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Low Cost Mechanical Ventilator with Controlled PEEP

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Abstract: This paper mainly focuses on the development of an efficient and adaptable breathing cycle for the patients who are suffering from respiratory problems. A precise and efficient lung circuit is designed by using MATLAB software. By considering the present circumstances caused by the COVID-19 pandemic, led to shortage of ventilators, numerous prototypes of low-cost ventilators are designed across the world [9]. The prime drawback with the low cost ventilators is that there is no peep control causes lung damage and has higher probability of causing Barro trauma this results high sedation to the patient, present model designed by producing a controlled peep that could provide better help to affected lungs.
Keywords: MATLAB, Peep control, Efficient, Barro trauma, flow and pressure triggered

I. INTRODUCTION

As one of the most common hospital instruments, ventilators are widely and mostly commonly used, to maintain sufficient oxygen for patients. Currently, there are many ventilation machines and they can be categorized into three types according to their function and method of operation: positive pressure, negative pressure, and high-frequency ventilators. [1]

Patients affected with Covid-19 have weaker lungs. More caution is necessary while providing ventilation. In mechanical ventilation the lungs are blown like a balloon. And hence might damage the alveoli. Mechanical ventilator is a device used for medical purpose which is usually utilized to ventilate patients who cannot breathe adequately on their own.it generally works on a principle where it gathers all the outdoor air into a building or a room, the main purpose of ventilation is to provide a healthy air by removing all the pollutants that may arise from the surroundings. People require ventilator when the person cannot get enough oxygen

There are several ways a person can receive ventilator support they include Face mask ventilators, mechanical ventilators, manual resuscitator bags, tracheostomy ventilators

A face mask ventilator is a non-invasive method of supporting a person's breathing. People with COVID-19 may use a face mask ventilator if they are facing any difficulty in breathing or if they do not have sufficient oxygen levels.

Mechanical ventilators are machines that completely take over the breathing process. It is used when a person cannot breathe on own.

Manual resuscitator bags are kind of equipment that allows people to control the airflow of their ventilator with their hands it has an empty bag which has to be pumped to pump air into the person lungs, This can be useful as temporary solution when there is a power outage, the person can use the manual resuscitator till the power comes back online.

Tracheostomy ventilators People who have undergone a tracheostomy require a different type of ventilator. A tracheostomy is a procedure where a doctor creates an opening in the windpipe and inserts a tube, which allows air to flow in and out. This enables a person to breathe without using their nose or mouth.

As one of the most common hospital instruments, ventilators are widely and mostly commonly used, to maintain sufficient oxygen for patients. Currently, there are many ventilation machines and they can be categorized into three types according to their function and method of operation: positive pressure, negative pressure, and high-frequency ventilators. [1]

It is clear that the respiratory rate of a child is faster than an adult. Out of them, paediatric (6-11 years aged) persons have the respiratory rate (RR) of 18-25 per minute. [2]

Triggering breathe cycle-Breathing cycle must be triggered based on the patient's comfort.

1) Pressure triggered (cmH2O)
2) Flow triggered (L/min)
3) Electrical activity triggered

Mechanical ventilation is an advanced respiratory therapy that is increasingly popular, and mechanical ventilation is a very powerful and effective means of saving lives because it maintains vital breathing functions in an artificial way

Mechanical ventilation can be performed using one of the three principles, from the fig.1 we observe a waveform of **IPPV** (intermittent positive pressure ventilation) [pao vs time] the base line is called as positive end expiratory pressure or **PEEP** using this a positive airway opening pressure is applied intermittently above the pressure line and by doing this the pa-o pushes the air into the lungs

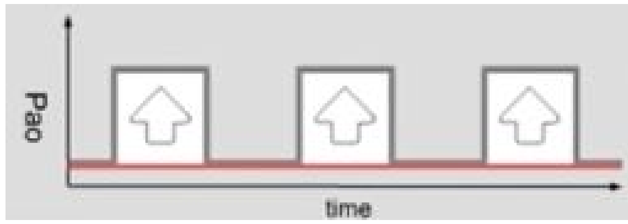


FIG 2.1 IPPV (intermittent positive pressure ventilation) [9]

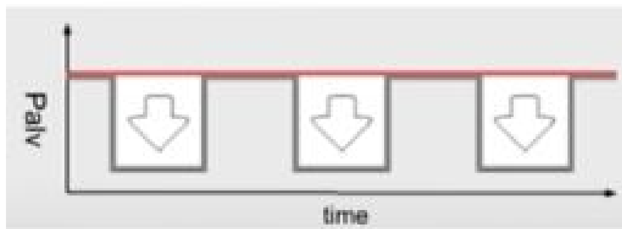


FIG 2.2 INPV (intermittent negative pressure ventilation) [9]

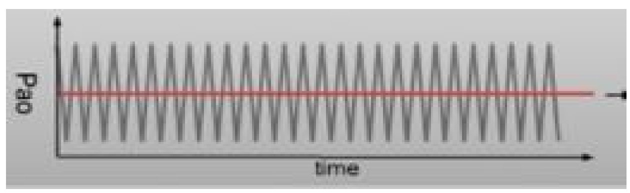


FIG 2.3 HFV (high frequency ventilation) [9]

II. LITERTAURE SURVEY

A. Al Naggar, Noman & Al-Hetari, Husam & Alakwaa, Fadhl"Simulation of Mathematical Model for Lung and Mechanical Ventilation", Journal of Science and Technology, DOI:10.20428/JST.21.1.1, Vol. (21) No. (1), 2016.

This paper proposes a new approach of Mathematical Model improvement for mechanical ventilation including Positive End Expiration Pressure (PEEP) and dynamic compliance (C) , which represents the relation between lung volume and pressure during artificial ventilation. The Mathematical Model has been expressed using linear, quadratic and exponential equations to represent the combination of inspiration and expiration in case Pressure Controlled Ventilator (PCV) and Volume Controlled Ventilator (VCV). Additionally, VCV and PCV signals have been simulated for both ideal and practical case. The MM has been constructed by MATLAB platform, where the simulator monitors artificial ventilation pressure, volume and flow curves of VCV and PCV with new considerations PEEP and dynamic compliance monitoring. The simulated Model provides a simple environment for testing and monitoring VCV and PCV and the lung function laboratory.

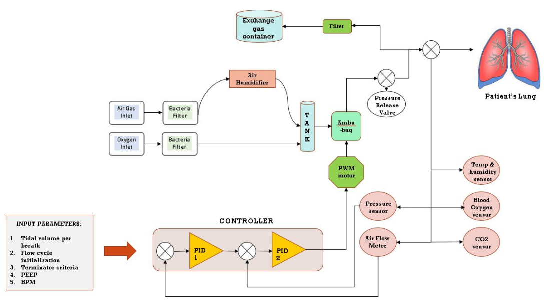
B. Shao-Yung Lu; Hau Lin; "Design and Study of a Portable High-frequencyVentilator for Clinical Applications" 41st Annual International Conference of the IEEE Engineering in Medicine and Biology Society, INSPEC Accession Number: 19127153, 23-27 July 2019.

This work presents the design of a portable high-frequency ventilator and a study of its practicality for further clinical medical applications. Through the integration of advanced electronics and mechanical instruments, we develop a portable high-frequency ventilator with reconfigurable oxygen flow rate, applied pressure, and air volume for the needs of individual patients. A miniaturized portable high frequency ventilator with digital controller and feedback system for stabilization and precision control is implemented. The efficiency of CO 2 washout using the proposed ventilator has been demonstrated in animal trials.

C. Mohammad Jaber; Lara Hamawy"Mathematical Model for Lung and Ventilator", 32nd International Conference on Microelectronics (ICM), INSPEC Accession Number: 20348129, 14-17 Dec 2020.

The idea behind this work is development of a computational model for the study of the impact of different ventilation modes on patient's respiratory system generally, and lungs more specifically. This model has been created using MATLAB/Simulink platform. The studied ventilation mode is the Pressure Controlled Ventilator (PCV) signal combined to single and two compartmental models in series and in parallel mathematical models' configuration of the lungs that represent the respiratory system parameters for testing. The ventilator's setup includes the following parameters: positive end-expiratory pressure (PEEP), pressure wave, respiratory rate (RR), tidal volume, and others

III. MODELING AND ANALYSIS



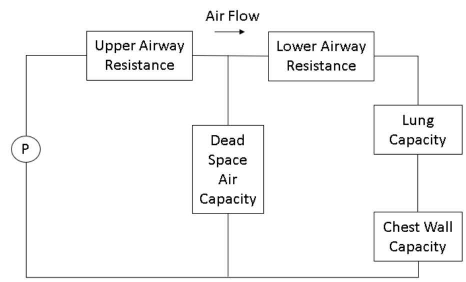


Fig: Block diagram Fig: electrical analogy of a Lung

An attempt was made to analyse the behaviour of a human lung in electrical analogy MATLAB,Simulink software an effected lung due to some diseases like pulmonary Emphysema and corona which has major effect on breathing .The major aspects to consider in a human lung to model its behaviour was the Upper airway resistance, lower airway resistance, Lung capacity i.e., the maximum volume of air that the lungs can hold, chest wall capacity i.e., the maximum extent to which the chest walls can expand and the dead space flow is the volume of air that is inhaled that does not take part in the gas exchange, because it either remains in the conducting airways or reaches alveoli that are not perfused or poorly perfused. Based on these factors, an electrical analogy of the lung model was designed and simulated.

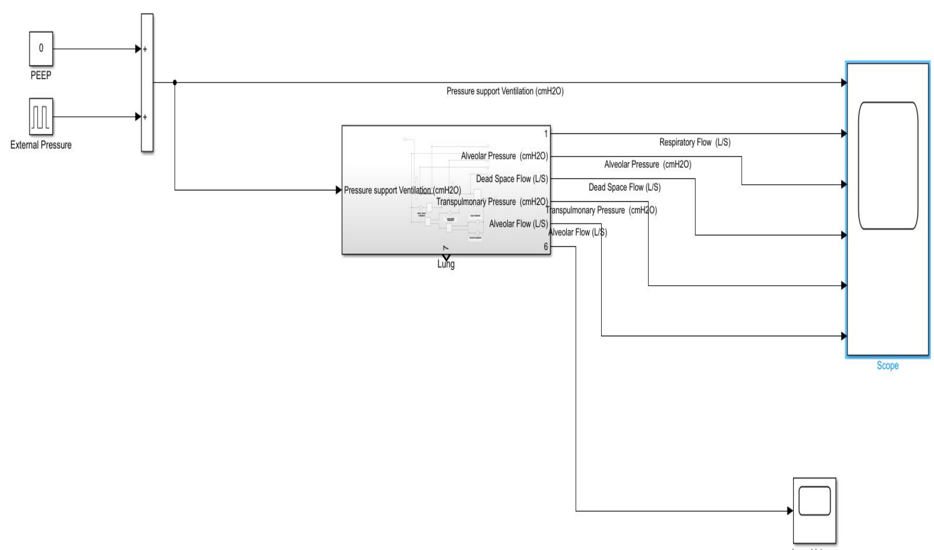


Fig Simulation diagram

The above simulation is a working model of a ventilator with controlled PEEP, with lung model. The various simulations of lung behaviour of normal and effected lungs can be determined through this system

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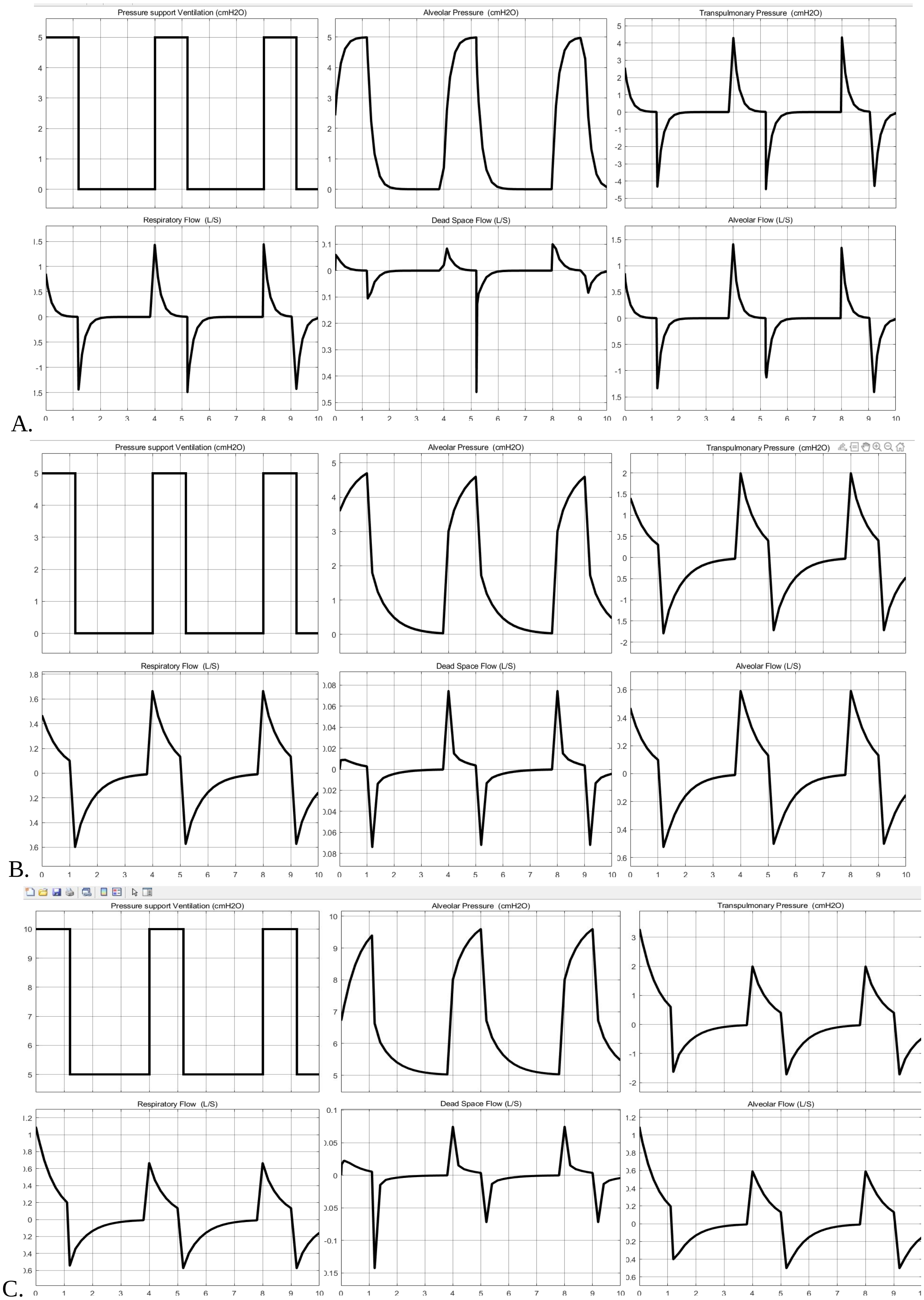
IV. RESULTS AND DISCUSSION



(A) Fig normal behaviour of a lung (B) Fig effected lung behaviour (C) effeted lung behaviour with PEEP control

A. Peep (CMH20)

Positive End Expiratory Pressure (PEEP) provides a constant positive to the alveoli to prevent it from collapsing at the end of each breathing cycle and helps open collapsed area of the lungs. Humidification is necessary.

A typical initial applied PEEP is 5 cmH2O. However, up to 20 cmH2O may be used in

Patients undergoing low tidal volume ventilation for acute respiratory distress

Syndrome (ARDS) Auto PEEP is the spontaneous development of PEEP caused by gas trapping in the lung resulting from insufficient expiratory time and incomplete exhalation

$$\text{Auto PEEP} = \text{Total PEEP} - \text{Set PEEP}$$

1) *Alveolar Pressure (Cmh20):* Alveolar pressure (Palv) is the pressure of air inside the lung alveoli. When the glottis gets opened and when there is no air is flowing into or out of the lungs, alveolar pressure is equal to the atmospheric pressure, that is, zero cm H2O
2) *Transpulmonary Pressure (Cmh20):* Transpulmonary pressure is the difference between the alveolar pressure and the intrapleural pressure in the pleural cavity. The normal lung is fully inflated at a Transpulmonary pressure of ~25–30 cmH2O.
3) *Respiratory Flow (L/S):* This indicates the inspiration and expiration flow in lung
4) *Dead Space Flow (L/S):* The flow in Mechanical dead space is the volume of gas breathed again as the Result of use in a mechanical device
5) *Alveolar Flow (L/S):* Positive pressure ventilation inflates the lungs by exerting positive pressure on the airway forcing the alveoli to expand during inspiration.

Expiration occurs passively.

Positive-pressure ventilators require an artificial airway (Endotracheal or tracheostomy tube) in invasive ventilation and in NIV includes BiPAP Mask, O2 mask, Nasal mask/cannula, O2 high concentrated reservoir mask etc. Inspiration can be triggered either by the patient or the machine.

Modes of mechanical ventilation are the Techniques that the ventilator and patient Work together to perform the respiratory cycle.

(1) Pressure Cycled Modes (2) Volume Cycled Modes (3) Time Cycled Modes

V. CONCLUSION

In this paper, a low-cost ventilator design was proposed that has the lung behaviour with PEEP control .A lung model been simulated by using MATLAB software to analyse the behaviour of lungs at different conditions. A controlled peep is given to maintain constant pressure in the alveoli

By using electrical analogy of a lung, analysed the behaviour of lung at different situations and three cases were taken into consideration that is 1. Normal behaviour of lung 2.effected lung behaviour 3.effected lung behaviour with a PEEP control

In normal behaviour of lung observations were made based on the alveolar pressure of a healthy lung and recorded different pressures which include transpulmory pressure, alveolar flow, respiratory flow and dead space flow. The same parameters were recorded from the effected lung behaviour and the observations from this case are that the alveolar pressure is decreased and the volume of lung is increased and parameters changed. Considering the third case where the control signal is given i.e. PEEP control, by introducing the peep control, improvement was observed in alveolar pressure the respiratory flow is improved

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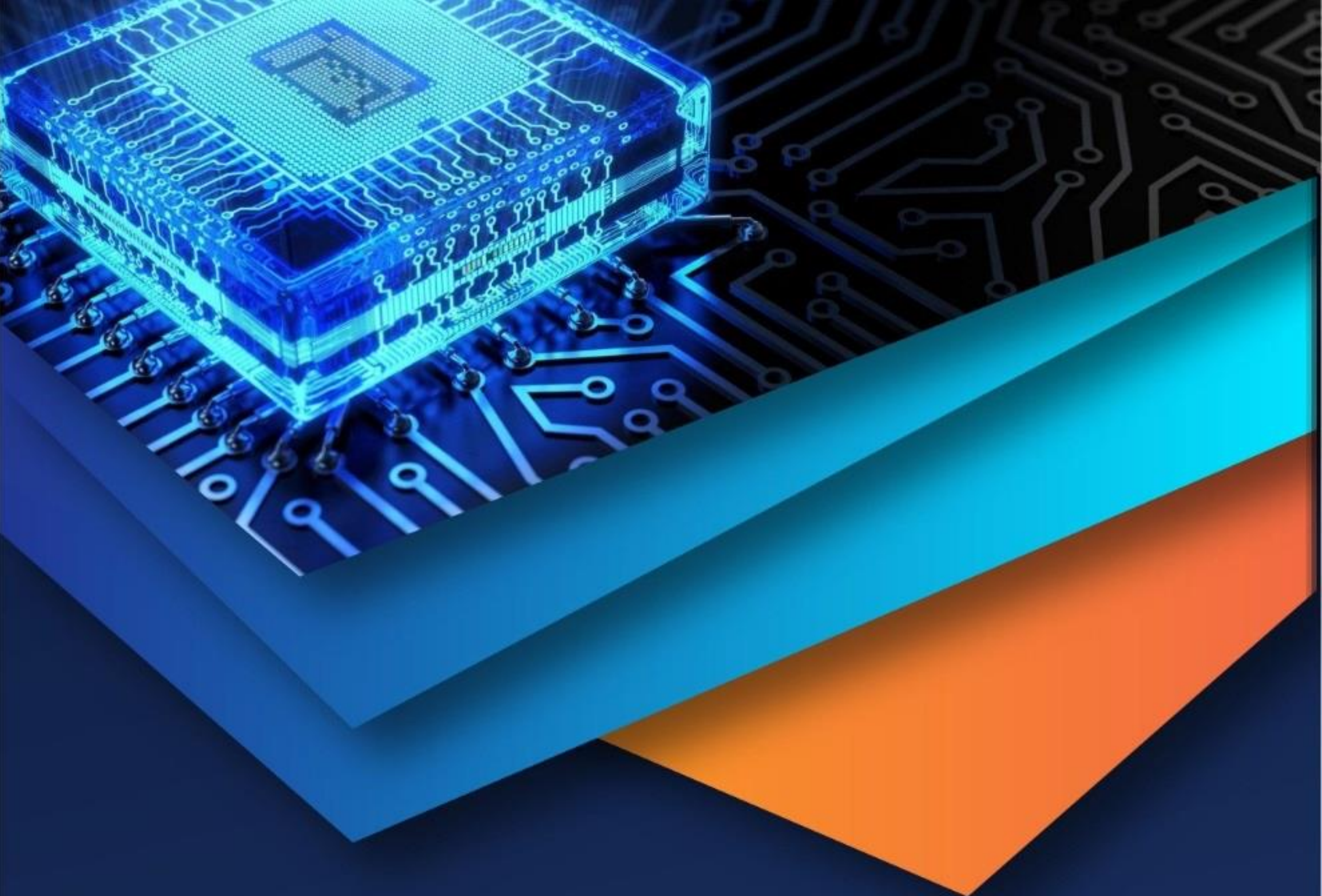

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