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Design and Implementation of Arduino based Low Cost Ventilator using Self Inflating Bag

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Abstract: ***The paper describes the design and implementation of a portable ventilator for ease of use. This portable mechanical ventilator is Arduino-based with a connected motor diver and having a Max 301000 sensor which is an oximeter and heart rate monitor sensor. Arduino gives the output given by the motor driver to the DC motors, MAX 301000 sensor, and the display. It is driven by an electric motor powered by a Power supply and features an adjustable tidal volume of up to 750 ml. Tidal volume and number of breaths per minute are set via user-friendly input knobs of the motor driver. Through this design of portable ventilator, the idea of compressing Ambu bag is proven to be convenient to give a low-cost portable ventilator at a fraction of the cost of existing technology. The ventilator delivers breaths by compressing a conventional bag-valve-mask (BVM) with Two 12V DC motors, eliminating the need for a human operator for the BVM (Also called a self-inflating bag).***
Keywords: Portable, Arduino, Covid-19, low-cost, Bag-valve mask, Ventilation, Low Power.

I. INTRODUCTION

Respiratory diseases like covid-19 and injury-induced respiratory failure make a big impact on public health problems in both developed and less developed countries. Covid-19, Asthma, chronic obstructive pulmonary disease, and other chronic respiratory disease are widely spread diseases across the world. These types of diseases are mainly caused by air pollution, smoking, and burning of biomass for fuel, all of which are on increasing in developing countries also the covid-19 which is spread by air medium or community transmission is very dangerous for human beings. Patients which are undergoing lung disease may have a respiratory failure under various circumstances and challenges can be more will get support by mechanical ventilation. These machines mechanically assist the patient inspires, oxygen level, and exhale, allows the exchange of oxygen and carbon dioxide to be done within the lungs, the process of inhalation of oxygen and exhalation of carbon dioxide is referred to as artificial respiration. While the ventilators which are used in modern hospitals are exceptionally reliable, functionally, and technologically sophisticated, their acquisition costs are correspondingly very high. High costs of technologically sophisticated mechanical ventilation prohibitively expensive for use in resource-poor and less developed countries. Additionally, these ventilators are often Delicate and vulnerable during continuous use, requiring costly service contracts from the manufacturer. In developing countries, this problem is overcome by such as sharing of ventilators among hospitals and purchasing less reliable refurbished bed units. Since the medical resources in these countries are concentrated in the major urban center areas, in some cases rural and remote areas have no access at all to the mechanical ventilators. The need for an inexpensive transport ventilator is, therefore, a high priority. The need for mechanical ventilation is one of the common causes of admission to the intensive care unit. It is important to understand the basic term ventilation what basically mechanical ventilation is.

Ventilation is an Exchange of air between lungs (Air in the other word is the process of moving air in and out of the lungs). Its most important effect is the removal of carbon dioxide from the body. This is completely off-label use, or you can say basic ventilation, but we recognize the global interest when a hospital has used up all ventilators and the only option is manual bagging a patient. We hope that such a system may serve as bridge devices and help with the urgency of the ventilators of available respirators and clinicians trained in respiratory therapy. This may allow less severe patients to be cared for by less specialized clinicians, while resources are focused on those who need it most. However, at no time patient should be unattended without someone skilled available to directly monitor their vital signs and suggest further. We are going through a very bad phase as the surge of covid19 is increasing day by day and all beds are fully occupied and there is also lack of oxygen as there is a number of patients are very big. In the developed world, where well-stocked medical centers are widely available, but this problem is of a different nature. While there are enough ventilators for regular use, there is a lack of preparation for cases of mass casualty such as influenza pandemics, natural disasters, and massive toxic chemical releases, and currently ongoing covid19.

One example of this shortage that occurred is the ongoing covid19 pandemic when there were insufficient numbers of ventilators, and personnel needed to be forced to resort to manual BVM ventilation. However, considering the fewer number of stocked ventilators and they are available currently at a high cost, so there is a need for an inexpensive portable ventilator for which production can be scaled up on demand and help to fight with a pandemic [4].

II. LITERATURE REVIEW

Versatile ventilators are utilized to convey room air or oxygen-improved gas into the breathing circuit, where it very well may be humidified by a warmed humidifier or warmth and dampness exchanger before conveyance to the patient from the oxygen pipe. This provides long-term support for patients who do not require complex critical care ventilators. It can also be used as first aid in emergency conditions. A lot of research is done on portable ventilators, some of the research on portable ventilators follows

The “Prana Vayu” low cost Ventilator developed at IIT Roorkee is a closed-loop ventilator. It is minimal effort, protected, dependable and simple to use as it is furnished with constant spirometry and cautions and can be immediately made. Also, it doesn't need compacted air for working and can be particularly valuable in situations when medical clinic wards or open zones are changed over into ICUs. It can consequently restrict high-pressing factors with an alert framework. If there should arise an occurrence of a disappointment, the circuit opens to the climate, which forestalls gagging. Some extra highlights are far off checking by wellbeing experts, contact screen control of every working boundary, moisture, and temperature control for inhaled air.

Portable Low-Cost Ventilator “DEVEN” designed by Harminder Singh Johar and Kuldeep Yadav is a dependable, convenient, and easy to use ventilator planned and created by those researchers of Dr. APJ Abdul Kalam Rocket Complex, RCI, DRDO, Hyderabad. It highlights practically identical to very good quality ventilators and would serve the prerequisites of an enormous number of ventilators under the present Coronavirus pandemic circumstance. Additionally, it is being a compact ventilator can be utilized in field applications utilizing a convenient air blower and repository. Subsequently, it may be utilized in a rescue vehicle, any portable vehicle, or for application in any remote/rural area [7].

“Advent” is another low-cost ventilator designed by Acute Ventilation Rapid Response Taskforce (AVERT) for patients with Covid-19.The Covid-19 pandemic has created basic deficiencies of ventilators around the world. There is a neglected requirement for quickly deployable, emergency-use ventilators with adequate usefulness to oversee Covid-19 patients with extreme intense respiratory pain disorder. The paper on Design and Prototyping of a Low-cost Portable Mechanical Ventilator by Massachusetts Institute of Technology, Department of Mechanical Engineering Boston University, School of Medicine portrays the plan and prototyping of an easy versatile mechanical ventilator for use in mass setback cases and asset helpless conditions. The ventilator conveys breaths by compacting a regular bag valve mask (BVM) with a turning cam arm, disposing of the requirement for a human administrator for the BVM [4].

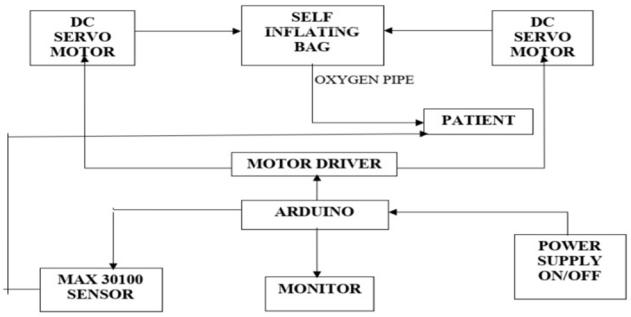
Design of Efficient Low-cost Ventilator for Emergency COVID19 Patients By Rouf-ul-Aalam et.al. proposed the plan of a ventilator which can be handily produced and incorporated into the emergency clinic climate to help Coronavirus patients. The unit is intended to help standard ventilator methods of activity, above all SIMV-PC (Synchronized Irregular Compulsory Ventilation) mode [12].

III. DESIGN CONSIDERATIONS

While the utilization of mechanical ventilation in clinical practice is regularly just utilized on patients that require it as a daily existence supporting the measure, unseemly ventilation of a patient could bring about harm to the lungs that would likewise be life-threatening.10–12 The breathing interaction may appear to be a moderately basic one from the start. There are various nuances that make the breath more unpredictable. Under ordinary conditions, inward breath is driven by the oblivious movement of a progression of muscles, fundamentally the stomach as the key muscle along with various other muscle gatherings of the chest divider, that increment the volume of the thoracic depression. This prompts a lessening of the pressing factor in the lungs which, at now is the ideal time, brings about the progression of natural air into the lungs through the aviation route. The resulting unwinding of said muscles builds the pressing factor in the lungs that delivers the exhalation. hence inward breath is generally delivered by a "negative" thoracic pressing factor, while exhalation is created by a "positive" thoracic pressing factor. At the point when mechanical ventilation is applied, ordinarily, through an endotracheal tube, the inward breath is not, at this point driven by negative pressing factor delivered by the patient, however by a sure pressing factor given by the ventilator that "powers" air into lungs, this is a finished distinct advantage in numerous faculties. For example, characteristic "negative" pressure motivation cannot over expand the lungs and its inner ramified structures, the alveoli, which can possibly be harmed by overpressure when "positive" pressure is applied.

This could prompt harm to the lung, which is typical as of now undermined by the hidden condition, for example, pneumonia brought about by Coronavirus. Accordingly, the volume per motivation (flowing volume) and the proper pressing factors across the breathing cycle should be restricted. In contrast, to sound subjects, who keep a little volume of air in the lungs once the exhalation is finished, basic patients sometimes produce a full exhalation, this causes the liquids that are in the lung to totally fill every one of the pits, which implies that it is harder to swell the lung again in the accompanying breath cycle, and making it more inclined to injury by the mechanical ventilation, hence, a negligible positive pressing factor (Positive End-Expiratory Pressing factor; PEEP) ought to be kept up in the lung toward the finish of the termination to forestall the breakdown of the lungs. It merits referencing that sack valve resuscitators are single-use items, hence, for each new quiet, another resuscitator is required. However, sterile guidelines are not difficult to follow, as the two instrument models themselves are not a piece of the pneumatic framework itself. Likewise, an associating hose between the sack valve framework and the veil or endotracheal cylinder will be required, which is typically not utilized in manual revival. The complete volume of that hose must be fundamentally more modest than the flowing volume siphoned to guarantee suitable weariness of the breathed-out CO2 to the climate. Notwithstanding the simply pneumatic contemplations, there are different perspectives to be considered. For example, compelling air into the lungs of a patient at a rate controlled by the ventilator rather than the characteristic cadence dictated by the patient is incredibly awkward and requires profound sedation, which may convolute different parts of the advancement assessment and treatment of the patient. Henceforth, a criticism instrument, ordinarily by pressing factor or stream, is alluring to trigger the breath pattern of the ventilator and along these lines improve the patient-ventilator synchrony. Moreover, the gas utilized for ventilation ought to be enhanced in oxygen content (FiO2) since the lung limit of the patient is reduced, and in a perfect world, the gas blend ought to be humidified and heated up since the endotracheal tube sidesteps the upper piece of the aviation route (nose and pharynx), which normally plays out these two capacities. During the month that the prototyping cycle took in our gathering, we attempted to fuse whatever number of the attractive qualities as could reasonably be expected to our models, notwithstanding, every level of complexity builds the expense of the gadget, the creation time, and above all the potential disappointment focuses. Even with the contingency cautious unwavering quality tests can not be altogether performed for fittingly extensive stretches [1],[4],[10],[13].

A. Block Daigram



In this portable ventilator, we are using 2 DC servo motors for pressing and contracting the self-inflating bag i.e. Ambu bag the self-inflating bag is useful for providing breathing as well as fresh oxygen to the patient. the motor driver is useful for controlling the speed of dc motors.MAX30100 sensor i.e oximeter, as well as heartbeat sensor, is useful for measuring the heartbeat of the patient as well as to measuring the oxygen level of the patient. the function of the screen shows the heart rate and oxygen level of the patient. When the power supply is on the supply goes to the Arduino Uno. Then by the programming of Arduino Uno Changes the speed of the motor according to oxygen requirement to the patient and receiving a signal from the MAX30100 sensor and display it to the screen. we have to decide how much oxygen is required for the patient and according to the requirement, we have to change the speed of the motor with the help of Arduino Uno. The Arduino gives output to the motor drives the motor start rotating as the motor start rotating, the shaft also moves results in pressing and contracting of the self-inflating bag (Ambu Bag) from both sides simultaneously 10-12 times per minute this will produce the required amount of oxygen. Then the oxygen flows through the pipes and goes to the patient. One MAX30100 Sensor will be attached to the patient finger and the output of the sensor is given to the Arduino Uno which will show the output of heart rate and oxygen level of the patient on the display monitor. In this way, we can also observe and monitor the health of the patient.

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IV. MODULE DESCRIPTION

A. Arduino UNO

Arduino is an open-source contraptions stage reliant on easy-to-use gear and programming. The board on a chip is a place which is outfitted with sets of cutting edge and basic input/output (I/O) pins that may be interfaced to various expansion board (shield) and different circuits. The board has 14 electronic I/O pins (six prepared for PWM output), 6 simple I/O pins, and is programmable with the Arduino IDE (Integrated Development Environment), through a benevolent B USB connect. It is directed by the USB interface or by an external 9-volt battery, anyway, it recognizes voltages someplace in the scope of 7 to 20 volts.

B. DC Servo Motor

An electric motor worked by DC (Direct Current) that converts direct current electrical energy into mechanical energy. The most commonly used sorts are reliable on the powers created by attractive fields. Virtually a wide range of DC motors have some inside instrument, either electromechanical or electronic, to intermittently alter the course of current in a part of the motor.

C. AMBU Bag

A bag valve mask (BVM), sometimes known by the exclusive name Ambu bag or conventionally as a manual resuscitator or "self-inflating bag", is a hand-held gadget usually used to give positive pressing factor ventilation to patients who are not breathing or not breathing enough. The gadget is a necessary part of revival units for prepared experts in out-of-clinic settings, (for example, Ambulance crew) and is likewise every now and again utilized in emergency clinics as a feature of standard gear found on an accident truck, in trauma centers, or other critical care settings.

D. Motor Driver

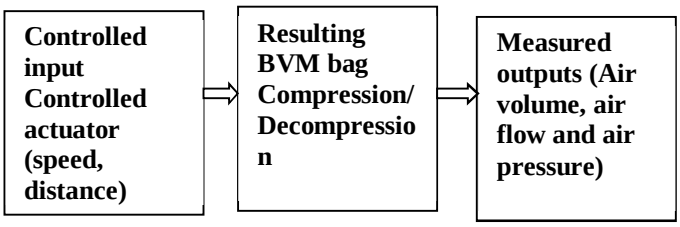
Motor drivers act as an interface between the motors and the control circuits. The motor requires a high measure of current while the regulator circuit chips work on low current signals. So, the capacity of motor drivers is to take low-momentum control signals and afterward transform them into a higher-flow signal that can drive a motor.

E. MAX30100 Sensor

The MAX30100 is incorporates heartbeat oximetry and pulse screen sensor arrangement. It joins two LEDs, photodetector, improved optics, and low-noise analog signal handling to detect heart-rate signals and pulse oximetry. The MAX30100 works from 1.8V and 3.3V force supplies and can be shut down through programming with an unimportant backup current, allowing the force supply to stay associated consistently.

V. PERFORMANCE PROCEDURE

Performance procedure was the controller input controlling the complete procedure firstly controller input controlled actuator movement i.e controlled the distance and speed resulting in BVM bag compression and decompression. At that point the Test results were broken down by estimating air volumes, streams, and pressing factors because of controlled BVM pressure and decompression



Schematic perspective on execution tests. Controlled actuator development prompts relating pressure and decompression of the BVM. The subsequent BVM pressure produces air streams. Flowing air volumes, wind currents, and pneumatic stresses were estimated at the same time.

VI. ADVANTAGES OF PROPOSED SYSTEM

The available ventilator prices are extremely high also the portable ventilator that is available in the market is very good value for money, but our portable ventilator will cost lower than that. For example, 'prana Vayu which is a closed-loop ventilator is designed by the IIT ROORKEE costs around ₹25000 which is equipped with state-of-the-art features which makes it more advance but our portable ventilator will be available around ₹10000. The other low cost and portable ventilators which is available in the markets are low cost and advance too but our portable is very handy to use, reliable and can easily handle by anyone without having proper knowledge of it and a common can use it as first aid at their home or working place. It will help the patients to get adequate oxygen and will clear the carbon dioxide. The compression technique which we use will cost exceptionally low for services as compared to other portable ventilators which are available in the market. Our portable ventilator will provide a continuous supply of fresh outside air to the patients. This portable ventilator can be driven either by a power supply or the battery supply as other ventilators will only work on a power supply or only battery supply. The portable ventilators give room air or oxygen-enriched gas into the breathing circuit to give adequate oxygen.

VII. DRAWBACKS OF OUR SYSTEM

As there are very overly complex, functionally, technically fully equipped sophisticated ventilators available in the market. We cannot match the highly efficient service given by those ventilators. Those ventilators use costly and technically strong equipment's to give prior result but in our, we are trying to make this ventilator cheaper as much as we can for that we didn't use high technologies or costly equipment's so maybe the reliability of this portable ventilator is less as compared to other portable ventilators or the fully equipped high-cost ventilators. Also, this portable ventilator we can't use on severe patients as there is no facility to give acute compressed oxygen which is the requirement of the severe patients.

VIII. PROBLEMS TO BE ADDRESSED

In a surge of the covid-19 pandemic, there are lots of casualties occur due to the lack of ventilator beds and lack of oxygen supply also there. In an emergency if a patient at home there is no way to provide ventilation to that patient until we shift them to the hospital but that span of time is very crucial for that patient if proper ventilation is not given to the patient there is chances of increase in problem to their health or maybe sometimes casualties also happen. In a rural area or say remote area there are no hospitals and there is not a convenient source to help them. This is not only for covid-19 patients, but other patients also face this type of problem. The ventilators are awfully expensive too and need proper expert servicing to work smoothly which increases its expenses.

IX. AIMS & OBJECTIVE

To overcome this problem we have to design a Portable ventilator that will help to get adequate oxygen to the patient. Our purpose to build this ventilator is to make it available for everyone that too at cheaper prices. Which will act as first aid for the patients and reduce the number of problems and casualties. Ability to give proper ventilation in acute respiratory distress syndrome to the patients. To provide the lowest possible cost for adequate oxygenation and ventilation. It will have open-source compatibility which will allow anyone to recreate this system. This portable ventilator is convenient to use in a remote area where ventilators are not available and helps them to give at least proper ventilation until they reach the hospital.

X. CONCLUSION

In conclusion, when we examine the available data and observe the environment it appears that one-third of patients admitted to the ICU will receive mechanical ventilator support for more than 12 hours [13].The reason for initiating mechanical ventilation will be an acute respiratory failure in 2 out of every 3 cases. So, in such situations, it can be seen that the ventilator plays a vital role but in rural areas, remote areas, and also patients at their home are unable to get proper ventilation until they go to the hospital, for that we design a low-cost portable ventilator.

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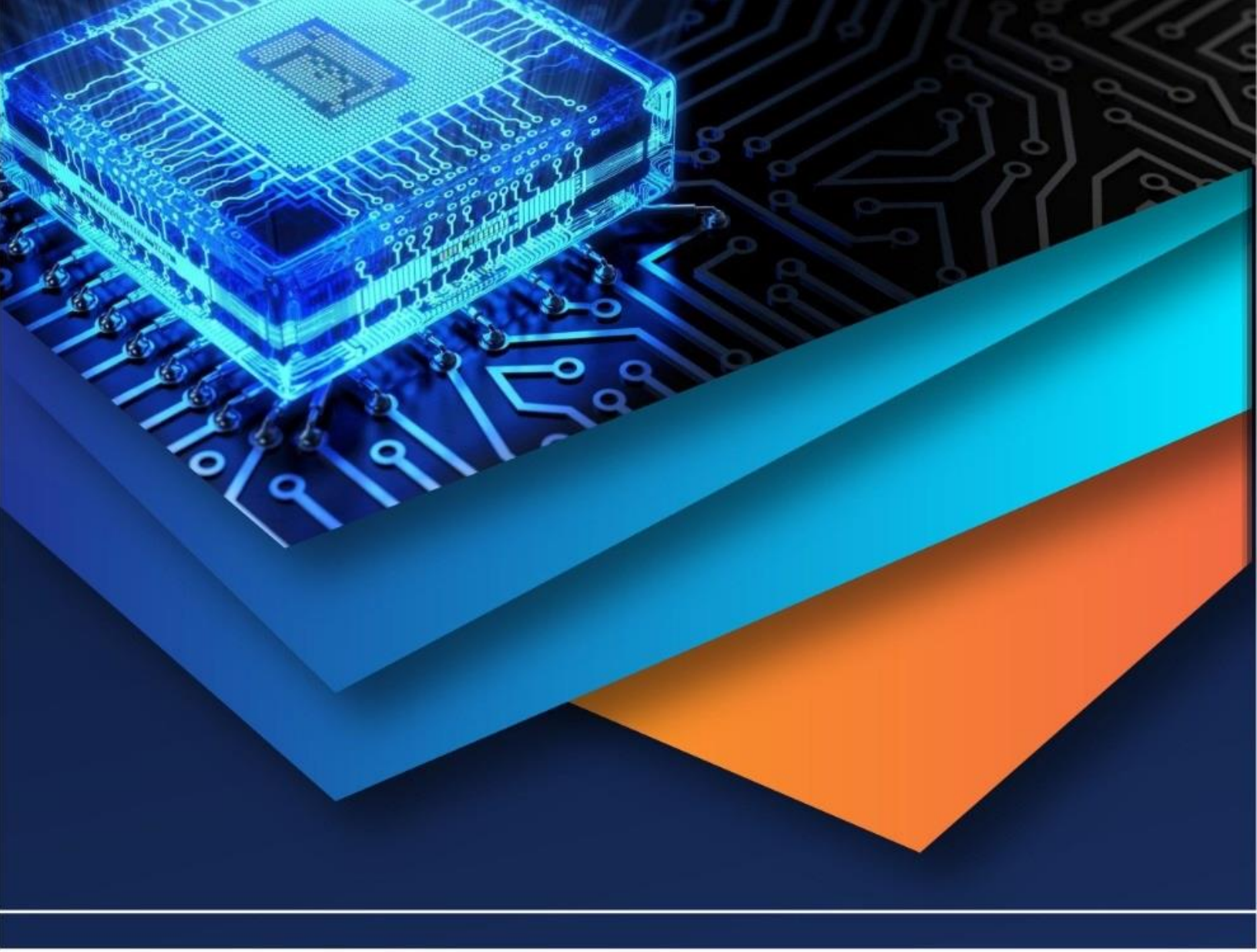

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