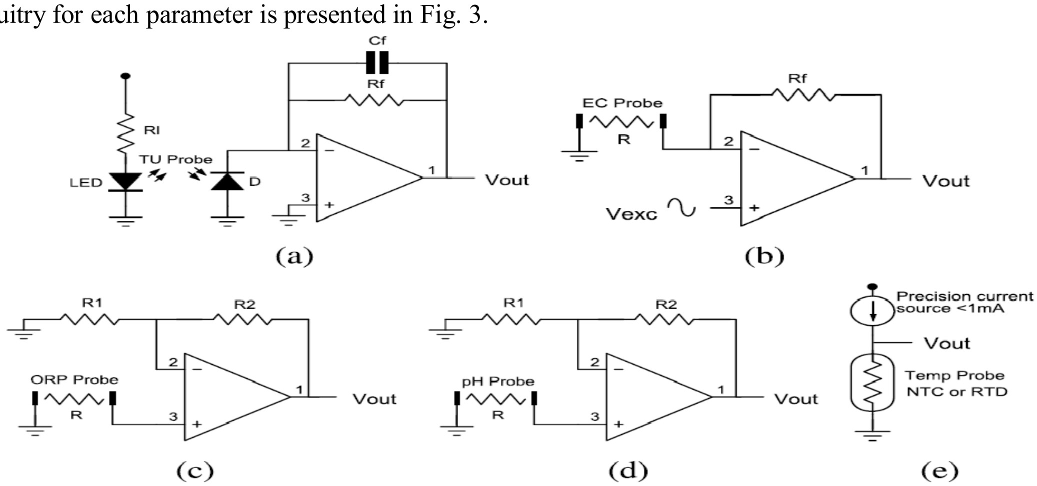

Fig-3. The first stage of analog signal conditioning circuitry.

(a) Turbidity preamplifier. (b) Conductivity preamplifier. (c) ORP preamplifier. (d) pH preamplifier. (e) Temp.

While Table I shows the results regarding laboratory evaluation (using standard buffer solutions and reference instruments) of each parameter along with the quality range suggested by WHO guidelines and EU standards.

Parameters	Measurement principle	Units	Range	Resolution	Accuracy	Quality range
Turbidity	Optical/infrared scattering	NTU	0-100	0.1	±0.5	0-5
ORP	Galvanic cell, platinum electrode	mV	-2000-2000	2	±10	600-800
pH	Galvanic cell, glass electrode	pH	0-14	0.05	±0.1	6.5-8.5
Conductivity	Conductive cell	µS/cm	100-20000	10	5%	500-1000
Conductivity	Inductive cell	µS/cm	200-3000	10	5%	500-1000
Temperature	RTD resistance	°C	-5-100	0.1	±0.1	-
Flow	Magnetic rotor, hall effect sensor	L/min	1-115	0.0015	15%	-

TABLE I*:* Specifications And Accomplished Performance For Each Monitored Parameter

The overall power consumption of the central measurement sensor node with the on board LEDs off and the RF transceiver module sending water quality data every 5s is about 50mA at 5V operating voltage. It worth mentioning that wireless communication is by far the largest consumer of the energy of the sensor node, compared to other functions such as sensing and computation.

V. EXPERIMENTAL PROOF

In this section we present the results of the experimental trials performed to validate the behavior and evaluate the performance of the developed hardware and algorithms on intentional contamination events. The experimental setup consists of the sensor node (central measurement node) that takes samples every 5s from potable water flowing through a flow cell. Intentional contamination of two important contaminants (Escherichia coli bacteria and arsenic) of various concentrations was injected at discrete time intervals and the performance of the event detection algorithms is evaluated on real time. Escherichia coli bacteria and arsenic contamination in drinking water is very severe problem causing serious poisoning to large numbers of people all over the world [11].

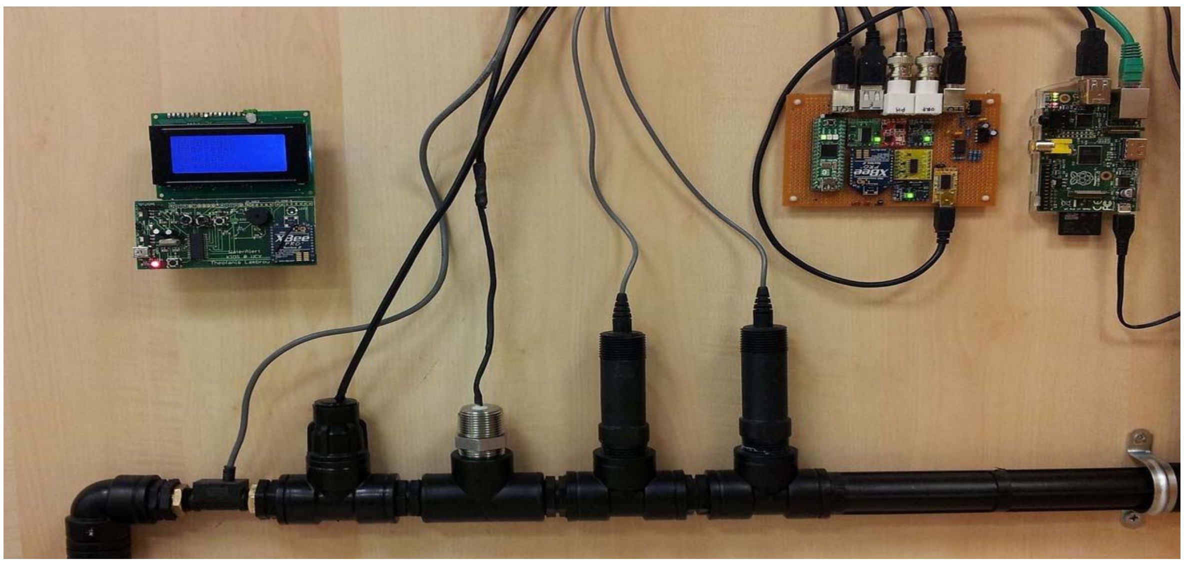

Fig-4 Complete system design

A. *Microbiologically (E.coli) Contaminate Drinking Water*

The first experiment considers the case of microbiologically (E.coli) contaminated drinking water. Most E. coli strains are in general harmless to humans, but some types can cause serious food and water poisoning. However, the presence of E.coli is used to indicate that other pathogenic organisms may be present (often of faecal origin). According to WHO guidelines & EU Drinking Water Directive E.coli parametric value is 0 CFU/100mL.

B. *Chemically (Arsenic) Contaminated Drinking Water*

The second experiment considers the case of chemically (Arsenic) contaminated drinking water[12]. Water contamination by toxic heavy metals and especially arsenic contamination is a common problem encountered in many countries due to undue deposition of mining, agricultural, industrial and urban wastes in water resources. Arsenic is known to affect negatively the mental and central nervous system function, to damage the blood composition, lungs, kidneys, liver, and other vital organs, as well as it contributes to certain neurological degenerative processes and causes skin cancer. According to WHO guidelines & EU Drinking Water Directive Arsenic parametric value is 10μg/L.

VI. CONCLUSION

In this paper, the design and development of a low costs system for real time monitoring of drinking water quality at consumer sites is presented. The proposed system consist of several in-pipe water quality sensors with flat measuring probes and unlike commercially available on closed loop system, it is low cost, lightweight and capable of processing, logging, and remote presentation of data. Such implementation is suitable for large deployments enabling a sensor network approach for providing spatiotemporally rich data to water consumers, water companies and authorities. In the future, we plan to investigate the performance of the fusion algorithm on intentional contamination events (biological, chemical, etc) and install the system in several locations of the water distribution network to collect spatiotemporally rich water quality data and characterize system/sensors response in real field deployments.

REFERENCES

[1] T. P. Lambrou, C. G. Panayiotou, and C. C. Anastasiou, "A low-cost system for real time monitoring and assessment of potable water qualityat consumer sites," in Proc. IEEE Sensors, Oct. 2012, pp. 1–4.
[2] M. V. Storey, B. Gaag, and B. P. Burns, "Advances in on-line drinking water quality monitoring and early warning systems," Water Res.,vol. 45, no. 2, pp. 741–747, Jan. 2011.
[3] Hach HST, Guardian Blue Early Warning System Brochure. Loveland, CO, USA: Hach Company, 2008.
[4] Bio Sentry Contamination Warning System Overview, JMAR, Wyoming ,MI, USA, 2006.
[5] S. Zhuiykov, "Solid-state sensors monitoring parameters of water quality for the next generation of wireless sensor networks," Sens. Actuators B, Chem., vol. 161, no. 1, pp. 1–20, 2012.
[6] M. Sophocleous, M. Glanc, Monika, J. Atkinson, and E. Garcia-Breijo, "The effect on performance of fabrication parameter variations of thick-film screen printed silver/silver chloride potentiometric reference electrodes," Sens. Actuators A, Phys., vol. 197, pp. 1–8, Aug. 2013.
[7] J. Atkinson, J. M. Glanc, M. Prakorbjanya, M. Sophocleous, R. Sion, and E. Garcia-Breijo, "Thick film screen printed environmental and chemical sensor array reference electrodes suitable for subterranean and
[8] subaqueous deployments," Microelectron. Int., vol. 30, no. 2, pp. 92–98, 2013.
[9] R. M. Manez, J. Soto, E. G. Breijo, J. I. Civera, and E. G. Morant, "System for determining water quality with thick-film multisensor," in Proc. Spanish Conf. Electron Devices, Feb. 2005, pp. 607–610.[9] R. Martinez-Manez, J. Soto, E. García-Breijo, L. Gil, J. Ibanez, and E. Gadea, "A multisensor in thick-film technology for water quality control," Sens. Actuators A, Phys., vol. 120, no. 2, pp. 589–595, 2005.
[10] Guidelines for Drinking-Water Quality, World Health Organization, Geneva, Switzerland, 2011.
[11] D. Hart, S. McKenna, K. Klise, V. Cruz, and M. Wilson, "CANARY: A water quality event detection algorithm development tool," in Proc.
[12] World Environ. Water Resour. Congr., 2007.
[13] J.Ramprabu and C.Paramesh "embedded based real-time monitoring and contamination detection in drinking water distribution system" (IJETTCS) Vol 3, Issue 5, September-October 2014 ISSN 2278-6856.

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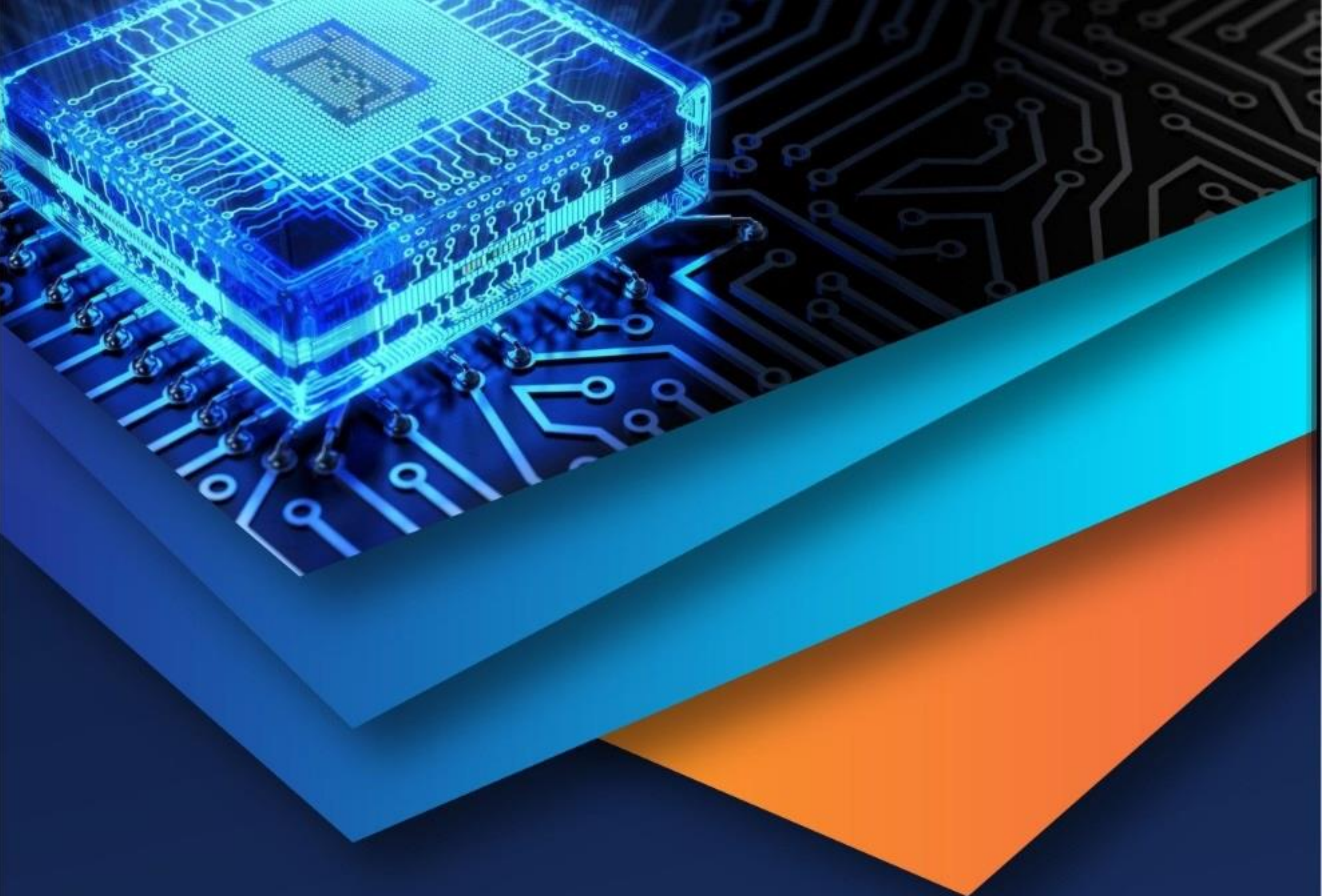

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